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CQ VHF Ham Radio Above 50 MHz

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Fall 2004

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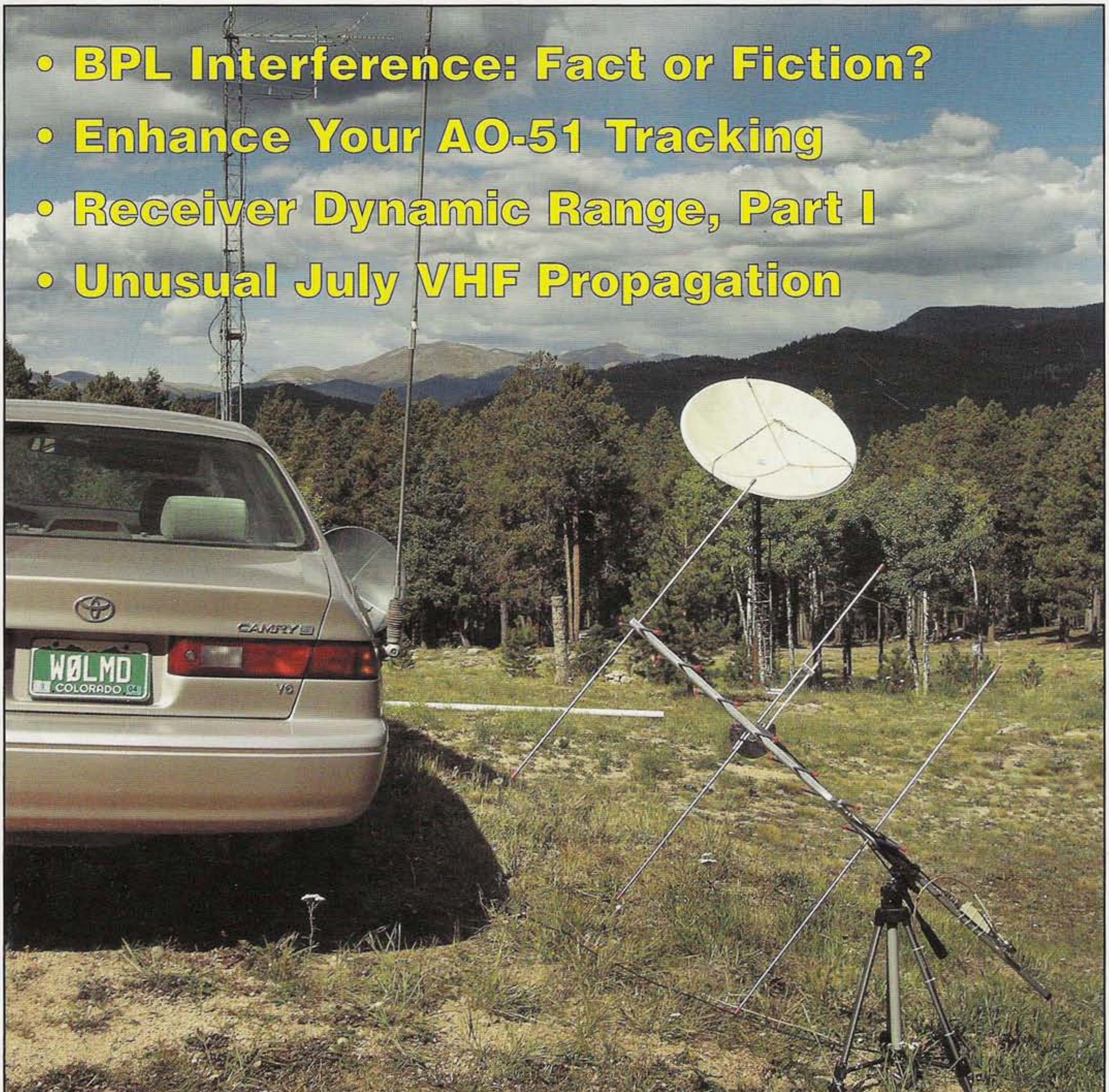
- BPL Interference: Fact or Fiction?
- Enhance Your AO-51 Tracking
- Receiver Dynamic Range, Part I
- Unusual July VHF Propagation



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WOW!

val•ue (văl´yo͞o) n from L valuta, worthy

1. a fair return in money or another medium of exchange for something. *"My Icom dual band mobile radio was well worth the money, a great value."*

2. the exact monetary worth of something. *"My Icom dual band amateur radio is a great value especially since the remote head cable comes standard; a savings of over $50.00".*

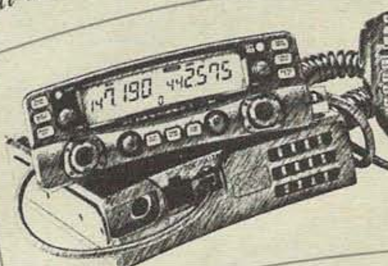

Fig. 1
IC-2720H

3. the relative worth, importance, or usefulness of something to somebody. *"My Icom dual band radio is invalueable to our local emergency communications preparedness".* **<positive value for the money> <the value of unimpaired communications during an emergency>**

4. a. a numerical quantity that is assigned or is determined by calculation or measurement **<the value of x>** *"If I have ten Icom dual band mobile radios, and I take away four, I am in extreme sorrow, and I am left with a value of six Icoms – which is still a hundred times better than any other radio, let me tell you!"* **b.** precise signification **<the word value of something>** *"My Icom dual band mobile radio is beyond measurable value when it comes to emergency preparedness."*

Fig. 2
IC-208H

5. a. the real or perceived duration of time a musical note is held. *"The clarity of sound my Icom dual band mobile gives is music to my ears."* **b.** the written representation of the quality of tone or a spoken sound. *"My Icom IC-208H has 2 Watts of audio output."*

6. a. the lightness or darkness of a color: LUMINOSITY **b.** the relation of one part in a picture to another with respect to lightness and darkness *"The amber value of my Icom's LCD display is adjustable to the environmental needs, and is perfect to see day or night."*

7. something (as a principle or quality) intrinsically valuable or desirable **<sought material values instead of human values>** *"I value my Icom IC-208H dual band mobile radio above any other due to the 50W UHF output."* value verb
Inflected Form(s): **val·ued; val·u·ing; got to have one**

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- Weather Alert

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- 50 watts
- CTCSS encode/decode w/tone scan
- Backlit remote control mic
- Mil spec 810, C/D/E*[1]
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- 113 alphanumeric memories

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- 2M/70CM
- 70 memory channels
- 6W output
- CTCSS encode/decode w/tone scan
- Auto repeater
- Easy operation!
- Mil spec 810, C/D/E*[1]

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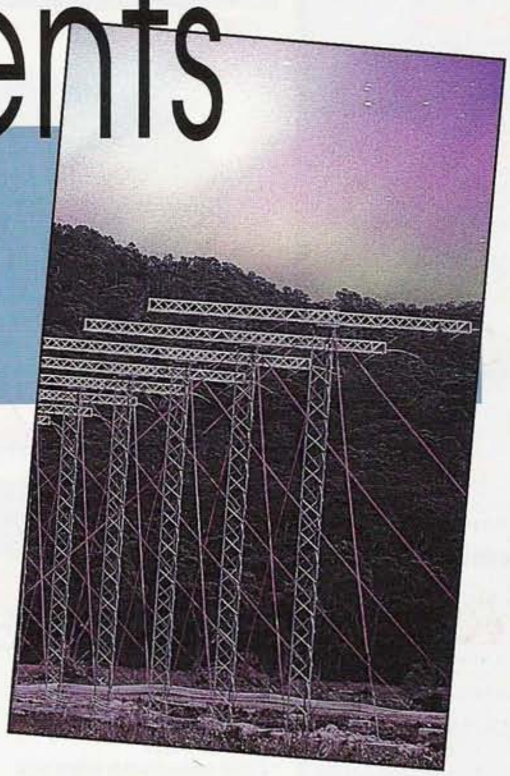

Fall 2004
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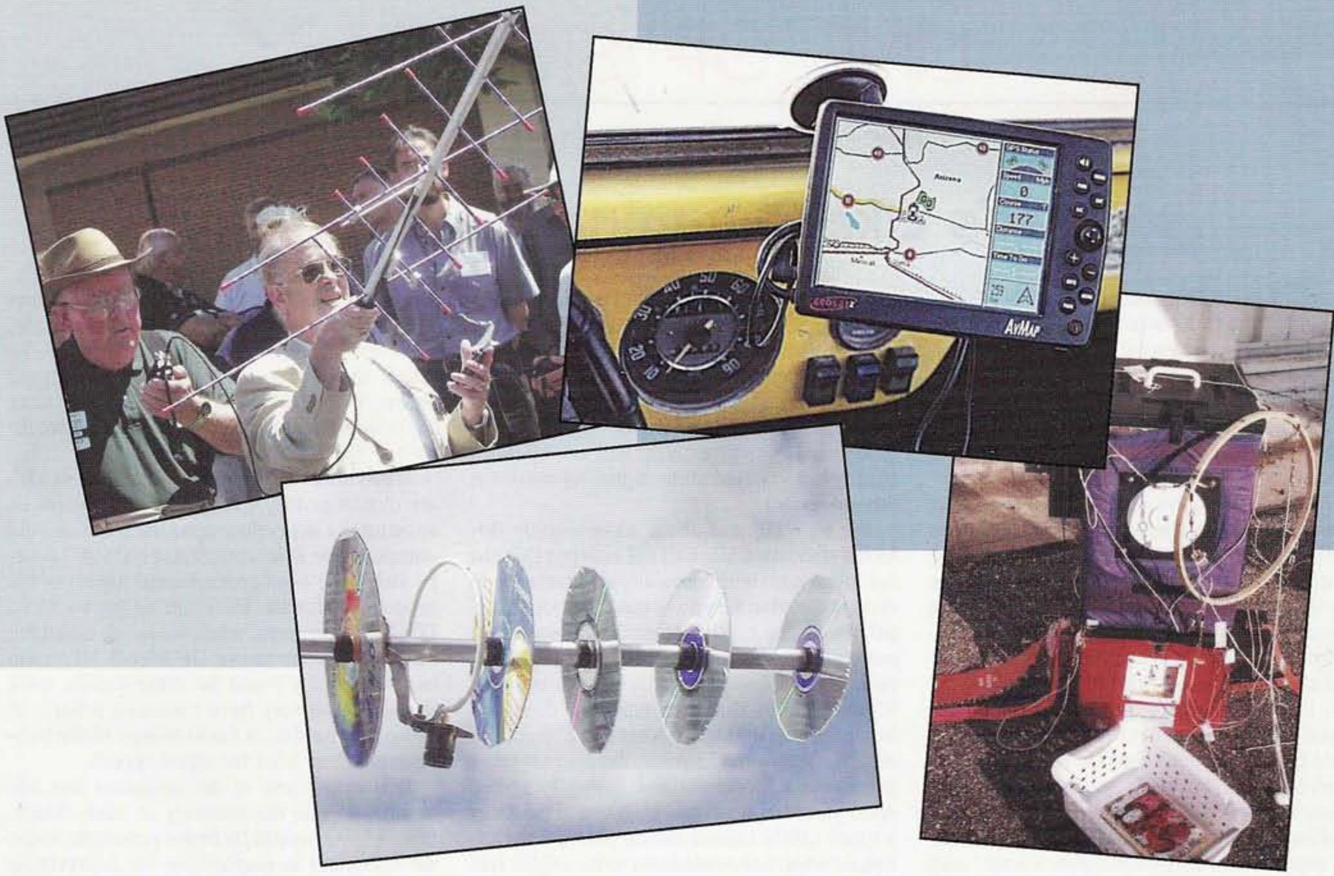
FEATURES



On The Cover: WØLMD has created an impressive system for picking up AO-51 FM signals by adding to an Arrow satellite antenna. For details see p. 10. (Photo by WØLMD)

CQ VHF Ham Radio Above 50 MHz

LINE OF SIGHT

A Message from the Editor

It's Like Changing Diapers

If you were to look back to the table of contents of the first issue of the new *CQ VHF* magazine, you would see a focus on content that leaned in the direction of weak-signal activities. There are two reasons for this. First, my specialty is weak-signal activities. When I became the editor of *CQ VHF*, I brought to the table this expertise.

The second reason is that only a few short years ago the predominant activities on the VHF and above frequencies consisted of FM repeater, packet, weak-signal, space (including satellite and ARISS), and amateur television operations, plus a small interest in radio control on 6 meters. Now, activities on the VHF and above frequencies also include ballooning and HSMM. Furthermore, within the weak-signal specialty there has been a growing interest in EME activities, thanks in large part to the work of Joe Taylor, K1JT, and the various iterations of his WSJT software which have been pushing the envelope of how weak a signal can be detected via EME communications—and what constitutes a QSO. It is the latter that has been causing so much consternation in the EME community as of late. This concern, while confined to EME, can have spillover effects to other activities as well.

Getting to the title of this editorial, it is said that the only person who really desires change is a wet baby. The rest of us, by nature, are resistant to change. Even so, as with diaper changing, change can be a bit messy, but change we must.

Here is where Joe Taylor's controversy began. At the 2004 EME Conference this past August, Joe proposed an entirely new concept of what he wanted to develop for his next software package—something that was going to nearly reach the limit of what level of intelligible signal can be detected. He incurred the wrath of those who do not want to change what they understand to be the rules of what constitutes a legitimate QSO.

In understanding what constitutes a legitimate QSO, we need to understand where this concept for us in the weak-signal community came from. It was most likely in the days when meteor-scatter communications on 2 meters was in its infancy. In 1953, two fellows, Paul Wilson, W4HHK, and Tommy Thompson, W2UK, were experimenting with communications via this mode and needed to define what was considered to be a QSO.

Here is the background: Our friends on HF have refined the QSO, and especially in contests, where they have streamlined the definition to often be just an exchange of callsigns and signal reports. In some net operations, it's become even more streamlined. The net control tells each station the other's call and asks simply that they exchange signal reports. The contact lasts mere seconds, and the net control declares that a contact is "complete" when he or she hears both operators correctly repeat the other operator's signal report—even though it's sometimes clear that one operator simply has guessed at the signal report of the other operator.

We on VHF and above have slightly different standards. We will not accept a QSO as complete until both operators acknowledge to one another that they have received both a signal report, or a grid locator, or some other mutually agreed upon exchange of information, and the complete calls of both stations. When did this different standard develop? Some believe that when what I call "fractional" (by "fractional" I mean the contact takes place over a predetermined, mutually agreed upon period of time, and by bits and pieces at a time) QSOs started taking place, a definition of what was considered to be a QSO had to be specified.

Probably one of the earliest examples of this was the first 2-meter meteor-scatter contact, which took place between Paul and Tommy. As this mode of propagation was experimental, there was no definition of what was considered to be a legitimate QSO. Therefore, Paul and Tommy looked to the League—specifically to Ed Tilton, W1HDQ, then editor of *QST*'s "The World Above 50 Mc." column—to define what was necessary for a completed contact. Ed determined that both operators had to acknowledge to one another that they had received both calls and the correct signal report; the latter had to be confirmed by repeating the signal report received back to the other operator.

Reliance on Ed's definition led to the rejection of Paul and Tommy's first claimed contact in August 1953. It wasn't until the second contact that both Paul and Tommy received enough information from one another for Ed to consider the QSO complete.

Over the passage of time, the definition of a QSO has undergone little change. The only minor modification is that the signal report received need not be repeated back to the other operator. A simple acknowledgement, using the word "Roger" on voice or "R" on CW, is considered sufficient. What has undergone change is what constitutes the signal report. For example, EME enthusiasts have adopted a "T M O" signal-report system, while meteor-scatter operators using voice have adopted an "S 1–3" signal-report system. These signal reports generally provide the only unique information exchanged between the two operators, because most of the time both callsigns and grid locators are known to both operators ahead of time.

In Joe's new version of his software, he wants to redefine what constitutes a signal report. Gone are the T M O reports, being replaced by a measurement of relative weakness in the signal as measured in dB.

If this is not bad enough for those of us who are challenged by change, Joe also wants us to be totally dependent upon the radio and the computer for what constitutes a QSO. This is probably the most controversial aspect of his proposed software. How can we say we had a QSO with someone when we never heard the other station? Even our HF friends rely upon having actually heard the other station, even though some may have mistaken a burst of noise as a number in the exchange of the two-digit numbers used for signal report.

It is in this use of the computer that Joe assures us that the integrity of what constitutes a QSO is actually better preserved, since the computer is responsible for interpreting the data received and displaying it on the screen. It is up to the operator to confirm that the data received is what was expected.

Even so, for some of us, it is illogical to consider that a computer can preserve the integrity of what constitutes a legitimate QSO better than we can. There is something tangible about actually hearing the signal.

This need to hear the actual signal takes me to one of the other newer users of our VHF and above spectrum, HSMM. Here the operators have no interest in hearing the signal. All they want to experience is what the computer is interpreting as data. Legitimacy for them is that the computer is receiving and translating a data stream into something intelligent. Hmm . . . this seems to me to be what Joe is also trying to accomplish, using the computer to interpret a data stream so that the operator receiving the data stream can decide as to its legitimacy, whether that legitimacy is a signal report from a very weak signal or a computer game played between two or more HSMM operators.

It's the change that we are most troubled by. In all change there are early adopters, those who eventually come on board, and finally, there are those who will never change. For those of us who are early adopters and those of us who do eventually come on board, it is my desire that we practice patience and tolerance of those who find it very difficult to change.

Perhaps we may be able to encourage our slow to adopt change fellow hams to come along with us as we change by gently reminding them that they, too, were once wet babies.

Until the next issue... 73, Joe, N6CL

QUARTERLY CALENDAR OF EVENTS

Contests

December: The third weekend of the **ARRL International EME Competition** is Dec. 4–5. This is the second weekend of the 50 MHz through 1296 MHz competition.

January: The ARRL VHF Sweepstakes is scheduled for the weekend of Jan. 22–24. Complete rules for the ARRL contests can be found in the *QST* issue the month prior to the contest or the month prior to the first weekend of contests extending over two or three months. Complete rules can also be found on the League's URL: <http://www.arrl.org>.

Meteor Showers

November: While another peak in *Leonids* activity is one or two years away, it is still important to pay attention to this shower, as it may produce a surprise ZHR in excess of 250 five days ahead of its predicted peak. It is predicted to peak at 0825 UTC on Nov. 18.

December: Two showers occur this month. The first, the *Geminids,* is predicted to peak at around 2220 UTC on Dec. 13. The actual peak can occur 2.5 hours before or after the predicted peak. It has a broad peak and is a good north-south shower, producing an average of 100–110 meteors per hour at its peak.

The second, the *Ursids,* is predicted to peak on Dec. 23. It is an east-west shower, producing an average of greater than 12 meteors per hour, with the possibility of upwards of 90 at its peak.

January: The *Quandrantids* or *Quads,* is a brief, but very active meteor shower. The expected peak is on Jan. 3, 2005. The actual peak can occur three hours before or after the predicted peak. The best paths are north-south. Long-duration meteors can be expected about one hour after the predicted peak.

For more information on the above meteor shower predictions, see Tomas Hood, NW7US's propagation column on page 67. Also visit the International Meteor Organization's website: <http://www.imo.net>.

Quarterly Calendar

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

Nov. 2	Moon Apogee
Nov. 5	Last Quarter Moon
Nov. 7	Good EME conditions
Nov. 12	New Moon
Nov. 14	Moon Perigee; poor EME conditions
Nov. 17	*Leonids* Meteor Shower Peak
Nov. 19	First Quarter Moon
Nov. 21	Good EME conditions
Nov. 26	Full Moon
Nov. 28	Very poor EME conditions
Nov. 30	Moon Apogee
Dec. 5	Last Quarter Moon; moderate EME conditions
Dec. 12	Moon Perigee and New Moon; very poor EME conditions
Dec. 13	*Geminids* Meteor Shower Peak
Dec. 18	First Quarter Moon
Dec. 19	Moderate EME conditions
Dec. 21	Winter Solstice
Dec. 22	*Ursids* Meteor Shower Peak
Dec. 26	Full Moon; very poor EME conditions
Dec. 27	Moon Apogee
Jan. 2	Moderate EME conditions
Jan. 3	Last Quarter Moon
Jan. 4	*Quadrantids* Meteor Shower Peak
Jan. 9	Very poor EME conditions
Jan. 10	New Moon
Jan. 10	Moon Perigee
Jan. 16	Moderate EME conditions
Jan. 17	First Quarter Moon
Jan. 23	Moon Apogee; poor EME conditions
Jan. 25	Full Moon
Jan. 30	Moderate EME conditions
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. 15	First Quarter Moon
Feb. 20	Moon Apogee; poor EME conditions
Feb. 24	Full Moon
Feb. 27	Moderate EME conditions

—EME conditions courtesy W5LUU.

New Product
The Alinco DJ-C7T Pocket HT

Alinco has introduced the DJ-C7T 2m/70cm HT, a pocket-size transceiver that succeeds the popular Alinco DJ-C5. The new HT is small in size, but big in added memories and modes.

One of the most noticeable improvements over the DJ-C5 is the audio quality. With a completely redesigned internal speaker, the DJ-C7 delivers audio quality that rivals many bigger radios. The new model also offers an SMA antenna port and a two-way antenna system that allows the use of an optional earphone cable to monitor FM broadcast reception while using the SMA antenna port for the helical antenna (included) or a choice of other optional antennas. The DJ-C7 can transmit up to 300 mw output with a powerful lithium-ion battery, which is included with the radio. Using optional external power, it can transmit up to 500 mw output.

The new DJ-C7T has 200 memories, two-way antenna systems, wide-band receive including FM broadcast and AM aircraft bands, auto repeater setting, VFO, memory and scan modes, and more. There are 39 CTCSS encode and decode settings (decode included as a standard feature) and four tone bursts that make the unit usable for repeater operations in many parts of the world.

The large display is easy to read and provides information to the user about a number of useful features. Alinco has added a split function and the ability to clone units by cable. Alinco DJ-C5T optional microphones/earphones are cross-compatible with the DJ-C7T.

For more information, contact Ham Distribution, Inc., 15 South Trade Center Pkwy, #B5, Conroe, TX 77385 (phone 936-271-3366; fax 936-271-3398; e-mail: <USREP@Alinco.com>; on the web: <www.alinco.com>).

Broadband over Power Lines (BPL) Interference: Fact or Fiction?

The following, which originally appeared in the July/August 2004 issue of The Canadian Amateur, appears here courtesy the author and the Radio Amateurs of Canada. Its contents were summarized in a presentation the author made at the Central States VHF Society conference, which was held in Mississauga, Ontario, Canada on July 23–24, 2004. Because VE4MA is both an active amateur radio operator and an electrical engineer in the field of power systems telecommunications, he brings a unique perspective to the BPL controversy.

By Barry W. Malowanchuk,* VE4MA

BPL is an exciting new variation of an old idea. This old idea proposes to use the wires of electric power systems through neighborhoods and in buildings to transport high-speed Internet (broadband) data signals for public customers and for utility applications. These modern power-line carrier-current system variants are in the process of undergoing technical trials and limited implementation in Canada and in the USA. Concerns have been raised as to possible interference to users of the radio spectrum between 1.7 and 80 MHz. This article will attempt to give some technical information concerning the systems being proposed, the user applications, the nature of the possible interference, the control measures being proposed, the testing activities underway to evaluate possible interference, and the state of BPL deployments in Canada and in the USA.

System Technical Description

To understand the technical issues associated with interference, a basic understanding of how BPL systems are created and the differences among them is necessary. The differences lead to significant changes between system characteristics as they are implemented, and consequently, will greatly vary the potential impact on the radio amateur.

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e-mail: <ve4ma@shaw.ca>

From a world perspective, BPL is not new. For at least a decade, BPL has been widely deployed in the United Kingdom. The reasons for early deployment there are not obvious, but consider that the heavily populated centers of Europe have already been "wired" for telephones. To rewire in order to deliver new or additional telecommunication services based on coaxial or fiber-optic cable is a very costly undertaking, which consequently would be unlikely to occur. The electric power system is, of course, already in place, and any technology that could make use of existing wires to deliver new services to customers is going to be a desirable option. This was also the motivation for the deployment of Digital Subscriber Line (DSL) modems on conventional telephone lines by the telephone companies.

European BPL

The electric systems of Europe are different from the electric systems in North America, and this goes beyond the standard use of 220 volts at 50 Hz, but rather is in the basic configuration. Each distribution transformer that converts the medium-voltage (MV) line voltage (4 to 40 kV) down to the low-voltage (LV) 220 volts has 200 to 250 customers who are connected to the LV side through coaxial supply cables. In the use of BPL, the distribution transformer is a significant obstacle, because the transformer, which is intended to pass low frequencies near 50 Hz, appears as an open circuit to the passage of higher frequency signals. Therefore, in order to provide telecommunications services to a large number of electricity system customers, a means of bypassing the transformer is necessary. This bypass operation is costly, as there are large voltages to deal with on the MV side of the transformer, and there are concerns with the transient voltages that are produced by lightning hits on the MV lines. The fact that 200 to 250 customers can be reached from the LV side of each transformer is the main reason for its early deployment in Europe, as the source of broadband data only needs to be delivered to each transformer by fiber-optic cable, DSL lines, or even broadband microwave radio. From the onset, this made the economics and practicality of BPL very attractive to reach European customers.

North American BPL

In North America, the situation is different, with a maximum of about 20 customers being served by a single distribution transformer, and in most cases the number of customers typically will vary from 1 to 8. Thus, providing BPL service to a large number of customers in NA will have a significantly higher cost than in Europe because of the need to attach to the LV side of a proportionately larger number of transformers at a much higher cost per customer. Otherwise, the transformer barrier needs to be crossed in

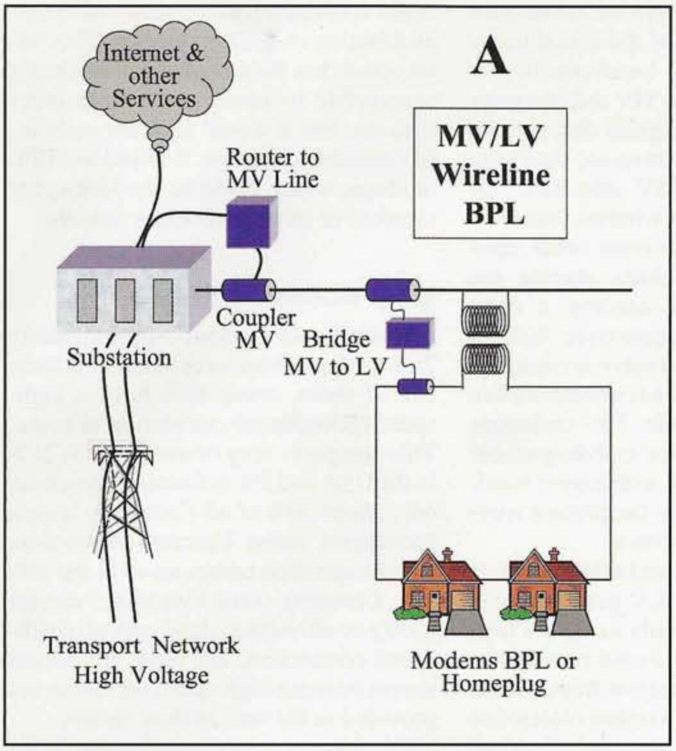

Figure 1. The configuration of a typical distribution network.

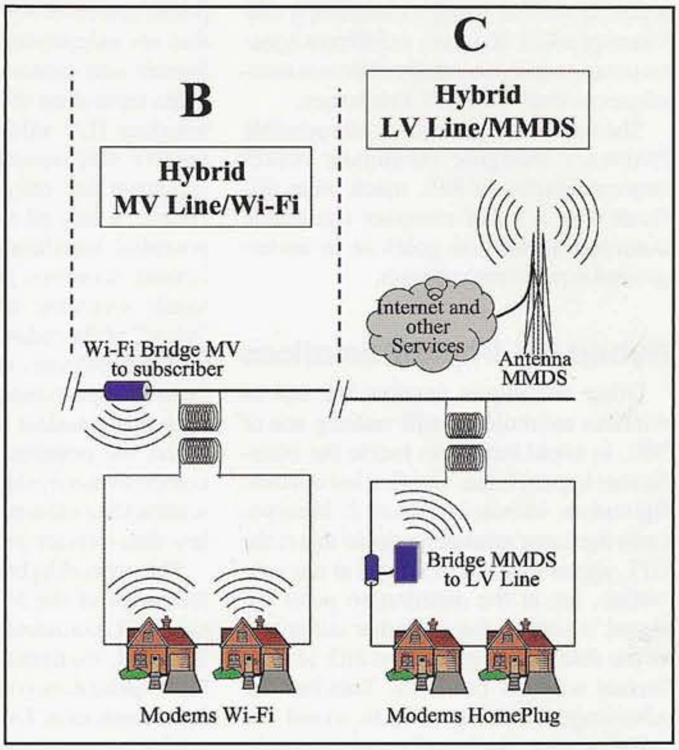

Figure 2. The first hybrid BPL configuration.

order to get a better utilization of the high-speed data line. The NA BPL manufacturers have had to concentrate on transformer bypassing. Consequently, they have a number of options to choose from, which ultimately defines the major differences in their systems. Each approach has its strengths and its weaknesses. Without getting specific as to the different manufacturers' approaches, let's consider the options as follows:

All Wireline BPL Implementation

From an electric-utility perspective, it would be important to keep the facilities provided by other entities to a minimum by using BPL throughout. In figure 1, the configuration of a typical distribution network can be seen. There are one or more high-voltage lines (typically 66–230 kV) which transport electricity to a substation. The substation will have large transformer banks to reduce the voltage to something in the range of 4 to 25 kV for connection to the many medium-voltage lines that distribute the electricity out to the MV-LV transformers, which are located near the customers.

Substations in an electric system will vary in their sophistication, depending on the age and the significance of the station to the electric grid. Often, significant stations will be served by utility-owned microwave-radio or fiber-optic cables. These telecommunications systems are necessary for the operation of the electricity system, which sometimes is capable of supplying higher data bandwidths than required by the station itself, and thus can provide surplus bandwidth to a BPL system. The BPL data system will require the installation of data-processing equipment at the station to interface to the high-speed data network (and ultimately the Internet) to launch or to inject BPL signals into the MV lines. The connection to an MV line is made by some form of coupling device, that being a capacitor-based network in its simplistic form, or realistically, some form of a wideband transformer. The coupler has to isolate the high MV voltages (4 to 25 kV) from the station's BPL data equipment. There are choices to be made as to how many conductors to couple to on the MV line. A single conductor is the minimum required, of course, but there are usually three phase conductors associated with an MV line, and better BPL transmission distances can be achieved by coupling to two phases.

The BPL signal will then propagate down the wires to the distribution transformer location, and the issue to be dealt with is bypassing the transformer. In the simplistic situation, the bridge to the LV side is performed by a capacitor or wideband transformer network similar to the coupler used to inject the BPL signals onto the MV line at the station. Thus, the same BPL signal that is carried on the MV lines is coupled onto the LV lines. In a practical BPL implementation, however, there will be a need to periodically regenerate the digital BPL signals. Of course, this must happen somewhere along the length of a contiguous MV line. The LV side of the transformer will have more complexity in the frequency domain, and it may be advantageous to translate the BPL signal to a different lower spectrum range before connecting to the LV side. This allows the regeneration of the BPL signal for both the MV and LV lines and eliminates any interference between these signals provided by cross coupling of the MV and LV wires. The degree of cross coupling will depend on the physical configuration of the lines on the distribution system. In Europe and in North America, there is a BPL product available for LV use that follows the "Homeplug" standard. The Homeplug products are available for home networking, using the local power system wires. Obviously, there is an advantage to using these in the customer interface of a BPL implementation as well as using a completely different product that uses a different spectrum range and potentially different techniques to deal with MV line issues.

The need for regeneration and possible frequency-changing equipment makes implementation of BPL much more difficult with a lot of complex equipment mounted outside on poles or in underground equipment cabinets.

Hybrid BPL Implementations

Other techniques involve the use of wireless technology, still making use of BPL to avoid having to tackle the transformer bypass issue. The first hybrid configuration, shown in figure 2, incorporates the same arrangements to inject the BPL signal into the MV lines at the substation, but at the distribution point the signal is sent to the customer using one of the data industry standard 802.11a/b/g format wireless products. This has the advantage of being able to avoid the transformer entirely and even creates the freedom to locate signal distribution points at technically convenient locations that are independent of the actual transformer and customer locations. It provides separation of the MV and customer interface (LV side) signals and permits the MV side equipment to use the entire spectrum for only MV side BPL. Of course, it has all the wireless issues of potential interference from other unlicensed wireless products sharing the same spectrum and needing a clear "view" of the radio access node. It could permit customers to receive service in a cellular-type manner and connect to more than one wireless node. This technique offers the potential for mobile/portable computer networking with higher bandwidths than offered by the present wireless data-service providers.

The second hybrid technique reverses the usage of the MV/LV lines and only uses BPL connected only to the LV line. The BPL equipment would receive the high-speed data connection from a wireless connection. This wireless connection could be provided by the standard 802.11a/b/g format wireless links or could use licensed microwave multipoint distribution (MMDS) systems. This latter option has the advantage of not being susceptible to interference from other systems, but it would lack the cellular-like portable coverage. It would use BPL modems, which could be the Homeplug standard or other proprietary models.

Why Bother with BPL?

Broadband Access: Approximately 75% of Canadians have Internet access, and of those, about 48% have a high-speed (Broadband) connection at home. This compares very favorably with 21% in the USA and 5% in Europe. Therefore, only about 30% of all Canadians have a broadband home Internet connection, and the question comes up as to the reason. Certainly some Canadians cannot justify or afford the added cost of a high-speed connection, but most are denied access because high-speed service is not provided in the area of their homes.

Providing service requires a significant capital expenditure by the service pro-

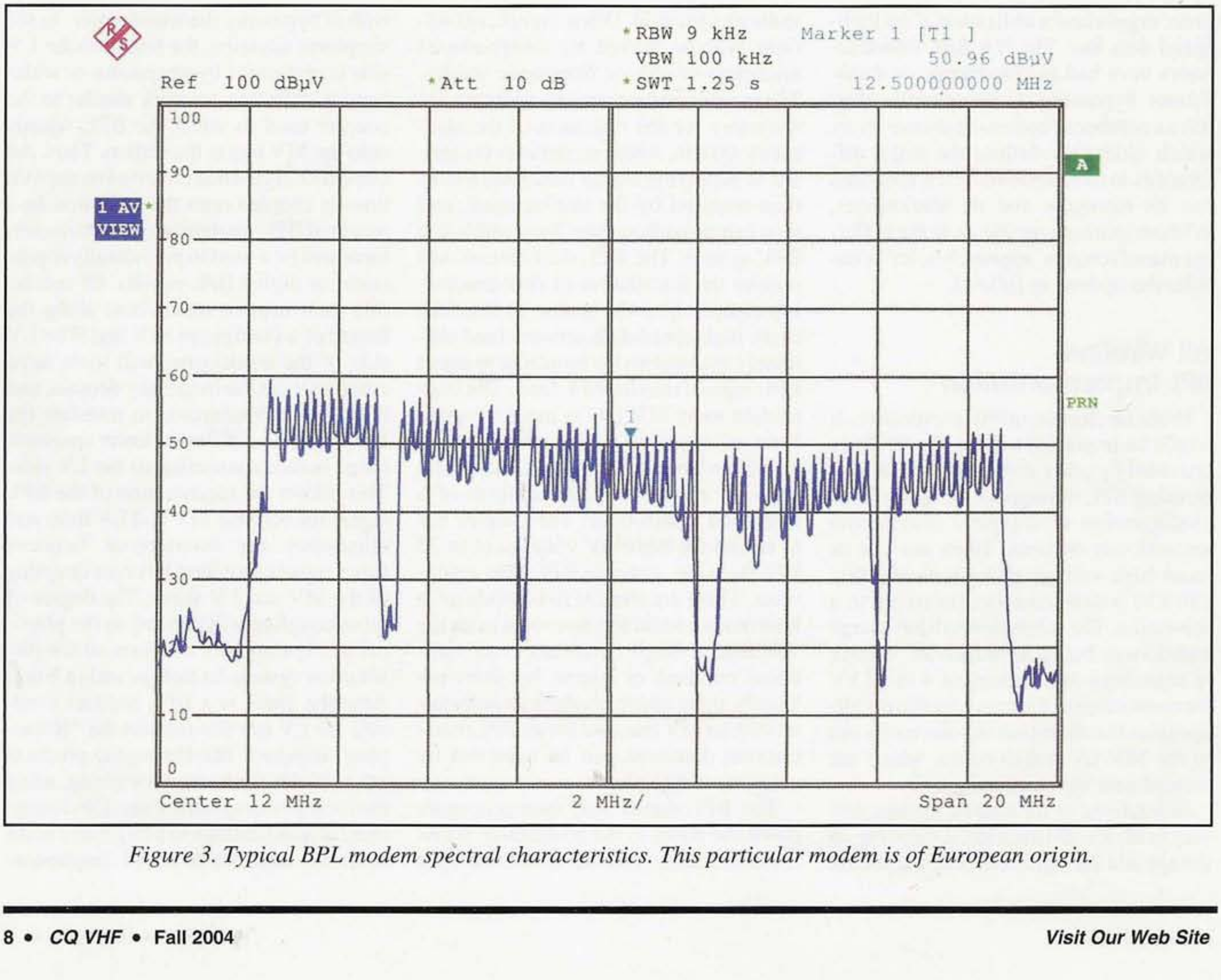

Figure 3. Typical BPL modem spectral characteristics. This particular modem is of European origin.

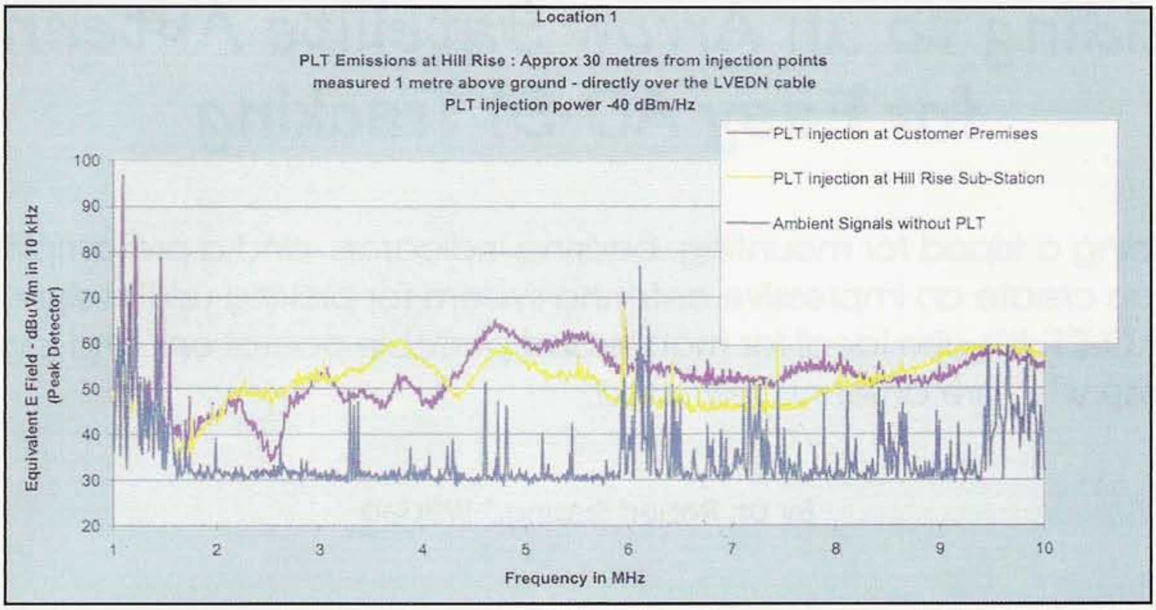

Figure 4. European BPL interference tests shows the possible impact of BPL signals on HF amateur operations.

vider, and unless there is the future prospect of a sufficient number of customers, service will not be extended to an area. The same is true for almost all of the delivery technologies, including DSL, cable modems, wireless, and even BPL. Only satellite service offers the potential to spread the required number of customers over a large territory. The case for BPL is that the power-system wires are already there and only the BPL equipment needs to be added. Thus, the opportunity exists to provide service where service cannot be delivered economically by other means. In areas that are already served by high-speed cable or by DSL providers, the prospect is that BPL can provide a lower cost option for consumers, and the added competition will force the cost of broadband Internet services lower.

All provincial and federal governments look at broadband Internet availability as being a key ingredient to providing a high standard of living for all Canadians. It holds the promise of being an enabler of advanced health care and education in rural areas, along with potentially providing even a new source of employment opportunities where few others exist. This is hoped to help stop the migration of people from the rural areas to the cities and towns. As a country, it should help lower the cost of doing business in a global marketplace. Governments fully support any initiative that can help fulfill the goal of getting broadband Internet to most Canadians.

Utility Applications: The equipment used by Canadian electric utilities to generate, transmit, and distribute electrical energy has a long economic life. Because the electrical systems expanded greatly after the end of World War II, much of that equipment is 50 years old, and it is in need of replacement. The modern replacements offer the promise of features that can enhance utility operations and improve customer service. These features require the remote retrieval of information through communications facilities. Until recently, utilities relied on narrowband data channels (and often dial-up service) to retrieve information from major stations. Smaller stations often had no means of data retrieval other than dial-up. Many utilities have been able to construct microwave-radio and fiber-optic based networks that now provide high-speed data access to the larger stations, yet the smaller (distribution or customer service) stations have not received these services. With extensive equipment replacement programs going forward in the near future, the expansion of utility data networks is necessary to facilitate use/providing of advanced services. BPL can help provide the missing link to the smaller stations and utility equipment that is located out on the lines.

BPL Modem Technical Properties

Much of the information concerning BPL modems is commercially confidential. Because of the controversy concerning radio interference, it seems especially well protected. There are certainly many ways to create high-speed modems, and the technologies used were developed in response to similar needs for high-speed data transmission in the wireless world. The main modem modulation techniques are as follows:

• DSSS—Direct Sequence Spread Spectrum

• FHSS—Frequency Hopping Spread Spectrum

• OFDM—Orthogonal Frequency Domain Modulation

All of these techniques are capable of delivering such a service, but because public information exists for OFDM BPL modems, that will be the subject of this discussion. The OFDM chip sets in use by at least two BPL manufacturers are manufactured in Spain by DS2. The modem characteristics are:

• 45 Mbps using 1280 distinct carriers

• Adaptive bit rate per carrier depending on channel S/N conditions

• Spectrum usable from 1.7 to >80 MHz

• Only 10 MHz of bandwidth used per modem

The 1280 individual carriers are effectively independent and can adapt dynamically to S/N conditions being experienced. Therefore, if the frequency response for a particular modem carrier is poor, the modem will adapt its modulation scheme to suit the circumstances and

(Continued on page 82)

Adding to an Arrow Satellite Antenna for Easy AO-51 Tracking

By adding a tripod for mounting, bearing indicators, and a pre-amplifier, you can create an impressive antenna system for picking up FM signals from AO-51. It's also ideal for mobile and portable operations and is great for those who are antenna restricted.

By Dr. Robert Suding,* WØLMD

The Arrow antenna systems can be used as they come for picking up the FM signals from AO-51—if you can hold the antenna in the correct direction for up to 15 minutes and don't mind listening to a very weak signal. However, by tripod mounting the Arrow (it's already tapped for a 1/4-20 tripod bolt) and adding bearing indicators and a pre-amplifier, you wind up with a real working antenna system. It's ideal for mobile and portable use and works great for those who are stuck with anti-antenna covenants.

The first thing to do after buying an Arrow antenna is to get a small, lightweight camera tripod (photo 1). I got mine from the local Best Buy store. It was designed for the latest generation of small digital video cameras. Taking the sponge rubber grip off the reflector end of the antenna will reveal four 1/4-20 tapped holes. I used a hole that resulted in the 432-MHz elements being horizontal and the 144-MHz elements being vertical. The 1/4-20 bolt on the tripod can be attached to the Arrow now, but mounting it this way makes a very nose-heavy antenna, and a lightweight tripod is prone to tipping over. Thus, I took an 18-inch length of 5/8-inch aluminum tubing from an old discarded antenna, filled it with a length of 1/2-inch steel rod, and added a plastic end cap so it would look neat. I next inserted the tubing with rod about 2 inches into the reflector end of the Arrow, and I noticed the improvement in balance. I drilled a 3/8-inch hole in the 5/8-inch tubing and steel rod where the Arrow beam attaches to the tripod so that this counterbalance is locked onto the beam. I also notched the bottom end of the sponge-rubber handle where it would interfere with attaching to the tripod. The beam can still be handheld if desired.

I found the signal from AO-51 too weak for comfortable listening on my ICOM 910H or Kenwood TS-2000, so I added an inexpensive Hamtronics 432-MHz preamplifier (photo 2). This preamp is not moonbounce quality, but it amplifies the very weak signal from AO-51 enough such that AO-51 comes in S9 or better when the antenna and the satellite are pointing at one another. A short piece of low-loss 50-ohm coax runs between the 432-MHz connector on the Arrow and the input to the preamplifier. A longer piece, about 18 feet long in my case,

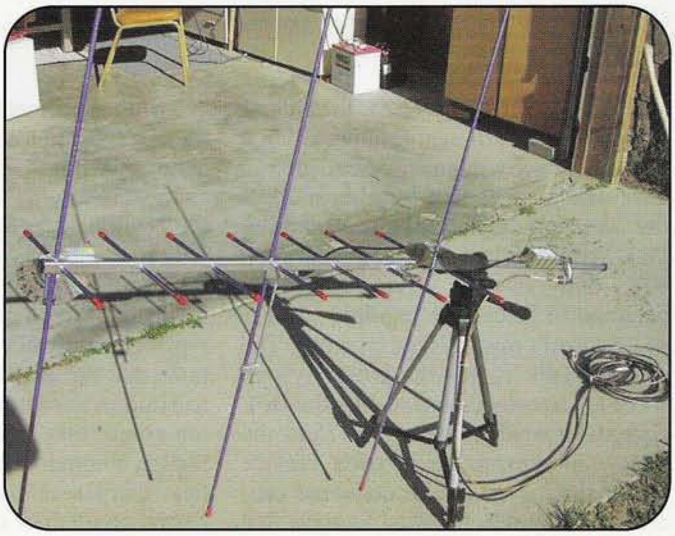

Photo 1. The Arrow antenna mounted on a tripod.

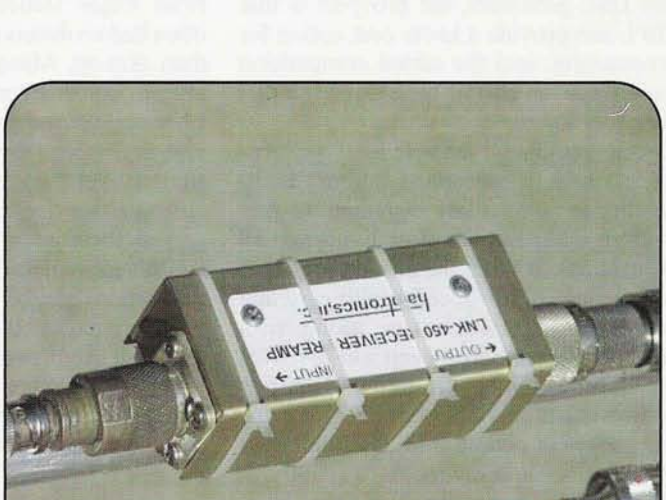

Photo 2. The Hamtronics 432-MHz preamplifier.

*27107 Richmond Hill Road, Conifer, CO 80433
e-mail: <robert@ultimatecharger.com>

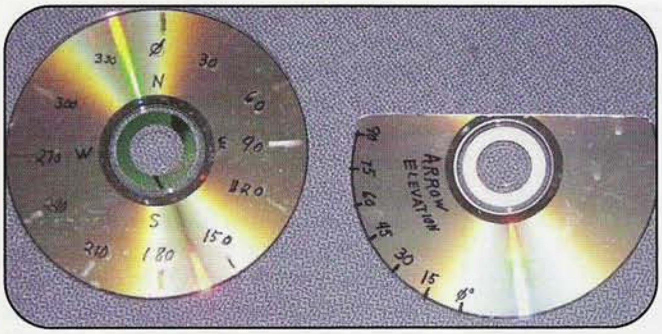

Photo 3. Unneeded CD-ROMs can be used to make an elevation indicator and an azimuth direction indicator.

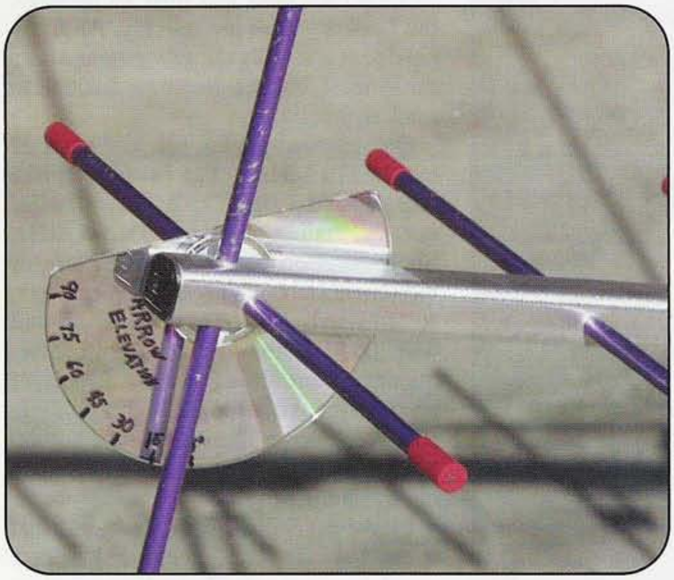

Photo 4. Hang the elevation-indicator CD-ROM disk on the antenna's front 432-MHz director, with the data side facing the boom.

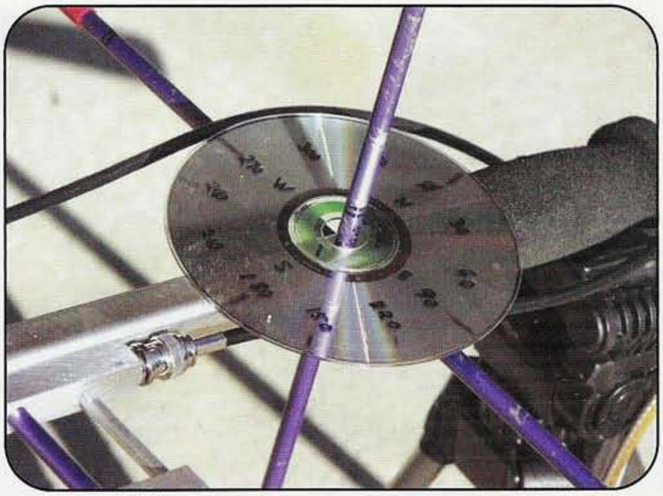

Photo 5. The azimuth direction-indicator CD-ROM disk can be slipped over one of the upper 144-MHz elements.

Photo 6. As an alternative, the azimuth direction-indicator disk can be placed on the ground.

runs between the output of the preamplifier and the antenna end of a bias tee. The bias tee puts 12 volts up the coaxial line to power the preamplifier.

Most satellite rigs have the ability to supply 12 volts up the coax to an antenna-mounted preamplifier or downconverter. The TS-2000 does not. A small RF choke in the preamplifier will also be needed for isolating the RF and the DC power to the preamp. Hamtronics has a kit with chokes and capacitor for making the bias tee and modifying the preamp.

Do you just throw away unneeded CD- ROMs? I use them for various useful purposes such as Christmas tree ornaments. An AOL CD-ROM with its top cut off (photo 3) makes a dandy elevation indicator. With a pair of scissors, cut the CD-ROM. Then hang the CD-ROM on the Arrow antenna's front 432-MHz director, with the data side facing the boom (photo 4).

Set the Arrow beam at horizontal, and place a small torpedo level with 0 degrees, 45 degrees, and 90 degrees bubble vials on top of the boom. Now, using an indelible marker, put a mark on the CD-ROM for 0 degrees elevation where the 144-MHz director is located. Put the beam at 90 degrees and put another marker where the144-MHz director is located. Do the same thing for 45 degrees. Take the elevation CD-ROM off and inter-

Photo 7. The small bias tee with Type-N connectors, which sits under the car's cigarette-lighter sockets and also supplies 12 VDC to the ClearSpeech DSP speaker when working HF.

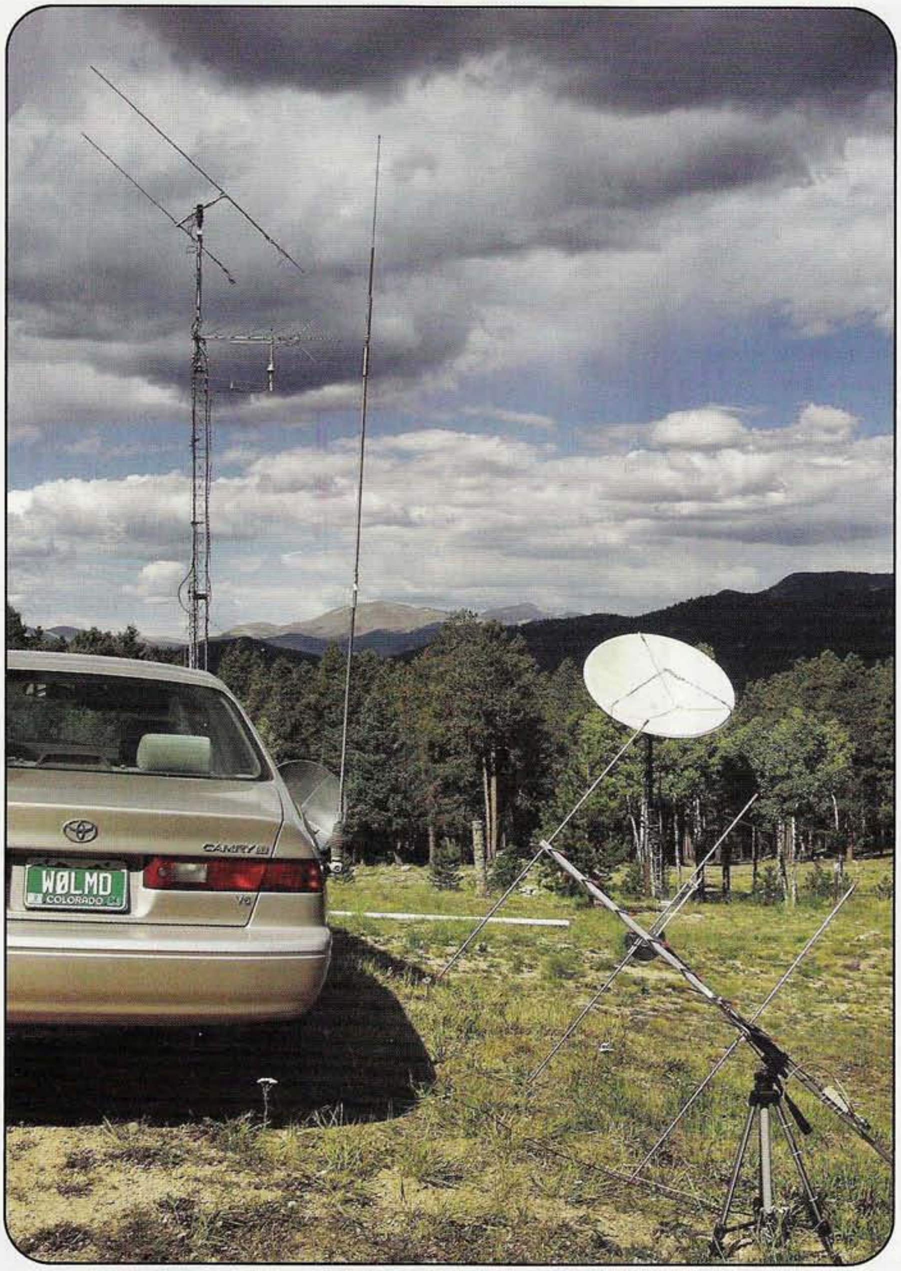

Photo 8. With this setup on his car, the author should easily be able to pick up AO-51 QSOs as soon asthe satellite rises above the horizon.

polate the 15, 30, 60, and 75 degrees points. Label the 7 points as "90 degrees, 75 degrees, 60 degrees, 45 degrees, 30 degrees, 15 degrees, and 0 degrees" as shown in the photos. The points will be slightly offset, since the 144-MHz director is about 1 inch offset forward from the 432 first director. Test your elevation disk by attaching the CD-ROM as shown in the pictures and setting the Arrow beam antenna to 45 degrees using the disk calibrations. Putting a bubble level on the boom should result in a centered bubble on the 45-degree bubble vial.

A second CD-ROM is used as an azimuth direction indicator. Using a standard protractor, put degree marks and calibrations on the data side of the CD-ROM from 0 to 330 degrees in 30-degree steps as shown. The azimuth disk can be slipped over one of the upper 144-MHz elements as shown in photo 5 or placed on the ground as shown in photo 6. Zero degrees is oriented toward the north in either case. If placed over a 144-MHz element, the direction is determined by the forward line of the boom. As the beam is turned, the 0 point on the beam has to be turned to face north to maintain calibration. The alternative azimuth pointing technique of laying the CD-ROM on the ground achieves calibration by facing the 0-degree mark on the CD-ROM toward north and then using the 144-MHz reflector as a coarse direction pointer.

In operation, first find true north. Then use some tracking program to find out all the bearings over your QTH. One person can read the tracking program, move the Arrow antenna, and operate, but it's much easier to have one person operating and another tracking and moving. Since a pass lasts less than 15 minutes, the fun is over all too quickly. An overhead pass is usually the strongest and lasts the longest, but it is the most difficult to track manually.

On overhead passes, set your receiver to 435.310 MHz in FM mode. Doppler will cause the signal to go down in frequency, ending at about 435.290 MHz. Short-duration passes at the eastern or western horizon have less Doppler effect, so you will find the satellite around 435.300 MHz, the nominal downlink frequency. Transmitting to AO-51 requires an FM signal on 145.920 with a 67-Hz subaudible tone. The 910H and TS-2000 can be made to operate AO-51 if taken out of satellite mode.

I have a TS-2000 with a remote head in my 1997 Toyota Camry car. I made a small bias tee with Type-N connectors (photo 7; a 820-pFd capacitor between the connectors and a very small inductor between the antenna connector and +12 volts from a cigarette-lighter plug works fine). This sits under the car's cigarette-lighter sockets and also supplies 12 VDC to my ClearSpeech DSP speaker when working HF. The 18-foot cable from the Hamtronics 432-MHz preamp goes to this bias tee, and a 3-foot lead from the bias tee goes to the 435-MHz Type-N connector on the back of the TS-2000.

Just before AO-51 rises above the horizon, after moving the car to a site where the whole pass can best be seen above the horizon, I set the Arrow up, pointing it in the AOS direction given by NOVA, my tracking program (photo 8). Then tuning around 435.300 to 435.310 MHz, in FM mode, internal preamp also on, I should easily be able to pick up AO-51 QSOs as soon as AO-51 rises above the horizon. I have also used this tracking system with a small 5-element 435-MHz beam with excellent results. Now if I can just figure out a way to make the antenna auto track while driving the car, I'll have it made! ■

A Dual-Band Flexi-Dipole

KA4LBE presents, in simple terms, the operation and construction of a portable, dual-band, flexible dipole antenna made by connecting center-fed dipoles in parallel at their feedpoints.

By Benson Smith,* KA4LBE

The connecting of two or more center-fed dipoles in parallel at their feed points is a method used by many hams. This parallel feeding saves feedline by requiring only one. For more information than is presented here, refer to several articles in the *ARRL Antenna Book.*[1, 2]

The purpose of this article is to discuss in simple terms the operation, pros and cons, of such an antenna system and to present a unique construction of the system. The author and XYL KA4LBD use a multi-band, parallel-fed dipole group spanning 160 through 30 meters that allows operation on harmonics through 12 meters. The system works very well.

A close-up of the completed antenna center area.

Construction

We will begin with the construction of a roll-up, two-band, portable, center-fed half-wave dipole. It is based on the use of TV-type 300-ohm twin-lead transmission line as the radiating elements. The twin lead[1] must be unshielded. The foam type is harder to use than the plain, flat ribbon type and offers no advantage in this application. Check to see that the type you plan to use is flexible.[3]

Our primary design goals were:

1. Build an antenna that does not require a tuner for effective operation.
2. Two-band operation.
3. Very portable, roll-up capability.
4. Easy to build.

Figure 1 shows a sketch of the antenna. Notice that the upper side of the twin lead has been trimmed to a shorter length (*B*) than the overall length (*A*). Because of the element spacing, it makes no difference if the shorter or longer dipole is on the top. The overall length is the dipole element for the lower frequency band, while the shorter length creates the dipole for the higher frequency. The two dipoles are fed at their centers as in all center-fed half-wave dipoles. We will limit our design to 6 meters through 70 cm.

An objection to this type of antenna is the loading on one of the dipoles from the other. With antennas built of separate conductors, tuning variations can occur if the wires move in relation to one another. Also, when building them using separate conductors, length predictability is poor. Using twin lead to create two-band operation overcomes these two objections, as the separation between element is fixed.

The overall length of a dipole is found by the formula:

$$\text{OA feet} = (492/Fo) \times K$$

where *Fo* is the design frequency in MHz and *K* is a combination of modifying factors (see text).

In so-called "free-space" there is no ground, no other conductors nearby the antenna, and the dipole is made of infinitely small diameter conductor. In that case, the value of the *K* factor in the formula above is one. Here on Earth we find totally different cases. Designing a dipole for HF and using conductors with diameters near that of AWG #12 copper wire and mounting this dipole in our atmosphere and at about 1/2 wavelength in height above ground and away from other conductors results in a *K* value of about 0.95.[4]

The *K* factor is then a combination of factors affecting the real-world length of the dipole. The common factor is related to the diameter of the radiator conductor versus the wavelength.[4] The dielectric constant of the surrounding environment is another factor. Yet another involves the distance to a ground return path. There are other factors, too. An important factor relates to inductive loading created by close distances to another conductor,

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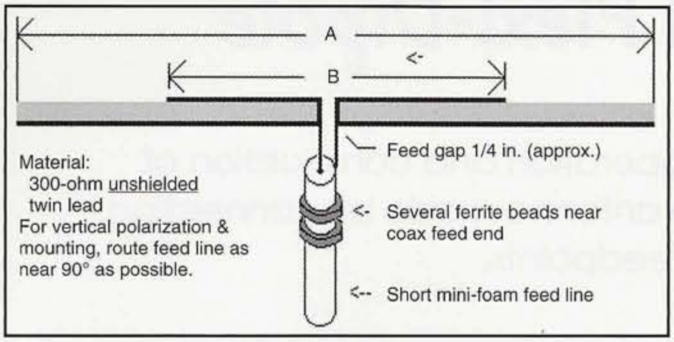


Figure 1. The multiband "Flexi-Dipole."

Center Frequencies (MHz)	IL (in.)	Length A (in.)	Length B (in.)
51 & 144.1*	112	105.25	33.75
53 & 146.5*	110	100.625	33.25
53 & 223.5	110	101	21.625
53 & 445	110	101	10.5625
51 & 425	112	105.25	11.1
146.5 & 445	44	36	10.75
144.1 & 425	44	36.625	11.25
146.5 & 223	44	36	22.5
223 & 445	36	23.625	11.125

**VSWR may be unacceptable (see text).*

Table 1. Initial length (IL) of the twin lead for several dual-band antennas.

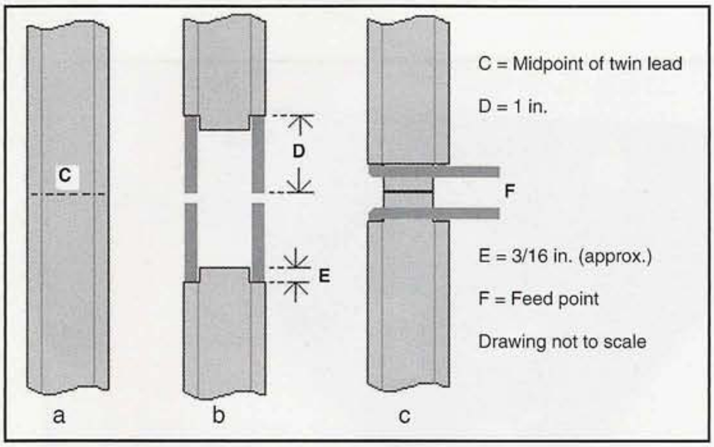


Figure 2. Feed-point construction.

especially if that second conductor happens to be resonant at the operating frequency. If you experiment, and I hope you do, keep this in mind. In developing the "Flexi," values of *K* from about 0.91 to 0.78 were experienced.

When the longer dipole's length is an odd harmonic length of the higher frequency, there is another objection to this design. When this occurs, the longer dipole and the shorter one are both resonant radiators at the higher frequency. The result may be a high VSWR at the higher frequency due to the low equivalent feed impedance. An analogy can be made by placing two resistors in parallel. The equivalent or resulting resistance is lower than the lowest of the pair. A dipole that is an odd harmonic of the higher frequency may not have a feed impedance of 50 ohms. In this situation, the equivalent (load) feed impedance can produce a VSWR that may be too high to accept. Spacing and other parameters enter into the calculations. In our designs, this problem becomes a question of acceptance only with a design of a 6-meter plus 2-meter pair. We will touch on this subject again later on.

One of our goals was portability. The choice of coax type and length is an important decision. The length should be only as long as required for deployment of the antenna Plan on mounting the antenna a bit higher than its overall length. Add a short distance to this. All of ours were made using 15-foot lengths of coax. Ours used RG-8X, since loss at this length can be accepted.

Step 1 in construction of a Flexi-Dipole is to measure an initial length, *IL,* of the twin lead. Table 1 gives this length for several dual-band antennas. These lengths may require some slight trimming if the builder uses twin lead other than the type used by the author.

The listed length of *IL* in Table 1 is slightly greater than the total length given in the calculation. This is to allow preparation of the center feed point. Any other design should add a short length (a couple of inches or so) to the calculated overall length.

Step 2 is the construction of the center feed point. This is shown in figure 2. Find and mark the halfway or mid-point of the initial length of twin lead. The easiest method is to hold both ends flat together and mark the point where the fold occurs. This is point *C* on the drawing, figure 2a. Cut the twin lead squarely at this midpoint (*C*).

The next step is to prepare the two ends which become the feed point (figure 2b). Trim the ends, exposing the conductors as shown. The center short tab, *E,* is to be cut as shown. The two tabs will produce the feed-point spacing desired.

Prepare the center insulator as shown in figure. 3. I used a scrap 2 ×4-inch piece of glass-epoxy printed circuit board. It was prepared by first removing all of the copper foil. Plexiglas was successfully tried as well. An alternate method of constructing a center insulator for twin lead can be seen in the previously noted *ARRL Antenna Book.*

The holes shown in figure 3 are for passing short pieces of nylon cord or plastic tie-wraps, which are used to tie down the twin lead and coax while cement dries. We will note the use of nylon cord for this purpose. The two twin-lead sections are placed across the top, and four short pieces of cord are—two on each twin-lead section. The coax is placed on the lower center area. Two pieces of cord are on the coax. Figure 4 shows a completed antenna center area.

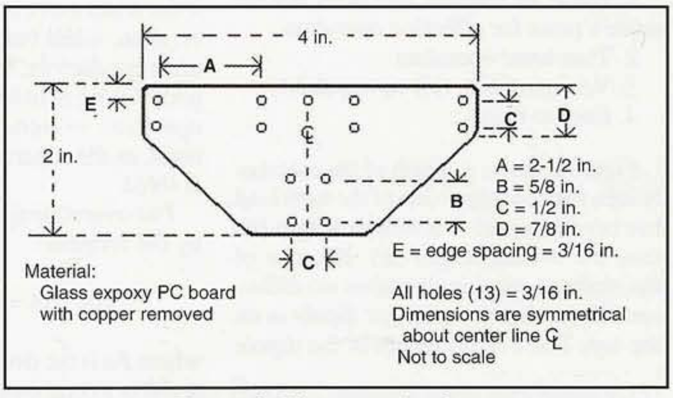


Figure 3. The center insulator.

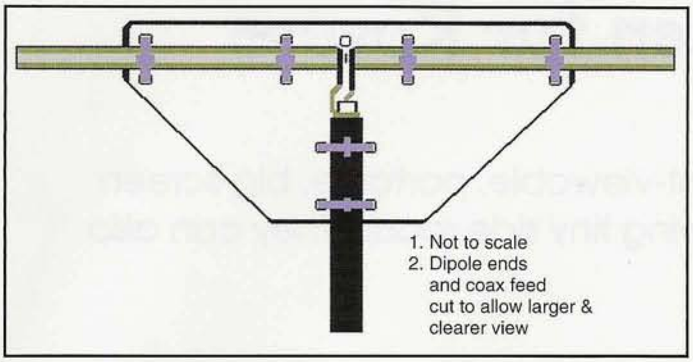


Figure 4. Attaching the coax and twin lead.

Thread four short pieces of nylon cord in the four hole-pairs for the twin-lead sections. Then set the center insulator flat on a piece of waxed paper. Flare the protruding cords upward from the upper holes and downward from the lower holes. Apply a liberal amount of "Goop" or similar cement to the left side twin-lead area. Place one twin-lead section there. Make certain the short tab, *E,* extends to the center, and the twisted conductor faces downward. Now tie the two cords tightly over the twin-lead section. Attach the remaining section of twin lead in the same fashion. See that their tabs, *E,* touch each other at the center of the insulator. Set aside the assembly to allow the cement to thoroughly dry.

The feed coax is first prepared by baring about one inch of center conductor and forming a twisted conductor separate from the shield. Bend the center conductor slightly to one side, opposite that of the shield. Thread two short cords from the rear of the center-insulator assembly through the four lower center holes. Fan these cord ends outward from the center. Apply a liberal amount of cement to the coax area. Lay the coax on the cement with the top of coax outer cover just slightly above the top cord. This should result in placing the two sets of coax conductors and twin-lead conductors in close, overlapped working distances. Set aside the assembly to allow the cement to dry. When the adhesive is fully cured, twist the mating conductors together and apply solder. The coax center conductor connects to the twin-lead pair of one side. The coax shield connects to the opposite side twin-lead pair. Be careful not to melt the plastic or adhesive. Trim off the excess leads.

It is now time to trim the two-element pairs to lengths *A* and *B*. See Table 1 for lengths of frequency pairs of your choosing. You may find it preferable to add a bit to the suggested length and then trim the finished antenna. Refer to figure 1. Lay the antenna out flat. Divide the determined length of *A* by 2. Measure off this length from the center of the feed point towards one end of the antenna twin lead, marking this point. Clip off the short piece of twin lead from this marked point to the end. Then measure from this clipped end towards the other twin-lead end, marking the point of the desired *A* distance. Trim the second end at the measured *A* distance. This should leave the overall (end-to-end) measurement to be *A*. A center hole at the upper center of the insulator was added as shown in figure 3. Use this hole to allow measurement from the center of the feed point.

Divide the distance *B* by 2. Measure this distance from the center of the feed point toward one twin-lead end. Mark this point. From this point measure the distance *B* towards the opposite twin-lead end and mark that point. Now carefully remove the section of the upper conductors from these last two marks to the ends. Refer to figure 1 for the pattern. Leave as much of the insulating plastic as you can.

Center-fed half-wave dipoles are balanced (feed) antennas and should be fed with a balanced feed. Coax is an unbalanced transmission line. I like to use ferrite or powdered-iron "beads" to act as a 1:1 balun by removing exterior shield RF currents from the coax.

I suggest the use of nylon twine or monofilament fishing line at both ends. Thread the cord through small holes in the insulating web area of the twin lead for hanging the antenna. These would form the required insulators.

This is a fine "hiker's special" antenna. The antenna might be used as the driven element in a wire multiband Yagi. I've included the dimensions for the 6-metes plus 2-meter pair even though the resulting 2-meter VSWR is a bit high (over 2:1).

Notice the dimension variations that occur on the same frequency, depending on the element being the longest or shortest of the design pair. For example, check 223-MHz lengths. This is due to inductive loading. ■

References

1. "Simple Twin Lead Antenna for HF Portable Operation," *The ARRL Antenna Book,* p. 15-1.

2. "Multiband (Center Fed Halfwave Dipole) Antennas," Chapter 7, *The ARRL Antenna Book,* p. 7-1.

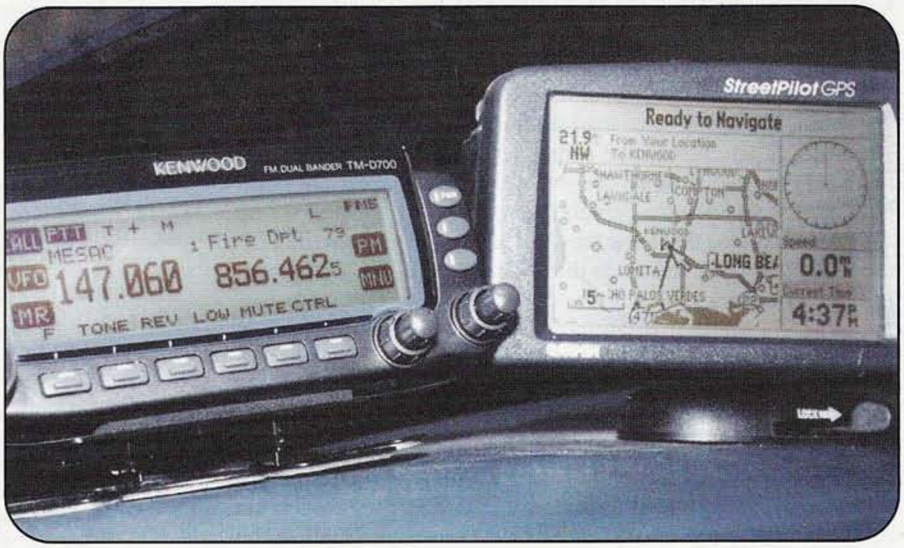
3. Twin lead used was RS-15-1158 (good flexibility) and RS-15-004.

4. "Antenna Fundamentals," Chapter 2, *The ARRL Antenna Book,* p. 2-1.

Big(ger) Screen for Rovers

There are new, incredibly fast, daylight-viewable, portable, big-screen GPS displays with detailed maps showing tiny side roads. They can also feed your APRS radio and TinyTrak.

By Gordon West,* WB6NOA



The Garmin Street Pilot® was the choice to tie into the ham APRS.

You have to appreciate all that VHF rovers go through to work multipliers. Their vehicles are loaded with beams and dishes, ready for an almost instant deployment when they finally get to the next hot spot. Inside the driver's compartment is all the communications gear, plus a dedicated VHF rig specifically for squawking automatic position reports. Feeding the APRS system might also be direction-finding and mapping software on a laptop. In addition, there is the trusty GPS unit.

The Garmin portable GPS is just such a unit. Garmin, along with Magellan, is celebrating over 25 years in the field of GPS. Both companies almost simultaneously broke the $999 price point for a civil (non-military), portable GPS receiver. Garmin was also the first to produce GPS equipment that would read out Maidenhead grid locators. In addition, for our 10-GHz gang, the "ham friendly" GPS also includes 5th and 6th sub-grid characters, pulling down the locator to within about 4 by 3 miles.

All of the Garmin units output the required NMEA 0183 data string for APRS connections. The least expensive units give you just numbers, and a step-up might give you GPS numbers plus a base map of big highways in the U.S. The next step would be the 2.2-inch wide by 1.5-inch high horizontal screen, which is capable of CD upload to show small streets and the big highways where you next plan to rove.

However, the Garmin unit of choice is the Street Pilot, with a larger, 3.3-inch wide by 1.7-inch high screen that includes a compact flash card to download CityNavigator CD-ROMs, allowing one to load in upcoming VHF roving areas. Garmin's latest version, Street Pilot 2610, features a brilliant color screen and even voice prompts to keep you on track for that secret VHF/UHF rover hot spot. I have a Garmin Street Pilot, and for just under $999, I figured this would be my ultimate rover navigator tool—that is, until I saw the new Italian AvMap, 12-volt DC, GPS mapping navigator with an eye-popping color, transreflective, daylight-viewable, 5.6-inch display. It is only one inch in depth and comes with a suction-cup mounting bracket for near-instant, heads-up dashboard mounting.

The color display utilizes a relatively new marine-electronics technique of transreflective illumination, wherein sunlight actually *enhances* any wide-angle view of the display. However, most amazing is the Arm9 200-MHz processor, which lets you scroll up and down, or left and right, on the city map and not wait for an agonizing couple of seconds of blank screen redraw. It automatically determines which way you are scrolling to pre-load mapping in the buffer, and you literally can zoom from Florida to Virginia without having to wait for reload. For those of us who regularly go off-road, the AvMap runs on Tele Atlas map data turn-by-turn mapping software. Tele Atlas, based in Menlo Park, California, is the world's premier provider of digital map databases and real-time traffic information in the United States (www.na.teleatlas.com).

The AvMap display system is indeed ham friendly, and was developed by Luca Padroni, IZ5AXT, with the company based in Marina de Carrara, near Piza, Italy. The company provides state-of-the-art charting systems for C-Map USA, as well as Avionics charting equipment seen at the PilotMall.com aviation superstore, with similar-type aircraft equipment.

However, for the ham rover who needs a big, bright display that may quickly be

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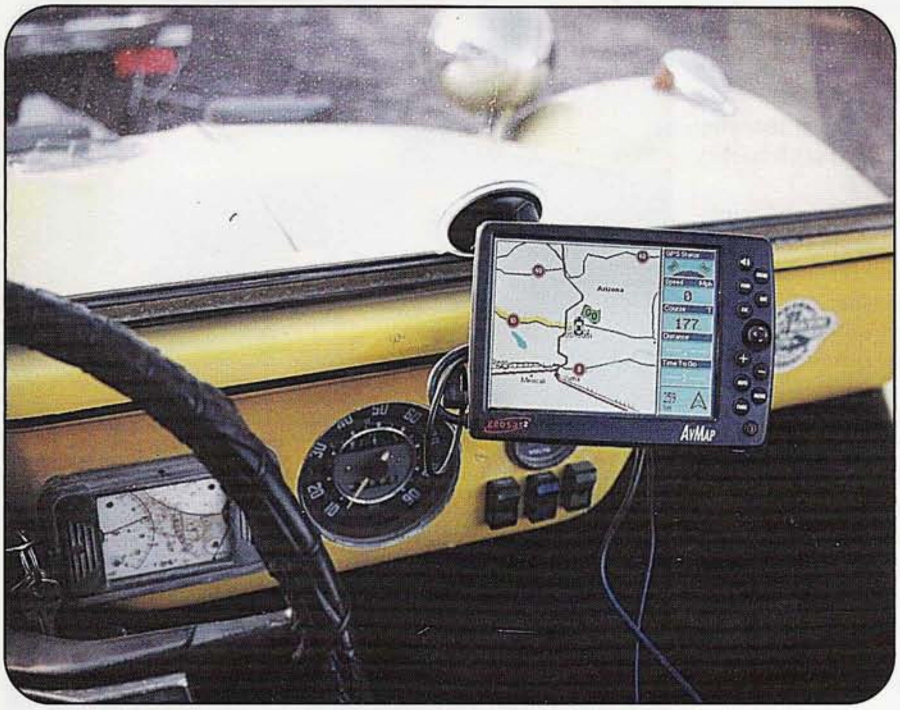

The new AvMap GPS mapping system offers a color transreflective screen for direct sunlight viewing!

moved from one vehicle to another, I recently tested with great success the AvMap at a ham/RV get-together in Quartzite, Arizona. It was an instant success, because it was the only unit that got all the way down to tiny-street and dirt-road levels. Best of all, though, the big(ger) screen is directly readable in sunlight, and all of the buttons are large enough so that you can easily rest your thumb on them as the rest of your hand is wrapped around the thin body. This lets you quickly search for a rover destination hot spot, electronically look for the nearest fast-food restaurant and calculate how many miles to get there, and then lets the AvMap take you to the destination. It does so by way of fun-appearing cartography (versus skinny straight lines) and voice prompts that keep you going in the proper direction when you come to big-road decision areas.

AvMap cartography shows the routes traveled in red.

I am still finding out a lot more about what this unit does other than just maps, point-of-interest locations, and moon and sunrises. It can speak in a couple of languages, keeps a chart-graph of your speed, holds planned routes to get you to your secret rover spot the night before (even when unplugged), and offers a USB port for PC connection for both uploading and downloading.

It also comes with four CD-ROMs of the United States, Alaska, and Hawaii. The GeoSend software allows you to update and transfer the mapping data from the CDs to the compact flash card located inside the AvMap. The supplied AvMap flash card is proprietary to C-Map USA, and you can order additional ones for about $95. However, you really don't need to, because loading-in new mapping regions through the USB port takes just minutes, and not hours as with other units! As I wanted a separate cartridge of Alaska, I have one for the United States West Coast, covering eight states, plus my Alaska card, also, so I don't need to erase my West Coast line-up.

Depending on which way you rove from state to state, you can load in regions with greater north-south coverage or greater east-west coverage. Soon we will hear of specific cities east and west, with corridor coverage on your travel from Ocean City to Ocean Beach!

For rovers, inputting latitude and longitude of a specific mountaintop is easy. Everything is done on the front keypad, and it even is backlit for nighttime operation. There also is no worry about disconnecting from the battery, as all of the information is saved without any 12-volt feed.

The GPS receiver is not built into the body of the AvMap! Everything is found in the hockey-puck-size, white antenna unit. The antenna/receiver comes with a magnetic mount that is plenty powerful enough to keep it in place. However, if it is stolen, the 12-channel GPS antenna/receiver is available separately from C-Map USA (www.avmapnavigation.com). It is a ceramic-patch design, gain of about 23 dB, noise figure of 2.0. It is absolutely waterproof, and the NMEA datastream is easily intercepted within the interconnect cable. Use the AvMap white and green wires to feed your TinyTrak or GPS-ready

Kenwood D700 or D7, or the ICOM or Alinco radios with the packet board installed. The AvMap manufacturer in Italy is soon to provide a convenient pigtail that is part of the GPS plug-in assembly. AvMap also has capabilities of accepting data *in,* so your APRS hits may also be located on the AvMap mapping screen! This will help you keep track of fellow VHFers who may be trying to rove to your same mountaintop!

The GPS receiver comes from the Silicon Valley and is infinitely more sensitive than most other mobile units I have tried on my tech bench. AvMap typically comes up on a warm start within 10 seconds of turn-on. Many of the other GPS equipment, inside my house, may take up to 3 to 5 minutes. AvMap typically would show seven satellites tracked *inside* my house, and my other GPS equipment might show only two or three, barely out of the noise. I am sure a lot has to do with the patch antenna and receiver sensitivity of AvMap versus a quadrifilar antenna design in my other units. You will be *very* impressed at how quickly this will start navigating on either a first-time cold start, or the more common next-day warm start.

For our recent 10-GHz mountain-topping, we went to some areas where there were absolutely no roads. We turned on the tracking mode, and it faithfully gave us our own entrance and exit to where we had set up. When we went back down the hill, our tire tracks and reverse route were absolutely on top of one another!

AvMap on the dashboard working the APRS radios, too.

Down the line I would expect TeleAtlas to offer AvMap topographic charts, probably in about six months. We may also see Maidenhead grid locators pop up on the screen, in addition to latitude and longitude down to the radius of a 6-foot circle.

No, it's not waterproof, so keep the display out of the rain. Other than that, I can't wait to see what mapping software groups will do next for on-screen travels. Wouldn't it be a trick to get a one-minute conversation about the local surroundings as you're headed down the big interstate? "On your left are the green lush hills, which have hundreds of caves for exploration . . . and on the right, our state's tallest 5,000-foot peak with a small paved road access to the top."

Hmm. Maybe it's a good spot to check for some VHF/UHF contest?

I understand that Ham Radio Outlet has signed on as the big dealer for this equipment. The suggested retail price of $999 includes all of the equipment, four CDs, computer cable, and that very hot GPS receiver/antenna system. Check it out at <www.hamradio.com>, and see one in action at an upcoming hamfest. Once you see the screen and how simple it is to hook it up, you will want one. I bought two, and I don't drive anywhere without one on the dashboard! ■

Flight of the Near-Space Pirate 2004C (NSP04C)

In the last issue of *CQ VHF,* WØZC covered the Great Plains Super Launch of 2004. In this issue, KD4STH discusses his payload, which was attached to one of the balloons launched.

By Paul Verhage,* KD4STH

On the 2nd and 3rd of July 2004, I attended the largest get together in the field of amateur near-space exploration, the Great Plains Super Launch (GPSL). The 2nd was a fun day, with opportunities to meet with the movers and shakers of the amateur near-space community and hear their presentations on topics related to this exciting field. Saturday the 3rd, however, was an even better day because of the six near-space launches that took place. In this article I will share some aspects of that Saturday with you. I'll explain the configuration of the "near spacecraft" that I launched and the results it returned. Along the way, I'll introduce you to some of the people who helped make GPSL and my flight a success.

My Little Near Spacecraft

I use a very modular design for my near spacecrafts. This design lets me take advantage of the benefits that come from standardization, thereby keeping the airframe and avionics weight low. The two modules in my near spacecraft for GPSL 2004, Near-Space Pirate 2004C (NSP04C), were the Copernicus II and the Eratosthenes (I like naming my modules after astronomers). Both modules were connected with Spectra kite line, but unlike many of my previous flights, no umbilical for data or power connected the two modules. I used a homemade 5-foot diameter parachute for recovery and a 1500-gram balloon for lift. A 1500-gram balloon is not the most frequently used balloon, but it is still fairly common in amateur near space. From the top of the filled balloon to the bottom of the lowest module, my stack was approximately 50 feet tall. This was a rather big beast.

The Copernicus II module carried a flight computer (which I call the Central Computer Programmable Sequencer, or CC/PS for short). The CC/PS is built around the Basic Stamp 2 plus (microcontroller), a Maxim 186 (8-channel, 12-bit analog to digital converter), Tiny Trak 3 (APRS tracker), and a RAMPack B (non-volatile memory for science data storage). My GPS receiver is a Garmin GPS35, and the radio is an Alinco DJ-S11, 340-mW, 2-meter HT. Inside the Copernicus II were a Geiger counter, a micro-weather station, and an APS camera with a 40-exposure roll of film. Also, I placed two T-shirts and several ounces of plant seeds inside the module.

The Eratosthenes module acted primarily as a back-up APRS tracker. Like the Copernicus II module, it carried a Tiny Trak 3 along with a Garmin GPS35 and Alinco DJ-S11. Above the APRS tracker I placed a Hitch Hiker, an experimental data logger that I am developing. On this mission, the Hitch Hiker

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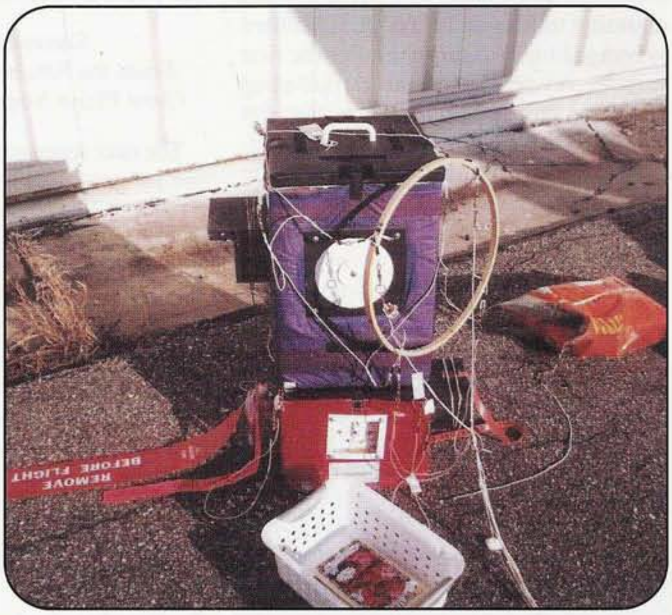


Photo A. The purple Copernicus II and red Eratosthenes modules sitting on the tarmac while the balloons were being filled.

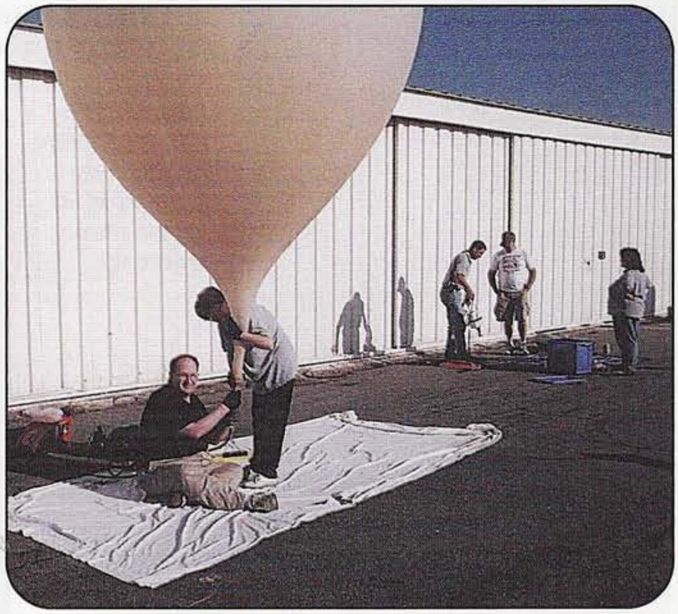


Photo B. Filling the author's 1500-gram balloon.

recorded data from a second weather station and operated a digital pencam. The Hitch Hiker also operated a release mechanism for a surprise during this flight. Finally, I tossed a commercial data logger into the Eratosthenes, a Hobo data logger, and connected a temperature and light sensor to it. Suspended below the Eratosthenes was my second surprise for Kansas, and I'll describe it a bit later in the article.

Surprises for GPSL 2004

I am a Kansas expatriate who currently lives in Idaho, where I teach electronics to high school students. Because I was returning to Kansas for GPSL, I decided to bring along two surprises. For the first surprise, my near spacecraft carried a bag of potato chips. The idea was that the potato-chip bag, which was sealed airtight, would expand in volume as the atmospheric pressure decreased during the balloon ascent. Like an over-inflated balloon, the bag eventually would burst and shower the landscape below with potato chips. To ensure that the potato-chip "bomb" worked properly, I flipped the bag upside down and taped over the bottom seal. This strengthening of the bag was to ensure that the weakest seal was now at the bottom of the bag.

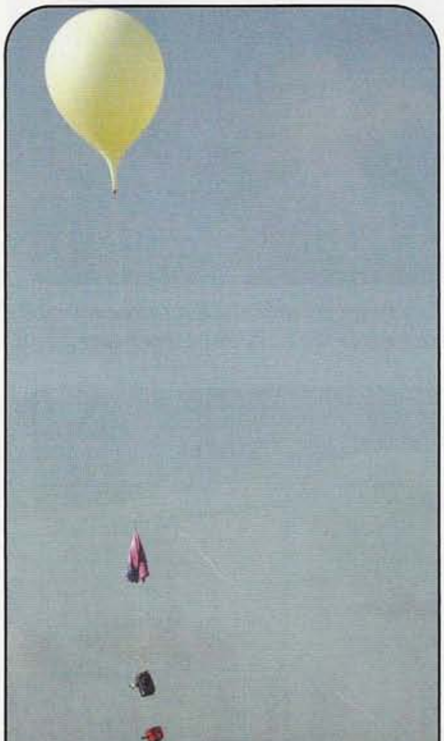


Photo C. Shari Conner, K9XTN, caught the author falling down on the job!

My second surprise was a stack of propaganda leaflets. A servo inside a release mechanism was connected to the Hitch Hiker. The Hitch Hiker was programmed to command the servo to pull back a pin in the release mechanism after about 50 minutes of flight. This would let the dozens of leaflets fall back to Earth. The leaflets were printed on bright-red paper and had the following message:

Surrender Kansas
From the forces of airborne Idaho
Great Plains Super Launch 2004

The near spacecraft was test assembled and programmed before I left Idaho. At GPSL, all I had to do was reassemble the modules in the near-spacecraft stack and help my launch crew fill the balloon. Before we could launch, though, we needed a weather report and a winds prediction, which fell to Mark Conner, N9XTN, of NSTAR. Before Mark could give his weather report, GPSL 2004 needed a place to meet and launch. That task fell to Zack Clobes, WØZC, of Project Traveler. Because of their terrific support, I was able to focus on getting my near spacecraft launched.

Saturday's Launch

Saturday morning was sunny with just a few clouds. Because the surface winds were almost non-existent, it was easy to fill and launch a weather balloon that morning. Helping me fill the balloon were Troy and his wife, with Don Pfister's HABITAT near-space program. This was their first flight, so this was also a training session for them. In the near-space biz, we're always happy to have novices and give them training.

It took about an hour to fill all six GPSL 2004 balloons. Afterwards, the teams carried their stacks out away from the hanger and to the tarmac for launch. The tarmac was a large open area from where we could launch the balloons safely, knowing that there were no aircraft nearby. On the tarmac, my launch crew, which had grown in size because of the recruiting of some nearby spectators (didn't I tell you we like to have novices join in?), raised the stack to its full height on lanyards. After raising the stack, the lanyards were used to hold down the stack. Now we merely waited for the word to launch before releasing the stack from its lanyards. Project Traveler released first. They launched first because their near spacecraft carried a camera, and it was hoped that they could record images of the other balloons on the ground as they drifted over us.

Just after the Project Traveler balloon passed overhead, and the word was given to the rest of us to launch. My crew quickly released the final lanyard holding down the near spacecraft. Instead of the gentle liftoff that I'm accustomed to, I watched my near spacecraft begin falling to the ground. I realized that the last lanyard had snagged the metal ring around the balloon nozzle and couldn't let go. Before my modules could be damaged from impacting the ground, I tried to grab the bottom module. Did you know that

Photo D. Mark Conner, N9XTN, calling in the recovery of the author's near spacecraft.

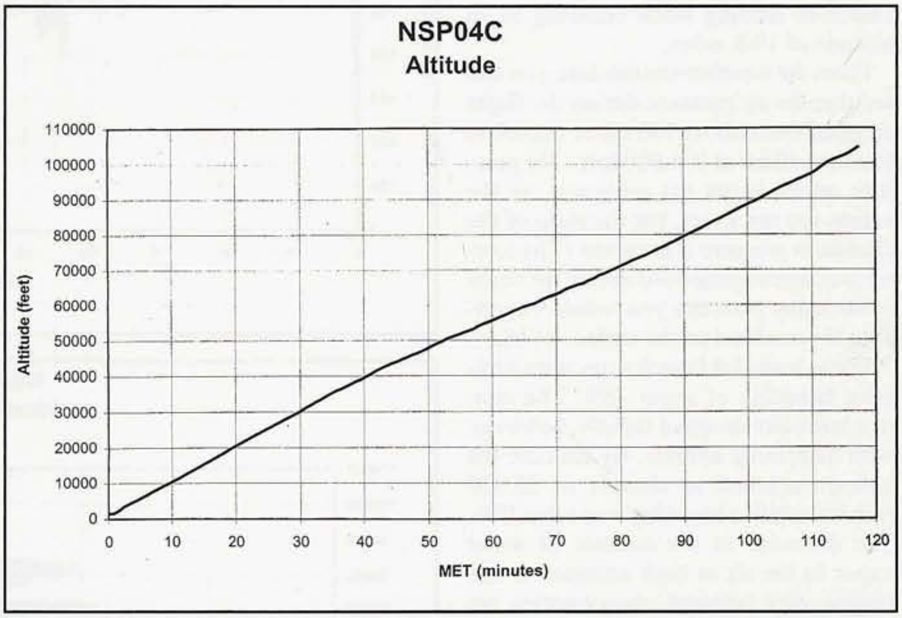
airports leave ropes lying around the tarmac? These ropes are used to tie down aircraft during high winds. Did you also know that when you run backwards over a rope, you can slip? I didn't discover this until that Saturday morning. Instead of trying to grab my near spacecraft, I was trying to grab the ground before the rest of me landed on it. As I hit the ground, I watched the last lanyard finally release the near spacecraft and the stack rise skyward. In the end, my running and slipping were for naught. Everyone was watching the six near spacecraft lift off, so I expected that no one saw my fall. I was wrong.

After this minor embarrassment, the rest of the flight went very well. For the chase, I rode with Mark, Shari, and their baby daughter. Forming the remainder of our caravan was Paul McCrone, KCØKXR. Because the wind speeds aloft were so low, we had plenty of time to stop at a restaurant while we waited for the balloon to burst. The ascent to over 100,000 feet took less than two hours.

After the balloon burst, we updated the near spacecraft's landing prediction and drove off to get as close to it as the roads would allow. We had about an hour before touchdown, so it wasn't difficult. The combination of our prediction, tracking skills, and the roads was good enough such that we managed to catch a glimpse of the descending near spacecraft under a full parachute from less than a mile away. Mark and I used his GPS receiver to guide us to it. It was recovered in pasture land only about 1000 feet off the road.

Good Results

My near spacecraft weighed 10 pounds, and its balloon carried enough helium to ascend at about 800 feet per minute for most of the flight. You'll notice in the altitude chart, however, that the ascent rate was a little higher for the first 30 minutes of flight. This is typical, although not fully understood. The balloon reached an altitude of 104,571 feet



before bursting. At 100,000 feet we could see the balloon as a small dot in the sky. With binoculars, we saw the round shape of the balloon, its translucent color, and the reflection of the Sun off its surface. The balloon passed through 50-mph winds at 20,000 and 90,000 feet. The rest of the flight experienced very mild winds. As a result of the low speed winds, my near spacecraft flew only 21.5 miles from launch to landing while climbing to an altitude of 19.8 miles.

From the weather-station data, you can see that the air pressure during the flight dropped from about 910 mb at launch to less than 10 mb at 104,000 feet. (My pressure sensor is not yet calibrated, so the values are not exact, but the ratio of the change in pressure is accurate.) The lowest pressure experienced during the flight is the same pressure you would experience if you stood on the surface of Mars.

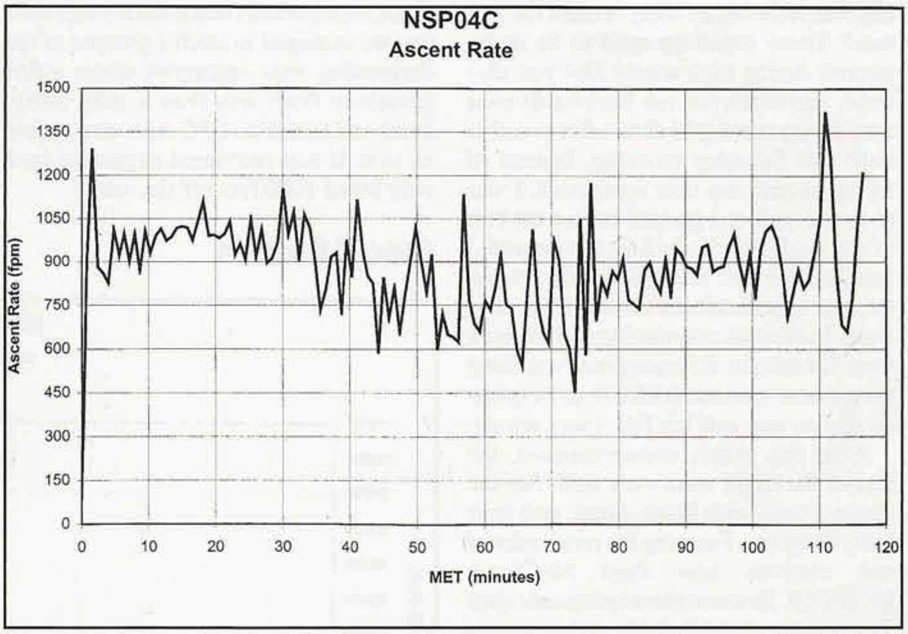
It was humid at launch time, with a relative humidity of about 78%. The relative humidity dropped rapidly, however, with increasing altitude. By the time the balloon reached an altitude of 25,000 feet, the relative humidity was a dry 25%. The decrease in the amount of water vapor in the air at high altitudes is one reason why infrared observatories are placed on mountaintops.

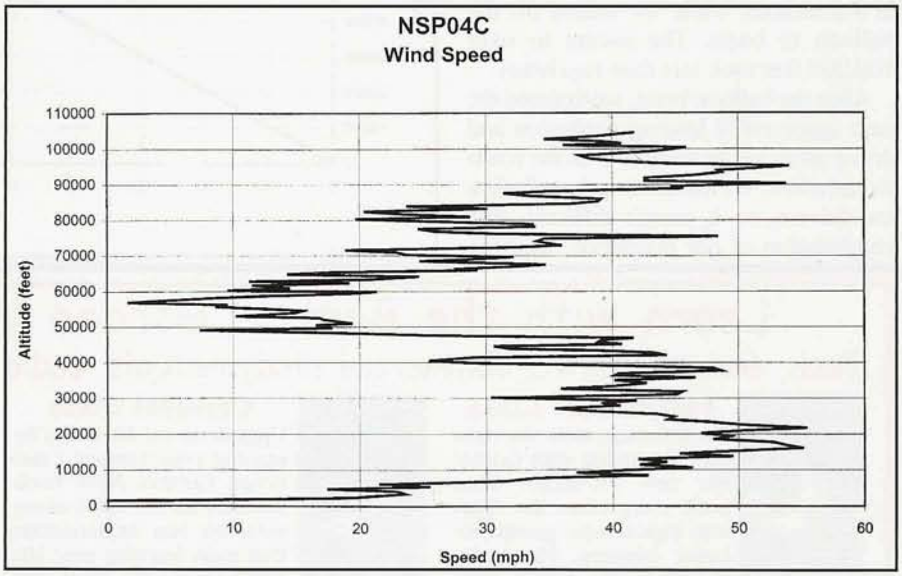
The air temperature at launch was in the upper 80s. By the time the near spacecraft reached an altitude of 58,000 feet, the air temperature had dropped to –40° Fahrenheit. This was not quite as cold as I had expected, and it occurred at a higher altitude than I usually see.

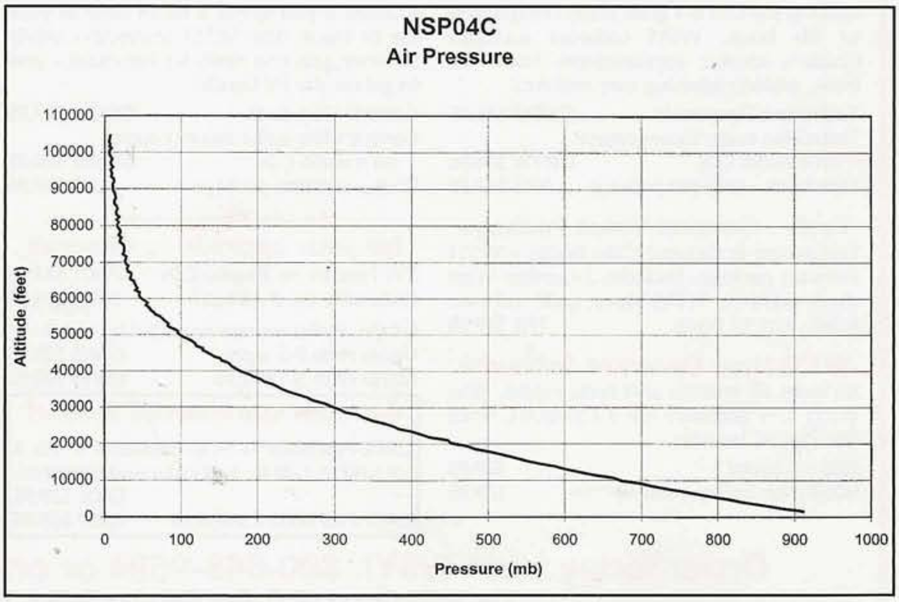
The Geiger counter measured an increasing cosmic ray flux as the balloon climbed higher into the atmosphere. As expected, the cosmic ray flux rate peaked out at 62,000 feet with a flux of 800 counts per minute. Our atmosphere shields us from cosmic rays, so as a near spacecraft rises, there is less shielding atmosphere above it to filter out the cosmic rays. At an altitude of approximately 62,000 feet, the cosmic ray flux decreases, because the Geiger counter begins to see more of the original cosmic rays before they can create many secondary cosmic rays through collisions with molecules in our atmosphere.

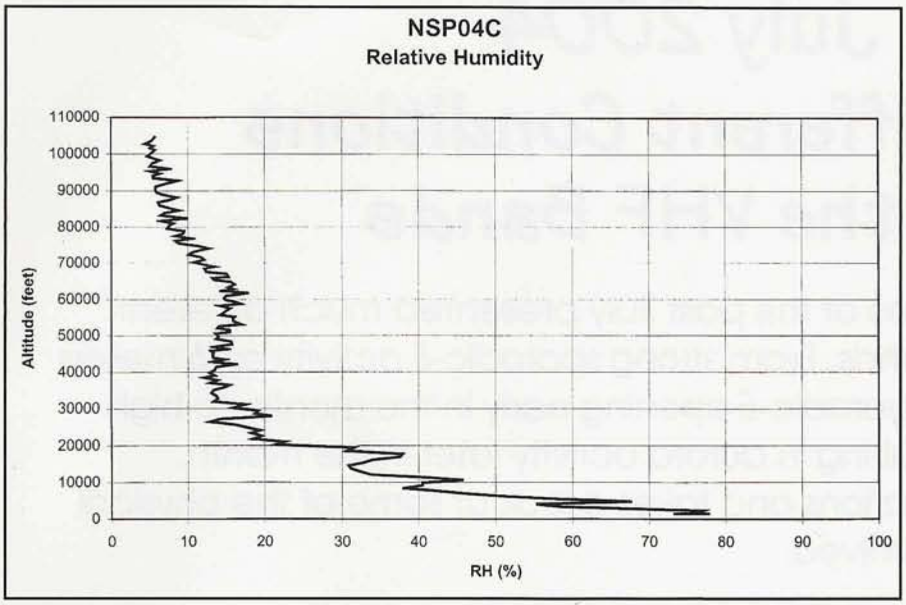
Less-Than-Spectacular Results

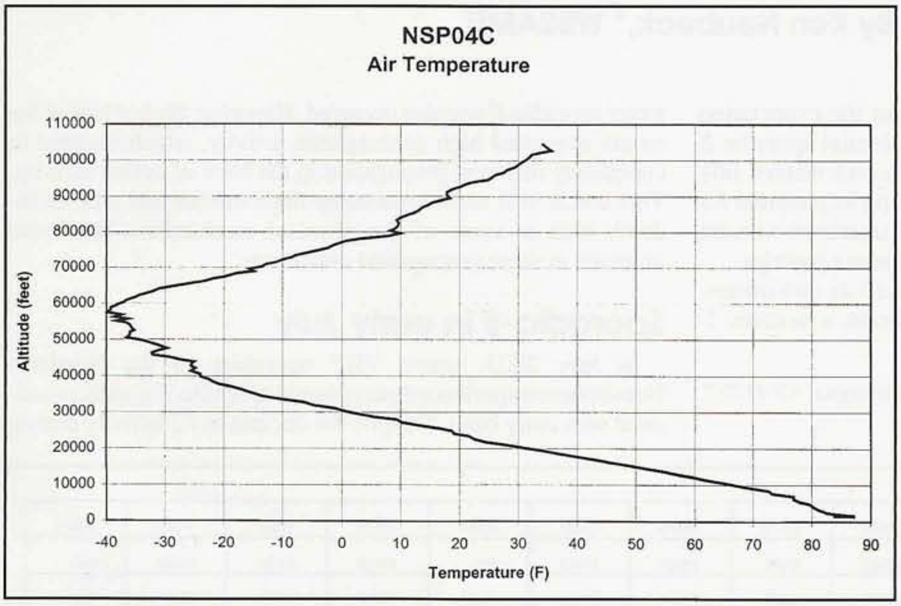
The APS camera took photographs during the flight, but its module was aimed far enough above the horizon such that the photographs show very little of











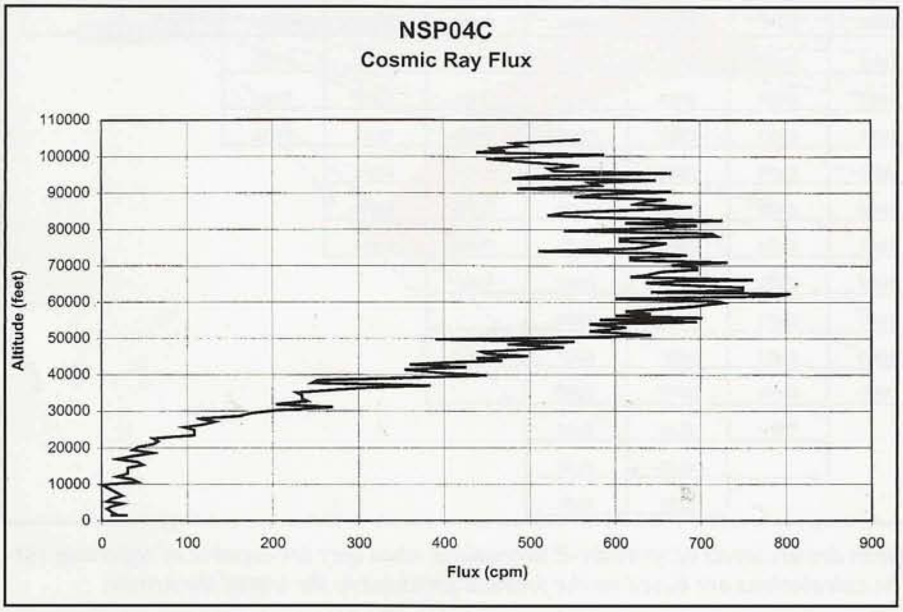


Photo E. Near-space potato chips anyone? (Photo courtesy of Zack, WØZC)

the Earth and lots of blue sky. The Hitch Hiker appeared to have had a dead battery, as it didn't operate at all during the flight. The light sensor from the Hobo was accidentally pulled out, so it didn't generate data. The leaflets were not on the near spacecraft when it landed. However, the drop pin had not been released either. Apparently, the leaflets fell out of their harness on their own. The potato chip bag? The bag did burst. Unfortunately, the bag burst at the top, so only air escaped from the bag. Overall, I'd say it was just another typical amateur near-space flight. The potato-chip bomb didn't work, but well, there's always the Great Plains Super launch 2005.

Final Notes

Parallax and *Nuts and Volts* magazine were sponsors of GPSL 2004. Because of their generous support, we were able to hold two competitions this year. The first-place winner was EOSS for the best landing prediction and for the highest altitude achieved. Second place was awarded to Project Traveler. Congratulations, guys. Let's have a showdown next year.

OnSet Computing, the manufacturer of the Hobo data logger, has created the OnSet Prize. The highest altitude flight achieved by amateurs with a weather balloon during 2004 will win a four-channel data logger, temperature sensor, and programming software. The author is keeping track of the highest flight and will announce the winner in December. If you are interested in participating, please let me know. Your altitude must be verified with an onboard GPS receiver. Good luck!

July 2004
Very Different Conditions on the VHF Bands

The first and second halves of this past July presented much different conditions on the VHF bands. From strong sporadic-*E* activity on 6 meters and a fantastic 2-meter sporadic-*E* opening early in the month, to high geomagnetic activity resulting in aurora activity later in the month, WB2AMU presents observations and takes a look at some of the physical mechanisms that were involved.

By Ken Neubeck,* WB2AMU

The arrival of summer always heightens the expectation level of VHF operators in terms of potential sporadic-*E* (*Es*) activity, particularly double-hop *Es* on 6 meters. July is usually the month focused upon, considering its potential for good conditions and the availability of VHF operators who are on vacation and visiting either rare grids or new countries.

As in previous years of strong sporadic-*E* activity on 6 meters, July 2004 began in a similar fashion. In addition, a fantastic 2-meter sporadic-*E* opening occurred. However, the last half of the month presented high geomagnetic activity, which resulted in completely different propagation in the form of aurora activity. This article will summarize some observations and take an in-depth look at some of the physical mechanisms that were involved in these propagation conditions.

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Sporadic-*E* in early July

In July 2003, many VHF operators in the Northern Hemisphere experienced exceptional sporadic-*E* conditions almost on a daily basis. Despite the decline in *F2* activity during

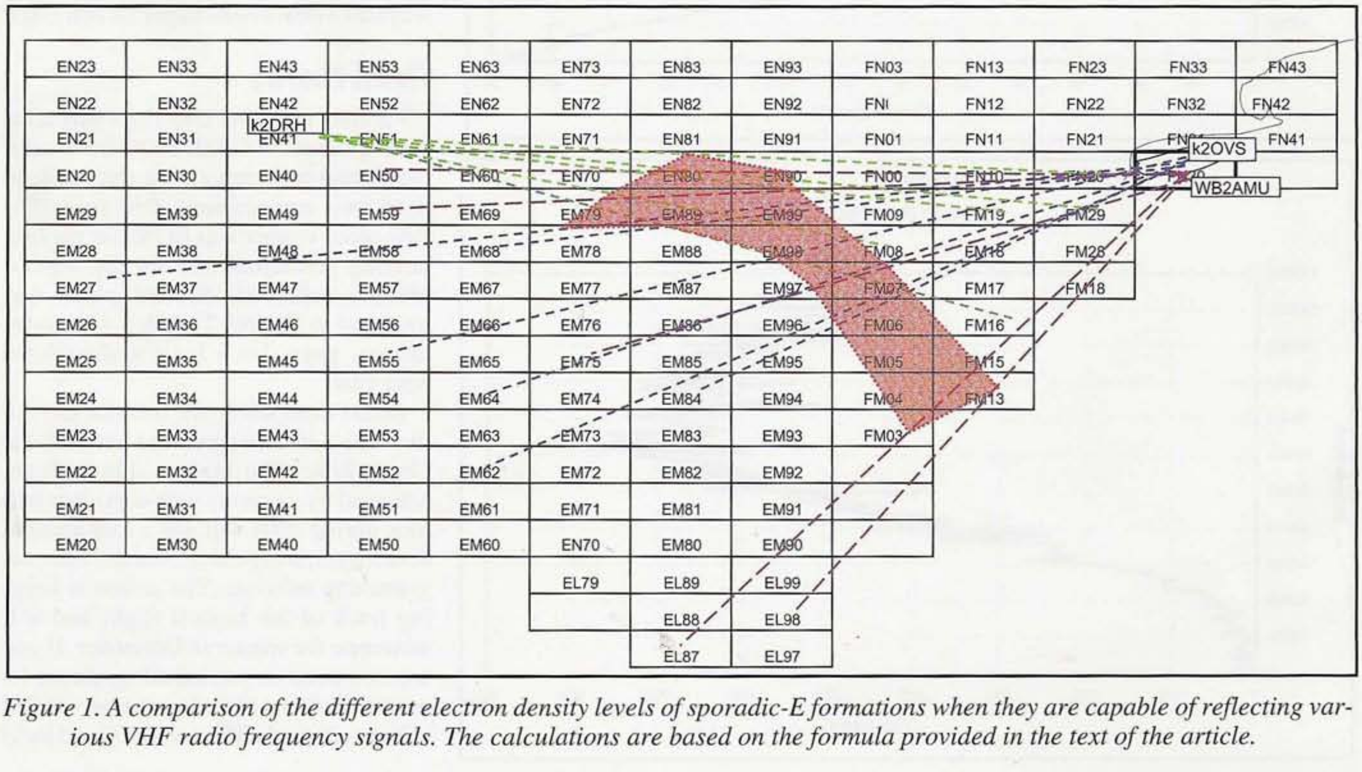

Figure 1. A comparison of the different electron density levels of sporadic-E formations when they are capable of reflecting various VHF radio frequency signals. The calculations are based on the formula provided in the text of the article.

the previous winter months, a fair amount of DX was present. July 2004 began in the same fashion.

Beginning on July 3rd, the 6-meter band was open to Europe just before 11 AM EST. At that time at my location in grid FN30, I worked both EH7KW in Spain and a special prefix for Portugal, CT14HZE. Finally, after very few transoceanic openings during the month of June, there was a decent opening from my area into Europe.

During the July 4th holiday the band was open into the southern states from my location, and a DX station, C6AGN, was heard running pile-ups. FP/N9OT was also running pile-ups from Miquellen Island. These conditions were expected at this time of year.

On July 5th things really got interesting. Again, the band was open to the south during the late morning hours. I had dropped off my wife at the mall, and I found a suitable tree in the parking lot to hang my portable 2-element Yagi for the purpose of feeding my Yaesu FT-100 in the car. I worked a handful of stations in the Georgia, North Carolina, and Tennessee areas. No doubt I could have worked some of these stations using my 1/4-wave vertical, but the Yagi gave a decent punch to the signal. Hanging it in a tree was worth the effort.

When I arrived back home, I heard a CW signal at around 50.095 MHz at 3:30 in the afternoon. I dropped my callsign. To my surprise, it was Mario, K2ZD, operating from Saba as PJ7M, which gave me a new country on 6 meters. By the end of July 5th, Mario and Jim, K4BI, had completed over 900 QSOs with 45 countries, and they continued to make many more contacts over the next few days. The action was so furious for the two operators that they had to have their meals served to them at the operating position! Both were CW operators, but they had to "relax" by going to SSB for a while. Their 569 signal very soon increased to 599. Then I heard NP3CW and other stations from Puerto Rico. Next I heard a fast CW signal on 50.103 MHz; V44KJ was cranking away at almost 40 wpm, but the signal was not very strong. After many tries, I finally got him, though.

At the same time I was working into the Caribbean, I was hearing a number of signals from Europe, such as EH7RM, EH7KW, and stations in Portugal. The 6-meter band was literally on fire! I had a major dilemma: Which way do I point my beam? Do I keep it pointed south for the Caribbean, or do I point it northeast for Europe? I ended up pointing it toward Europe, and I worked Jose, EH7KW. I heard CT1HZE, but because I had worked him a few days prior to that, I did not pursue him. The band was packed with signals.

Two big pile-ups ensued during the afternoon of the 5th—CN8LI on 50.210 and ZB3B on 50.180. They were massive because of the number of paths that were available at the time as a result of multiple sporadic-*E* formations. There were many stations screaming their callsigns. Well, it was nice to hear 6 meters sound like the 20-meter phone band.

July 6th was typical of days in July of other years when 6 meters was open all day to my location on Long Island in grid FN30. When I called a general CQ in the CW portion of the band, I suspected that it would be a special day. P43JB responded to my call, running 7 watts! Over the next several hours after that QSO, I made a number of contacts with southern states on 6 meters. By the time the day ended, 6-meter activity had become really interesting.

I made a short trip to my father's house. My father is Ray, W2ZUN. On the way to his house I continued to work stations with my mobile setup. When I got there, I looked at his TV, which was connected to an external antenna. Channels 2, 4, and 5 were completely obliterated by sporadic-*E* interference. This indicated that the maximum usable frequency (MUF) of the *Es* opening was going past 80 MHz and into the FM broadcast band, which starts at 88 MHz. There was even a trace of interference on Channel 7. At that point, I suspected that 2 meters would start seeing some activity.

On the way back home, I worked WB4MSG in North Carolina on 6 meters. Because of the distance between North Carolina and my location, it suggested a 2-meter opening. (I learned from other 6-meter operators that they had observed the same conditions in terms of the distance that was covered.) Because of what I had seen on my father's TV, I decided to pull into a park-and-ride lot, where I listened on 2 meters at 2200 Z. Incredibly, I was hearing a few stations! I rummaged through the trunk of my car to find a 1/4-wave, stainless-steel whip for 2 meters. After I pulled out the 6-meter vertical and laid it on the roof of the car, I quickly connected the 2-meter antenna. Normally I would have preferred to set up my portable 3-element beam, but there was no time to run home and get it, particularly if this was a typical 2-meter *Es* opening, which might last for only minutes. Then I cranked up the power to 40 watts and spun the dial on the rig.

I heard KX9X from grid EM59 in Illinois calling CQ, and after a few repeats of my call, he came back to me. My first 2-meter sporadic-*E* QSO! I started spinning the dial again. Next I had a short QSO with Ivars, KC4PX, in grid EL98 in Florida. I then realized that the vertical antenna was not necessarily the worst antenna for an *Es* opening, and just like on 6 meters, it is possible to make a fair amount of QSOs. I worked two more stations in Florida (KD4ESV and NW5E), another station in Indiana (N9LR), and W4HP in Tennessee. The QSO with W4HP required a second attempt, as the signal faded out after the initial comeback. Fortunately, he came back up in signal strength approximately two minutes later, and the QSO was completed. There were quite a few signals that were experiencing rapid QSB, almost as if they were 30-second meteor burns. However, some signals seemed to stay around longer.

Activity started to slow down a bit, so I decided to make a dash for home. In my haste, I forgot about the 6-meter vertical that I had just left lying on the car roof. I had traveled almost a mile before I realized what I had done! I turned back and looked frantically for the vertical, which was made out of stainless steel. This antenna had traveled many miles with me. During the trip back to the parking lot, 2 meters was still hot, and I worked KB4TCU, EM81, in Georgia with 59 signals on both ends using the 2-meter vertical. Despite walking up and down the streets along the path I had taken, I could not find the 6-meter vertical. The next day, however, I found the antenna approximately 1/4 mile from where I had operated!

By most accounts, the opening lasted over two hours, with some quiet periods during that time. Perhaps the density of the cloud was changing and not always supporting 2-meter reflections. Figure 1 shows the approximate required density of a sporadic-*E* formation for a 2-meter opening as compared to a 6-meter opening. This comparison can be accomplished with the formula used in radio physics to calculate the characteristic frequency or plasma frequency for radiowave reflection:

$$F_p = 9\sqrt{Ne}$$

F_p represents the plasma frequency in terms of Hertz, and Ne is the number of electrons per cubic meter. As can be seen in figure 1, the average density of a sporadic-*E* cloud that is capable of reflecting 2-meter signals is 850 times greater than one which can only reflect up to 6 meters. Remember that a sporadic-*E* cloud is not a uniform formation, so we are talking about average density here. Thus, it can be seen that the significant increase in electron density is why 2-meter sporadic-*E* openings are more rare.

This was the first major sporadic-*E* opening that I had the pleasure of working on 2 meters. Veteran VHF operators such as Jay, K2OVS, on Long Island (FN30), and Howard, WB4WXE, in Alabama (EM74), told me that this was the best 2-meter *Es* opening that they had ever experienced. WB4WXE worked as far north and east as grid FN41 (N1XZW), and K2OVS worked as far west and south as grid EM09, working NØLL. This seems to be true for many of the stations located in the eastern part of the U.S. I seem to recall that a tremendous *Es* opening took place about 15 years ago on 2 meters during the June VHF contest. It involved stations primarily in the southern and western states.

Figure 2 shows a plot that I made using the 2-meter log data from me in FN30, from K2OVS in FN30, and from Bob, K2DRH, in EN41, for a 25-minute period at the beginning of the opening. I used this particular time period for the graph because I was able to coordinate the data from three different stations at the same time. No doubt, more data would have allowed me to refine the shape of the cloud, but even the data from three different stations gave a general ideal of the sporadic-*E* cloud shape.

I was quite surprised when I looked at the logs of other stations I had contacted using my vertical. I had kept up with the pace of the stations running higher power and bigger antennas. The stations were spread out on the 2-meter band between 144.170 and 144.250 MHz, which was helpful. A significant number of stations on the band helped minimize pile-ups.

The MUF reached the 220-MHz band, as K2DRH worked three stations on 220—W4WA (EN84), NG4C (FM16), and WD4KPD (FM15)—showing that the density of the formation was capable of reflecting higher up than 2 meters for certain areas of the country.

Prior to my experience during this opening, I perhaps had a preconceived notion that a vertical would not work during a 2-meter sporadic-*E* opening. In the case of a strong opening such as this, I now know that it is possible. Thus, based on my experiences and the input of others, my following misconceptions about 2-meter *Es* were corrected:

- If the opening is strong enough, you do not always need very high power to work 2-meter *Es*.
- When the opening is strong, you do not always need a directional antenna to work 2-meter *Es*. However, if there are many stations on the air at the same time, a beam can help break pile-ups.
- 2-meter *Es* openings can actually last longer than 30 minutes!

Concepts that were reinforced are as follows:

- QSB is more significant when *Es* occurs on 2 meters. You can really hear the change in signal strength.
- For the most part, 2-meter *Es* QSOs seem like 30-second meteor -scatter contacts; signals seem to drop out and then come back.

As it turned out, this was the only major 2-meter *Es* opening observed in July 2004. Also, within a week there was a noticeable difference in 6-meter aporadic-*E* as well. The reason for this appeared to be the increasing levels of solar activity that occurred for the second part of the month.

Aurora in Late July

One would think that it would be unusual to have a terrible July in terms of overall sporadic-*E* activity. When I checked my records, I was surprised to see that there was a similarly poor July in 2002, only two years earlier, with an occurrence of less than 15 days of sporadic-*E*! It would be fair to speculate that the high amount of geomagnetic activity that was experienced during the last half of July 2004 was a major inhibiting factor in sporadic-*E* formation in the higher latitudes. I observed only three days of *Es* after July 15th, while there were at least five days observed here (a few more days in higher latitudes) of aurora activity on 6 meters.

During a good July, sporadic-*E* will be observed in all directions, with a lot of skip activity going toward Canada and Newfoundland. As we have discussed in previous *CQ VHF* articles, the combination of aurora and high geomagnetic activity seems to envelope sporadic-*E* formations (resulting in Auroral-*E* or *AuE*), which probably impedes the movement of sporadic-*E* ions in the *E*-region as well. It was noted that there was no transatlantic *Es* activity between the northeast U.S. and Europe in the second half of July.

Also, it is highly unusual to have so many days of aurora activity in July. Typically, the equinox months are the best periods for aurora, as the Earth is in more of a geo-effective position in relation to the sun wherein solar activity affects the poles of the Earth. What the observations of July 2004 show is that even though the Earth was not in the optimal position in relation to the sun (as it is during the equinox) for geomagnetic events, it seems apparent that the eruptions left the sun and traveled in a generally Earthward direction. It is difficult to determine which solar flares and coronal mass ejections (CMEs) will affect Earth! For example, we had the largest X-level flare ever observed in November 2003, and, with no aurora activity, it did not impact the Earth at all. July 2004 saw much activity when there were no expectations otherwise!

During July there were several periods of high geomagnetic activity. On July 17th, the *K*-index reached 6, resulting in some aurora openings in the higher latitudes. During the period July 22–27, there were several three-hour intervals when the *K*-index reached 6, and on the 27th of July, the *K*-index reached as high as 9!

In the northeast U.S., openings on 6 meters were observed on July 16, 22, 25–26, and 27. Most of these openings occurred in Canada and in the northern U.S. On the morning of July 27th, the opening into my area of Long Island was intense, providing me with an opportunity to work stations.

I set up my 2-element 6-meter Yagi at my work QTH. At 6 AM local time, prior to the beginning of my scheduled work day, I started working a number of stations on 6 meters, mostly in the New England area, and as far north as VE1YX in Nova Scotia. I actually heard N1BUG in FN55 on 2 meters for a short period, but I could not get him. Around this time the *K*-index was at the 8 level.

Indeed, having five days of aurora activity was a new record for me. Previously, three days in the equinox month of October would have been the most that I would see. However, this was July, a month in which a large amount of aurora activity normally does not occur. The old sun may not be finished with solar activity yet, and we may see more aurora events during the fall equinox of 2004.

By the end of July, going into August, the *K*-index started settling down to values of 2 or less. Some significant sporadic-*E* activity was observed, including some great openings into higher latitude locations in Canada. It almost seemed like there was a backlog of *E*-region ions available for sporadic-*E* formations after having been suppressed for several weeks by the high geomagnetic activity!

Summary

July 2004 was not a record-breaking month of sporadic-*E* activity for anyone in the U.S. and Canada. However, it had some very good individual days of *Es* propagation. The several days of aurora activity were surprising as well. There was a noticeable drop in the number of transatlantic QSOs between the U.S. and Europe on 6 meters. However, a fair number of north-south paths between the U.S. and the Caribbean occurred, as well as between Europe and the Caribbean. Perhaps the overall reduction in activity for July and for much of the summer season was a disappointment to VHFers. One learns, however, that at any time, anything can happen, as witnessed by the July 6th 2-meter *Es* event! ■

Receiver Dynamic Range—Part 1

Reprinted from *DUBUS Magazine*, in this two-part article SM5BSZ discusses how to correctly measure receiver dynamic range using a measurement method that mimics the critical situation.

By Leif Åsbrink,* SM5BSZ

Receiver dynamic range is the ability of a receiver to receive a weak signal without loss of readability while a strong signal is present. Although the general concept is very easy to understand, sometimes the published measurements are based on non-valid assumptions. They may actually be measuring something else, which means that published dynamic-range data cannot be used as the basis for selecting the better of two transceivers. Using a measurement method that actually mimics the critical situation makes it easy to get reproducible and well-defined receiver dynamic-range data.

This article will focus mainly on VHF receivers, but most of the comments are relevant to all frequencies.

Introduction

The traditional figures of merit for the dynamic range of a receiver are the third-order intermodulation intercept point IP3 and the blocking dynamic range BDR. Actually, there are many different receiver overload effects, and each one defines the upper end of a separate dynamic range. However, the receiver's responses to third-order intermodulation and blocking are generally assumed to be a good indication of its overall strong-signal handling capabilities.

Different authors define and measure BDR completely differently. Even though the definition of IP3 is always the same, the measurement procedures defined to measure IP3 may differ—and some measurements do not actually measure IP3.

Let us start from the beginning with the following fundamental definitions:

1. **Noise-floor power density (NPD).** Receiver noise power level in a 1-Hz bandwidth (W/Hz or dBm/Hz), referred to the receiver input. This is the lower end of all the dynamic ranges defined below.

On the air, noise-floor power density is a property of the receiving system, because in addition to the receiver noise temperature, T_{RX}, it must include the effective noise temperature of the antenna system:

$$NPD = k(T_{RX} + T_{ANT}) \quad (W/Hz) \qquad (1)$$

For dynamic range measurements, the receiver input is always connected to some kind of resistor (e.g., the output attenuator of a signal generator) which generates thermal noise. If this resistor is assumed to be at 290K, it can be shown that:

$$NPD = -174 + NF_{RX} \quad (dBm/Hz) \qquad (2)$$

where NF_{RX} is the receiver noise figure (dB). Equation (2) is actually one way of formulating the definition of the noise figure.

2. **One-signal dynamic range.** Max undistorted level of a single desired signal in the receiver passband. Measured in dB above the noise-floor power density.

3. **Two-signal dynamic range.** Max level of a single undesired signal that will degrade the S/N of a very weak desired signal by 3 dB or less. Measured in dB above the noise-floor power density. The two-signal dynamic range is a function of the frequency separation.

4. **Three-signal dynamic range.** Max level of two equally strong undesired signals that will not produce intermodulation products above the noise floor. Measured in dB above the noise-floor power density.

Traditional definitions measure dynamic ranges in a specified bandwidth. Different product reviewers use actual CW or SSB bandwidth of the receiver, or some may recalculate the data to a standard 500-Hz or 2.5-kHz bandwidth. Defining the dynamic range in relation to the power density of the noise floor (dBm/Hz instead of just dBm) normalizes all measurements to a 1-Hz bandwidth. This avoids ambiguity and is also very convenient for the measurement methods described below, where the output of a receiver is measured with an audio spectrum analyzer.

The One-Signal Dynamic Range

When you tune to a really strong SSB signal, the audio output may become severely distorted. This is not much of a problem for amateur SSB, but it is important for some data modes and may be essential in other services. The in-channel distortion caused by receiver overload can be avoided by use of better AGC circuits, ultimately an AGC-controlled RF attenuator at the antenna input as described by Ulrich Rohde in reference 1. There is no limit to how high one can make the one-signal dynamic range this way, but when AGC is used, the signal/noise (S/N) ratio does not continue to improve. Because the one-signal dynamic range is not relevant to the main subject of this article, I see no reason to go deeper into measurement procedures.

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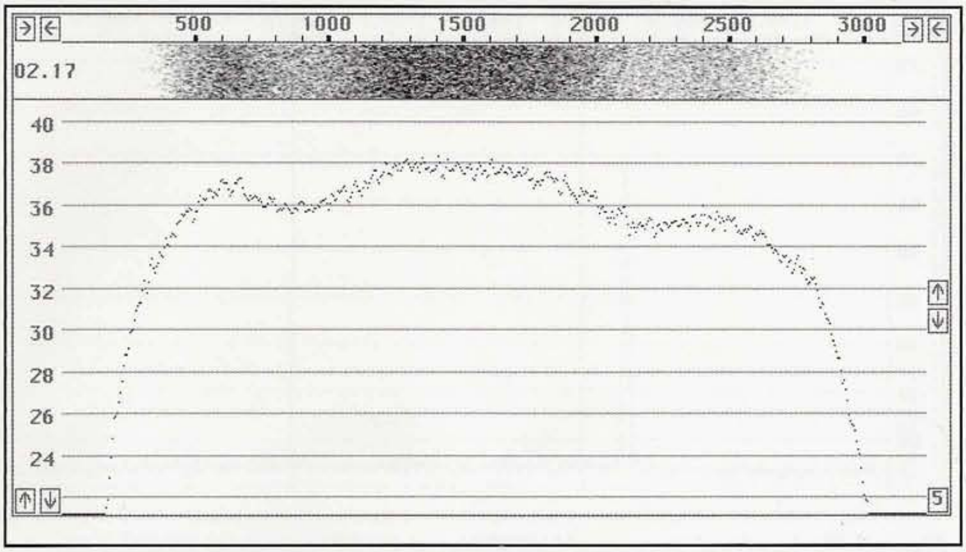

Figure 1. Frequency response of an IC-706MKIIG. The passband ripple is on the order of ±2 dB and would be invisible at a "normal" y scale.

Added noise signal relative to main signal (dB)	Signal level change (dB)
−30	0.00
−20	0.04
−15	0.13
−10	0.41
−9	0.51
−8	0.64
−7	0.79
−6	0.97
−5	1.19
−4	1.46
−3	1.76
−2	2.12
−1	2.54
0	3.01
+1	3.54

Table 1. Adding a second noise source increases the noise level like this. For example, if both noise levels are equal (0 dB), the sum is 3.01 dB above a single signal, and the sensitivity is about ±0.5 dB for a ±1 dB change of the added noise. If the added noise is 6 dB below the original noise, the sum is 0.97 dB above the original noise, but the sensitivity is only about ±0.2 dB for a ±1 dB change of the added signal.

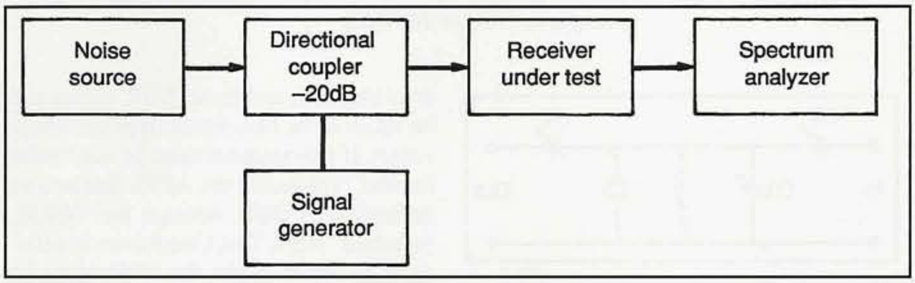

Figure 2. Setup for NF measurement on a receiver.

The one-signal dynamic range is closely related to blocking, as explained later.

The Two-Signal Dynamic Range

This is the most important quality of a VHF receiver. In principle, the measurement procedure is very simple: Set the signal level of a first signal generator to a suitable low level. Monitor the S/N of this signal with an audio spectrum analyzer at the audio output. Then increase the level of a second signal generator (P_{GEN}) until S/N is degraded by 3 dB. The level of the second generator in relation to the noise-floor power density is the two-signal dynamic range.

$$DR_2\,(dB_{Hz}) = P_{GEN}\,(dBm) - NPD\,(dBm/Hz) \quad (3)$$

(The units of DR_2 are dB. The abbreviation dB_{Hz} should be read as "dB, referred to a 1-Hz bandwidth.")

The degradation of the S/N can occur by several different mechanisms that either reduce the signal or increase the noise level. These mechanisms are discussed further at the end of this section, but the main two are identified here. Reduction of the signal level is called *blocking* and is discussed below. A noise-free strong signal can cause an increase in the noise level because of *reciprocal mixing* between that signal and the noise sidebands of the receiver's local oscillator. The two-signal dynamic-range measurement, as defined here, does not question which of these two effects is happening, or what the causes are; it simply measures the practical total effect upon S/N. That is all a receiver reviewer needs to measure, because it shows readers what will happen on the air. Only the receiver designer needs to measure blocking and reciprocal mixing separately, because the ways to improve them lie in different parts of the receiver.

The two-signal dynamic range varies with the frequency offset between the wanted and unwanted signal in a way that depends on the receiver architecture. When the mechanism is reciprocal mixing, DR_2 follows the spectrum of the sideband noise on the local oscillator(s). However, when the mechanism is blocking, it depends on which stage of the receiver is the one which overloads and how much effective selectivity there is before that stage when the mechanism is blocking.

The practical problem with DR_2 measurement is that the strong signal generator must not produce significant sideband noise at the frequency to which the receiver is tuned. This is where a crystal filter is needed. On HF bands, it is possible to use the steep edge of a crystal bandpass filter to remove the sideband noise from the strong signal, but on VHF this is not possible; a crystal notch filter must be used instead (see later). At VHF, normal crystals do not like the power levels needed to test good receivers. It is possible, of course, to make very-low-noise crystal oscillators for this test, but it is not so easy to be sure that the test oscillator really is as good as one thinks.

The definition of DR_2 above is closely related to the conventional definition of blocking dynamic range, BDR (references 3 through 8). The amount of degradation associated with the DR_2 value as I have defined it here is 3 dB, rather than 1

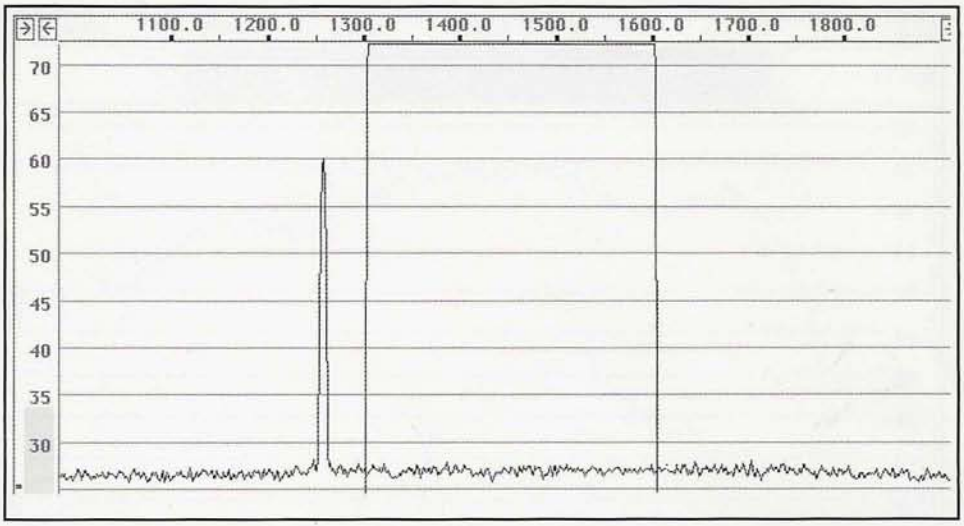

Figure 3. The baseband spectrum of Linrad when doing NF measurements with a signal generator. The input signal is the audio from the same IC-706MKIIG as used in figure 2 when a –130-dBm signal is applied to the input. Straight lines are drawn between the pixels to make the figure better visible in print. The rectangular filter goes from 1300 to 1600 Hz.

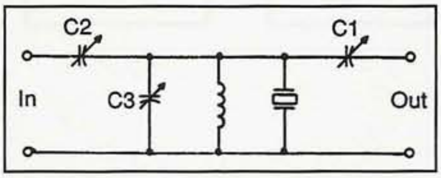

Figure 4. The basic crystal notch filter. The coil and C3 form a parallel resonator, which is selectively loaded by the crystal. C1 and C2 are equal. Smaller values for C1 and C2 gives deeper notches, but the passband becomes narrower.

dB, which is often used in other definitions. The reason to use 3 dB in the definition is twofold. First, the measurement is faster. This is important because the whole measurement must be repeated at several frequency offsets to see the complete picture. When the S/N degradation mechanism is reciprocal mixing, and one wants to find the level of the strong signal within 1 dB, one has to measure the noise floor very accurately if one wants to determine the level of the strong signal within ±1 dB, as can be seen from Table 1. The 1-dB degradation calls for a noise-level measurement within ±0.1 dB, which in narrow bandwidths takes a lot of time to achieve statistical accuracy. For the 3-dB degradation, ±0.25 dB is sufficient accuracy for each noise level, saving a factor of 6 in time.

The BDR (blocking dynamic range) values measured by the ARRL lab and published in *QST* show that when a receiver is blocked, and these BDR values can be taken to be one-signal dynamic-range values if the measurement is not "noise limited." (Note that the ARRL has its own definition of BDR through the "ARRL Standard" BDR Test Conditions in reference 2.) For example, the BDR value for the FT1000D published by the ARRL lab is "larger than 154 dB"; that refers to a bandwidth of 500 Hz, so by the definitions above, the one-signal dynamic range of the FT1000D is more than 181 dB_{Hz}.

The second reason for using 3-dB degradation rather than 1 dB when measuring DR_2 is that for a receiver in which performance is limited by reciprocal mixing only, the numerical values become equal to the oscillator phase noise (dBc/Hz). Comparing the receiver DR_2 with the transmitter sideband noise may also show if there is a further problem caused by noise modulation in the transmitter amplifier stages (a common problem).

As noted above, the definition of DR_2 does not discriminate between the many different mechanisms that may be the reason for loss of S/N for the desired signal. This list of possible mechanisms is not complete. It just contains phenomena that I have encountered in real life:

1. Blocking—the sensitivity of a saturated receiver is degraded.

2. Reciprocal mixing—because of phase noise from the local oscillator.

3. Amplitude modulation in RF amplifiers or LO buffer amplifiers.

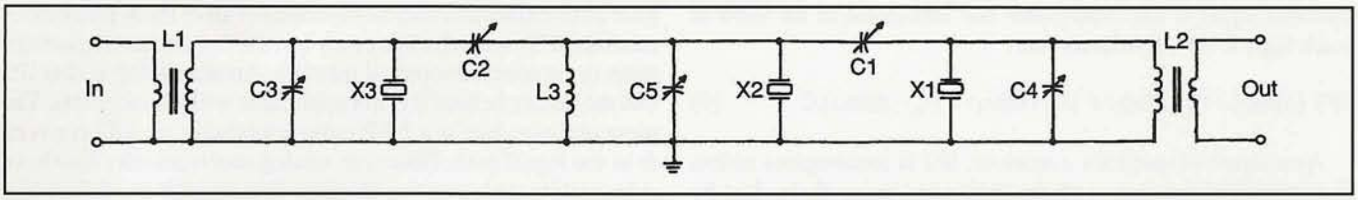

Figure 5. A 14-MHz notch filter. C3 and C4 are 20-pF trimmers tuned near the minimum capacitance. C1 and C2 are 60-pF trimmers tuned to about 20 pF. The inductors are wound on Amidon T80-6 toroids.

4. Phase noise (time jitter) in CMOS switched mixers.

5. Phase noise in (time jitter) in frequency dividers.

6. Noise bursts caused by movement of small particles inside ceramic capacitors.

The list should also include wideband interference caused by strong signals. On top of that, there are the discrete spurious responses. At some particular frequency separations there are false responses for the strong signal, and such spurs degrade DR_2 at those frequencies. As well as giving the wideband performance, preferably as a graph, the complete DR_2 performance should include a list of spurs, but presenting such a list is not as simple as it first seems. First-order spurs such as the mirror-image frequency could be tabulated formally as DR_2 numbers for specific frequencies because the DR_2 value equals the spur suppression in dB. However, receivers also have higher order spurs, things such as (8×LO – 5×RF), which may appear at very high RF signal levels whenever the result becomes equal to the IF frequency. Applying the DR_2 definition directly is impossible for these higher order spurs, because the result will depend on which signal level one has chosen for the weak signal. One way of describing higher order spurs is as a list stating: the frequency—what the level of the spur is for an input signal close to the wideband DR_2 level; and the order of the spur, which tells you by how many dB it decreases when the input level is reduced by 1 dB.

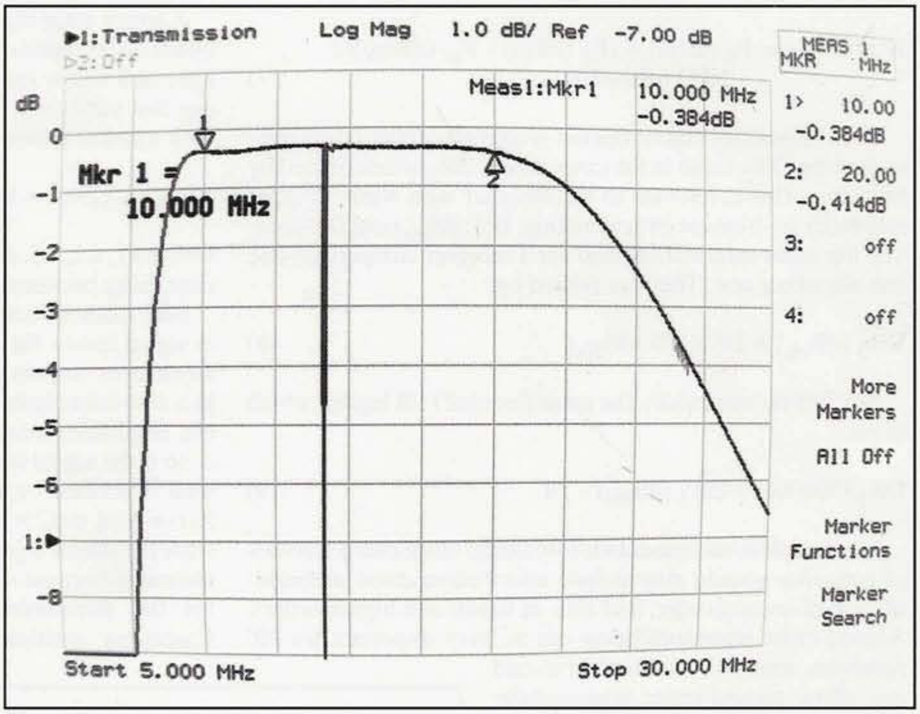

Figure 6. Frequency response of filter in figure 5 from 5 to 30 MHz. The filter attenuation is 0.3 dB from 10 to 20 MHz.

Three-Signal Dynamic Range

The measurement is conceptually simple: Set the signal level of a first signal generator to a suitable low level. Then increase the levels of a second and third signal generator until the level of the third-order intermodulation product equals the level of the weak signal as measured with an audio spectrum analyzer at the audio output. The second and third signal generators should have equal amplitudes, and their frequencies have to be set for the third-order intermodulation product to be within the receiver passband.

When measured this way, the third-order intermodulation product accurately follows the theoretical third-order law, because the first signal is used as a pilot tone which makes the measurement unaffected by AGC circuits after the IF filter. If the receiver uses dual-loop AGC (reference 4), the third-order law will not hold at signal levels high enough to make the AGC reduce the RF gain.

With P_W for the power of the first generator in dBm and P_S for generators 2 and 3, the third-order law is like this:

$$3P_S\ (\text{dBm}) = P_W\ (\text{dBm}) + 2k\ (\text{dBm}) \quad (4)$$

where k is a constant, identified below.

If the power level of generator 1 (P_W) is set to equal the NPD, and the output powers of generators 2 and 3 (P_S) are increased together until the third-order intermodulation product appears at the same level as P_W, then the third-order dynamic-range DR_3 is simply the difference in dB between P_S and P_W. The formula becomes:

$$DR_3\ (\text{dB}_{\text{Hz}}) = P_S\ (\text{dBm}) - \text{NPD}\ (\text{dBm/Hz}) - \{P_W\ (\text{dBm}) - \text{NPD}\ (\text{dBm/Hz})\}/3 \quad (5)$$

The constant k in equation (4) is in fact the third-order intercept point IP3 (dBm). This is the point where P_S and P_W would become equal if the third-order law continued to be valid at such high levels. It follows that:

$$IP3\ (dBm) = P_S\ (dBm) + \{P_S\ (dBm) - P_W\ (dBm)\}/2 \quad (6)$$

As a figure of merit for a receiver, IP3 is meaningless unless it is specified together with the associated noise floor. Just by adding a 10-dB attenuator, one would improve IP3 by 10 dB, but the distance between IP3 and the noise floor would not improve since the noise floor would also be raised by 10 dB. One can specify IP3 in dB above the noise floor in 1 Hz like this:

$$IP3\ (dB_{Hz}) = P_S\ (dBm) + \{P_S\ (dBm) - P_W\ (dBm)\}/2 - NPD\ (dBm/Hz) \quad (7)$$

The IP3 number that comes out is typically about 10 dB larger than the DR_2 value in the cases where DR_2 is determined by blocking. This is relevant to the *designer* who wants to separate blocking from reciprocal mixing. IP3 (dB_{Hz}) and DR_3 convey the same information, and for a receiver comparison one can use either one. They are related by:

$$DR_3\ (dB_{Hz}) = 2/3 \times IP3\ (dB_{Hz}) \quad (8)$$

In a 500-Hz bandwidth, the noise floor is 27 dB higher, which gives:

$$DR_3\ (500\ Hz) = DR_3\ (dB_{Hz}) - 18 \quad (9)$$

The complete intermodulation dynamic-range characteristics of a receiver should also include information about intermodulation of second order, and also of fourth and higher orders. Second-order intermodulation can be very important for HF receivers, where a broadband front-end can allow second-order intermodulation between, say, two 7-MHz signals with the product causing interference at 14 MHz. However, it is normally of little interest on the VHF bands, where we routinely use narrow filters at the RF frequency. Fourth and higher orders occur only near saturation when lower order IMD is already very strong, so these are of very little practical interest.

Note that intermodulation performance is a function of frequency separation of the two unwanted signals from the wanted frequency. This is for essentially the same reasons as blocking, namely the amount of effective selectivity ahead of the stage(s) that suffer intermodulation. It also means that a full intermodulation report will be quite an extensive table.

The Meaning of IP3

The third-order intercept point, IP3, although a number that is obtained from an extrapolation, has a real physical meaning, and it is well defined. The fact that different standardized procedures give different results may be because not all of these procedures measure IP3 correctly. They may be based on incorrect assumptions or on some theoretical mistake. Another thing is that IP3 and the theory behind it is not applicable with all receivers. The most obvious case is a DSP radio containing an A/D converter in the signal path. However, analog receivers may also have side circuits such as noise blankers that contain amplifiers that produce intermodulation at signal levels where the main signal path is very linear. Such intermodulation may leak into the main signal path because of inadequate screening or buffering, causing irregular behavior at low signal levels.

A single stage that causes intermodulation can be described by a transfer function that is very close to a straight line for voltages well below saturation. If the input is denoted X(t), a voltage that varies with time, the output Y(t+d) can be described with a power-series expansion in amplitudes only:

$$Y(t+d) = k_1X(t) + k_2\{X(t)\}^2 + k_3\{X(t)\}^3 + \ldots \quad (10)$$

where k1, k2, k3, etc., are constant coefficients; and d is the time delay between input and output (not important here).

Such a description is valid if the input signal is small. At larger signal levels, there will also be a phase shift because semiconductors contain a capacitance that varies with the voltage in a non-linear fashion. Any reasonable analog circuitry (mixers, amplifiers, iron cores, whatever) will have $k_1 > k_2 > k_3 > \ldots$ so if the signal levels are really low, the transfer function is well described by the first "linear" term only. By making $X(t) = A \times \{\sin(2 \times p \times f1) + \sin(2 \times p \times f2)\}$ one can easily find what the output signal Y(t+d) becomes. Third-order intermodulation is because of k_3, k_5, k_7 ... and k_3 alone is responsible for the third-order intermodulation at very low levels. Cascading multiple stages will not change this analysis;

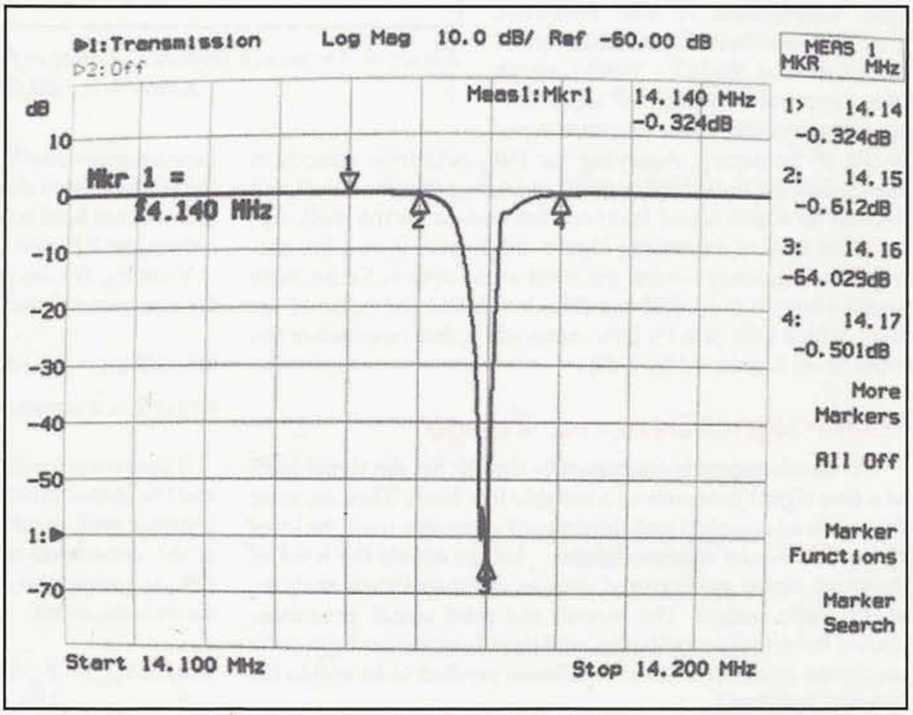

Figure 7. Frequency response of filter in figure 5 from 14.100 to 14.200 MHz. The filter attenuation is less than 0.5 dB at 10 kHz away from the notch, which is 50 dB deep or more over 1.5 kHz.

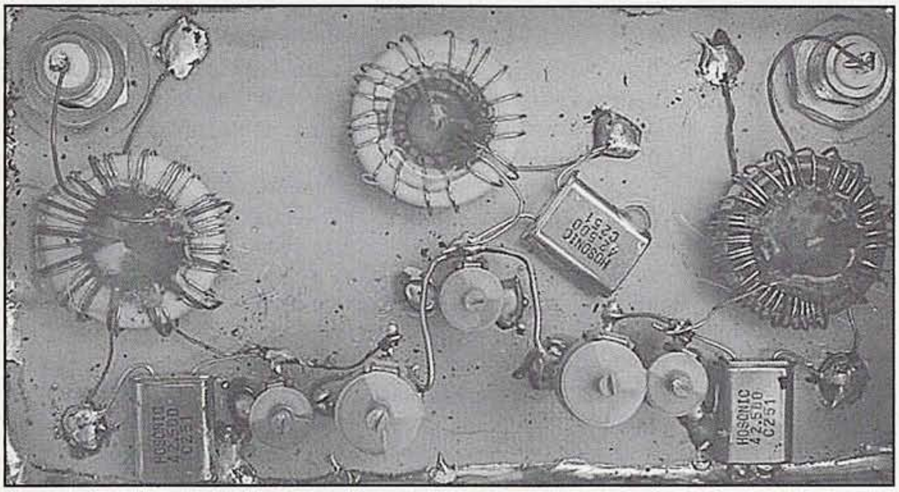

Figure 8. The 14-MHz notch filter built in a box made from double-sided PCB material. The components are soldered to ground and the toriods are glued.

the complete cascade of stages will still be characterized by equation (10), but with a new set of coefficients that can be computed from the individual stage coefficients.

IP3, the number we use to express k_3 of the transfer function, should have an exact relation to DR_3, which is another number we may use to express the same thing. If you find (for example in some *QST* reviews) that measured IP3 values do not have the correct relation to measured DR_3 values, this may indicate a measurement mistake or that the tested receiver has a leakage of intermodulation from some saturated stage that is not part of the signal chain. The ARRL lab measurements of the TS-690S (reference 9) show an extreme example, in which the third-order intermodulation falls off by only 0.5 dB for an 1 dB reduction of the input level rather than the expected 3 dB. I have looked carefully at a TS-450S, which was reported (reference 9) to have the same behavior as the TS-690S, but found no sign of that peculiar behavior. The serial number was much higher, and maybe the signal-leakage problem had been cured.

IP3 and DR_3 are both good figures of merit to describe the analog front-end of a receiver, because they both are related to the fundamental transfer equation (10). However, A/D converters used in digital radios are not well described by equation (10). If multiple strong signals are allowed to enter the A/D converter, the relevant figure of merit is the A/D saturation limit. Below this limit, A/D converters are typically very linear; they produce practically no IM3 all the way up to the saturation limit, where they fail completely. A digital receiver will have IP3 and DR_3 values that look very good, but in real life they cannot be compared to "good old analog" receivers that will continue to function with input voltages high above the range indicated by DR_3. For example, an analog receiver that is subjected to ten signals at the DR_3 level will produce IM3 for all combinations of these signals, but these spurious responses will be near the noise floor. A digital receiver will see the ten signals sometimes add in amplitude to give a peak level that is 20 dB higher, so it may become heavily saturated and useless. At the present state of the art, digital receivers need roofing filters to limit the number of signals entering the A/D converter. However, inside the roofing filter bandwidth, they remain vulnerable to saturation effects when the band is crowded with very strong signals. Test procedures must take realistic account of this.

A receiver that has a signal leakage at low input levels is not well characterized by an IP3 number. There is no point at and below which the third-order intermodulation follows a third-order law. IP3 and DR_2 should be presented only if the measurements show that they are valid figures of merit, and any observed deviations occur at levels low enough to be insignificant; otherwise the entire curve of intermodulation versus input signal levels should be presented as in reference 9. An EME operator looking for signals 20 dB below the SSB bandwidth noise floor might find the TS-690S receiver with the performance reported in reference 9 completely useless, while other operators not looking for signals below the noise floor might find the leakage insignificant. In real use on the air, the noise floor is typically 10 to 20 dB higher than during the IM3 measurement because of "noise from the antenna on HF or because of the noise from the tower-mounted preamplifier for weak-signal VHF/UHF use.

There is a detailed analysis, and some accurate measurements, at <http://antennspecialisten.se/~sm5bsz/dynrange/intermod.htm>. This internet site illustrates the validity and limitations of IP3 and DR_3 for characterization of receiver intermodulation.

Practical Measurement of Noise Floor

First of all, the noise floor has to be established. Methods that use a signal generator and an RMS voltmeter and rely on the known bandwidth of the receiver under test have accuracy problems because the audio frequency response is often not very flat. For example, figure 1 shows the frequency response of an IC-706MKIIG.

A typical (old) procedure would be to use a signal generator and an RMS voltmeter to locate the 6-dB points, which would be found at about 300 Hz and 2800 Hz. One would then place the signal generator at the frequency of maximum and determine at what signal level the reading of the voltmeter has increased by 3 dB. This is the point where the signal power equals the noise power, so one would then say that the noise power in 2500-Hz bandwidth equals the power level of the signal generator. The error in taking the 6-dB bandwidth rather than the true noise bandwidth (equivalent "rectangular" bandwidth giving the same noise power) will, of course, depend on the details of the frequency response. For the IC-706MKIIG in figure 1, the actual noise bandwidth is only 1.6 kHz, so the error is 1.9 dB. All uncertainties add together, so by measuring the noise floor properly, we can improve the accuracy of dynamic-range measurements by several dB. Using an RMS voltmeter at the output may introduce errors if the AGC is not completely disabled. With a standard multimeter that is not a true RMS voltmeter, "other" uncertainties are added as well.

To measure the sensitivity accurately, an audio spectrum analyzer should be

Generator		S (in 10-Hz BW)	N (in 300-Hz BW)
Signal	Noise		
off	off	25.8	40.1
off	on	28.5	42.8
on	off	48.8	39.9
on	on	46.3	41.8

Table 2. RMS power levels for the signal frequency and the noise floor with all four possible combinations of generators on/off.

used. These days such instruments are readily available in the form of computer programs for a standard PC computer. There are many alternatives, but (since I wrote it myself) I prefer Linrad, which is free Linux software and can be downloaded from <http://antennspecialisten.se/ ~sm5bsz/ linuxdsp/ linrad.htm>.

Besides the audio spectrum analyzer, a power reference is needed. It may be a calibrated noise source with a known noise temperature, but it may equally well be a signal generator with a well-known output level near the noise floor.

If you have a calibrated noise source, use the setup of figure 2. The noise source can be switched between two known noise temperatures, usually called "hot" and "cold." If you have access to an old vacuum-tube (diode) noise source, the hot noise temperature is known from the anode current by theory. Such noise sources are typically supplied with a plate-current meter that is calibrated directly in noise figure, and one is supposed to adjust the plate current for the noise level in the receiver to increase by 3 dB when the current is switched on. The noise source may also be a semiconductor diode, which presumably is calibrated so you know what the "hot" noise temperature is when you give it the prescribed current. Without any current, the noise source will have a "cold" noise temperature that equals the room temperature or a little higher; the temperature of the resistor inside the noise source may be a little above room temperature. Noise figures are specified for a standardized temperature of 290K. If you make the measurement with the noise source at a different temperature, there will be an error that you should correct if you look for an accurate noise figure.

When the current is switched on in the noise source, there is another side effect besides the increased noise temperature. The impedance will change slightly. In case the gain of the receiver under test is very sensitive to the source impedance, the noise floor will change also because of the changed gain and not only because of the changed noise temperature of the noise source. For the purpose of evaluating dynamic range, a modest accuracy of the NF is sufficient, but for measurements of low-noise figures, the accuracy has to be much higher. Rainer Bertelsmeier, DJ9BV, has written in detail about these problems (reference 10). One typically uses an attenuator to reduce this effect because it makes the impedance change smaller, but the noise source preferably should be calibrated with the attenuator permanently in place.

With the setup of figure 2, the purpose of the signal generator and the directional coupler is to supply a pilot signal with constant amplitude. By monitoring it on the audio spectrum analyzer, one can compensate for modest changes of the receiver gain that may be caused by AGC action or source impedance changes. Note that the losses in cables and in the directional coupler affect this measurement. These components can be treated just like attenuators near room temperature. It is not difficult to correct for, but keeping the losses small enough to be neglected is a better idea. The 20-dB directional coupler shown in figure 2 is a good value because it avoids significant loss of noise power due to coupling into the branch line, and it also avoids coupling significant thermal noise from the branch line into the main line.

The measurement is straightforward. First, set the signal generator so the pilot signal is well visible on the screen. Monitor the noise floor and make sure the signal level is low enough so as not to change the noise floor by more than a few tenths of a dB. The only concern here is signal leakage: Make sure the signal really comes through the directional coupler and that it does not leak into the receiver some other way. There are four power levels to measure: the noise floor and the signal level, each for the "hot" and "cold" states of the noise source. Do not change the tuning between measurements. The only adjustments allowed are the on/off switch on the noise source and the controls on the spectrum analyzer. The four measurements are as follows:

N_C = "Cold" noise floor
N_H = "Hot" noise floor
S_C = "Cold" signal level
S_H= "Hot" signal level

If you use Linrad, the signal levels are obtained in dB from the S-meter. S_H and S_C should be measured with a bandwidth that makes the noise negligible. Make it 10 Hz, for example. Check by switching off the signal generator. The reading should go down by at least 20 dB. N should be measured with as much bandwidth as possible. Note that the statistical error in a noise power measurement is proportional to the square root of the measurement time and inversely proportional to the square root of the bandwidth. Just make sure the signal generator and any other spur that may be present are outside the passband selected. The difference between S_H and S_C is the gain change caused by switching on the noise source. It does not matter if the change is due to the AGC or due to an impedance change in the noise source as long as the gain change is modest.

The change in the noise floor because of the temperature change (N_{DIFF} measured in dB) is obtained from

$$N_{DIFF} = N_H - N_C + S_C - S_H \quad \text{(dB)} \tag{11}$$

When converted from dB to a linear power scale, N_{DIFF} becomes the Y factor:

$$Y = 10 \times \text{antilog}_{10}(N_{DIFF}) \tag{12}$$

Because noise power is proportional to noise temperature, we can re-write equations (11) and (12) in terms of noise temperatures:

T_H = Hot temperature of the noise source
T_{CP} = Cold temperature of the noise source
R_X = Noise temperature of the receiver

Then we get the well-known equations:

$$Y = (T_H + T_{RX}) / (T_C + T_{RX}) \tag{13}$$

$$T_{RX} = (T_H - Y \times T_C) / (Y - 1) \tag{14}$$

$$NF = 10 \times \log_{10}(1 + T_{RX}/290) \tag{15}$$

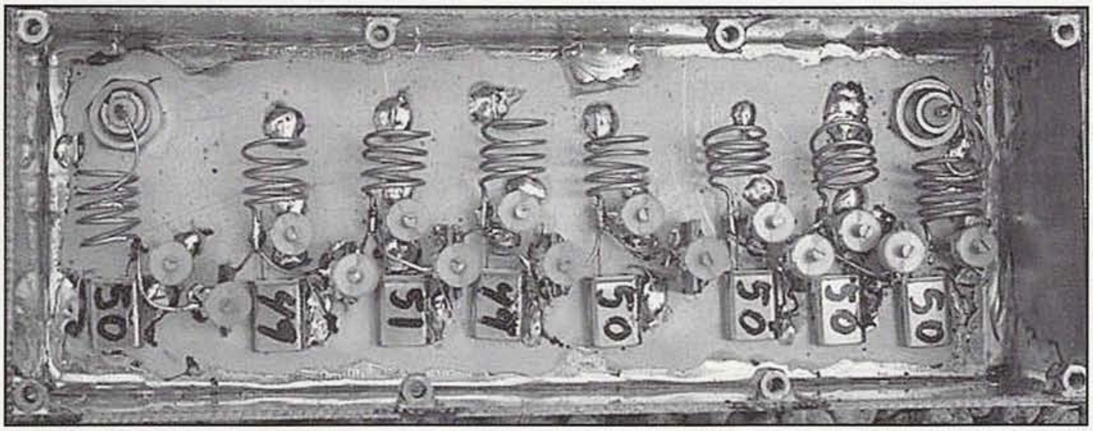

Figure 9. A notch filter for 144 MHz. There is no iron. The impedance is stepped up by connecting the input and the output 1.5 turns from ground on coils having 4.5 turns.

This is the good old warm/cold measurement method for noise figures. The equations suggest that you can use ice water at 273K and the kitchen stove at 523K to get N_{DIFF} = 2.6 dB if the noise figure is 0.5 dB. At SSB bandwidth, the uncertainty is large, maybe 0.3 dB for N_{DIFF}, but at higher bandwidths, the absolute accuracy may be quite good. Liquid nitrogen for T_C improves accuracy dramatically at low NF values, but has extra technical problems of its own.

If there is no AGC and the receiver gain is insensitive to the source impedance, S_W and S_C will be equal, and then there is no need for the directional coupler and the signal generator. Then you just connect the noise source to the receiver and use the audio spectrum analyzer as an RMS voltmeter. This also removes the uncertainty because of the insertion loss of the coupler.

To illustrate the above, I made some measurements on an IC-706MKIIG. With a good preamplifier connected, the AGC enabled, and the RF amplifier disabled, the IC-706MKIIG S-meter shows S0 for the noise floor when the signal generator and the noise source are off. The signal generator only lifts the S-meter to S1, and the noise source lifts the S-meter to S4. Signal and noise source together also gives a reading of S4.

Table 2 shows the resulting signal levels in Linrad with the four combinations of on/off for the signal generator and the noise source.

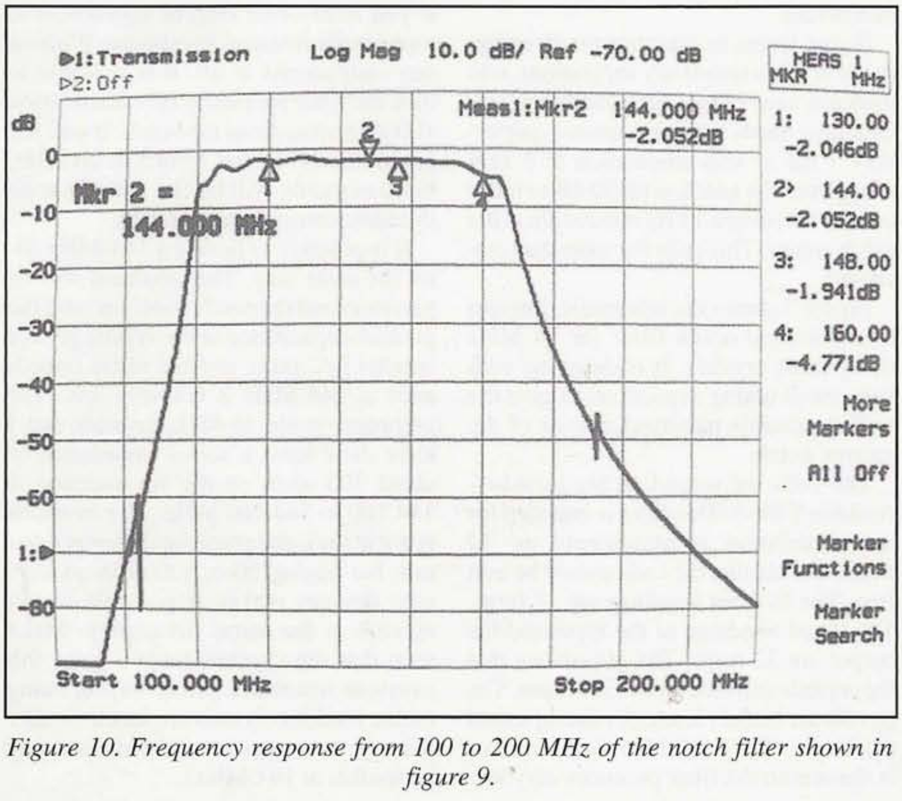

Figure 10. Frequency response from 100 to 200 MHz of the notch filter shown in figure 9.

In a conventional setup without the signal generator, one would get the Y factor (in dB) as 42.8 – 40.1 = 2.7 dB. Using equation (11) above, however, we get N_{DIFF} = 41.8 – 39.9 + 48.8 – 46.3 = 4.4 dB. The noise source was a temperature limited vacuum diode set for "3 dB," which means that it would give a Y factor of 3 dB if the noise figure were 3 dB. T_H is then 870K. On a linear power scale, the Y factors are 1.86 and 2.75, respectively, and with T_C = 295K, the rx noise temperatures given by equation (15) become 373 and 34K, respectively. Converted to noise figures, the results become 3.5 and 0.5 dB, respectively. In this case, the error in NF caused by AGC action in a normal measurement would have been 3.0 dB! With a signal generator to monitor gain changes, one obtains the correct result even when the AGC is fully activated. With my noise source (a Magnetic 123) and the AGC compensation applied, the noise figure of the barefoot IC-706MKIIG comes out as 4.4 dB with the RF amplifier on and 8.7 dB with the RF amplifier off.

The other way of measuring the noise figure is based on the use of a signal generator with a known signal level. One just connects the generator to the receiver under test and evaluates the audio S/N. It does not matter whether the AGC is on or off. The audio spectrum analyzer evaluates S and N in the audio passband, and both of them are equally affected by the AGC. Figure 3 shows the Linrad screen when a –130.0 dBm signal was sent into the IC-706MKIIG. The RF amplifier was enabled. The Linrad S-meter readings were S = 49.3 dB and N = 34.8 dB. To get a very precise measurement for S, the bandwidth was reduced to about 10 Hz. Because all the signal energy is still inside this narrower filter, the signal is completely unaffected. S/N is very good in 10-Hz bandwidth, so a very stable S-meter reading is obtained. Because the filter used to measure N is the precise rectangular filter of Linrad with 300-Hz bandwidth, these numbers give S/N 39.3 dB_{Hz} which means that the noise floor is at –169.3 dBm/Hz. From equation (2) the noise figure comes out to be 4.7 dB. With the RF amplifier off, the noise figure with the signal-generator method is 9.1 dB. These results compare quite closely with those obtained above, using the noise source method. The somewhat higher results with the signal-generator method are mainly because the passband of the IC-706MKIIG is not quite flat between 1300 and 1600 Hz. To improve the accuracy, one can calibrate Linrad to make the noise floor flat within less than 0.1 dB, but that would not help much because it is difficult to generate a weak signal with a precisely known power level.

For the purpose of reporting the sensitivity of VHF receivers, especially if the noise figure is lower than about 4 dB, the signal-generator method is beyond the useful limits of its accuracy. Any authoritative product review should be based on noise-generator measurements. However, for the purpose of evaluating the dynamic range of a receiver, an error on the order of 1 dB may be acceptable, and that is within reach with normal signal generators.

Crystal Notch Filters

Both DR_2 and DR_3 measurements are easy if one has signal generators that are much better than the receiver under test. The big problem is how do we know? Standard signal generators are surely not good enough for serious work. One has to build something better—but how do we know it really works as intended?

Crystal notch filters are the solution. Of course, a crystal bandpass filter also could be used to improve the spectral purity of a signal generator, but that is practical for DR_2 measurements only. One would need one filter for each strong generator for DR_3 measurements, and one would then lose the essential flexibility to measure intermodulation at several frequency separations. Figure 4 shows a basic crystal notch filter.

A parallel LC circuit is loaded by a crystal. The higher the impedance of the LC circuit is when not loaded by the crystal, the deeper is the notch. The LC circuit is a bandpass filter. To get a high impedance at the same time as large bandwidth, one should use a large L/C ratio.

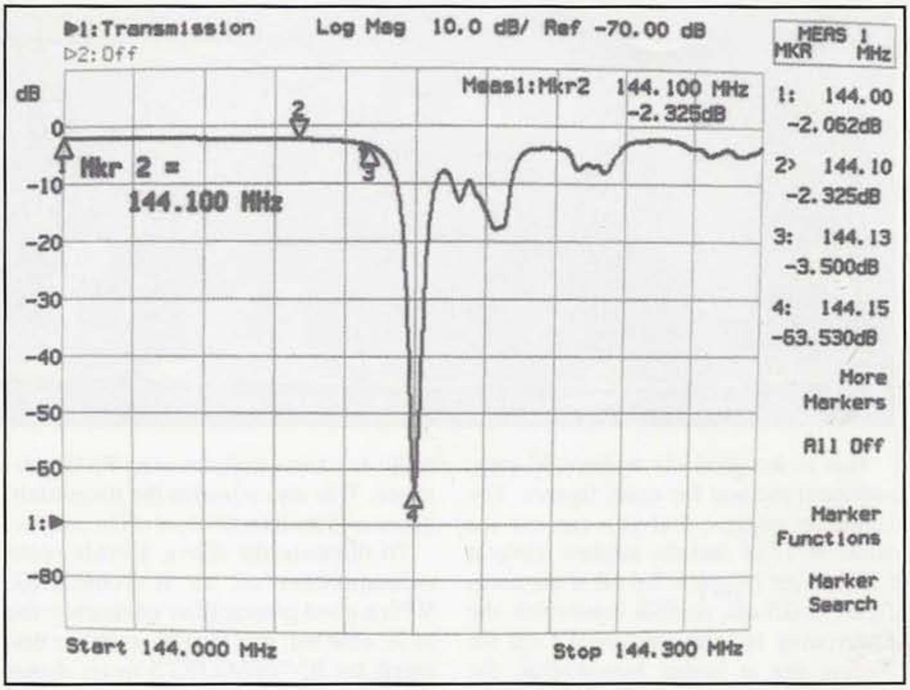

Figure 11. Frequency response from 144.000 to 144.300 MHz of the notch filter shown in figure 9.

This means keeping C3 small so that the parallel capacitance of the crystal itself is the dominating capacitance. In practice, it is also advantageous to do the impedance transformation inductively on the coil, rather than using coupling capacitors as shown in figure 4, because that allows a larger L/C ratio and some more bandwidth.

If one wants to measure the dynamic range at close frequency separations, one does not need only a deep enough notch. One also needs it to be narrow—preferably 1 dB or less attenuation at 5 kHz away from the notch, with 30 dB or more attenuation over a 1 kHz bandwidth at the notch center. This calls for more than one crystal.

Figure 5 shows the schematic diagram of a practical notch filter for 14 MHz using three crystals. It is designed with very small tuning capacitors, to give the widest possible passband outside of the narrow notch.

The coils are wound on big toroids—Amidon T-80-6. This filter is intended for intermodulation measurements on 14 MHz, and ideally, the coils should be iron free. The 50-ohm windings are 13 turns. The tuned windings of the input and the output are 32 turns. The impedance that the crystals will load thus is 300 ohms. The toroids are heavily loaded by the input and the output. The loaded Q is low, and that is the reason the filter produces very low intermodulation despite the iron cores. The frequency response of this notch filter is shown in figures 6 and 7.

The layout of a notch filter such as this is not critical. Figure 8 is a photograph of how I made it. Tuning a filter such as this is like tuning a bandpass filter with three LC resonators—not difficult at all if you have some kind of instrument to monitor the frequency response. Without any instruments at all, it is possible to tune the filter for nearly zero attenuation 100 kHz away from the notch. It will not automatically be flat from 5 to 20 MHz, but it certainly will be flat enough to do dynamic-range measurements.

It is possible to design a 144-MHz filter the same way. The passband will be narrower and the notch wider because the parallel capacitance of the crystal gives a smaller L/C ratio, and the series impedance at 144 MHz is not very low. The computer-grade 16-MHz crystals that I have used have a series impedance of about 300 ohms on the 9th overtone at 144.100 to 144.160 MHz. The overtone is not at the same place for different crystals, but buying 50 or 100 of these low-cost devices makes it possible to get enough at the same frequency. Make sure that the crystals have a good 9th overtone resonance before buying many (some modern crystals are much smaller than the can suggests, and therefore may be useless at 144 MHz).

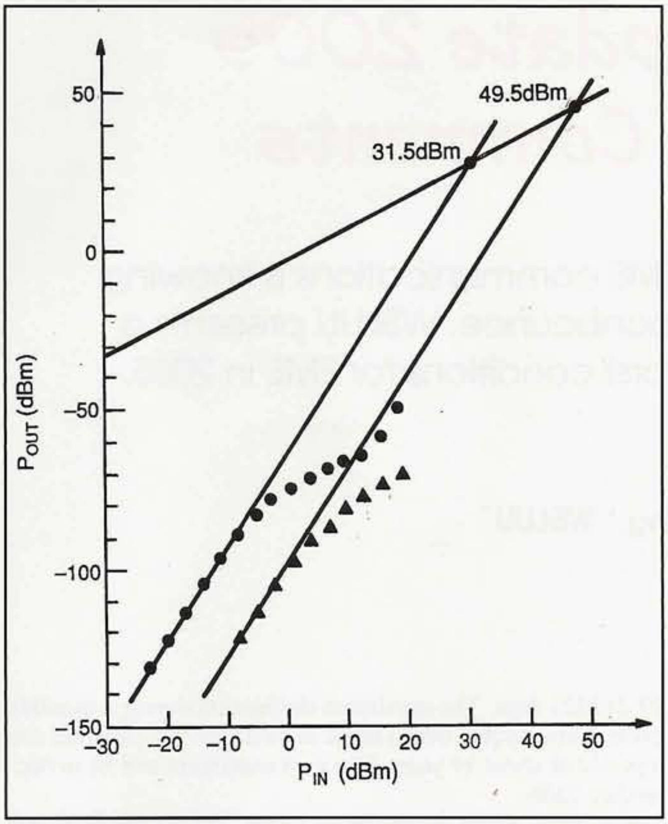

Figure 12. Signal levels at the output of a 144-MHz crystal notch filter in a two-tone test. Circles are for 20-kHz frequency separation, triangles for 100 kHz. The third-order behavior from very low levels is extrapolated toward the third-order intercept points at +31.5 dBm for 20-kHz separation and at +49.5 dBm for 100-kHz separation. The intermodulation is created within the notch filter.

Figure 9 shows a 144-MHz filter using eight crystals. It is basically the same configuration as shown in figure 5. This 144-MHz notch filter gives a 60-dB deep notch. The frequency response is shown in figures 10 and 11. A 16-MHz crystal has false resonances above the main 9th overtone resonance. That gives rise to the spurious notches above the main notch in figure 11, so this kind of filter is not suitable to measure DR_2 and DR_3 with the undesired signals close to and above the desired signal.

Also, a crystal notch filter will produce third-order intermodulation in DR_3 measurements if the strong signals are close to the crystal resonance. At these frequencies, the third-order intermodulation products do not obey a third-order law, even when the power level is far below the main signals, and amplifiers and mixers are behaving correctly. One has to go to very low power levels indeed to get true third-order behavior near the notch frequencies, which is not so easy. To see it, one has to use a very good receiver.

Figure 12 shows the level of IM3 coming out from the 144-MHz notch filter at the notch frequency. The level of one of the two tones is also plotted for a 1:1 straight line. The two curves are measured at frequency separations of 20 kHz and 100 kHz, respectively. For this measurement, 1W class A amplifiers followed by circulators were used in front of the combiner. The IM3 levels of the input signal to the notch filter are negligible. The notch filter was followed by an attenuator that was used to set the input to the RX144 converter well below the point where intermodulation is produced within the receive system. (The RX144 converter is the 144 MHz input of my high-performance receiver hardware for Linrad. It is a quadruple frequency-conversion radio with crystal oscillators only. The last conversion is from 2.5 MHz to DC, where a Delta44 soundcard converts wideband audio I and Q channels to digital form. For details, see <http://antennspecialisten.se/~sm5bsz/linuxdsp/optrx.htm>. The bandwidth was set to 3 Hz, and the Delta44 was run at maximum gain to achieve good sensitivity for the intermodulation products. It is quite clear from figure 12 that a crystal notch filter does not have the behavior we are used to seeing in amplifiers and mixers. The third-order behavior, which must be obeyed at very low signal levels, stops already when the IM3 product is about 100 dB below the level of the signal pair. The third-order behavior is extrapolated from low levels in figure 12: The third-order intercept point for the notch filter is +31.5 dBm for two signals separated by 20 kHz, and +49.5 dBm for two signals separated by 100 kHz.

With two test signals at +16 dBm, the notch filter gives IM3 73 dB below the signals, so for normal amplifiers and mixers, IP3 values up to +45 dBm can be measured accurately at 20 kHz separation at this power level. Without the notch filter, the IM3 levels are at –74 dBm, allowing measurement up to IP3 values of about +55 dBm. However, if the circulators are removed, the IM3 is at –52 dBm. Because the notch filter is needed anyway for the DR_2 measurement, it may be easier to use it than to make class A power amplifiers.

In summary, a crystal notch filter is a very practical piece of test equipment. It allows measurements to be done with standard laboratory signal generators, which otherwise are often too noisy to allow evaluation of DR_2. Measuring IM3 at the noise floor is difficult; a notch filter is one of the possible tools one can use, but the unusual behavior of IM3 products must be remembered, especially when working close to the notch frequency.

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(To Be Continued)

Moondata Update 2005 and Related Comments

One of the most important factors in EME communications is knowing when it is best to communicate via moonbounce. W5LUU presents a summary and table of the best and worst conditions for EME in 2005.

By Derwin King,* W5LUU

While a number of factors affect EME communications, the distance from the Earth to the Moon and the cosmic-noise temperature in the direction of the Moon are predictable, cyclical variables that set the basic day-to-day quality of the Earth-Moon path. Other effects being equal, best EME conditions occur when: (1) the Earth-Moon distance is at the absolute minimum; and (2) the moon is positioned, in RA and DEC (see definitions below), in the coldest part of the sky along the Earth-Moon path. In practice, this ideal occurs very rarely, and the EME signal-to-noise ratio is reduced by the DGRD factor (see below), which varies relatively slowly, but continuously with time. DGRD along with other pertinent data are tabulated in the accompanying table for each Sunday at 0000 UT to provide a guide to weekend EME conditions—particularly for 144 and 432 MHz.

In 2005 the average DGRD remains higher than normal as Moon perigee occurs at southern declinations in the region of high sky noise (temperature), and Moon apogee occurs near the maximum lunar northern declination. There are no Good weekend days before May 15. However, after mid-year conditions improve somewhat. From May 15 – November 11 there are three Very Good and five Good weekends, but all of these have low declination and are not ideal contest dates. Selection of contest dates will again be a problem and a compromise in 2005.

EME conditions will improve slowly over the next two years as perigee, on the average, moves ~ 2.7 hours RA per year along its ~9 year cycle. In 2007–10 DGRD will be much lower for many days each month as perigee occurs at north declinations and within a few hours of cold sky.

Definitions

DEC (deg): Moon declination in degrees north and south (–) of the equator. This is cyclical with an average period of 27.212221 days. The maximum declination during a monthly cycle is also cyclic, with a range of 18.15 to 28.72 degrees and a period of about 19 years. The next maximum will be in September 2006.

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

144 MHz Temp (°K): The 144-MHz cosmic noise in direction of Moon expressed as absolute temperature.

Range Factor (dBr): This is the additional EME path loss (in dB) due to Earth-Moon separation distance being greater than absolute minimum (348,030 km surface-to-surface). It varies from 0 to 0 .7 dB at perigee to 2.33 ±0.1 dB at apogee.

DGRD (dB): The degradation in EME signal-to-noise, in dB, due to: (1) the excess sky noise temperature (in dB) at the listed position of the Moon compared to the lowest cold sky temperature and the system noise temperature (all at the frequency of interest); plus (2) the Earth–Moon range factor (dBr) for the listed time and date. The tabulated DGRD is referenced to the lowest possible sky noise temperature along the Moon path, to a system noise temperature of 80°K at 144 and 60°K at 432 MHz, an antenna beamwidth of ~15°, and to the absolute minimum Earth-Moon (surface-to-surface) distance. The dBr affects DGRD equally at 144 and 432 MHz, but at 432 MHz sky noise effects are lower. During a monthly lunar cycle, DGRD can vary up to13 dB on 144 MHz and 8 dB on 432 MHz. DGRD varies less with small antennas than with large ones.

Moon Phase: Shows New Moon (NM) and Full Moon (FM) along with the number of days (d) or hours (h) before (–) or after (+) these events. At NM sun noise is a problem, while at FM the nighttime conditions are usually more stable.

Conditions: Summary of EME conditions as controlled by DGRD at 144 MHz and NM. Conditions may be worse, due to ionospheric disturbances, but not better than indicated. In general, 144-MHz DGRD <1.0 dB is considered Excellent, 1.0 to 1.5 is Very Good, 1.5 to 2.5 is Good, 2.5 to 4.0 is Moderate, 4.0 to 5.5 is Poor, and over 5.5 is Very Poor. High sun noise at NM can make conditions very poor, irrespective of the DGRD.

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The information and accompanying table are printed here in CQ VHF *on a non-exclusive basis courtesy of Derwin King, W5LUU.*

W5LUU Weekend Moondata for 2005
For Sundays at 0000 UTC

2005	DEC (deg)	RA (hrs)	144 MHz Temp (°K)	Range factor (dBr)	DGRD (dB) 144 MHz	DGRD (dB) 432 MHz	Moon Phase	Conditions
Jan 02	6.2	11.6	238	1.88	3.0	2.1		Moderate
09	–27.7	17.8	2734	0.12	10.7	4.2	NM – 1.5d	Very Poor
16	2.8	0.7	275	1.16	2.8	1.6		Moderate
23	28.0	6.5	415	2.34	5.4	3.3	FM – 2.4d	Poor
30	1.6	12.1	272	1.83	3.4	2.2		Moderate
Feb 06	–28.1	18.5	2123	0.28	9.8	4.6	NM – 2.7d	Very Poor
13	6.9	1.2	287	1.07	2.8	1.5		Moderate
20	27.6	7.1	349	2.32	4.7	3.0		Poor
27	–3.1	12.7	313	1.68	3.7	2.2	FM + 3d	Moderate
Mar 06	–27.6	19.2	779	0.49	5.9	2.6		Very Poor
13	10.6	1.6	303	1.09	3.0	1.6	NM + 2.4d	Moderate
20	26.6	7.7	262	2.28	3.7	2.6		Moderate
27	–7.6	13.2	317	1.44	3.5	1.9	FM + 1.1d	Moderate
Apr 03	–26.1	19.9	406	0.64	3.6	1.5		Moderate
10	14.1	2.1	331	1.24	3.5	1.8	NM + 1.1d	Moderate
17	25.0	8.3	201	2.25	2.8	2.4		Moderate
24	–11.6	13.8	336	1.18	3.5	1.7	FM – 0.4d	Moderate
May 01	–23.4	20.7	335	0.67	2.9	1.3		Moderate
08	17.5	2.7	360	1.47	4.0	2.1	NM – 0.4d	Moderate
15	22.8	8.9	172	2.26	2.4	2.2		**GOOD**
22	–15.1	14.3	368	0.99	3.6	1.6	FM – 0.8d	Moderate
29	–19,8	21.5	347	0.57	3.0	1.1		Moderate
Jun 05	20.9	3.3	361	1.71	4.2	2.3	NM – 1.9d	Poor
12	19.9	9.4	180	2.30	2.5	2.3		**GOOD**
19	–18.3	14.8	403	0.91	3.9	1.7	FM – 3d	Moderate
26	–15.8	22.1	271	0.41	2.0	0.8		**GOOD**
July 03	23.9	3.9	364	1.89	4.5	2.6	NM – 3.5d	Poor
10	16.5	10.0	187	2.32	2.7	2.3		Moderate
17	–21.4	15.3	442	0.94	4.2	1.8		Poor
24	–11.8	22.7	244	0.26	1.5	0.6	FM + 4d	**VERY GOOD**
31	26.3	4.6	422	1.97	5.1	2.9		Poor
Aug 07	12.7	10.5	201	2.29	2.9	2.4	NM + 2d	Moderate
14	–24.3	16.0	514	1.02	4.9	2.1		Poor
21	–8.0	23.2	244	0.21	1.4	0.5	FM + 3d	**VERY GOOD**
28	27.8	5.3	497	1.98	5.7	3.1		Very Poor
Sept 04	8.7	11.1	213	2.20	3.0	2.4	NM + 5h	Moderate
11	–26.7	16.7	755	1.08	6.4	2.5		Very Poor
18	–4.1	23.7	247	0.30	1.5	0.7	FM – 2h	**VERY GOOD**
25	28.5	5.9	500	1.95	5.7	3.2		Very Poor
Oct 02	4.7	11.6	240	2.07	3.2	2.3	NM – 1.4d	Moderate
09	–28.2	17.5	1816	1.04	9.9	4.1		Very Poor
16	0.0	0.2	259	0.53	1.9	1.0	FM – 1.5d	**GOOD**
23	28.5	6.5	411	1.93	4.9	2.9		Poor
30	0.7	12.1	270	1.93	3.5	2.3	NM – 3d	Poor
Nov 06	–28.5	18.2	2617	0.87	11.3	5.3		Very Poor
13	4.6	0.7	276	0.82	2.4	1.2	FM – 3d	**GOOD**
20	27.7	7.1	353	1.96	4.4	2.7		Poor
27	–3.1	12.5	313	1.86	3.9	2.4		Moderate
Dec 04	–27.8	19.0	870	0.60	6.5	3.0	NM + 2.6d	Very Poor
11	9.6	1.4	292	1.06	2.9	1.5		Moderate
18	26.3	7.7	270	2.06	3.6	2.4	FM + 2.3d	Moderate
25	–7.0	13.0	313	1.87	3.9	2.4		Moderate

CQ VHF Reviews

The Cushcraft ASL670 50–450 MHz Log-Periodic Antenna

By Phil Salas,* AD5X

Recently, my interest in the VHF/UHF bands returned after an absence of many years. My first introduction to the VHF bands was when I operated 6 meters back in my high school days (1965) during Field Day with a club in Maryland. I was WA3BCQ back then. Shortly after Field Day, I purchased a Lafayette HA-650 1-watt AM 6-meter rig and a Cushcraft 6-meter Squalo antenna. I mounted the antenna on my dad's chimney, and for the next several years I had a ball on that band. When conditions were right, the possibilities with my modest low-power setup on that "magic" band absolutely amazed me. I worked into Cuba and Mexico. Quite frequently, I worked halfway across the country.

Fast forward to 2004. Now I am an HF CW operator. Lately I've been exploring possibilities with my ICOM IC-706MKIIG (used strictly for portable operation until now), and I have been wondering about those higher frequency bands that I haven't operated in years. With a little pressure from Bill Conner, K5GMX, and Paul St. John, N6DN, I decided to get back on 6 meters. I was also curious about the activity on 2 meters and 70 cm, so I decided to work those bands as well. In considering these three bands and my environment, my dilemma became which antenna would best be suited for my situation.

The Antenna

I live on a relatively small lot, with no real room for a tower. Consequently, my HF operation is accomplished with a ground-mounted Butternut HF-9V, which is located in a corner of my yard. The advantage of VHF/UHF antennas is that they are relatively small and therefore can be roof-mounted. Even so, multi-band coverage can make for an "ugly installation" (non-ham term for antennas) if multiple antennas are required, even if the antennas are small in size. There is a solution, however, if one considers using a log-periodic antenna.

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Photo A. All of the Cushcraft ASL670 parts prior to assembly.

The log-periodic is a broadband antenna that can cover multiple ham bands. A great deal of information on these antennas can be found in the *ARRL Antenna Handbook,* and I won't rehash it here. With the log-periodic, some gain over separate antennas is lost, although the trade-off is not that bad. As an example, a 3-element, 6-meter beam has a forward gain of 8 dBi, whereas a same-length (6-foot) log periodic has a forward gain of 6.5 dBi. I'm willing to trade 1.5 dB for a single multi-band antenna.

The antenna I chose is the Cushcraft ASL670 log-periodic, which offers continuous coverage from 50 MHz through 450 MHz. The antenna is no larger than a TV antenna. It even resembles a TV antenna, and it can easily be rotated with an inexpensive TV rotator. The ASL670 specs are listed in Table 1.

Antenna Assembly

The assembly of the ASL670 is not bad at all. You can get a good feel for this yourself by downloading the assembly manual directly from the Cushcraft website at <http://www.cushcraft.com/support/pdf/951450.pdf> and reviewing it prior to ordering one.

The antenna is shipped in two separate boxes. One box contains the booms and elements, and the other has the remainder of the hardware. Photo A shows all the parts prior to assembly of the antenna.

The ASL670 is very rugged and very well made. The hardware is stainless steel, and all the antenna parts are aluminum. The instructions are well written, and the full assembly is very straightfor-

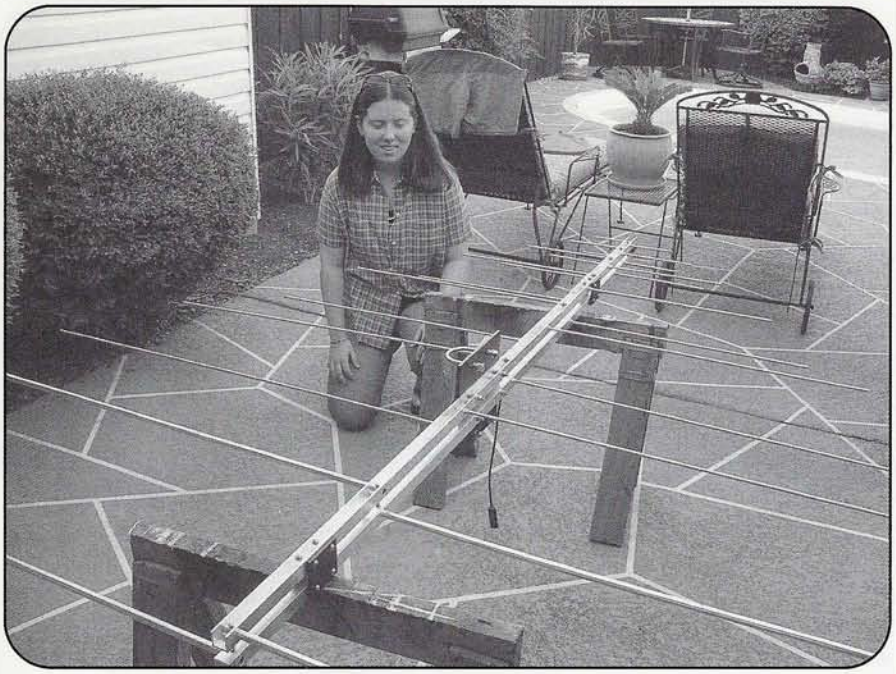

Photo B. Stephanie, AC5NF, AD5X's daughter, critiques her dad's completed antenna.

ward. If you pay attention to the alternating top-bottom positioning of the elements, you can't go wrong. The only problem I ran into was that the four aluminum "crush" spacers that fit into the two antenna channel "U"s were about 0.015 inches too wide to fit, so I had to file them down slightly. As it turned out, the total assembly time for me was approximately two hours, with 30 minutes of that time spent filing the spacers. All but the last two elements are made of solid rods that are threaded at the end for adjustment where they attach to the booms. The rear two elements are made of telescoping rods that must be adjusted to the proper length by using small stainless-steel hose clamps. In order to make the antenna easier to carry around, I did not extend these back two elements to their full length. Photo B shows the completed antenna.

Mounting the ASL670

The simplest and best place for me to mount the antenna was on my chimney. To do this, I purchased two pairs of RadioShack RS15-839 Ratchet Chimney Mounts. Another good mount is the Channel Master Model 9067 chimney mount, which is available from Warren Electronics at <www.warrenelectronics.com>. Both of these mounts include galvanized-steel mounting brackets and stainless-steel straps that wrap around the chimney. To give myself some safety margin, I used two pairs of mounts. I figured that the extra $20 was well worth the extra piece of mind. For example, if one stainless-steel strap ever breaks, the antenna will not come down! Incidentally, when you are installing the mounts on your chimney, wear eye protection and leather gloves, because those stainless-steel straps are both springy and sharp!

A small TV rotator will work fine with this light antenna. The RadioShack RS15-1245, the Hy-Gain AR-35, and the ECG U105 rotators will work well. Also check out eBay. I've found similar rotators made by RCA, Gemini, Magnavox, and Channel Master for $20-50 there. All these rotators use a three-conductor rotator cable. RadioShack sells 100 feet of three-conductor rotator cable for $13 (RS 15-1150). However, I wound up using some CAT-5 cable that I had for the 50-foot run, which was necessary in my installation.

The ALS670 antenna needs a mast size of at least 1.5 inches in diameter (2 inches maximum diameter). Because the RadioShack and Channel Master chimney mounts take mast sizes up to 1.5 inches in diameter maximum, I used a 1.5-inch diameter aluminum tube for both the chimney mount and the antenna mast. For the mast, I purchased a 6-foot long, 1.5-inch diameter aluminum tube from Texas Towers (http://www.texastowers.com). Texas Towers has a $25 minimum order

for shipped items, but if you buy the aluminum tube, coax, and N-male connector discussed later, you'll meet their minimum-order amount. Texas Towers also sells the ASL670. I cut the 1.5-inch diameter aluminum tube into 4-foot and 2-foot sections. The 4-foot section is used for the rotator support mast, and the 2-foot section is used for the antenna mast. For my feed-line, I used LMR-400 coax, which is a relatively inexpensive and fairly low-loss cable. The advertised loss is 0.9 dB/100 feet on 6 meters, 1.5 dB/100 feet on 2 meters, and 2.7 dB/100 feet on 70 cm. With 50 feet of coax needed in my installation, I should be getting half of those loss values.

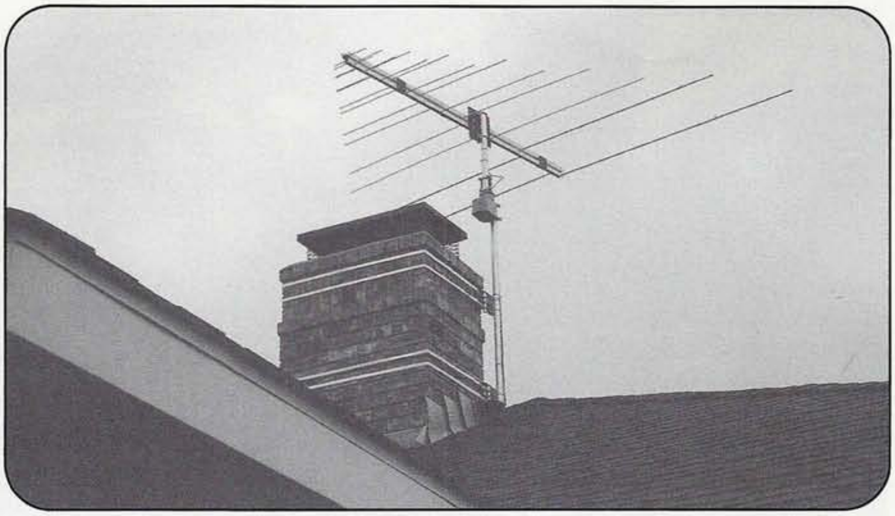

Photo C. Final installation of the ASL670 log periodic.

The ALS670 antenna includes a feed cable that is terminated in a female N-type connector. I built up a 2-foot piece of RG-8X coax, terminated with a PL-259 on one end and a male N-type connector on the other 9913 N-male solder-on with RG-8X reducer. RG-8X is very flexible, which provides the "twist" relief needed for the rotating antenna. I used a UHF "bullet" to attach the RG-8X to the LMR-400 cable. I coated all connectors with Liquid Electrical Tape to waterproof them. Liquid Electrical Tape is available from most hardware stores.

Finally, use UV-resistant tie-wraps to secure the coax and rotator cables to the mast. As mentioned earlier, I had left the rear two elements of the ASL670 retracted. I did this to make the antenna easier to carry onto the roof and install on the rotator mast. After installation on the rotator mast, I adjusted the ASL670's rear two elements to their proper lengths.

That's all there is to it. No antenna tuning is required. Photo C shows my final installation.

Operation

Obviously, with this broadband antenna all you have to do is pick your band and frequency, and transmit. Most of my operation has been on 6 meters, where the ASL670 has performed extremely well for me. My activity on 2 meters and 70 cm has been limited to a few contacts, but I'm looking forward to trying the antenna on an upcoming contest weekend to give it a real workout on the higher bands.

Frequency: 50–450 MHz, continuous
Elements: 14
Gain: 6.5 dBi, 4.5 dBd
Front-to-Back Ratio: 20 dB
SWR: 1.5:1 average
Power: 300 watts
3 dB Bandwidth H Plane: 110°
3 dB Bandwidth V Plane: 80°
Longest Element: 127 inches (3.2 m)
Turning Radius: 6.25 feet (1.9 m) Horizontal Mount
Turning Radius: 3.80 feet (1.15 m) Vertical Mount
Boom Length: 6.75 feet (1.9 m)
Wind Surface: 2.52 sq. feet
Weight: 11.25 lbs. (5.2 kg)

Table 1. Specifications of the Cushcraft ASL670 log-periodic antenna.

Conclusion

The Cushcraft ASL670 log-periodic provides the ham operator with a single antenna that covers the most popular VHF and UHF bands. This antenna is compact, easy to assemble, and easy to install. It can be rotated with an inexpensive TV rotator. Because it resembles a TV antenna, you probably won't have to put up with too many neighbors complaining about its "ugliness." I'm extremely pleased with the antenna's versatility and ease of use. I think you will be as well.

CQ's 6 Meter and Satellite WAZ Awards

(As of September 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

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

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

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

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

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By Gary Pearce,* KN4AQ

FM

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

Tone Deaf

I think that the SouthEastern Repeater Association (SERA) Board of Directors really didn't anticipate the storm of protest that developed in June when it voted to require tone on all repeaters in its eight-state coordination area. However, that's just what happened—on the air, on message boards such as QRZ.com and eHam.net, and in e-mail and phone calls to SERA officers. The announcement touched a nerve that has been lying close to the surface for years. The furor caused SERA President Roger Gregory, W4RWG, to attend the big Shelby, North Carolina hamfest "incognito," not wearing his distinctive red SERA shirt and not spending time at the SERA booth. The tactic didn't work. Angry hams found Roger in the flea market and gave him an earful. As this issue of *CQ VHF* is being prepared, SERA is reconsidering the decision, as I'll explain below.

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SERA is the frequency coordination body for amateur radio repeaters in Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and parts of Virginia and West Virginia. At its semi-annual meeting near Knoxville, Tennessee last June, Mississippi Director Steve Grantham, AA5SG, was discussing the FCC proposal to permit auxiliary stations to operate on 2 and 6 meters. SERA expects that plan could increase the number of stations using repeater inputs to link IRLP, Echolink, and other VoIP networked computers to local repeaters as hams take the easy way and just connect the computer to their base-station radio. That, in turn, could increase the problems with interference to co-channel neighbors, especially during band openings. (See details on the proposal later in this column.)

That was the immediate catalyst for Steve's motion to "require the use of CTCSS/DCS on both transmit and receive on all new FM voice repeater coordinations, effective June 13, 2004" and extend the requirement to all existing repeaters by July 2006. It surely wasn't the only reason for SERA to consider the policy. With more and more repeaters going on the air, more repeater owners are complaining about signals from users of their co-channel neighbors appearing on their inputs. They're also complaining about their users hearing the co-channel neighbor repeater's output as they drive around town. They want the frequency coordinators to "do something" about it. It seems that some repeater owners actually expect to be able to operate on a completely clear frequency except maybe in the wider band openings. That may be what was really on the minds of the coordinators when they voted unanimously to pass Steve's motion. You may notice that I'm trying hard to avoid using the word "interference."

Although the vote was unanimous, some directors were not present at the meeting and later indicated that they

The SouthEastern Repeater Association (SERA) coordinators at their summer 2004 board of directors meeting.

would not have voted for the motion. Also, among the staff at the meeting not all were totally pro-tone. Tim Berry, WB4GBI, an assistant director in Tennessee who owns several carrier-access repeaters, noted that tone doesn't really solve problems; it just masks them. He also pointed out the effort and expense some repeater owners would face to add tone to their machines. I added that from the user's perspective, tone was "traveler hostile," making repeaters difficult for hams to use while on the road away from home. For the most part, though, the SERA staff felt the time had come to actively encourage the use of tone to reduce the problem of annoying, weak signals from co-channel neighbors.

The motion that the SERA board passed was unequivocal: New repeaters will be required to use tone in order to receive coordination, and existing repeaters will need to adopt it in two years. However, during discussion before the vote, someone asked if repeater owners who chose to keep their machines' carrier access would automatically be decoordinated. The reply, according to my notes, was a "fuzzy 'yes.' Those repeaters would not automatically be decoordinated, but SERA would not entertain an interference complaint from a non-tone repeater." That language exists only in my notes and the article I wrote for SERA's magazine, the *Repeater Journal.* It does not appear in the motion or the meeting minutes.

The August quarterly issue of the *Repeater Journal* featured the story on the front cover. That started a buzz on some mailing lists. The ARRL picked up the story and put it on their website, and the debate was on. Debate may be too polite a word. Passions ran high, and not all in opposition to tone. There are plenty of tone advocates who have equally strong feelings. One ham came up to me at the Shelby hamfest (where I had the courage to wear my red shirt and stand in front of the SERA table), waved a copy of the *Repeater Journal,* and proclaimed, "It's about time!" It seems his club had been having its own debate about adding tone to its repeater when the *Journal* landed in mailboxes, supporting his position. He was happy.

The balance of comments, though, tipped well in favor of the tone opponents. They questioned tone itself. They questioned SERA's authority to impose the condition, and they wondered why SERA hadn't asked its membership for their input before implementing the policy. Some were polite. Some let their passion overcome their civility. Most ignored the tempering note about carrier access repeaters not being decoordinated and pushed their arguments to the limit. Hyperbole knew no bounds.

The merits of tone have been debated for years, and little new was added to the pot. Let's take a quick review.

Tone Doesn't Solve Problems; It Masks Them

This is true. If you have unwanted signals on your repeater input—whether they come from co-channel neighbors or mixes, spurs, and other grunge at a busy tower site—tone doesn't make the signals go away. All it can do is keep them from keying up the repeater. If the signals are fairly strong, they still will interfere with weaker signals from your users. Truly solving mix and grunge problems and eliminating the signals can be time consuming and expensive. Getting your co-channel neighbor's users to keep their signals out of your repeater can be politically difficult. I'd say that most of the time the unwanted signals a repeater owner has to deal with are weak and irritating, but don't present significant real interference. Masking them by using tone is an effective enough solution that's quick and cheap to implement. At least that's the way it seems at first.

Tone is Traveler Hostile

This is my complaint. A ham driving cross-country has a real problem with tone repeaters. How does he (or she) know what tone to use, and how does he plug that tone into the radio while driving? There are lots of partial solutions. Repeater directories list tone for most repeaters. Voice IDs can announce the tone (*beacon it*—don't wait for activity). Areas can cooperate with regional tone, so if you know the tone for one repeater in town, you know the tone for most of them. Do some homework before you head out, program some memories, and you can put yourself ahead of some of the problems. If you have a passenger who can operate the radio (or drive the car while you operate), tone is not so imposing. If you are solo, though, and didn't plan ahead, it can be dangerous to try to thumb through a directory and program a radio while driving.

Tone scan is a radio feature that can help, but it's only available in newer

The August 2004 quarterly issue of the SERA's Repeater Journal.

radios, and it's poorly implemented in most of them. In theory, if you hear a repeater but don't know the tone, you start tone scan and your radio finds the tone frequency and sets itself to transmit that tone. In practice, only a few models have a convenient, dedicated tone scan button on the front panel or the mic. Most make you hunt through a menu or three, put the radio in tone mode, and then start the scan. Some radios make you put the radio in tone decode mode, so you can't hear the conversation in progress until the scan finds the tone. *Attention manufacturers:* Tone Scan is a selling feature—get it right!

The ideal tone-scan implementation has you push one button, and the radio goes hunting. When it finds the tone, it beeps or something to let you know and turns on its encoder so you're ready to talk. However, that presupposes that the repeater you want to use is on the air and is sending tone. Not all repeaters send tone (SERA's plan requires sending tone). In addition, they're certainly not on the air all the time. There are a couple of suggestions to fix that, too: Use a second, "universal" tone (100 Hz is the common suggestion), and have a touch-tone that bypasses the tone (LiTZ, or Long Tone Zero, is among the recommendations). This is getting complicated!

Old Radios Don't Have Tone

This is the #1 complaint of users and repeater owners alike. I took some heat for editorializing that radios are cheap today and that I had "no sympathy" for the ham who only had a museum piece with no tone encoder. Tone has been universal since 1990 at the latest. New HTs are priced below $100. New mobiles are well below $200. They're loaded with features, including tone encode and decode, and that is a historic, rock-bottom price. It's true that young hams with no income, and old hams with fixed incomes, may have a hard time affording even these bargains. I do have sympathy for them, but this small segment of our service can't drive technology decisions. Get together with your club and help out these people. Don't make them "human shields" in your anti-tone battle.

Users Don't Know How To Program Tone

This is the #2 complaint, a close second to #1 above. It rates another "no sympathy" award from an "arrogant" KN4AQ (that's what one ham called me). I have championed the no-code license. I have defended new hams against the charge that they have a "dumbed down" license. I have maintained that getting a license is the *beginning* of learning, not the end. I have led club-meeting programs on programming radios . . . and I have programmed more than a few for local hams. Come on, guys! Yes, today's radios are complicated and feature-burdened. Each manufacturer has its own way of doing things, and there are no standards. Even I can't pick up an unfamiliar radio and make it do everything I want without checking a manual – and now and then I can't remember something esoteric . . . okay, even something basic . . . about one of the old radios on my shelf that I don't use much anymore. *But,* you *can* learn to program tone and store a toned channel in memory in your radio. Take out the manual and try. Ask a friend for help. Whether your coordination group has a tone policy or not, there are now thousands of tone repeaters out there, and you are limiting yourself if you avoid all of them.

Then go tackle something really difficult, such as setting the clock that's blinking 12:00 on your VCR.

A Toned Repeater Is a Closed Repeater

True in 1965. False in 2004.

Emergencies (and Lawsuits)

I've seen many comments from hams worrying that tone makes repeaters harder to use in emergencies, or that a ham who encounters a problem on the road won't be able to summon help if repeaters require tone. A few hams ratcheted it up higher: They worry that a repeater owner might be sued if a ham with an emergency can't use the repeater because it requires tone. (I'd really like to see that one on *Judge Judy*.)

This is really just an escalated version of the arguments already stated above. It's a good argument in that it's based in truth, and it does lend more urgency to the debate because emergencies are more important than routine rag chewing. However, are we saying that we should not make tone a normal part of FM repeaters because it inhibits emergency use (the same way it inhibits everyday use)?

I got the impression that the hams were playing the "emergency" card in an effort to discredit the SERA tone policy, suggesting that a repeater owner who put his machine in carrier access during an emergency risked his frequency coordination. I wish I could say I never made an exaggerated argument like that, but I can only say I haven't done it in a long time . . . at least since the last column (I'd have to go back and look).

Emergencies do make the problems of tone more serious, and they make the need to address and solve those problems more urgent. However, they don't roll us back to the days of all-carrier-access repeaters. If you intend to be an asset in emergencies, you need to know how to use all the repeaters in your area, tone and otherwise. You need to be flexible in operating your radio.

"Send Your Own Tone" and Mix Problems

Some of our more technical hams, probably repeater owners, jumped on the requirement that a repeater encode its tone, not just decode. Encoding tone allows your local users to use their decoders and avoid hearing your co-channel neighbor and most other noise in their heavy RF environment. It also lets travelers discover your tone with tone scan.

If you have a mix problem, though, and a bit of your own transmit energy and audio is getting back into your receiver, you may have switched to tone decode to solve . . . err, *mask* . . . the problem. Then you don't want to encode your own tone or the mask is useless. However, to hear all the hams who latched onto that point and hammered away at it, you'd think this was a rampant problem, not the rare one it really is. I think SERA would give you a get-out-of-jail-free card for this one.

Commercial Radios Need Programming

Your ham rig lets you program tone, and all the other operating parameters, yourself. If you're using a commercial rig, you probably can't—you might have to pay a radio shop to do it for you. Why use a commercial radio? They're physically tougher than ham rigs, able to take more punishment without failing. Also, they can have more intermod-immune receivers. When you make that choice, you concede that if your repeater "environment" changes—new repeaters come on the air or existing ones make changes —you have to get reprogrammed. Don't ask the world to stop for you.

This is Just a Secret Plan for Putting Repeaters Closer Together

What makes you think it's a secret? While activity on repeaters may have declined in the past few years, not many repeaters have gone off the air, and coordinators continue to receive requests for channels from prospective new repeater owners. The 2-meter band in particular is full in metro areas and many rural areas. Sometimes a coordinator can identify a spot where a repeater can be squeezed in if the usual 100-mile separation guideline can be reduced a bit. Tone will allow repeaters to exist a little closer together.

Now ham repeaters have some unique requirements, or at least desires, compared to their commercial cousins. A police repeater operator would be happy to have solid coverage to the city limit, then stop cold. A ham who puts up a repeater would like to cover the maximum distance possible given the site he can acquire. He wants every ounce of sensitivity he can squeeze from the receiver, and weak signals drifting in from a co-channel neighbor are not welcome. Pull that neighbor in a little closer, and the chance of getting those signals increases, and maybe not always so weak. Tone will keep the repeater quiet, but if there's a signal on the input, a local user, one using an HT in a marginal location, just might have a problem.

Can a repeater operator today reasonably expect that clear channel? Should we accommodate that user with the HT in your town at the cost of a group 85 miles away that gets no repeater at all?

There are Already Too Many Repeaters

That is a value judgment. There are a lot of repeaters that see little activity. However, anyone who wants frequency coordinators to start making the call about whether a group or individual *deserves* to put up a repeater isn't thinking about the consequences. This is quicksand. Sure, we can shoot from the lip and say that some of the repeaters in our town are going to waste, but can we formalize a procedure that's fair and applicable to all and stick to it?

Does the Coordinator Have the Authority to Require Tone (or anything else)?

We're no longer talking about the merits of tone, but this is a question raised by more than one complainant, so I thought I'd cover it. Some hams accused coordinators of trying to be quasi-, or not so quasi-, governmental groups, exceeding their "authority" and adding bogus rules.

They are not. Coordination is voluntary, and a coordinator can do nothing about a repeater owner who chooses not to be coordinated. That's not the end of the store, though.

There are two sections of the Part 97 rules that address frequency coordinators—what they are, what they can do, and what the consequences are if a repeater owner chooses to operate an uncoordinated repeater. They are:

97.3 Definitions. (a) The definitions of terms used in Part 97 are: *(22) Frequency coordinator.* An entity, recognized in a local or regional area by amateur operators whose stations are eligible to be auxiliary or repeater stations, that recommends transmit/receive channels *and associated operating and technical parameters* for such stations in order to avoid or minimize potential interference.

97.205 Repeater station. (c) Where the transmissions of a repeater cause harmful interference to another repeater, the two station licensees are equally and fully responsible for resolving the interference *unless the operation of one station is recommended by a frequency coordinator and the operation of the other station is not.* In that case, the licensee of the noncoordinated repeater has primary responsibility to resolve the interference.

I highlighted the section on *associated operating and technical parameters* to show that a coordinator can make tone a condition of frequency coordination. The line *unless the operation of one station is recommended by a frequency coordinator and the operation of the other station is not* addresses the consequences of not being coordinated. The FCC's Riley Hollingsworth routinely questions repeater owners about the status of their coordination (and double-checks with the coordinating bodies) when he receives an interference complaint about a repeater. He frequently has required the uncoordinated repeater to take steps to solve the problem, and in a few cases required a repeater to cease operation until it could find a way to become coordinated.

That elevates the importance of coordination and coordinators. Will the FCC examine the tone issue if hams complain about that aspect of coordination? Perhaps. The issue hasn't been pushed that far yet.

SERA Didn't Ask

One final issue: SERA didn't poll its membership, or non-member repeaters, before it passed the motion to require tone, and many repeater owners and users considered it a dictatorial step. It may well cost SERA some membership.

This issue isn't just about SERA. It comes up in any representative democracy. Should "the people" get to call the shots, or do they let their elected representatives make the tough calls (and explain themselves at re-election time)? Any repeater owner can be a SERA member, although many choose not to be (it's \$20/year, but it's probably more the principle that leads some owners to exclude themselves). Only members can vote, and the only thing they can vote for (or against) is their state director and vice director. The board makes all the decisions. That's a lot like the ARRL's system, and the ARRL takes some shots for it as well.

As I said at the beginning, the SERA board misjudged the potential reaction. It could have published the plan as a proposal in the *Repeater Journal* and asked for reaction, and that may have mollified some of the critics. It may also have caused SERA to enact a somewhat different plan.

What Will Happen?

By the time you read this, it should already have happened. Look on the SERA website (www.sera.org) for an update. As I write this in mid-September, the SERA board is reviewing a proposal that would make it clear (and official) that tone remains voluntary, while retaining the idea that a repeater owner who chooses carrier squelch will have no avenue of complaint about co-channel signals. So far there is much more internal debate than we saw with the original motion. The board heard its members, but it still intends to provide leadership on a difficult but important issue.

FCC Proposes Permitting Aux Links on 2 Meters

The FCC has proposed permitting auxiliary links on the 2-meter band, following a petition by Kenwood for a rules change that would make its Sky Command system legal in the U.S. Aux links are currently permitted only on frequencies above 222.15 MHz. This proposal is among many in a wide-ranging NPRM released as Docket 04-140 on April 15, 2004.

If the NPRM becomes a rule, it would have a significant impact on the use of 2-meter stations as repeater links, particularly for repeaters connected to the internet for VoIP (IRLP and Echolink) operation. Over the past two years, many hams have linked computers connected to IRLP and Echolink to their repeaters "the easy way," by connecting the computer to a base-station radio transmitting on the repeater input.

I consider those to be auxiliary links, not legal on 2 meters. Such links are legal, but not a good idea on 220 or 440 either, because of the possibility of a high-occupancy automatically-controlled transmitter causing interference to a co-channel repeater during a band opening.

In the NPRM the FCC state, "because we have no basis to conclude that auxiliary stations transmitting on the 2 m band would cause harmful interference or that user coordination would not be possible, we believe that Kenwood's proposed rule change will be consistent with our flexible-use policy in the amateur service."

If the NPRM becomes a rule, 2-meter auxiliary links could be considered as part of the coordination of a repeater. The point will be to carefully contain the link signals by using low power and directional antennas so they have little chance of affecting a co-channel neighbor. A simple connection between a repeater user's computer and base-station radio might not be coordinated and might put a repeater's existing coordination in jeopardy.

The NPRM also proposes permitting spread-spectrum on bands from 6 meters up, and many other rules changes. Kenwood's Sky Command is a system that permits remote operation of an HF station using a dual-band base radio. Since most dual-band radios are 144/440, Kenwood pushed for auxiliary operation on 144.

FCC to Favor VHF/UHF and 60 meters for Emergency Communications Declarations

The FCC announced a "clarification" of its policy on Emergency Communications Declarations in August. The Commission will now issue ECDs only for VHF/UHF (mostly for repeater operation) and 60 meters. The FCC's text is on the ARRL's website at: <http://www.arrl.org/FandES/field/emcom-declarations.html>.

Until now, most ECDs were issued for 40- and 80-meter frequencies and gave the requesting group a fairly effective tool in convincing other hams to leave a frequency clear for emergency operations. Few ECDs were issued for repeater frequencies.

Your FM guy finds this a curious change, one I don't understand. Perhaps *CQ*'s Fred Miai, W5YI, will have some explanation in his column. It sounds to me like they just don't want to be bothered with them any more. Repeaters are generally pretty easy to control in emergency situations and don't have the interference problems that HF frequencies can. Sixty meters can use the shot in the arm; you don't hear much about use of the band for emergencies, and relatively few hams are equipped for the band yet.

Forty- and 80-meter emergency nets aren't out in the cold. Emergency communications still has priority on any band. However, the FCC ECD club had some weight to it and helped keep a frequency clear in those gaps when there was little traffic being passed.

K7IJ and Repeater Control

I was in San Francisco for a brief visit recently. I didn't have much time for hamming, but I was curious about the state of the K7IJ repeater across the Bay in Berkley. The FCC has a thick file on this repeater, home of some notorious operating practices either ignored or condoned by an absentee licensee and some "tolerant" control operators.

I kept an HT on the frequency for several hours each day over a long weekend and I heard almost nothing. Once, the repeater ID'd, prompting the clever response, "Who the **** cares?" I don't know if that's now routine for the repeater, or if I just caught them on a few slow days.

Of more interest to repeater owners, I came across a comment about the K7IJ repeater that Riley Hollingsworth made at the Southwestern Division ARRL Convention last year. He was quoted in *WorldRadio*:

> The difficulty in working a repeater case like that is you just can't tell the repeater operator that if you have certain kinds of violations, you have to shut it down. That would just open the door to people who want to get that repeater shut down to come on the air and do just that. If they have the mindset that they want that repeater shut down, they'll make sure those violations occur. That defeats the purpose. It's a complicated process to work your way through a repeater case. Those guys are doing a good job, and I think we'll see some improvements there.

It's good news that Riley sees it that way. He's right—if a repeater control op shut down a machine just because someone came on and burped, he'd be handing control over to the lid. Repeater owners shouldn't see this as license to take an "anything goes" attitude, though. Fortunately, most repeaters have little to no problem with this kind of thing. On most repeaters, the mantra "ignore them and they'll go away" works pretty well.

That's it for this edition. If you have FM/repeater-related news or comments for the column, send me e-mail. Thanks to the many hams who have passed along their appreciation. ■

By John Champa,* K8OCL

HSMM and Information Security

September 11, 2001 changed everything in America. We have often heard that phrase. Did we think it would apply to U.S. radio amateurs? It certainly does increasingly apply to our clients, the local emergency operations centers and other disaster-response agencies. They welcome the capability of high-speed multimedia (HSMM) equipped and trained teams of hams providing internet-type emergency radio communications services anywhere, anytime, in the field during a disaster. Being able to have simultaneous voice, video, data, and text at a digital rate more than 5000 times faster than conventional packet radio is impressive. However, increasingly, such agencies are expecting that our ham services be secure from unauthorized individuals. How do we accomplish that goal within the traditional bounds of the Amateur Radio Service?

That was the question faced by the ARRL's HSMM Working Group (WG) earlier this year. Subsequently the working group developed a proposal that was enthusiastically endorsed by the ARRL Board of Directors at its meeting this summer. The Board directed its legal counsel to incorporate the HSMM WG proposal into current efforts toward proposing new regulations for the service. What follows is the full text of this historic milestone proposal in amateur radio.

Security and Data Integrity on a Modern Amateur Radio Network

By Paul J. Toth, NA4AR
Emergency Communications Specialist
ARRL HSMM Working Group
Amended 6/29/2004

Executive Summary

This document has been prepared by the ARRL High Speed Multimedia & Networking Working Group (HSMM) to highlight a growing need for regulatory change governing high-speed, wireless data stations operating in the Amateur Radio Service. The HSMM respectfully requests the support of the ARRL Board of Directors for development and filing of a Notice of Proposed Rulemaking (NPRM) *permitting the use of encryption and strong security protocols on domestic transmissions above 50 MHz.*

Part 97 has, for decades, required that all Amateur Radio Service communications be conducted "in the clear." ITU regulations and treaties, to which the United States is a signatory, prohibited the use of ciphers and schemes designed to conceal the meaning of transmitted communications. However, an amendment made to Article 25.2A (1A) at the 2003 World Radio Conference no longer specifically prohibits the use of encryption and other strong security measures on transmissions between amateur radio stations within the same jurisdiction.

Several recent events are driving the need for stronger station access and content security. These include:

• The need to prevent access to amateur radio stations by millions of unlicensed commercial and non-commercial users operating under Part 15 of the FCC's rules.

• The need for amateur radio operators providing emergency communications services to observe significant changes in security and privacy regulations.

• The continuing threat to Homeland Security since the 9/11 attacks have caused numerous federal, state, and local agencies to mandate more secure communications.

The Amateur Radio Service has shared spectrum in harmony with other FCC-licensed radio services, primarily non-commercial government operators. However, commercial, for-profit traffic and messages that are prohibited under Part 97 are now routinely transmitted by millions of unlicensed businesses and individuals on bands previously allocated for non-commercial use. Unlike Part 97 operators, these non-licensed users are free to employ strong industry-standard security protocols to prohibit unauthorized access and to protect the integrity of the transmitted content.

The availability of these unlicensed devices, coupled with an armada of sophisticated software tools, has severely compromised amateur radio operations on numerous bands. Most notable are bands above 902 MHz, including those allocations where the Amateur Radio Service is designated the Primary Service. At the same time, hams are prohibited from securing their transmitters, the computers, and other technology connected to the transmitters, and the information those systems store from unwanted intruders. It could be said that this has left licensed amateur radio operators swimming totally unprotected amongst a sea of hungry sharks.

This new landscape seriously compromises the relevance of amateur radio communications in our 21st century society. As laws governing society and information mandate more privacy and security, the Amateur Radio Service finds itself hamstrung by outdated and outmoded regulations. The existing regulations are in direct conflict with policy changes and regulations now being used by many disaster-response organizations previously served well by Amateur Radio Service licensees. The events of 9/11 have changed the landscape for all communications, particularly emergency and disaster-related transmissions. Without the legal authority to employ strong security protocols, the Amateur Radio Service will be out in the cold, unable to serve and fulfill one of our prime mandates. These prohibitions will also serve to stifle continuing technological innovation, a cornerstone of amateur radio.

The HSMM Working Group believes a solution to this dilemma is achievable. Changes to international regulations governing amateur radio communications permit the local governing authority, the FCC, to legalize the use of encryption and strong security protocols on domestic transmissions. Further, the FCC has pub-

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licly stated that a policy allowing it to easily monitor Amateur Radio Service transmissions is no longer enforced on frequencies above 50 MHz.

Thus, the HSMM Working Group respectfully asks the ARRL Board of Directors for their support of this needed regulatory change and urges the Board to support the development and filing of a Notice of Proposed Rulemaking (NPRM) *permitting the use of encryption and strong security protocols on domestic transmissions above 50 MHz.*

Key Points

The HSMM Working Group was established by the ARRL Board of Directors to further develop high-speed digital operations under Part 97. Our work has focused on several key areas, including:

Frequency Allocations Best Suited for Broadband Operations. Amateur radio has several allocations above 420 MHz that are well suited for broadband digital operations. These include: 420–450 MHz, 902–928 MHz, 1240–1300 MHz, 2390–2450 MHz, 3300–3500 MHz, 5650–5925 MHz, and 10.0–10.5 GHz.

Band Sharing with Other Licensed Services. Several of the bands noted above are shared with non-commercial licensed radio services, primarily the federal government. While the opportunity for interference exists, we do not see this as a major issue.

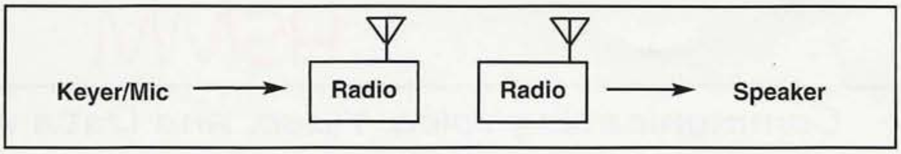

Figure 1. A "traditional amateur radio communications system.

Band Sharing with Unlicensed Operators. In recent years, the FCC has encouraged unlicensed commercial and non-commercial utilization of these bands. In fact, WRC-03 made a global, *primary* allocation of 5150–5350 MHz and 5470–5725 MHz for "wireless access systems, including RLANS." The development and mass marketing of low-cost, low-power Part 15 transmitters has resulted in millions of these devices operating on the 902–928 MHz, 2400–2450 MHz, and 5650–5925 MHz bands. This significantly increases the probability of illegal use of unsecured amateur radio transmitters by Part 15 operators and other security breaches that can lead to loss of data and the compromising of attached ancillary systems.

Station Security. Part 97 requires Amateur Radio Service licensees to prevent unlicensed operators from access to their stations. However, Part 97 prohibits licensees from using the industry-standard 802.1x and other security measures found on low-cost 802.11(a)(b)(g) transceivers. This leaves licensed stations open to unwanted and illegal access by unlicensed operators, many transmitting commercial content, jeopardizing the licensee's privileges.

Data Integrity. Part 97 prohibits the use of ciphers and symbols to hide the meaning of transmitted message content. The continuing threat to Homeland Security following 9/11—coupled with the enactment of stringent privacy policies and laws, like HIPAA—prevents amateur radio operators from providing needed communications services to many disaster-response agencies and organizations previously served. This new landscape seriously compromises the relevance of "open" amateur radio communications in our information-driven 21st century society. This will have a chilling impact on the recruitment of new licensees, on future innovation and discovery in the wireless realm, and on the ability of the Amateur Radio Service to provide emergency communications services as needed.

The submission and enactment of a Notice of Proposed Rulemaking (NPRM) permitting the use of strong security and content encryption will enable amateur radio operators to abide by existing regulations prohibiting unlicensed use of station facilities. It will, further, re-affirm the Amateur Radio Service as a relevant and responsive part of the domestic communications fabric.

The Challenges

If someone requested a diagram of a "traditional" amateur radio communications system, it would probably look like figure 1. One operator, using a Morse Code keyer or a microphone, sends a message on some assigned frequency to another operator who receives the message with a similar radio equipped with a speaker.

It has been 70 years since the Congress and the Communications Act of 1934 formalized the Amateur Radio Service. While this basic communications model is still a valid representation of how radio amateurs can communicate, the Federal Communications Commission and advancements in communications technology now enable us to communicate in many other ways.

For example, the advent of the personal computer in the 1980s led to

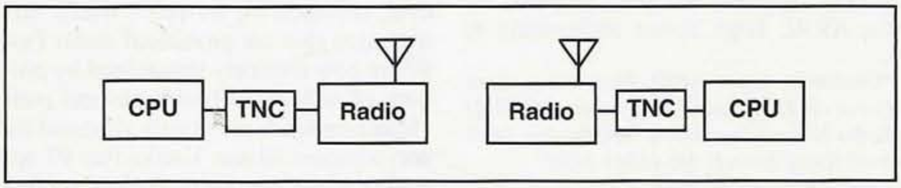

Figure 2. Packet radio system configuration.

Packet Radio (figure 2), where a computer connected to a Terminal Node Controller and a radio allowed operators to send text to one another, keyboard to keyboard, in real time or by transferring files located on a disk.

The security of the information and the computer technology connected to the amateur radio transceiver was not in question because of the relative simplicity of the systems and the lack of connectivity to other computers.

The invention of Ethernet, a technology now widely used to link computers and other information devices together in a network, further expanded our ability to communicate over wired media with these devices. Computer networks are now commonplace in business and in many homes.

More recently, in the mid-1990s, an Information Revolution was fueled when computers of various shapes, sizes, Operating Systems, and purposes connected to the internet. A creation of DARPA in the late 1960s, the internet had been used primarily for research by various colleges and universities as well as by the federal government. The commercialization of the internet at the end of the 20th century was responsible for an exponential proliferation of digital information systems, capable of reaching halfway around the world and providing access to information in milliseconds. Schools, hospitals, businesses large and small, and millions of home worldwide are now linked together via the internet. The potential for significant benefit from this degree of connectedness is almost boundless; however, the potential for great harm from providing access to malicious individuals is also increased.

As computers got smaller, faster, capable of processing many different kinds of information, a growing clamor arose for low cost, unlicensed wireless connectivity. The groundwork for this use of the radio spectrum had been laid by the FCC with the allocation of several unlicensed bands under Part 15. Most of the early Part 15 broadband devices were slow and expensive. But with demand in the marketplace exploding, coupled with the legalization of DSSS and OFDN, low-cost Part 15 devices became plentiful.

Part 15 transceivers operate with low power output and other restrictions that limit their overall range. Manufacturer adoption of several IEEE standards, including 802.11(a)(b)(g), has empowered millions of unlicensed individuals,

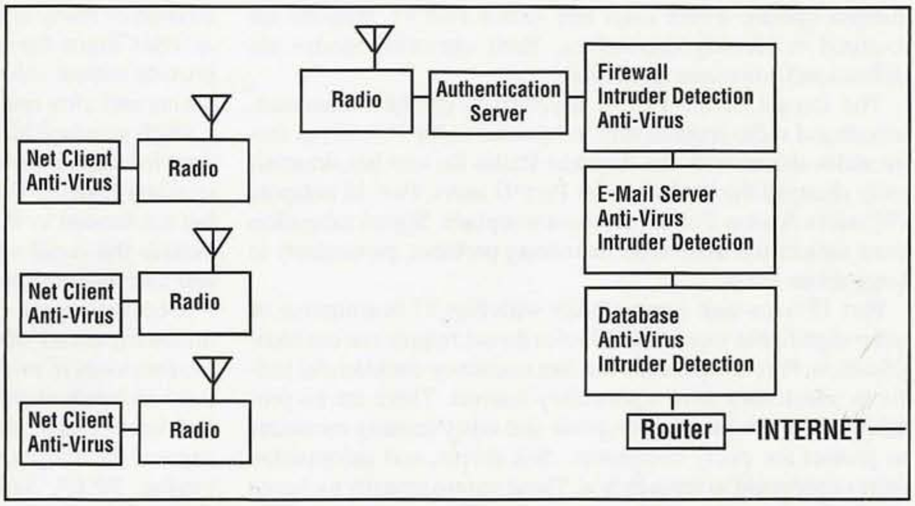

Figure 3. A typical Part 15 wireless network operating with IEEE standard 802.11a/b/g radio technology.

businesses, and government organizations to get on the air. In some cases, remote offices are now connected to the main office using these radio transceivers, eliminating costly data circuits leased from the local phone company. Much of this activity uses spectrum that overlays the Amateur Radio Service allocations at 902 MHz, 2.4 GHz, and 5.7 GHz. Further systems may include the use of Part 15 frequencies that reside within the Amateur Radio Service bands between 1240–1300 MHz and 3300–3500 MHz.

Amateur radio operators have successfully shared spectrum with other licensed, non-commercial Radio Service users, including the government. These other stations operate within rules that mirror Part 97. Stations are required to identify themselves. Their operating modes are defined and emissions quantified.

The impact of the FCC's decision to permit unlicensed, broadband radio transceivers to operate under Part 15 on frequencies shared with the Amateur Radio Service has dramatically changed the landscape for Part 97 users. Part 15 hotspots (Wireless Access Points) are commonplace. Signal saturation from unlicensed users is an increasing problem, particularly in large urban areas.

Part 15 rules lack compatibility with Part 97 in a number of other significant ways. Part 15 rules do not require station identification. Part 15 operators are free to convey commercial traffic in which they have a pecuniary interest. There are no prohibitions on the use of encryption and other security measures to protect the many computers, disk drives, and information stores connected to these radios. These strong security tools can also be freely used (and are commonplace) to secure the authentication process as authorized users attempt to gain wireless access to the information resources, including the internet, connected to these Part 15 transceivers.

A typical Part 15 wireless network, operating with IEEE standard 802.11a/b/g radio technology may look like figure 3.

It is a common and best industry practice for User Authentication and passwords to be transmitted using strong security protocols. It is also a common and best industry practice for messages and other data to be "tunneled" using Virtual Private Networking, sets of protocols that purposely make it extremely difficult for data theft by radio-signal interception to be successful. As you can easily see, this is significantly more complex than the communications model shown at the beginning of the article.

If radio amateurs are to exercise the operating privileges they have been granted on several assigned bands now openly used by non-licensed Part 15 operators, we, too, will need the freedom to utilize the same security tools and protocols to keep these unlicensed users from accessing our stations. Computer programs, such as NetStumbler, permit anyone with a WLAN transceiver to eavesdrop and intercept broadband data signals and decipher their content. This has led to numerous computers and networks attached to these wireless transceivers being breached, compromised, and ransacked. Several state and federal courts have ruled it is the responsibility of the wireless-transceiver operator to prevent would-be intruders from breaching these transceivers and the information resources attached to them. Without the use of Authentication servers and protocols, firewalls, Virtual Private Networks, Secure Socket Layers, and other Information Management tools, these radio transceivers and the other technology and data connected to them are indefensible to attack.

Remedies

Radio amateurs are *required* to *secure* their transmitters and prevent access by anyone not holding a valid Technician Class or higher amateur radio license [97.5(a)]. Because the industry-standard tools needed to accomplish this are prohibited under Part 97, this requirement has created a virtual impossibility.

Further, laws and regulations governing information security and release have changed dramatically as concern over personal privacy has increased. The HIPAA laws and private and governmental Privacy Policies have raised the bar on the transmission of many kinds of information and personal data. This severely limits the ability of the 21st century radio amateur to provide critical, relevant communications service and conduits during and after real emergencies.

IEEE standard 802.1x exists to provide a roadmap and standard for station authentication and access to broadband, wireless data systems. Other industry-standard protocols, including but not limited to WEP, EAP, and LEAP, are commonly used outside the Amateur Radio Service to provide secure station and user authentication.

Licensees in the Amateur Radio Service need to be free to utilize these and other industry-standard security and authentication tools to protect the integrity of their stations, particularly on bands shared with Part 15 operators. Amateur Radio Service licensees should also be allowed to protect the security and the integrity of the information their stations are conveying. PPTP, Secure Socket Layer (SSL), Secure Shell (SSH), Virtual Private Networking, and other standard protocols and tools are routinely used to convey information in a secure manner on wired and wireless links. Amateur radio operators should be permitted to use these tools, as they represent "good engineering practices" in modern data and information management. Information conveyed in the clear is no longer an option for many essential service providers who rely on amateur radio operators when normal communications systems are not available.

These measures will enable Amateur Radio Service licensees to successfully co-exist with operators governed by other rules and operate in accordance within other Part 97 specifications, resulting in a minimum of interference and security concerns. They will allow the development of amateur radio infrastructure capable of yielding new, innovative capabilities and methods, proving out those capabilities and methods under a variety of operating conditions, allowing licensees to communicate in ways never before possible. This will lay a solid foundation for Amateur Radio Service licensees nationwide to use our assigned spectrum and license privileges to provide essential, relevant emergency communications services to our communities when they need us the most.

The popularization of the internet has fueled an information-driven society. Then add to this a policy of spectrum sharing and the events of 9/11/2001. The realities of the 21st century present a difficult and challenging operating landscape for the Amateur Radio Service. It is time to modernize Part 97 to reflect these changes. This will allow U.S. radio amateurs to continue a proud tradition of innovation and service when it is needed most.

Acknowledgements

This document was developed with significant input and expertise from members of the HSMM Working Group, including:

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Carl R. Stevenson, WK3C
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By Chuck Houghton,* WB6IGP

MICROWAVE

Above and Beyond, 1296 MHz and Up

A Single-Thermistor Power-Meter Adapter

My last column covered something I found while trying to resurrect an old military-surplus microwave power meter, the USM-174. The reason I put my efforts into repairing this old-world unit was because it came with a single, unbalanced thermistor power-meter head for 24 GHz, and I was trying to upgrade my test equipment for 24 GHz.

Power-Meter Head Operation

First let's cover some common power-meter head operation.

Most power-meter heads in operation today use a temperature-compensated power-meter head with two sets of thermistors, one for RF and one for temperature balance, making for a very stable-reading-RF power-meter head. There are other power-meter heads which use diodes and other elements in the RF head. They are very good, even superior, but they are very expensive.

Finding the USM-174 and its compartment of various single-thermistor power-meter heads was quite a thrill. There are four RF heads—100 MHz to 8 GHz, 8 to 12 GHz, 12 to 18 GHz, and 18 to 25 GHz. The experimentation that followed as I was trying to repair the instrument gave me new respect for these power-meter heads. The RF heads are from the 1950s era of microwave test equipment, and they still seem to be available at swap meets and such. They require the older tube-type power meters to function like the Hewlett Packard 430 series of meters (vacuum-tube units). Most of the older power meters are just not available, but the heads keep turning up.

Knowing that simple resistance testing of the more popular HP-478 series dual thermistor (used with 431 and 432 power meters) was a simple resistance test of the two thermistors internal to the head, I tested the old, single power-meter head's thermistor out of curiosity to see if the head was functional. It had a similar resistance of a few thousand ohms. The test was to first determine if it was alive.

Photo A. The original HP-432-KO5 adapter.

I might have been wasting my time, but further investigation was warranted. I found a friend who had an old HP-430 power meter. I borrowed it and tested the single-thermistor heads with RF applied in normal operation on the bench. All heads functioned okay, with RF from 1 GHz to the head that I was most interested in at 24 GHz. Now the hunt was on, trying to make these older power-meter heads function with more modern power meters or repair the older USM-174 meter. Yes, I could have put an old 430 power meter on my work bench. However, this workhorse of the 1950s was about 6 inches too tall to fit with the lower, more modern profile of the HP-432, HP-435, and HP-436 power meters.

At this same time I was working on another project, and I contacted a friend concerning some surplus PC-board material from which we were recovering diodes for our 47-GHz mixer project. The power-meter and the single-thermistor heads came up during the conversation, and my friend mentioned that it was too

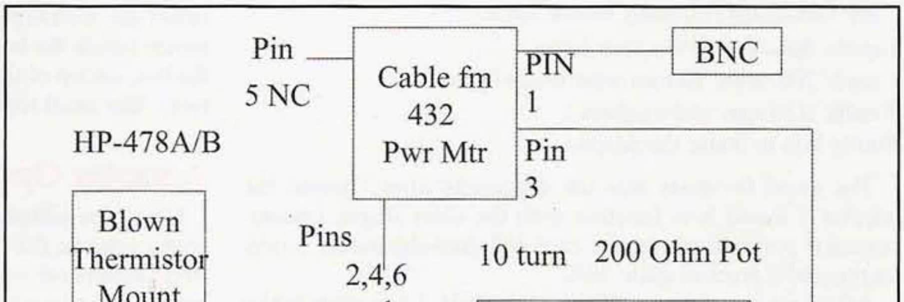

Figure 1. Adapter schematic diagram.

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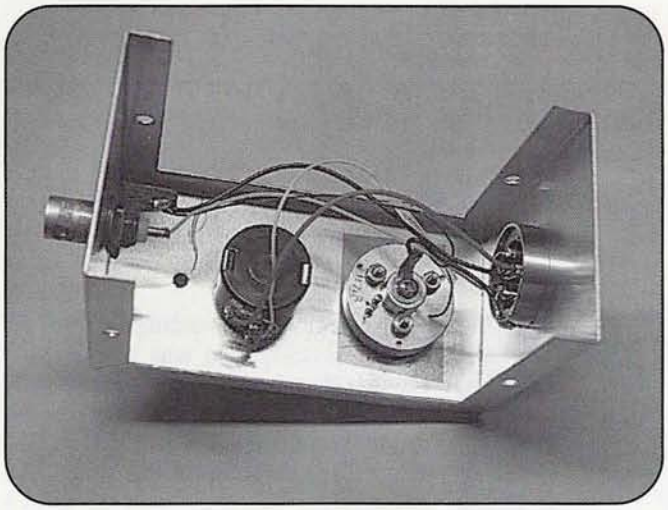

Photo B. The test unit built by the author.

bad I did not have one of the single to dual power-meter adapters made many years ago by HP for such applications. My curiosity certainly was piqued, especially when he mentioned that he had one. I borrowed the adapter, and the rest of this column is history.

I received an HP part #432-KO5 adapter (photo A); a small, 3" × 3" × 1" metal box with a BNC connector on one side; a 6-pin, 432-type power-meter connector on another; and a balanced potentiometer on the third. Opening up this adapter and looking at the very few parts inside proved to me that this nut was a very simple one to crack and somewhat easy to duplicate. The parts list follows:

1 each: BNC connector
1 each: 6-pin HP 432 male HP connector
1 each: HP power-meter head from defective HP-478.
Use the temperature-compensated thermistor, as the RF thermistor is usually blown open.
1 each: 464-ohm, 1/4-watt resistor
1 each: 200-ohm, 10-turn wire-wound pot
3 each: 2/56 nuts and washers
Sturdy box to house the adapter

The quest for parts was on, especially after I tested the adapter. I found it to function with the older single, uncompensated power-meter heads on a 432 dual-thermistor power meter, and it worked quite well.

After looking at the problem for a while, I was stymied by where to pick up the HP 6-pin chassis connector and the thermistor temperature-compensated mount. The 200-ohm, 10-turn pot was a little bit of a problem also. In surplus I could find pots from 5K up, but not lower values, until I looked in the Mouser Electronics catalog. Mouser (telephone 800-346-6873) had the exact Vishay/ Spectrol 10-turn Met Shaft 200-ohm precision pot part #594-53411201, MFG part # 534-1-1-201, and they cost $8.67 each. Now with the 1/4-watt resistor, the BNC connector, and the small Bud box, the project was taking off quite well.

My search for the HP temperature-compensated thermistor mount and an HP 6-pin male 432-style power-meter chassis connector started and stopped almost immediately. I realized that when the HP-478 dual power head is blown, it almost always blows the RF thermistor, but a good thermistor remains in the temperature portion of power-meter head. Also, the connector on the top of this same blown 478 power-meter head was exactly the 6-pin male-connector chassis connector I was looking for, which made construction and duplication of the adapter quite simple. Blown 478 HP power-meter heads are a dime a dozen. Good ones, on the other hand, are expensive, and thus began the quest for a blown head to prove I could build this adapter.

The box I built worked just as well as the original HP adapter I had borrowed. The Bud box could have been made from a thicker aluminum material to improve temperature effects, causing a slight drift of the system's adapter. However, the concept was proven.

Testing and Repairing HP-478 RF Heads

When testing HP-478 RF power-meter heads, good units should measure between 1000 and 5000 ohms on pins 1 and 3 each to ground (case ground) and balanced to less than 10%. A blown head will have one thermistor open, most likely the RF device on pin 1. Pin 3 should have a reading of between limits stated as above 1K to 5K ohms.

Now for the repairs: Open up the blown 478. Save the 2/56 hardware screws that mount the sealed head to the "N" input RF portion of the head, as the screws will be needed to mount the sealed thermistor mount on the box's side wall. Leave the connecting wires intact. Unsolder the leads from the 6-pin connector, leaving the ground strap on pins 2, 4, and 6. Carefully remove the thermistor head by unscrewing the three 2/56 screws, saving the insulating mounting material and the three-hole gold-plated PC-board spacer. The spacer will be used for a drill-hole position marker for the three 2/56 mounting screws. There is an insulating material between the goldplated PC board and the chassis. I used a small piece of Kapton, and it worked well.

Once the holes for the thermistor mount were drilled, I placed the Kapton over the holes and with an X-Acto® knife cut slots for the 2/56 mounting screws. I then placed the Kapton inside the box and pushed the 2/56 screws through the Kapton in preparation for mounting the gold-plated PC board and thermistor mount inside the box. The 2/56 nuts should be on the inside of the box, on top of the phenolic insulators (part of original structure). Use small retaining washers.

Adapter Operation

Using the adapter is simple. First connect the 6-pin connector plug on the adapter to a 432 power-meter cord, and the BNC connector to a thermistor mount. Turn on the 432 AC power; the meter usually will peg in one direction or another (set the meter to coarse zero). Use the 10-turn pot on the adapter to balance the adapter to the meter's left zero position. Once on zero, test as you normally would with the power meter's dB-range switch and RF head selected for the frequency used for the test.

Note: There are two types of single detector element power-meter heads— thermistor mounts, which are negative-compensation devices (HP-478 heads), and Barretters, which are positive-compensation devices. However, Barretters are not usable. They usually use a 1/100-amp fuse for the RF detection device or a small piece of platinum wire.

Operation of the adapter is very easy and allows the utilization of power-meter heads of the single-thermistor type, be it coaxial or waveguide models. Using a heavy cast-aluminum box may minimize the temperature effects on the thermistor in the adapter. This is versus the thin-metal Bud aluminum box I used to test the feasibility of the circuit. As shown in photo B, note that I left the wiring harness long so all components, with the exception of the BNC connector, can be unscrewed and placed in another heavier box when I locate one!

If you obtain a 478 thermistor head that has out-of-balance thermistors, don't fret. Here is a second trick for repairing over-stressed 478A power-meter heads that are out of balance but still have thermistor continuity. In testing 478A power-meter heads, you may find one that has a DC resistance on both pins 1 and 3 but they are out of balance 20 to 30% or so. If you test on a 432 power meter, they will not balance at all. You are lucky, though, because the power-meter head can be brought back into balance by the simple addition of a small value of resistance to the lowest thermistor value as measured on an ohmmeter. The exact value needs to be found by adding the 200-ohm pot used in the above balance test in series with the low-resistance thermistor and its circuitry. Cut the thermistor lead in mid wire, leaving ends to reconnect to the 1/4-watt resistor, once you determine the value needed to bring the mount back into balance. Note that the value to bring the mount back into balance is quite low in comparison to the measured ohmmeter DC resistance.)

478A/B Mount Conversion

Open up the 478A mount and determine which thermistor is lowest in resistance balance. Place a small pot (100 ohms or so) in series with the lowest tested value thermistor and the power-meter circuitry while attached to the power meter. Turn on the power meter. The meter will pin hard up or down scale while on calibrate. Next adjust the low-value pot for balance. Turn off the power and disconnect the pot used to balance the meter. If your test is like mine, you will find the resistance of the test pot to be in the range of a couple ohms to about 12 ohms. Select a 1/4-watt resistor close in value to the pot reading, and insert in series with the same lowest value thermistor, just like where the test pot was previously.

Turn on the power meter and calibrate for balance. Then use the meter, which should now balance with this small-value (by test) 1/4-watt resistor attached internal to the 478A power-meter shell. With the four heads I repaired this way, the test of the calibration to my workbench test setup was quite good. Errors were in the tenths of a dB, from 100 MHz to 12 GHz, which is not bad for the 15-cent, 1/4-watt resistor used to rebalance the power-meter head that was totally defective as far as balancing in the power meter.

I don't know if this repair technique can be used with other power-meter heads. I suggest gathering blown power-meter heads. Bring an ohmmeter to a swap meet for testing purposes, and you likely will find heads that can be repaired or adapted into a single adapter to be used as surplus power heads for microwave use on your workbench.

On my bench, I use a pair of HP-432A power meters and 478 heads for general work. For high-sensitivity work, I have a pair of HP-436 digital power meters and a pair of 8440 sensors, which are good down to –65 dBm. The HP-436 is a great meter, but you have to be very careful with the extremely sensitive power-meter heads (8440). The 8440 heads can be blown by signals in the –20 dB to –10 dBm power range. Power of zero can be measured on the 436. All you have to do is use a 30-dB pad, and it will read 0 dB, as in normal calibration to the front-panel reference oscillator, 0 dBm at 50 MHz.

Summary

Good surplus hunting! I hope this column has provided you with some good power-meter, power-head information and workbench test and repair methods. By repairing blown heads and purchasing a surplus 432 power meter, you too can have a quality microwave power meter on your workbench without going to any great expense. If you have questions, please e-mail me at <clhough@pacbell.net>.

OP ED

One Reader's Opinion

Ham Radio's Three Imperatives

By James G. Alderman,* KF5WT

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

If ham radio is to survive in the years to come, it's imperative that we be granted three key protections.

In past decades amateur radio has often enjoyed special protections and dispensations under the law. When mobile-scanner bans and cell-phone bans were proposed, we were exempted. When cities stopped us from putting up outdoor antennas, we got protection from PRB-1.

Yet in many ways, our days of "reasonable accommodation" are becoming a thing of the past, and unless government quickly intervenes to enact additional protections for ham radio, we will scarcely exist 20 years from now.

Antenna Protections

Although PRB-1 offers protection from restrictive city and state regulations, hams are anything but free to operate from home. Today private covenants and deed restrictions have become a true modern scourge.

Although government entities can't ban ham antennas, rich developers can, and do. Until federal law intervened a few years ago, they even banned TV and satellite antennas. Something is fundamentally wrong with a system in which a TV antenna is federally protected, but a ham antenna is not.

Although some call these restrictive covenants "voluntary," nothing could be further from the truth. In reality, antennas are only allowed in the older, less desirable, and often declining neighborhoods. Younger families in their prime naturally want newer homes in good neighborhoods with good schools. These "best and brightest" hams are prevented from participating in amateur radio in the traditional sense. Today, buying a new home that doesn't come with an antenna ban is like trying to buy a new car without an airbag. It simply can't be done.

If we hams aren't allowed to practice our skills on our own property, and on our own time, we will be of no practical use when we're needed during an emergency. Somebody who just reads books about radios and antennas, but has no hands-on experience, can't be expected to make them work reliably when disaster strikes. I liken it to a chef who has read cookbooks, but never turned on a stove.

Nothing short of nationwide, universal, federally mandated protection of ham radio antennas will give us needed protection from greedy real-estate developers. Given how important amateur radio is to the nation's emergency communications system, if we can't get protection now we never will.

Ham Radio In Schools

The League's "Big Project" educational initiative represents our best hope for the future of amateur radio. However, in many schools ham radio is not only frowned upon, it's banned entirely by state laws and school policies. Texas public schools are one example. A recent study in the North Texas section highlights the magnitude of the problem.

In the seven-county area encompassing the greater Dallas/Ft. Worth metroplex there are nearly a million public-school students. Three out of four are prohibited by school policies from even possessing a ham radio or other RF device at school. Half of those students are further banned from having one outside of school hours at off-campus locations during nights and weekends if the student is doing something "school related." In many Texas schools, possession of an RF device is as serious an offense as possession of crack cocaine, guns, or bombs.

Texas public schools are allowed to ban RF devices—both in and out of school—because of an obscure 1980's-era law originally enacted to cut off communications among campus drug dealers. However, the law was so broadly written that it banned all things RF, and even today provides no exception for amateur radio.

This problem is a common trend in many other states as well. *The Dallas Morning News* recently reported that a dozen states have laws banning RF devices in schools, and none make exception for amateur radio.

Having a ham radio program in a school where RF devices are banned is like trying to have an auto-mechanics program where socket sets are banned. It simply can't be done. If the Big Project is to proliferate throughout the schools of America, all 50 states and their individual schools must be compelled by law to allow educational ham radio programs.

Repeater Protections

We got ourselves into these first two predicaments when we silently sat by and let entities other than the FCC begin regulating the RF spectrum and the use thereof. Our final predicament is simply a matter of money.

Most clubs maintain repeaters on a shoestring budget. It's a testament to our ingenuity that we often can do a lot with a little. Paying for tower space, though, is out of the question. Today ham repeaters increasingly are being evicted by

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tower owners and replaced by revenue-generating wireless customers.

Our SKYWARN nets and emergency communications are conducted primarily on repeaters. The simple fact is that if we don't have repeaters, the lion's share of ham radio activity—and our emergency communications capability—ceases to exist. Perhaps a federal law is needed to offer tower owners special tax credits for donating space for ham repeaters. Perhaps tower owners should be required to donate outright a small percentage of their "vertical real estate" for amateur radio or other homeland-security communications.

Whatever the means, at the end of the day we must have tower space, and we must have it for free. Otherwise, most ham radio activity in America goes away.

Good News

The good news is that although all of these key protections must be provided to us by government, none cost the government any money. And given the millions of dollars worth of free communications services we provide each year, nothing could be a better bargain.

James Alderman, KF5WT, has worked in the electronics and wireless industry for 18 years. He enjoys speaking to schools, Scout troops, and civic groups about the virtues of amateur radio. James serves as a Volunteer Examiner and is a registered Radio and Weather Merit Badge instructor.

***Editor's note:** In the aftermath of the shootings at Columbine High School in Colorado in 1999 and the September 11 attacks of 2001, many states have eased some of the restrictions imposed on students having two-way radios in school. According to the Education Commission of the States, only five states currently ban electronic communication devices statewide, and most of those authorize local school boards to grant certain exemptions. Seven additional states (including Texas) give local school boards the authority to ban communication devices in school. A dozen other states have recently revised or repealed their broad prohibitions. For more information, see "Pagers and Cellular Phones on School Property" on the ECS website at : <www.ecs.org>.*

Intense July 2004 Aurora

A widespread, intense, and long-duration aurora opening occurred July 25–27, 2004. Noteworthy were the number of hours aurora QSOs were worked and how far south the aurora went. This might have been the last widespread aurora opening of solar Cycle 23.

By Jon K. Jones, MD,* NØJK

The late July auroras were sparked by multiple CMEs (coronal mass ejections) from giant sunspot number 652. This sunspot was so large it could be seen by the naked eye, and it harbored energy for M- and X-class solar flares.

From July 20 through July 27 solar flares erupted from sunspot 652. On July 24–25 a strong geomagnetic storm began. On July 25 several M-class flares erupted powerfully from 652. These would spark aurora that was seen as far south as California, Nebraska, and Utah.

The aurora occurred due to the high speed of the solar wind (clocked at over 1,000 km/s) and the IMF (interplanetary magnetic field) Bz vector pointed south.

The aurora occurred due to the high speed of the solar wind (clocked at over 1,000 km/s) and the IMF (interplanetary magnetic field) Bz vector pointed south. A south-pointing IMF allows the Earth's magnetic field to link up with the sun's, opening a door through which energy from the solar wind can reach the Earth's atmosphere.

On the evening of July 25 (26 UTC) radio aurora was workable as far south as Kansas, Oklahoma, and even Texas. I operated portable from EM18 and worked KØGU DN70 on 2-meter aurora at 0025 UTC, July 26 while running only 20 watts. Jay always has a great signal on aurora and worked south to Oklahoma and Texas. I made only a couple of 2-meter aurora QSOs besides Jay—WYØV EN13 and NØKQY DM98. I heard many stations, but with only 20 watts and a 7-element Yagi, I found it difficult to be heard. Radio aurora was spotted most of that night and on into the next morning, at which time it faded.

The aurora returned with a vengeance the next evening. Spaceweather.com reported, "an intense geomagnetic storm began at 2300 UTC, July 26." Radio aurora began to be worked around 2300 UTC. K5SW EM25 worked W2KV FN20 on 2-meter aurora at 2333 UTC. Seeing the aurora was back, I again drove out to EM18. I operate portable, as I live in a CC&R no-outside-antenna restricted neighborhood. This time I brought a 150 amplifier, which definitely helped!

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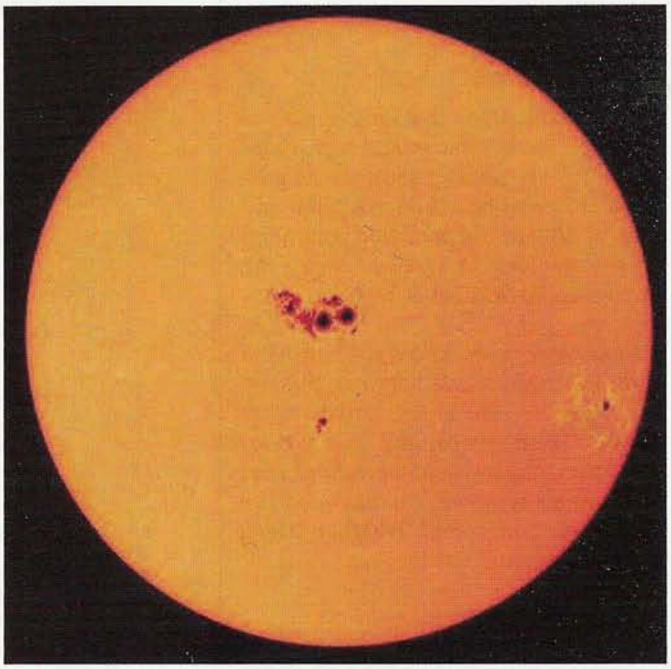
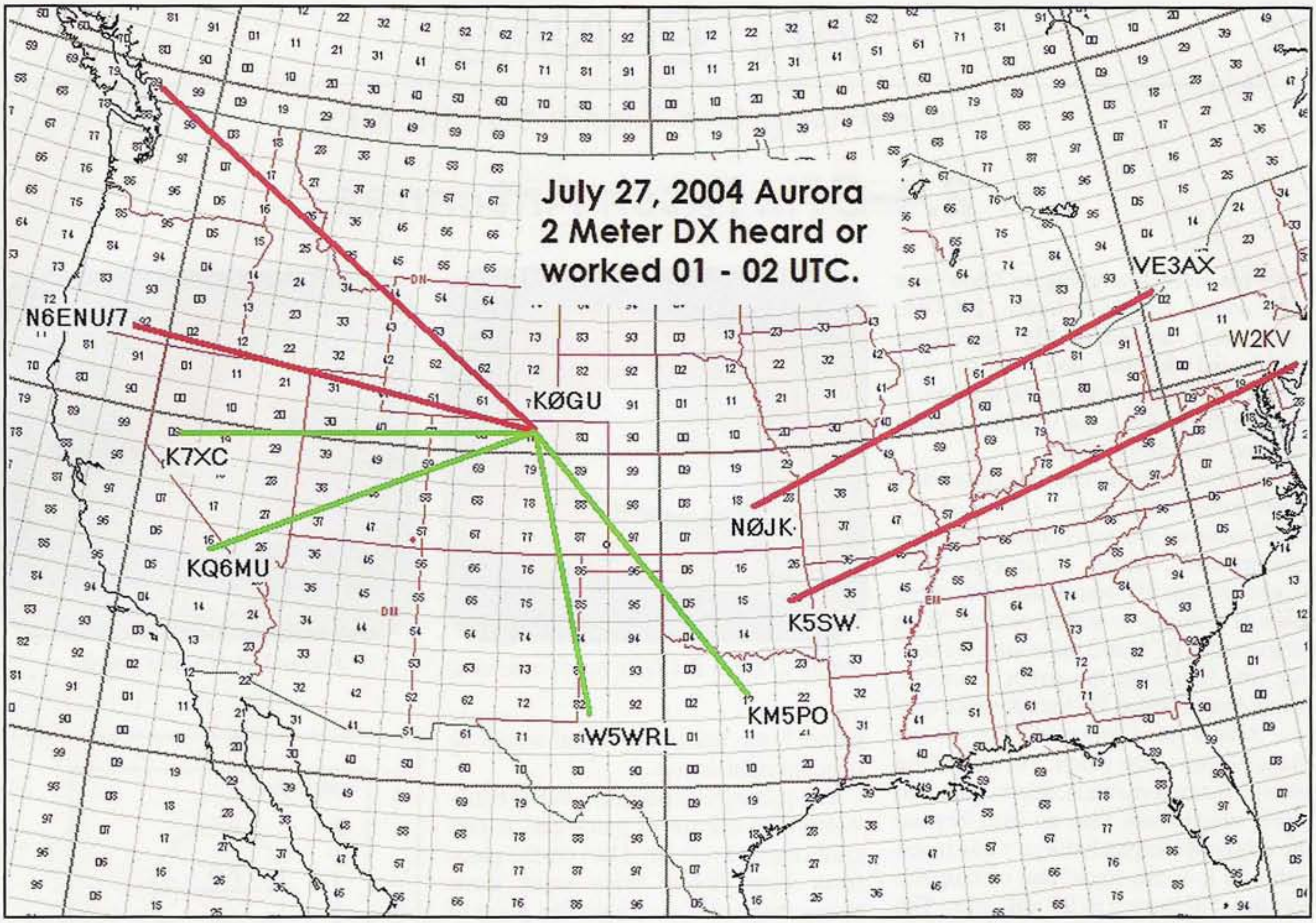


Sunspot 652 on July 23, 2004. (Image courtesy SOHO/MDI)

The aurora had been going on for almost two hours by the time I arrived at my operating location and got up the 2-meter Yagi. At 0110 UTC on July 27, I copied Peter, VE3AX, "59A" on 144.195 MHz working 8- and 9-area stations. I heard Peter work N8IE EN92 at 0112 UTC and called him after he signed. We worked at 0113 UTC. Peter e-mailed, "You were really not that strong and was getting QRMed badly, but had no trouble pulling you through. I was aiming at 300 degrees for this QSO." Peter is 1525 km from me. He was the best DX I worked on 2-meter aurora that evening.

At 0126 UTC, July 26, K5SW spotted "NØJK/p EM18 144.201 AU @ 40 deg." I was only hearing a couple of stations at that time, including VE3AX, who was in for almost an hour on aurora. The aurora seemed to drop out at 0150UTC. At 0157 UTC I QSYed to 144.250 MHz to call NØPB EM39 for his



Map showing the DX heard or worked on 2 meters from 0100–0200 UTC during the July 27, 2004 aurora opening. (Note: Green = heard, and red = QSOs)

SWOT net. I called a couple of times on CW and was surprised to hear a loud KØGU answer me via aurora! Jay reported, "I bumped into NØJK on ~144.250 J KØGU DN70." A few minutes later Jay was spotted on 144.200 aurora by KM5PO EM12, AG4V EM55, and W5WRL DM82.

At 0217 UTC, N7CZ DN47 noted, "The solar-wind velocity has pegged the meters at over 1000 km/s!" Jay was my last 2-meter aurora QSO for this session, and I was headed home by 0230 UTC. The aurora continued for stations farther north until around 0430 UTC, when K2YAZ EN74 reported "au gone now." It came back at 0622 UTC for NØPB EM39, who heard N4VC EM66 via aurora, and at 0935 UTC with K9VHF EN53 hearing K8TQK EM89. K1TEO spotted VE2FUB/b and the W1XR/b via aurora at 1006 UTC. The aurora continued for the northern stations for a couple more hours.

Spaceweather.com observed that the aurora was strong and sustained most of the night by a south-pointing IMF. Visual aurora was observed as far south as Anza-Borrego Desert State Park in Borrego Springs, California by photographer Dennis Mammana. His picture of the aurora is posted on the Spaceweather website.

The July 25–27 aurora openings were widespread, with reports from all call districts noting aurora QSOs. Stations as far south as Oklahoma, Arkansas, Texas, and California reported radio aurora contacts.

The July 25–27 aurora openings were widespread, with reports from all call districts noting aurora QSOs. Stations as far south as Oklahoma, Arkansas, Texas, and California reported radio aurora contacts. Some of the longer 2-meter aurora QSOs I am aware of are VE7 to KØGU DN70 at 1600 km, NØJK EM18 to VE3AX FN02 at 1515 km, and K5SW EM25 to W2KV FN20 at 1871 km. Some 222-MHz aurora QSOs were made, such as W7FHI CN96 to K7XC DM09 at 0049 UTC on the 27th. This group of auroras was sparked by M-class flares. I wonder how big it would have been had an X-class flare erupted from sunspot 652?

Despite the aurora being widespread and intense, activity seemed to be down. I noted only a handful of stations coming through on 2 meters via aurora at any one time. Activity seemed to be highest in the northeast. With the aurora coming in late July, I wonder if many VHF operators were on vacation or busy with outdoor recreational activities. Perhaps some had "worked their fill" during the big July 6 144- and 222-MHz *Es* opening and found this aurora "boring." In any case, the aurora of July 25–27 was outstanding and may well be the last big radio aurora opening until the next solar cycle peak. ■

By Kent Britain,* WA5VJB

ANTENNAS

Connecting the Radio to the Sky

2.4-GHz Patch Antennas

This time I'm going to show you some simple-to-build 2.4-GHz patch antennas. My styrofoam wall-board designs don't work well above 1500 MHz or so, as the material is just too thick. Thus, we will be building this one "DeadBug" style.

The ground plane can be almost any sheet metal. I like to use a sheet of PC-board material, but you can use sheet aluminum, brass, copper, tin, or even steel. If you do use PC-board material, there are a few things to watch out for. With single-sided PC board make sure the copper side is toward the patch. If you're using double-sided PC board, make sure you have a good ground to the ground plane closest to the patch. The size of the ground plane somewhat affects gain, but going much more than an inch beyond the edges of the patch doesn't add much gain. As it is, the round and rectangular patches will have 9 to 9.5 dBi gain. The circular-polarized version has about 6 dBi vertical gain and 6 dBi horizontal gain for 9 dBiC (dbi circular).

The patch needs to be something to which you can solder. Sheet brass or tin works best. It doesn't have to be square, and as you notice from the photographs, none of the three featured patch antennas are square.

The first patch is round. There are few advantages to a round patch, though. It can be a bit harder to build using hand tools, and it tends to be narrower in bandwidth than a square or rectangular patch. There are some tricks such that the circle is really an oval; it's fed slightly off center and develops circular polarization. Many of the VHF and UHF patch antennas on AO-40 use this technique, but when using hand tools, this antenna is more of a novelty. I found the bottom of a Campbell's soup can was about the right size and used it to mark my circle on sheet brass. The point of attachment was found experimentally using a network analyzer.

Maximum gain is perpendicular to the patch. Looking at the example shown in photo 2, the maximum signal would be directed right at you.

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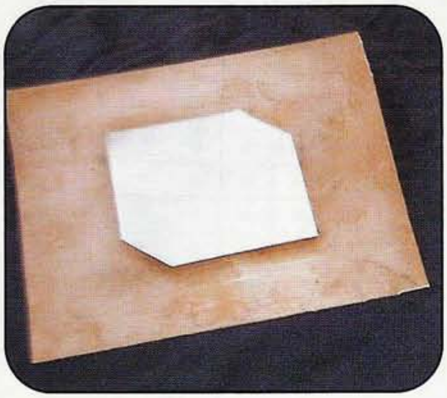


Photo 1. Some 2.4-GHz patch antennas.

Photo 2. A circular patch.

The rectangular patch has better bandwidth than the round patch and is certainly easier to cut out. I just cut the patch from sheet hobby brass using some heavy-duty scissors. Again, the point of attachment was experimentally determined. Construction can be fun, and there are a lot of ways to do it. Using a fine soldering iron, just get in there and solder it. I found it easier to solder a blob onto the end of the coax connector, tin the back of the patch, and then just briefly heat it with a micro torch. All three of these patches are mounted 1/4 inch off the ground plane, so a 1/4-inch rod positions the patch while I'm heating it.

The –10 dB return loss or 2:1 SWR points show a bandwidth of 150 MHz or so. I feel a future column on dB return loss coming. When it comes to calculations, SWR is a very clumsy system to use. Most test equipment is calibrated in dB return loss. That's how many dB's lower the reflection is compared to the through signal. A –10 dB return loss is about a 2:1 SWR; –20 dB return loss is close to 1.2:1 SWR; –30 dB return loss is about 1.05:1 SWR; and that flirt you see with –40 dB return loss would be a 1.02:1 SWR.

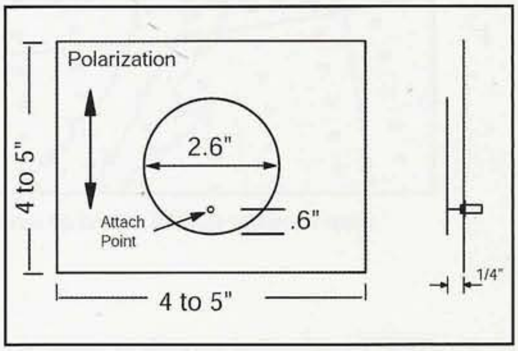


Figure 1. Circular patch dimensions.

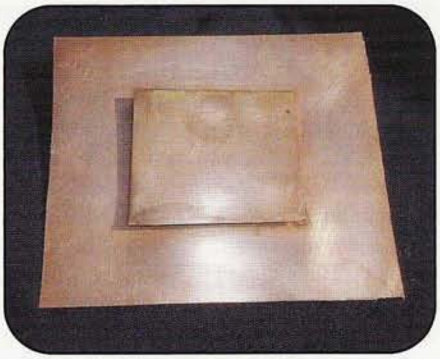


Photo 3. A 2.4-GHz rectangular patch.

Circularly-Polarized Patch

As we covered in the previous "Antennas" column in the Summer issue of *CQ VHF*, there are many ways to generate circular polarization from a patch antenna, but trimming the corners a bit is one of the easiest ways. I've tried to find some rules for the depth of those cuts, but none seem to equal my measured results. Thus, the .6 inch was determined by trim-

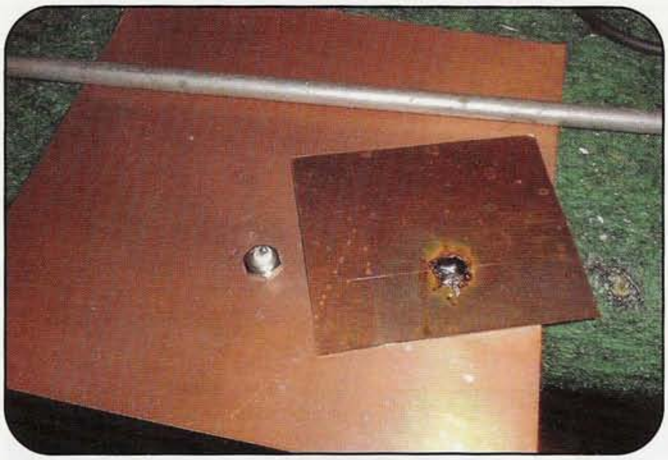


Photo 4. Construction of the patch.

Photo 5. Construction of the patch.

ming, trimming, and trimming a little at a time until the gain didn't change as I rotated the patch 90 degrees when pointed at the source antenna.

Gain vs. Dish Diameter

First, the antenna can be mounted at the focus of a dish to give you more gain. How much more gain? Well, that depends on a lot of factors, but an 18-inch dish, which is about the smallest size you would want to use on 2.4 GHz, will give you about 15 dBi gain. A 3-foot dish would give 22 to 23 dBi of gain. Bigger? Okay, a 6-foot dish would give in the 29–30 dBi range.

Just remember that when you use a circular-polarized antenna as a dish feed, the feed is bouncing the signal off the dish. Therefore, the world is seeing a mirror image of the feed. If you want a right-hand circular-polarized dish, you need to install a left-hand feed. This feed will work great with OSCAR AO-51 or almost any S-Band bird.

Wi-Fi

This antenna also makes a good little antenna for your Wi-Fi experiments. Like the AMSAT version, it can be mounted at the focus of a dish if you are working on a really long shot. (I have heard of one lad pointing one of these at a local motel for internet access, but I can't condone such actions!)

Letters, Letters . . . We Get Letters

From Jeff we received some questions on tweaking Cheap Yagis and similar antennas.

First, make sure the coax is attached correctly. At the Central States VHF Society antenna range last July, I saw a Cheap Yagi with the coax reversed. The coax shield was to the tip of the "J" and the center conductor was to the middle of the element. This person had noticed that the coax was hot, so he put a long string of ferrite beads on the coax. This did keep RF off the coax, and the antenna performed up to spec on the antenna range. Frankly, that's not something I would have expected. However, it's a lot easier if you connect the coax per my diagrams.

Next, trim the free end of the "J" for best SWR. This is much like trimming or adjusting the driven element of any Yagi.

Last, I have my own "Yagi Tweaker," which I've shown before (see photo 10). Short pieces of Yagi element material are taped to the ends of a wood stick. Putting the tweaker near

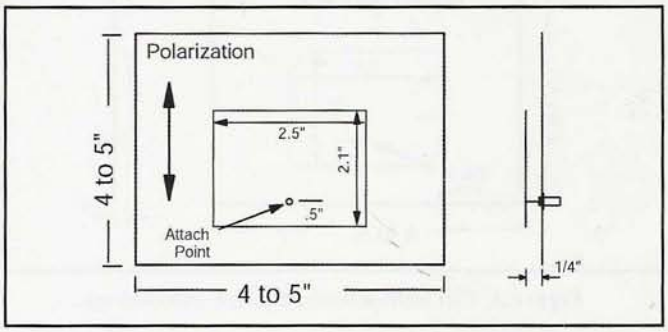


Figure 2. Rectangular patch dimensions.

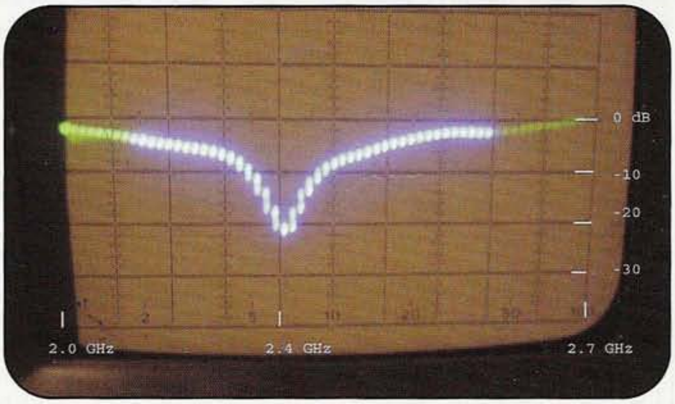


Photo 6. Rectangular patch frequency response.

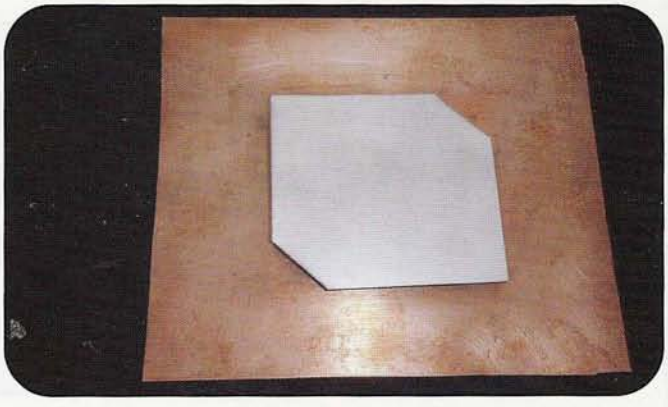


Photo 7. A 2.4-GHz circular-polarized patch.

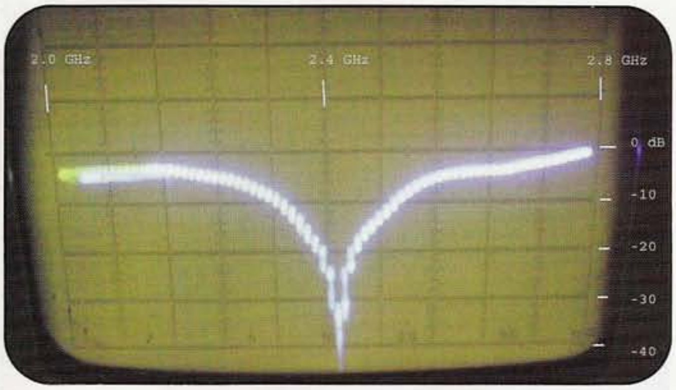


Photo 8. Circular-polarized patch frequency response.

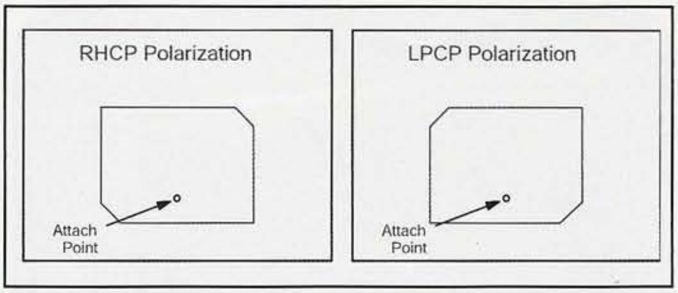


Figure 4. Left- and right-hand circular-polarized notches.

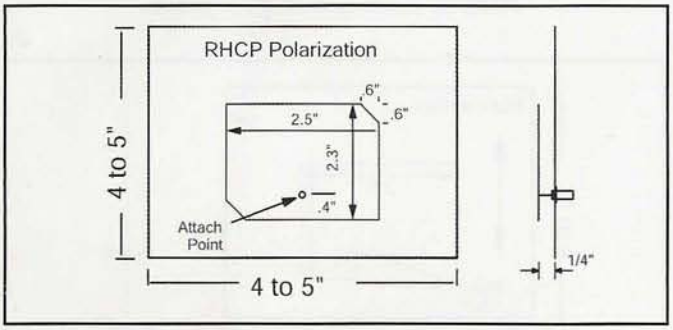


Figure 3. Circular-polarized patch dimensions.

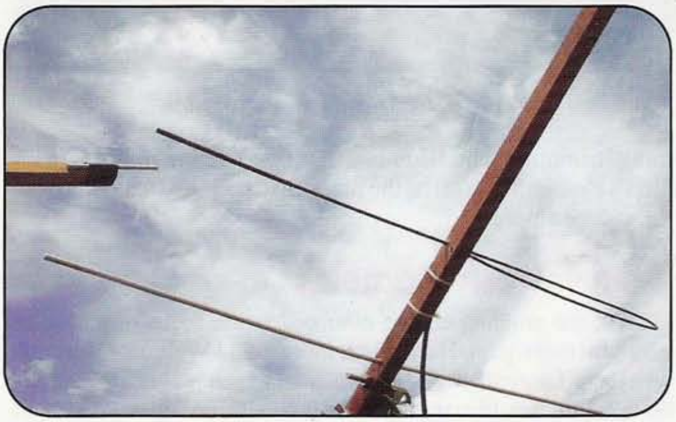


Photo 9. The author's "Yagi Tweaker."

the tips of each element quickly shows you the most sensitive elements. If the SWR starts going up as the tweaker gets near the tip of the element, then the element is too long. If the SWR dips as you get the tweaker near the tip of the element, then it's too short.

This really needs to be done on an antenna range. Retuning a Yagi for a super-flat SWR destroys its pattern, and that's not going to get you anywhere. However, a slightly long director #1 is the quickest way to kill the SWR of a Cheap Yagi.

Photography Note

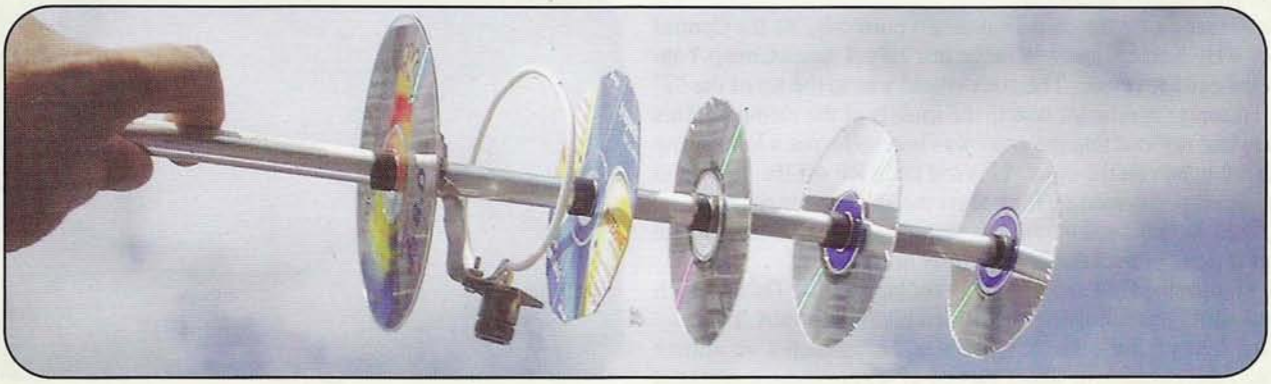
Photographing a good old analog network analyzer CRT is fun (not). Getting the sweep and the shutter to almost sync is the hardest part. It takes about ten shots to have one come out, so until I get my $100K analyzer, you'll have to suffer through my camera shortcomings.

Have fun with antennas, and we'll see what makes it out of my lab for the next "Antennas" column.

A Fun Antenna

Last July at the Central States VHF Society antenna contest, Bob, VE3BFM, showed up with this interesting 900-MHz antenna made out of AOL CDs. Not bad! It measured right at 10 dBi gain!

The design is known as a "Disk and Rod" or sometimes a "Cigar" antenna. Bob found that a straight CD resonates at about 850 MHz, so he used one as a Yagi reflector. The other CDs had been trimmed down in diameter somewhat so they could act as Yagi directors. I think I've figured out how to model one of these around a Cheap Yagi driven element, so we just might have a fun project in the near future if I can come up with an easy way of cutting down the diameter of a CD. That brings up the question of the antenna gain of music vs. data CDs . . . or maybe rap vs. easy-listening vs pop CDs. You certainly can get all the free AOL element material you need at your local post office!



A fun antenna for 902 MHz.

By Tomas Hood,* NW7US/AAA0WA

PROPAGATION

The Science of Predicting VHF-and-Above Radio Conditions

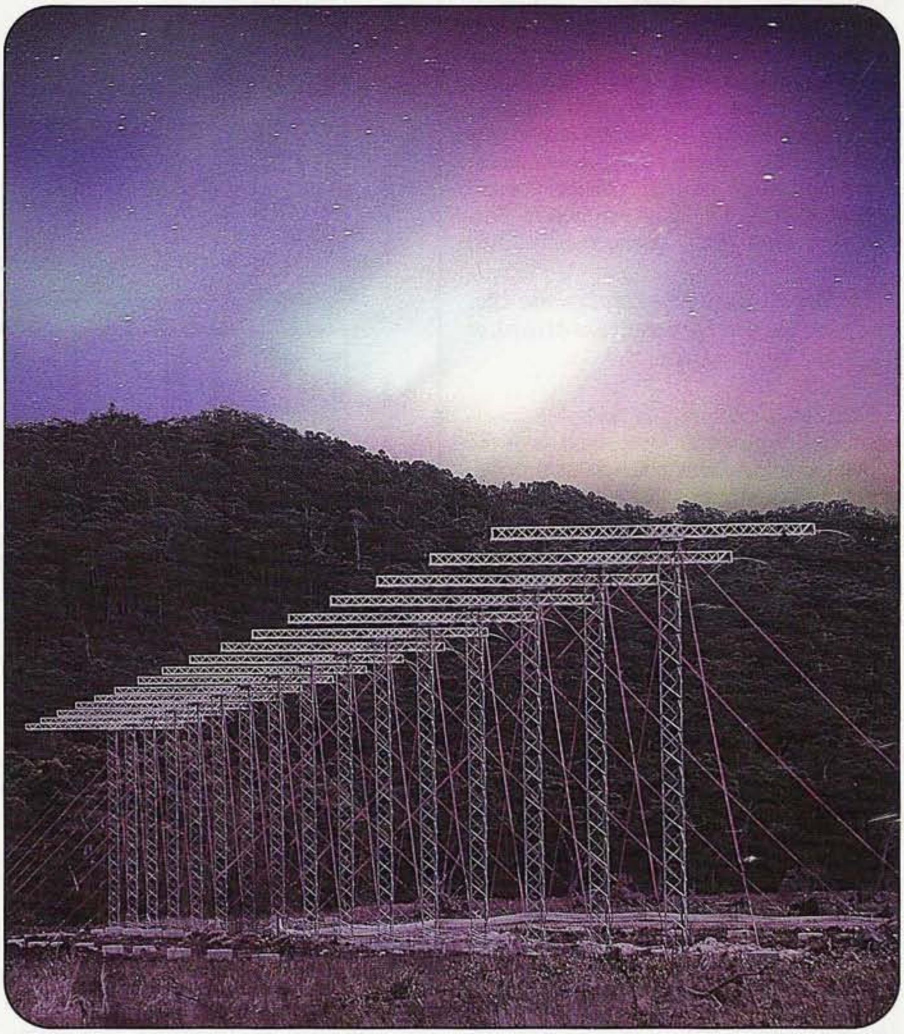
The Cold Facts

Solar Cycle 23 is moving steadily toward the years of minimum activity, predicted to be toward the end of 2006 and the beginning of 2007. The monthly smoothed sunspot counts for each month in this period are expected to be between 28 and 23. Compare that with last year's 57 to 52, and 2002's 85 to 81. The resulting solar activity, as measured in the 10.7-cm flux, is quite a bit less this year than the last few years. Under such lowered activity levels, will there be much *F2* VHF propagation this season? Without the supporting energizing influence of a moderate to highly active sun, with 10.7-cm flux readings above 200, it is unlikely that we'll see significant VHF long-range DX via *F2* propagation.

Autumn (November through January) is also not known to be typical transequatorial propagation (TEP) season. TEP, which tends to occur most often during spring and fall, requires high solar activity, energizing the ionosphere enough to cause the *F*-layer over the equatorial region to support VHF propagation. The normal TEP signal path is between locations on each side of the equator. However, without the level of solar activity needed to keep the *F*-layer energized enough for VHF propagation, these paths don't materialize. The fall season of TEP usually tapers out by mid-November. This year, though, TEP is not a major player.

What could become an exciting mode of propagation this season is sporadic-*E*. This summer's sporadic-*E* season was one of the best on record, surprising many VHF veterans, some of whom claim that this summer's *Es* was the best since the 1960s.

If you remember, I talked about possible causes of sporadic-*E* in the Fall 2003 issue of *CQ VHF,* and in the Spring 2004 issue I made the following predictions:



Aurora over the SuperDARN TIGER site in Tasmania, operated by the La Trobe University in Australia. (Composite image courtesy of photographer Danny Ratcliffe and the TIGER Consortium; source: National Science Foundation)

> Weather experts predict that 2004 will be a year of slightly elevated hurricane and storm activity in the Atlantic region, but that neutral conditions will exist into the summer, in the El Niño Southern Oscillation (ENSO). The ENSO refers to the seesaw shift in surface air pressure at Darwin, Australia and the South Pacific island of Tahiti. When the pressure is high at Darwin it is low at Tahiti, and vice versa. El Niño and La Niña are the extreme phases of the southern oscillation, with El Niño referring to a warming of the eastern tropical Pacific and La Niña a cooling. If the El Niño influence is slight there could well be an increase in hurricane conditions.
>
> Based on these predictions, I expect moderate to occasionally strong sporadic-*E* starting in May, and peaking in July and August 2004. According to the Climate Prediction Center, the possibility of a development of either El Niño or La Niña is low during 2004.

Recent hurricane activity in the Caribbean and Gulf of Mexico, with numerous heavy-hitting storms arriving one after the other, seems to follow the predictions of those weather experts. What is more interesting is that my assessment of the ENSO data and weather predictions for mass patterns led me to predict a "mod-

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erate to occasionally strong sporadic-E" season peaking in July. This surely was the case.

The latest ENSO Diagnostic Discussion <http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/> states:

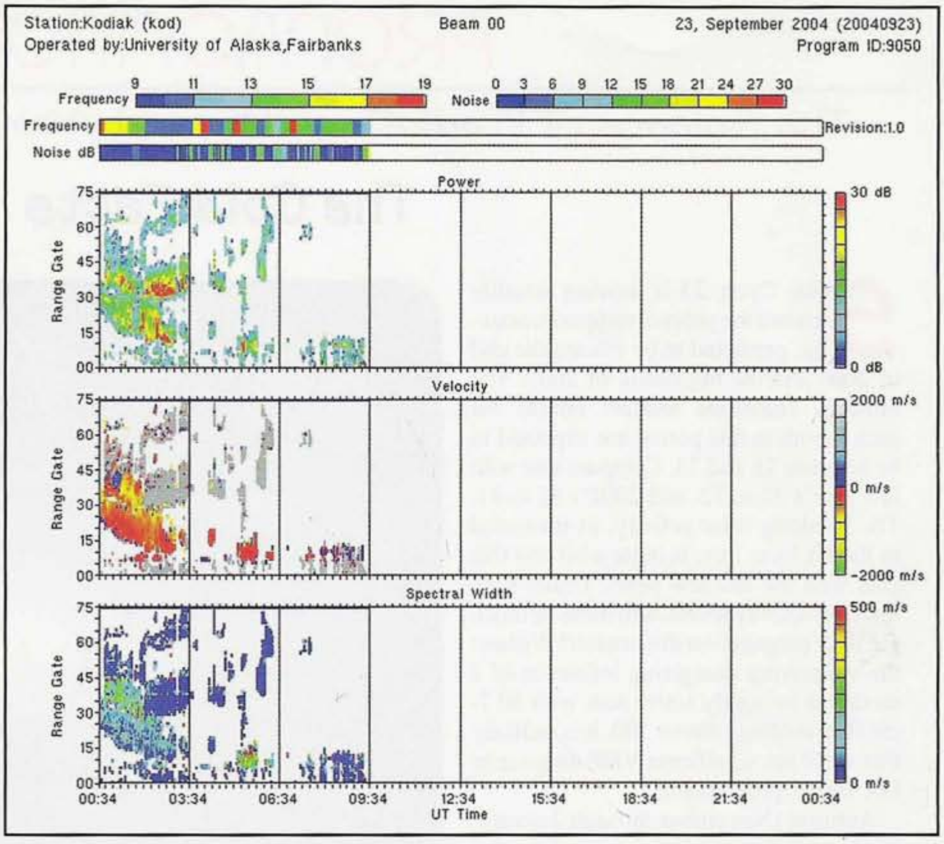
> The NOAA operational definition for El Niño [Oceanic Niño Index (ONI), a three-month running mean of the Niño 3.4 index, greater than or equal to +0.5°C] was satisfied for the period June–August 2004, with a value of +0.7°C. Based on the recent evolution of oceanic and atmospheric conditions and on a majority of the statistical and coupled model forecasts, it seems most likely that SST anomalies in the Niño 3.4 region will remain positive, at or above +0.5°C, through early 2005.

Further discussion <http://www.cpc.ncep.noaa.gov/products/outlooks/hurricane.html> states:

> This outlook is based on favorable conditions now in place in association with the ongoing active Atlantic multi-decadal signal, which includes warmer than normal sea-surface temperatures in the tropical Atlantic. However, weak El Niño conditions are possible during the next few months, which makes the probability of an above-normal season slightly less likely from that stated in May, and the probability of a near-normal season slightly more likely. Whether El Niño forms or not, considerable tropical storm and hurricane activity is expected this season.

My original idea is that certain weather patterns and systems cause wind-shearing conditions, which can help form highly dense ionized clouds in the E region. If this season's weather creates such favorable conditions, it could be expected that *Es* activity will be moderate, maybe even strong, from late November through January. Statistically, *Es* peaks toward the very end of December and is short-lived. However, if the El Niño conditions are prominent and we see continued hurricane activity, the type of wind shear created might be counter productive in creating sporadic-E ionized clouds.

Surely, this weather-to-*Es* correlation must be explored in greater depth. I've begun to gather data, but I am open to your insights and observations. The fact that comet dust also plays a factor in many *Es* cloud formations is to be taken into consideration, as well. With the December meteor showers, it could be that the increase of *Es* during the December period is directly related to this meteor activity.



Time series from Kodiak SuperDARN radar site. (Source: University of Fairbanks, Alaska; SuperDARN; National Science Foundation)

Keep your station ready for any possible sporadic-E opening. If no one is on the air testing the conditions, no one will know an opening has occurred. Several e-mail reflectors have been created to provide an alerting service. One is found at <http://www.gooddx.net/> and another at <http://www.vhfdx.net/sendspots/>. These sporadic-E alerting services rely on live reports of current activity on VHF. When you begin hearing an opening, you send out details so that everyone on the distribution list will be alerted that something is happening. They, in turn, join in on the opening, making for a high level of participation. Of course, the greater the number of operators on the air, the more we learn the extent and intensity of the opening. The bottom line is that you cannot work sporadic-E if you are not on the air when it occurs. Some of these services then also create MUF maps and other aids.

In addition to live reporting, there is a very powerful resource available on the internet. Check out <http://superdarn.jhuapl.edu/>. SuperDARN (Super Dual Auroral Radar Network) is an international radar network for studying the Earth's upper atmosphere and ionosphere. Using the SuperDARN real-time data 24-hour overview, you can view the day's ionization activity at the northern polar region. You can also view live radar displays of the same area. These graphs help identify *Es* clouds existing in the higher latitudes. One use for this would be the detection of a variation of *Es* known as auroral-E. See E. C. Jones, <http://ecjones.org/radar.html>, for some examples of using SuperDARN data.

Other Modes of VHF/UHF Propagation

Tropospheric ducting propagation during this season is fairly non-existent, as the weather systems that spawn the inversions needed to create the duct are rare. On the other hand, using tropospheric scatter-mode propagation is possible, but one needs to have very high-powered, high-gain antenna systems. Having dual receivers in a voting configuration would also help. The idea is to use brute force to scatter RF off water droplets and other airborne particles, and capture some of that signal at the far end with dual-diversity, high-gain receivers—not everyone's cup of tea.

Aurora activity has potential, especially after September 22, 2004, the Autumnal Equinox, when we see a seasonal increase in aurora. We are in the decline of the Cycle 23, so we are seeing many coronal holes, some of which have great potential of causing long-duration geomagnetic disturbances and possibly strong aurora.

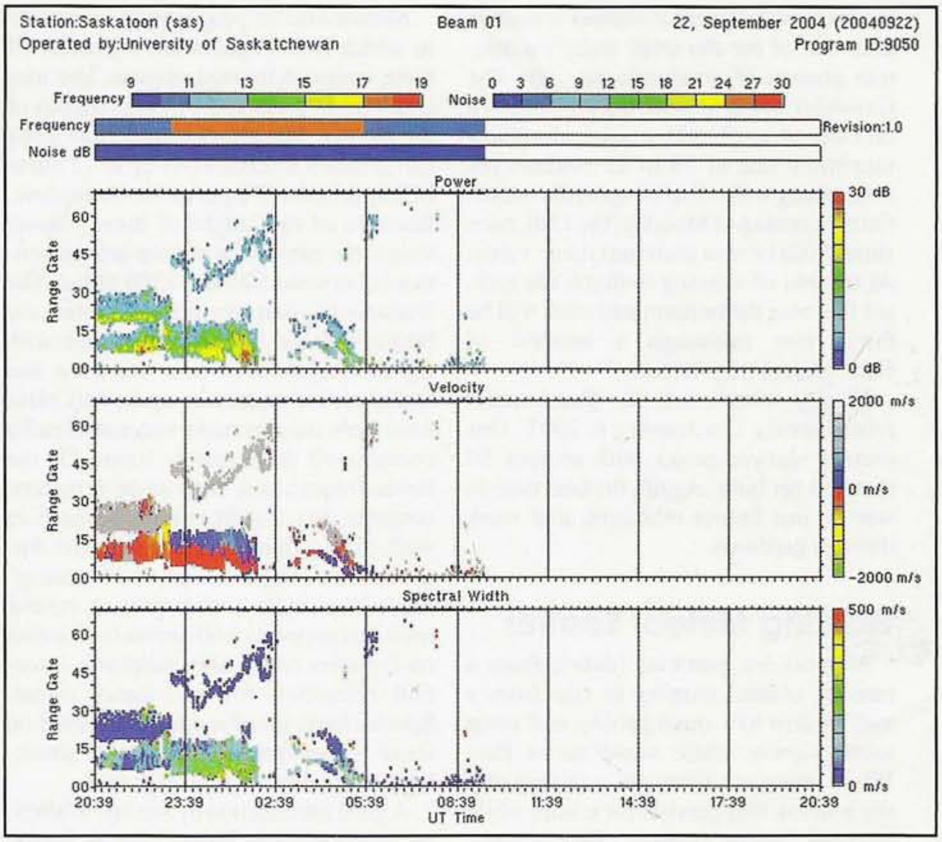
Many years of auroral observations reveal that peak periods of radio aurora occur close to the equinoxes. Of the two yearly peaks, the greater peak, in terms of the number of contacts reported, occurs during October.

When the interplanetary magnetic-field lines are oriented opposite to the magnetosphere's orientation, the two fields connect and allow solar-wind particles to collide with oxygen and nitrogen molecules in the upper atmosphere of these ovals. This causes light photons to be emitted. When the molecules and atoms are struck by these solar-wind particles, the stripping of one or more of their electrons ionizes them to such an extent that the ionized area is capable of reflecting radio signals at very high frequencies. This ionization occurs at an altitude of about 70 miles, very near the *E*-layer of the ionosphere. The level of ionization depends on the energy and amount of solar wind particles able to enter the atmosphere.

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

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

The *K*-index is a good indicator of the expansion of the auroral oval, and the possible intensity of the aurora. When the *K*-index is higher than 5, most 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.



Time series from Saskatchewan SuperDARN radar site. (Source: University of Saskatchewan; SuperDARN; National Science Foundation)

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

The Autumn Meteor Shower Season

There are a number of opportunities during this period to try your skill and employ your equipment in meteor-scatter propagation. One of the largest yearly meteor showers occurs in November.

For the 2003 *Leonids* shower, several smaller outbursts were predicted. At least two of these materialized, each with a peak zenith hourly rate (ZHR) of about 20 and 70. So far no such predictions have been made for 2004. Appearing to radiate out of the constellation Leo on the night and morning of November 17–18, the *Leonids* are known to create intense meteor bursts. Since the source of the *Leonids,* the Tempel-Tuttle comet, passed closest to the sun in February of 1998, the years following were expected to produce very strong displays. The greatest display since 1998 was the peak of 3700 per hour in 1999. Every year since has been significantly less spectacular. However, a few forecasters think that we still might have a meteor storm with an hourly rate of thousands sometime in the next several years. If this pans out, we'll see a rate of several hundred per hour, although that is unlikely. The more probable rate will be 10 to 20 per hour. A few leftover *Taurids* also appear from radiants near the Pleiades and Hyades. The best window to start trying meteor-scatter-mode propagation is just past midnight, peaking after 2 PM local time and continuing until morning twilight. Any morning between the 16th and the 20th might be good, based on last year's results.

The *Geminids* are possibly the most reliable of the annual showers. While the duration of this meteor shower is shorter than that of the *Perseids,* there's a definite plateau of maximum activity. The *Geminids* begin to peak during predawn on December 13, with a quick climb to a maximum rate of 50 to 75 meteors per hour, along with 10 to 20 sporadic bursts. On the evening of Monday, the 13th, rates should still be near their maximum value. At the end of evening twilight, the radiant lies near the horizon and rates will be fairly low (although a handful of Earthgrazers may be seen).

Finally, check out the *Quadrantids* from January 1 to January 4, 2005. This meteor shower peaks with around 50 meteors per hour. Again, the best time to start is just before midnight, and work through predawn.

Working Meteor Scatter

Meteors are particles (debris from a passing comet) ranging in size from a spec of dust to a small pebble, and some move slowly while some move fast. When you view a meteor, you typically see a streak that persists for a little while after the meteor vanishes. This "streak" is called the *train* and is basically a trail of glowing plasma left in the wake of the meteor. The *Leonids* are fast meteors and they leave a high number of long trains. They enter Earth's atmosphere traveling at speeds of over 158,000 miles per hour. Besides being fast, the *Leonids* usually contain a large number of very bright meteors. The trains of these bright meteors can last from several seconds to several minutes.

Meteor-scatter propagation is a mode in which radio signals are refracted off these trains of ionized plasma. The ionized trail is produced by vaporization of the meteor. Meteors no larger than a pea can produce ionized trails up to 12 miles in length in the *E*-layer of the ionosphere. Because of the height of these plasma trains, the range of a meteor-scatter contact is between 500 and 1300 miles. The frequencies that are best refracted are between 30 and 100 MHz. However, with the development of new software and techniques, frequencies up to 440 MHz have been used to make successful radio contacts off these meteor trains. On the lower frequencies, such as on 6 meters, contacts may last from mere seconds to well over a minute. The lower the frequency, the longer the specific "opening" made by a single meteor train. A meteor train that supports a 60-second refraction on 6 meters might only support a 1-second refraction for a 2-meter signal. Special high-speed methods are used on these higher frequencies to take advantage of the limited available time.

A great introduction by Shelby, W8WN, on working High-Speed Meteor Scatter mode is found at <http://www. amt.org/ Meteor_Scatter/shelbys_welcome.htm>. OZ1RH wrote "Working DX on a Dead 50 MHz Band Using Meteor Scatter," a great working guide <http://www.uksmg.org/ deadband.htm>. W4VHF has also created a good starting guide at <http://www. amt.org/Meteor _Scatter/letstalk-w4vhf. htm>. Links to various groups, resources, and software are found at <http://www. amt.org/ Meteor_Scatter/default.htm>.

The next big meteor shower, after November's *Leonids,* is the yearly *Geminids,* December 6 to 19 with a possible ZHR of 60, peaking on December 14 at 1510 UTC. After this one comes the *Quadrantids,* December 28 to January 7 with a ZHR of about 50, peaking on January 4 at 0450 UTC. There are many smaller showers during the fall meteor-shower season. Check out <http:// comets.amsmeteors.org/meteors/ calendar.html> for a good look at what is in store.

The Solar Cycle Pulse

The observed sunspot numbers from June through August are 43.2, 51.0, and 40.9, continuing on a slight plateau since January. The smoothed sunspot count for December 2003 and January and February 2004 are 54.8, 52.0, and 49.4, all showing the steady decline of Cycle 23.

The monthly 10.7-cm (preliminary) numbers from June through August 2004 are 97.4, 118.5, and 110.1. The smoothed 10.7-cm radio flux for December 2003 through February 2004 is 118.0, 116.3, and 115.3.

The smoothed monthly sunspot numbers forecast for November and December 2004 and January 2005 are 28.1, 25.9, and 23.2, while the smoothed monthly 10.7-cm is predicted to be 87.6, 85.7, and 83.0 for the same period. Give or take about 15 points for all predictions.

The smoothed planetary *A*-index (*Ap*) from December 2003 through February 2004 is 18.6, 18.1, and 17.7. The monthly readings from June through August 2004 are 8, 23, and 10.

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

Feedback, Comments, Observations Solicited!

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

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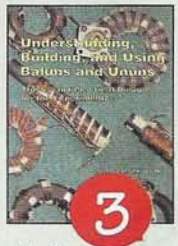

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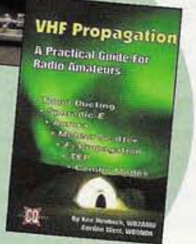

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By Joe Moell,* KØOV

HOMING IN

Radio Direction Finding for Fun and Public Service

T-hunters Help the Public . . . and Fellow Hams

An unmodulated carrier had been jamming marine VHF Channel 12 for three days when Troy Waters e-mailed for help on the morning of April 28. His company, Jacobson Pilot Service, operates the pilot boats that guide tankers, barges, and other large vessels into and out of Long Beach (California) Harbor. The jamming was making his primary radio channel unavailable, causing confusion and consternation among the pilots and sea captains.

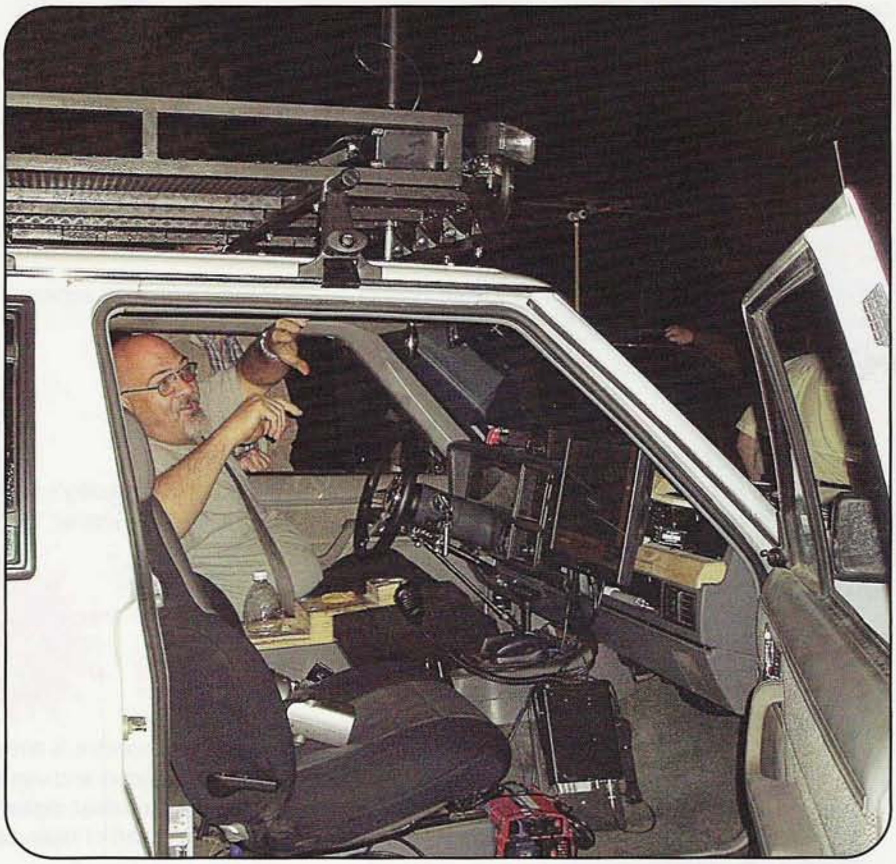
Troy had Googled "radio direction finding" (RDF) on the web, finding my site[1] and the Southern California T-Hunters site.[2] After reading about our mobile T-hunt adventures, he e-mailed to our reflector, "How would you like to participate in a waterborne T-hunt? We have a pilot boat that we could put you on and would be most grateful if you thought that you could locate the source of this transmission."

When Troy's e-mail arrived, I had already gone to work. Mailing-list moderator Steve Heinemann, N6XFC, got it and immediately called Troy. Then he called Mike Obermeier, K6SNE, and Dave Balgie, N6MJN. "I got them all in contact and left it up to them to track it down," Steve told me.

K6SNE picks up the story: "Jacobson had asked the Coast Guard for a bearing but was told that its marine direction finders only work on Channel 16, the emergency frequency. Then Jacobson asked the Marine Exchange at Ft. MacArthur for a bearing 'cut,' as they called it. It went from the Exchange right through the banana warehouse at Long Beach Harbor and out to sea."

"I was on the way to work at about 10:45 AM when Steve got me," Mike continued. "I fired up the Doppler set in my truck, which was all I had for RDF on the marine band (see photo). I had no problem getting a bearing from Santa Ana. It took less than a half hour to follow my bearings about 20 miles down to Long Beach Harbor."

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



Mike Obermeier, K6SNE, gestures to explain how he just installed a new mount for his rotating 2-meter Yagi RDF antenna. His well-equipped truck also has a Doppler set linked to a GPS-based computer navigation system that he used to help locate a stuck marine transmitter at Long Beach Harbor. (Photo by the author)

N6MJN headed out from Newport Beach about the same time and ended up next to the banana warehouse. About ten minutes before Mike arrived, Dave got past the guard, through the gate, onto the dock, and up to the side of the *Chiquita Brenda,* a combination container and banana boat that visits ports of call from Los Angeles to South America. He was sure that was the source of the signal.

"Dave couldn't get a response out of any of the Russian deck crew, so he met me in the parking lot," Mike explained. "We went back together in my truck, got out looking as official as we could, and I asked who was in charge of the deck. When one disinterested fellow said he was, I put on my 'war face' and my hard hat and told him to come down to me right away. I explained the interference situation and his attitude changed. He immediately took N6MJN up to meet the captain on the bridge. Dave looked around for a minute and snapped off the power switch to the bridge VHF radio. End of problem! Apparently it had a stuck relay or mic button.

"When we went to the Jacobson office and told the story, they were very happy and thankful. They treated us to pilot T-shirts and hats. It's a good thing we were able to respond right away, because the ship was just three hours from setting out to sea. The interference could have plagued the entire harbor district until it reached the radio horizon."

N6XFC added, "After Mike and Dave left the harbor, I received a phone call from Troy thanking me tremendously for sending out a team. It was great to hear the compliments about how fast it was taken care of. From the time I first talked to him on the phone to turning off the radio on the ship was about two and a half hours. He said he will be sure to call us if something like that ever happens again."

QRM in Music City

To these experienced T-hunters, this was just another hunt, and not a difficult one at that. However, to the pilots it was a great example of how experienced and prepared ham radio operators can use their skills to help the public. Some T-hunters around the country are doing it in a more organized way, as members of Civil Air Patrol, US Coast Guard Auxiliary, and other search/rescue organizations. For others, it's just a matter of being in the right place at the right time.

Ken Harker, WM5R, recently e-mailed to tell about an article in *The Tennessean* about two hams who solved a serious interference problem and got great publicity for ham radio in the process. For the full story, I contacted Steve Rich, W4BZU, vice president and co-owner of CommTech in Nashville. His company sells and installs radio equipment for businesses such as Opryland and governmental agencies such as police, fire, and emergency medical services. The suburb of Franklin is one of his governmental accounts.

"The Franklin PD called and said they were having problems on their 460-MHz repeater, primarily with their portable radios," Steve told me. "When they were away from town center where the repeater was, they were being clobbered by some sort of interference.

"The repeater input is tone-squelch protected," he continued, "but interference on the input was causing the portables' signals to be garbled and to drop out. Brad Adams, N4PYI, and I couldn't hear the noise while driving around town, so we went to the repeater site and put a spectrum analyzer on the input antenna. There it was, continuous but wavering around, level about –90 dBm, bandwidth 40 to 50 kHz, sweeping back and forth. We told them this could take a while, and loaded up with Yagis, cables, and a service monitor, and headed out in the direction of the QRM.

"As I drove through the neighborhood with Brad holding a 6-element UHF Yagi out the window, it was constant but very weak. It narrowed down to a little section with three or four houses. We got out of the vehicle with antennas and attenuators. Everything was pointing to one house, and at about this time a guy came out and asked what we were doing. That's when I realized that we needed the police there. I called in on their system and they sent out a couple of officers.

"The owner was cooperative, but he said he didn't have a clue what it could be. We went in with the officer and didn't see anything, but it was very strong in the house. I explained to the owner that we could be sure it was in his house if he would let us kill the main circuit breaker. I warned him that he would have to reset all his VCRs and so forth, but he said to go ahead.

"We snapped the main breaker and boom . . . it was gone. We turned it back on and there it was. We turned off the sub-breakers one by one until it went away again. The owner said, 'That goes to the upstairs bath. . . . Oh, wait a minute, I gave my son two walkie-talkies for Christmas and I'll bet they're in that bathroom.'

"We went up there with two officers and sure enough, there were two little Audiovox FRS radios in a charger. I unplugged the charger and the noise went away. The radios were in some sort of goofy mode. They wouldn't power on or off, as if the battery had run down and they were in limbo. 'Take them!' he told us. I asked the officer to try his portable and he said, 'First I've been able to use it all day!'

"The whole thing took about four hours. We had a stockpile of Kenwood FRS radios on hand, so I grabbed two of them and took them back to the house to give to the kids when we went there with the newspaper reporter. They were thrilled, because these were much better radios."

Besides the newspaper coverage, Steve and Brad's adventure was the lead story on the evening news of a TV station in Nashville. The report can be viewed in streaming video at the CommTech website.[3]

This was not the first time that something in a battery charger had caused QRM in Nashville. "Several years ago we had interference to one of our community repeaters," Steve explained. "It turned out to be a bar-code reader in a charger in the back of a Wal-Mart store, spurring like crazy. They had to call company headquarters in Arkansas before we could go in with test equipment to find it."

These hunts prove again what I say in my T-hunting talks to ham clubs: When you set out on a hunt, you never know where you'll end up, nor what you will find when you get there. A similar surprise awaited ARES members in Lexington, Kentucky when they set out to find interference to State Division of Emergency Management radios on 143.0 MHz. It had been present only on weekends for about six weeks, and then it became continuous.

The hunt led to a house on the University of Kentucky campus. Almost all of the electrical outlets in the house, as well as all the data lines, carried the noise. The culprit turned out to be a little modem, about the size of a cigarette lighter, on a computer hub line for security dispatch.

According to the report on the web, "We later found that the house has an electrical ground problem. When it rained, the noise was never there because the soil outside the house was damp enough to shunt the offending signal. We mainly heard it on weekends and holidays, because that is when the alarm was on. Recently, the system quit working, but no one ever turned it off. Thus it was ongoing all the time in dry weather."

Balloons Know No Boundaries

Balloon flights provide another opportunity for RDF fans to help their fellow hams and the public. Groups such as Edge of Space Sciences in Colorado[4] find it fun and educational to launch electronic packages into the stratosphere. Weather sensors, ATV cameras, cross-band repeaters, and other experiments rise about 20 miles, giving very wide signal coverage. Then the balloon bursts and everything parachutes back to Earth. The landing point depends on prevailing winds and length of time that the package is airborne.

Recovery of the package is a perfect task for transmitter hunters. This is truly a "Mother Nature's no-holds-barred hunt," because it obeys no man-made rules nor boundaries. Sometimes it's easy, but my first balloon-hunt adventure certainly wasn't. Bill Brown, WB8ELK, and Mike Henkoski, KC6CCC, launched an ATV package shortly before sunset in southern California to get views of an annular solar eclipse from above the cloud cover.

At that time there was no GPS. Computer programs to predict landing points were not nearly as refined as today.

WB8ELK postulated that after its fall from 100,000 feet, the package would end up 52.6 miles from the launch site on a bearing line of 87.5 degrees. At the time of impact that Saturday night, eight mobiles full of T-hunters were converging on his predicted spot in the mountains north the tiny town of Anza. The roads were rough and rutted. My rotating antenna mast broke from the flexing, sending me home to make repairs before midnight.

Normally, southern California T-hunters are fiercely independent, with "No Clues!" as the battle cry. This night, they had to cooperate when they realized that there were no accessible roads to be found for closing in. A couple of teams in four-wheel-drive vehicles got stuck and had to be winched out.

Four hams set out on foot in the wee hours. The remaining hunters stood by to take bearings on the signal and on the hikers, to keep them from getting stranded in the dark. At this point, they voiced their envy of balloon hunters in the Midwest. It must be nice to be able to track them in flat, cultivated terrain with roads at least every mile on a grid, worrying only about whether a farmer will show up with a shotgun. Here they were at a 4500-foot elevation, shoulder-deep in manzanita bushes that made it a Herculean effort to move forward while encumbered with RDF gear.

The bearings kept indicating "It's just over the next ridge." However, by dawn Sunday the hunters had had enough. Cold and exhausted, they headed out for breakfast and some rest. It was starting to rain. Most of them had 100 miles to drive to get home.

When I got up the next day, I learned that the package had not been found and that a storm front was due in a few hours. I called Gary Holoubek, WB6GCT, and we headed back out to the area in his 4WD Isuzu. The beacon was still strong. We spent the morning and early afternoon driving, walking, RDFing, and peering through binoculars into the foggy hills. One promising road ended up in the back yard of a local resident, Chris Christensen. It turned out that Chris had "back of his hand" knowledge of the hills, where he had frequently gone horseback riding.

We inquired about roads into the area where the bearings showed the greatest promise. "You can't drive in," he said, "but I can show you the old horse trails." With that, he took off at a rapid gait and we had little choice but to hustle after him.

Bearings were good from the high spots, but soon the wind and sleet arrived, forcing us to turn back. We exchanged phone numbers, and Chris hinted that he might try to find the box on his own when the weather cleared.

On the repeater on Sunday night KC6CCC announced that the 2-meter beacon batteries would die within 24 hours. That motivated four T-hunters to make a last-ditch effort. They headed out to the site at dawn to find cloudy weather and six inches of snow on the ground. Would it still be on the air? Yep, still going!

It was another day of searching for roads and tramping through the snowy manzanitas. Local hams assisted with 4-wheeling and hosted the T-hunters' families. Jim Roberts, N6XTJ, flew over the area to attempt aerial bearings.

Suddenly at 1715 hours, the signal level began to flutter. Was the battery dying or the package moving? Sure enough, Chris and his brother-in-law had set out after work. Following the line of bearing we had given to Chris on Sunday, they had discovered it on a hillside less than 300 feet beyond Sunday's quitting spot. It had crashed into the manzanitas, three quarters of a mile from the nearest accessible road.

I can almost hear you asking, "This is the 21st century, so why not dispense with the T-hunt and use GPS and APRS to tell exactly where the balloon has fallen?" Most groups do just that.[5] However, what if the GPS set or its antenna fails in the extremes of temperature and shock on its balloon ride? RDFers are still an important backup for the recovery team.

Even with GPS on board, RDF adds fun to a balloon hunt. Hams in the Netherlands are holding this year's annual high-altitude experiment as I write. Launched from the Royal Dutch Meteorological Institute headquarters, the package includes beacons on 2 meters and 80 meters, an ATV station on S-band, a 70cm-to-2m transponder, and GPS telemetry.[6] According to the announcement from Hans, PE4HB, Dutch hams are invited to participate by trying to be the first to locate the downed balloon by tracking the 2-meter or 80-meter beacons. Upon locating it, they are asked to leave it in place for other hunters to find.

Rocketeers and RDF

Model rockets don't fly as high, as far, or as long as weather balloons, but they still must be located after they return to Earth. Most of them have very little room for electronics. Weight is a major design issue that makes GPS capability impractical.

RDF is ideal for finding downed rockets, but there are special challenges. The transmitter and batteries have to be tiny and featherweight. The same is true for free-flight model gliders. Typical transmitter power is 30 to 50 milliwatts. Pulsing the transmitter every second or so instead of running it continuously preserves battery life.

Over the years, I have corresponded with model-rocket and glider fans who have experimented to optimize their transmitters and tracking equipment. One of them—John Hepner, KA8ZSB, of Farmersville, Ohio—has tried RDF on all ham bands from 2 meters through 30 cm for his 43-inch long by 1.64-inch diameter rocket.

"Mine goes up to 3000 feet," he wrote. "All rockets tend to drift a good bit after parachute deployment if there is wind. Despite some interesting adventures, we haven't lost a rocket since starting to track with radio."

Two meters gives good tracking range and accuracy if a full-size transmitting antenna can be mounted on the rocket. Higher frequencies are attractive, because antennas are smaller. UHF RDF typically is more difficult than VHF due to greater signal reflections, but this "multipath" phenomenon is minimal in the flatland boonies preferred by rocketeers.

KA8ZSB had good results with a 927-MHz RDF system. "The signal tends to quit rather abruptly when the rocket reaches ground level or falls behind a hill," he wrote. "However, the bearing is relatively sharp until then."

Practical equipment and techniques for rocket and glider tracking could easily fill an entire "Homing In" installment. I would like to do that in a future issue, so if you are involved in low-power tracking such as this, please write to me. I also welcome hearing about more instances of transmitter hunters helping the public with RDF. My e-mail and postal mail addresses are on the first page of this column.

Notes

1. <www.homingin.com>
2. <www.thunter.org>
3. <www.commtechradio.com/video>
4. <www.eoss.org>
5. See "Great Plains Super Launch 2004," *CQ VHF,* Summer 2004, p. 6.
6. <www.ballonvossenjacht.nl>

By Keith Pugh,* W5IU

The First Days of AO-51 . . . and more

First let me introduce myself. I was first licensed in August of 1953 as WNØQMG in Dodge City, Kansas. I listened for, but did not hear, *Sputnik I* in October of 1957. College at Kansas State University and the start of my career in Aerospace and Airborne Avionics Systems at General Dynamics (later Lockheed Martin Aeronautics) kept me away from the amateur radio satellites until 1982, just before the launch of AO-10. Since 1982, these satellites have become a major part of my life. Involvement in the amateur radio satellite program is the best way I can think of to combine radio communication technology with computer technology and gain first-hand knowledge about the space program.

My RF interests have moved from HF to VHF, UHF, and on to the microwaves. Computer knowledge has grown from a little FORTRAN programming at work to using computers to do orbital prediction, station control, telemetry processing, digital imaging, etc. Best of all, I have had fun and learned a lot in the process!

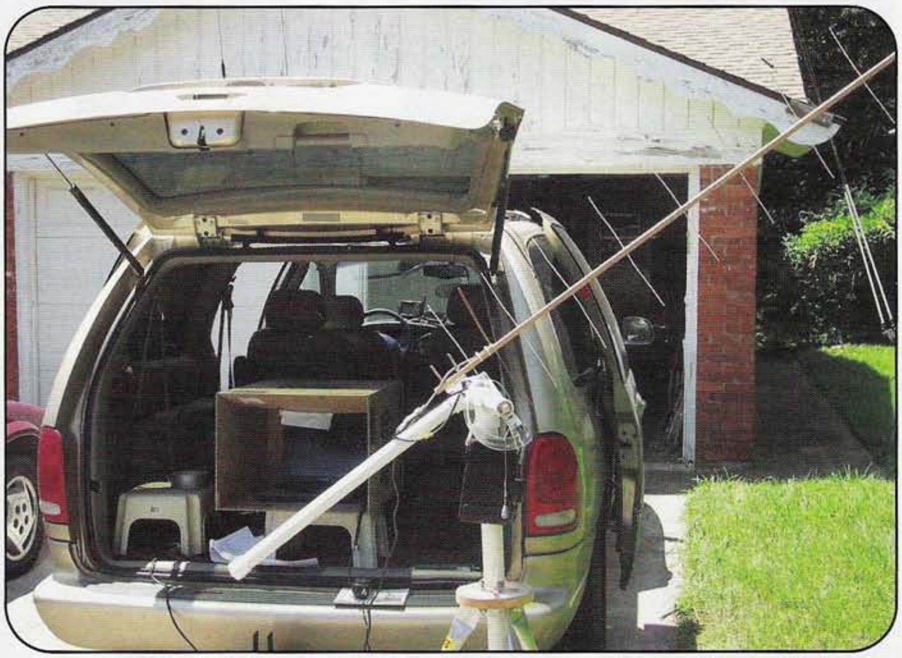


Photo 1. *Operating AO-51 in the driveway from W5IU's mini-van.*

Photo 1A. WA5VJB's 10-element "Cheap Yagi" on W5IU's "Cheap Positioner."

Photo 1B. Notebook computer in "sun shield" connected to the Kenwood TH-D7.

First Days of AO-51

The Summer 2004 issue of *CQ VHF* had an excellent article on the launch of AO-51 by Lee McLamb, KU4OS, entitled "From ECHO to OSCAR 51." Since the launch on 29 June 2004 much progress has been made. Checkout of all basic hardware, verification of power budget, software loading, and functional inter-operability testing by the command stations occupied the first month in orbit.

During this period users learned and re-learned how to copy and de-code 9600-bps, FSK, packet information. To the uninitiated, it took quite a while to realize that 9600-bps data on an FM receiver sounds like a slight rise in the noise level and nothing else. With the downlink power levels utilized for initial checkout and the lack of recognizable signal content, many hams had difficulty just locating the "bird."

Reading the AMSAT-BB reflector during this period was interesting. Once it became obvious that gain antennas and pre-amps were necessary for adequate signals, operations improved greatly. Another "stumbling block" was the learning curve on 9600-bps modems and TNCs. Many hams, this author included, discovered the value of the Kenwood TM-D700, TS-2000, and TH-D7 radios with their built-in TNCs and 9600-bps modems for use with this new satellite.

Initially I used a Kent Britain, WA5VJB, "Cheap 70-cm Yagi," an ARR 70-cm pre-amp, my TH-D7 HT, and my notebook computer to copy and de-code the telemetry. The antenna was hand positioned on a homemade tripod with protractors for azimuth and elevation indicators. Photo 1 shows this setup in the

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Photo 2. N1JEZ pointing the Arrow antenna at AO-51 while VE3FRH and W2GPS supervise.

Photo 3. AO-51 "lunchtime demo": N1JEZ at the computer, W2GPS with the Arrow antenna and TH-D7, and W3IWI with the camera.

Photo 4. Another AO-51 "lunchtime demo": W5IU with the TH-D7, VE3FRH with the Arrow and PDA.

Photo 5. Entrance to the GB4FUN van at the AMSAT-UK Colloquium.

back of my minivan in the driveway. The telemetry capture was handled by TlmECHO by KE4AZN, one of the AO-51 command stations. This software is available from the AMSAT website, <http://www.amsat.org>. Later, at higher power levels from the satellite and more operator experience, successful data capture was obtained with only an Arrow Antenna, the TH-D7, and the notebook. Demonstrations of telemetry capture were performed at the Central States VHF Conference. More information about that will be provided later.

On 30 July 2004, the FM voice transponder was opened to the users for the first time. My initial impressions of this operation were obtained while at the AMSAT-UK Space Colloquium at the University of Surrey in Guildford, England. The Radio Society of Great Britain (RSGB) GB4FUN mobile station was utilized by Robin Haighton, VE3FRH, AMSAT-NA president, to make one of the first contacts through the transponder. The early days of this activity were marked by difficulty getting through the transponder with low power. Everyone wanted to try the new "bird," and excessive power from many stations coupled with the FM capture effect made life difficult for the station with an HT and an Arrow antenna, or less. Again, a storm of activity on AMSAT-BB, and some operating notes by Emily Clark, WØEEC, on the AMSAT web page helped make people aware of the situation, and operations have now improved.

From the beginning, Wednesday, UTC, has been declared Experimenter's Day. On this day each week a new feature of the satellite is tried. The first such experiment was to enable the S-Band downlink for testing. A follow-on to that successful operation was to couple the VHF receiver to the S-Band downlink and make a V/S transponder. This was very successful, with many folks using their AO-40 S-Band downlink antenna and down converter to copy the satellite.

It was an "eye opener" to keep that kind of antenna pointed at a Low Earth Orbit (LEO) bird while compensating for ±50 kHz of Doppler. It was soon determined that the signal levels from the bird are such that much less antenna gain can be used, making the tracking easier, and Doppler compensation in 5-kHz steps is adequate.

A natural progression to a mode L/S transponder was next, and again there were successful operations by several folks. Manual operation is still possible,

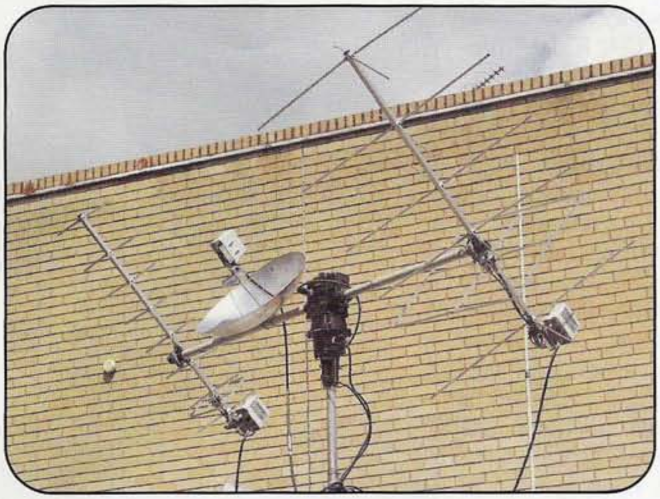

Photo 6. VHF, UHF, and microwave antennas on the GB4FUN van.

Photo 7. The GB4FUN van ready to operate on all bands.

but the high Doppler on the uplink as well as the downlink adds to the challenge. Computer-aided antenna pointing and Doppler correction are very desirable for these modes. Fortunately, software and hardware to accomplish this are now readily available.

Experiments with the 9600-bps "store and forward" capability utilizing the mode V/U digital transponder were next and proved to be very successful. This capability is now available regularly in accordance with the original plan. It is interleaved with telemetry transmissions to monitor the health and welfare of the bird. Successful experiments have also been carried out using the 38.4-kbps data rate on the S-Band downlink.

As this is being written, tests are being made utilizing a 10-meter USB uplink of PSK-31 data to feed a UHF FM downlink. Initial operations have met with limited success. The jury is still out on this one, but progress is being made.

AO-51 has come a long way since launch and still has a long way to go. It is proving to be challenging, while providing a basic "Easy Sat" utility as well. For additional details and operating schedules, visit the Project ECHO pages on the AMSAT website. Additional reports will be provided in this column in the future.

AMSAT at the CSVHF Conference

Every year I try to attend either the Central States VHF Conference or the AMSAT-UK Space Colloquium. Most years they are on the same weekend in July, making it impossible to attend both. This year was the exception. I was able to attend Central States in Toronto, Ontario on one weekend, spend a few days touring Scotland next, and finish up on the following weekend at the AMSAT-UK Space Colloquium at the University of Surrey in Guildford.

AMSAT-NA was well represented at Central States this year by Robin Haighton, VE3FRH, president; Rick Hamby, W2GPS, executive vice president; Tom Clark, W3IWI, past president; Bill Tynan, W3XO, past president; Bob McGwier, N4HY, former board member and software contributor; Mike Seguin, N1JEZ, area coordinator and microwave guru; and yours truly. I'm sure there were many others there as well.

Central States is the oldest conference of this type in North America and was the pattern for the AMSAT-NA Space

Photo 8. "Gassing up" NTBP launch #11.3 at the Hillsboro, TX airport.

Symposiums that came along later. Central States is made up of weak-signal experimenters and operators. As such, it is a natural for the active satellite operator and experimenter. Central States is also a regular financial supporter of AMSAT.

This year's conference had the usual number of high-quality papers presented, including an excellent one on Software Defined Radios by Gerald Youngblood, AC5OG, and Bob McGwier, N4HY. It was pointed out during this presentation that AMSAT plans to heavily use Software Defined Radio technology in their next satellite, Eagle.

During the antenna-range activity, an AO-51 demo was presented to illustrate the simplicity of finding and listening to the new bird. Photo 2 shows Mike Seguin, N1JEZ, pointing an Arrow antenna at the bird under the watchful eyes of Rick Hamby, W2GPS, and Robin Haighton, VE3FRH. That evening telemetry was successfully captured and a decision was made to attempt it again during the lunch break on Saturday. A plan was also "hatched" to do an early voice demo with the cooperation of a command station. Photo 3 shows Mike (with his back to the camera) looking at the telemetry on his notebook, while Rick holds the TH-D7 and the antenna. Tom Clark was providing supervision and acting as the "official photographer." Bob McGwier, N4HY, is not shown, but he was the official liaison with the command station, Jim White, WD0E, via cell phone. Photo 4 shows yours truly trying to talk to Jim via the bird while Robin Haighton, VE3FRH, points the Arrow antenna and holds a PDA running PocketSat+ for pointing information. The voice contact was not successful due to a command-station error discovered as the bird went below the horizon, but a great time was had by all. Credit should also be given to Bill Tynan, W3XO, for taking the pictures of this operation with my camera.

AMSAT-UK Space Colloquium

Held every year at the University of Surrey, England, this event is the premier European amateur radio satellite conference. It is the equivalent of the AMSAT-NA Space Symposium and Annual Meeting held each year in the fall (this year's symposium was 8–10 October 2004 in Arlington, Virginia). Approximately 100 to 150 space enthusiasts attend from all over the world, especially Europe. Highlights from this year's Space Colloquium follow:

AO-40 Status – In a conversation with Viktor Kudielka, OE1VKW, I learned of a shift in AO-40's orbit (change in mean motion) that occurred at about the same time the satellite lost at least some of its internal batteries and consequently went off the air. This was later confirmed by Peter Guelzow, DB2OS, president of AMSAT-DL, during his talk. We still do not know what caused the shift in orbit. Theories abound regarding the cause. Unfortunately, there is no good news about AO-40.

ECHO and Eagle – Robin Haighton, VE3FRH, AMSAT-NA president, presented a report on the status of ECHO, now AO-51, and AMSAT-NA's next project, Eagle. Robin had the honor of making one of the first European contacts through ECHO from the GB4FUN van while at the Colloquium. Project Eagle had been the subject of a meeting in Orlando, Florida two weeks before the Colloquium. Robin reported on the plans for this bird, which include another spaceframe design by Dick Jansson, WD4FAB, a transponder suite that relies heavily on Software Defined Radio concepts under the direction of Bob McGwier, N4HY, and a new C-Band transponder conceived by Tom Clark, W3IWI, in his paper "C-C Rider," presented at last year's AMSAT-NA meeting in Toronto and more recently in the *AMSAT Journal.*

Phase IIIE and Mars Orbiter – Peter Guelzow, DB2OS, president of AMSAT-DL, reported on the status of these projects. Phase IIIE is an AMSAT-DL near-term project to place another High Earth Orbit (HEO) satellite in orbit. This will be the anxiously awaited replacement for AO-40 and the other Phase III satellites. It is being constructed in Germany, at the present time, in a left-over AO-13 spaceframe. Of course, the transponder suite has been updated in keeping with the times. Launch is predicted to occur as early as late 2005.

The Mars Orbiter, otherwise known as Phase 5A, conceived by Karl Meinzer, DJ4ZC, past president of AMSAT-DL, is a long-term AMSAT-DL project aimed at placing a satellite in orbit around Mars in the 2007 timeframe. Related talks on how hams might participate in this project were presented by Charles Suckling, G3WDG, and James Miller, G3RUH.

Beagle 2 and Into Space with Reg Turnill – Prof. Colin Pillinger, head of the Beagle 2 Project, gave a very entertaining talk on the events leading up to the Beagle 2 landing on Mars last Christmas and the search for it since then. Unfortunately, Beagle 2 has not been heard from, but Prof. Pillinger has a very positive outlook for this type of operation. His enthusiasm was infectious.

Reg Turnill was the BBC aerospace correspondent during the Apollo lunar landings. Reg entertained us with his experiences during manned space efforts in general and specifically the Apollo program. Reg has spent a major portion of his long life covering space for the news and has known many of the participants, such as Dr. Wernher von Braun, personally. He recently authored a book entitled *The Moonlandings—An Eyewitness Account,* which is an excellent read.

GB4FUN

The GB4FUN (Great Britain for Fun) van was present and open for use throughout the AMSAT-UK Colloquium, and status was presented by Carlos Eavis. I was so impressed by this project that I have decided to report on it separately. Sponsored by the Radio Society of Great Britain, this van tours the UK on a regular basis and visits schools, fairs, sympo-

Photo 9. "Up, up, and away," NTBP just after liftoff.

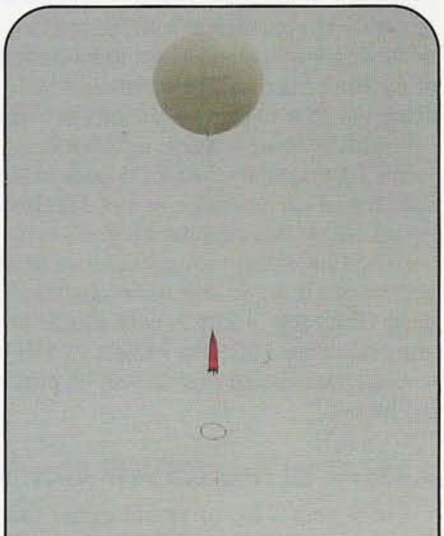

Photo 10. NTBP #11.3 (top to bottom): balloon, parachute, communications package, and ATV package.

Photo 11. Working satellites from the "cotton patch"—WA5VJB's circular-polarized 2-meter, 4-element "Cheap Yagis" and 10-element, 70-cm "Cheap Yagi" on W5IU's "Cheap Positioner."

siums, etc., promoting amateur radio and amateur radio in education. It is staffed full time and at the present has such a busy schedule that addition of more vans is being considered. GB4FUN has the capability of operating on and demonstrating nearly all bands and modes available to amateur radio operators. It is self-contained and can be in full operation within 30 minutes after arriving at a demonstration site. Photos 5 through 7 illustrate the GB4FUN van and its antennas.

The United States would require too many of these dedicated vehicles to provide similar coverage due to the geography involved. However, it might be possible, with backing from the ARRL, AMSAT, and other organizations, to train people and provide guidelines for utilization of radio club vans, RACES vans, etc., to accomplish this task. Food for thought!

ARISS

Amateur Radio on the International Space Station (ARISS) activity is on the rise. The current crew has taken a very positive attitude towards amateur radio operations. Coupled with the installation of some new radios, this attitude has produced many successful school contacts, renewed packet and APRS activity, more general contacts, and a new capability—a voice repeater. All of this activity is available on the 2-meter and 70-cm bands. Unfortunately, the ISS will not accommodate all of this activity at once; therefore, operations are scheduled and occasionally activities such as space walks, etc., take priority. Check out the activity on 145.800 MHz. This is the master downlink and will tell you what is going on. Packet uplink is 144.49 MHz in Region 2, while voice repeater uplink is 437.800 MHz.

One other item: There was an ARISS International Meeting this year in conjunction with the AMSAT-NA Space Symposium in Arlington, Virginia. Dates were 11–13 October.

Beyond the Edge of Space: NTBP #11.3

Balloons were featured in the Summer 2004 issue of *CQ VHF* so I won't belabor the issue, but balloons carrying amateur radio are really neat club projects and are like satellites in many ways.

The Lockheed Martin Aeronautics Amateur Radio Club successfully accomplished its third attempt at its eleventh launch, North Texas Balloon Project (NTBP) #11.3, on 4 September 2004. Hillsboro, Texas was the launch site, and the entire payload was located and recovered by the DF (direction finding) team from a location near Granbury, Texas. Peak altitude was just over 90,000 feet and distance traveled was about 36 miles. All of the payloads—crossband repeater, APRS beacon, TV camera and transmitter, and a still camera—performed flawlessly during the 2.5-hour mission. Photos 8 through 10 were taken during the preparation and launch of the mission.

During this mission, I set up a satellite station at the launch site from my mini-van and made several contacts through AO-7 (our oldest active satellite), AO-51 (our newest satellite), and FO-29 with the mobile rig and two WA5VJB Cheap Yagis shown in Photo 11. Never give up a chance to show off the satellites!

Next Issue

The next "Satellites" column will feature a full report on the AMSAT-NA Space Symposium and the Amateur Radio in the International Space Station Joint Meeting. I also plan to start featuring details of ground stations required for "working the birds." Until then . . .

73, Keith, W5IU

obtain the best data transmission possible to contribute to the aggregate output of the modem. It is possible that a particular frequency may be totally unsuitable for transmission and not contribute at all to the output. The modem chip sets are capable of operating up to 80 MHz, but the expectation is that the frequency response will be best and the losses will be lowest at the lower frequencies. However, this is subject to the spectrum being available for use. The 10-MHz bandwidth requirement is for one particular modem, so depending on how the transmit/receive functions are handled in the modem set, there may be two or three times the 10 MHz required to handle all the data transmission requirements.

Typical BPL modem spectral characteristics are shown in figure 3. This particular modem is of European origin, but the important thing to note is the closely spaced carriers and the absence of carriers at certain frequencies, which just happen to coincide with many of the amateur radio allocations!

The next generation of BPL modems that are reported to be capable of 100 Mbps are currently undergoing test and are expected to be available for commercial service later in 2004. The spectral characteristics are unknown, but because the manufacturers were attempting to obtain authority to operate at higher signal levels, one can imagine that higher S/N ratios are required to support operation of modems that provide higher data rates. It is possible that this was desired to preserve the existing use of only 10 MHz of spectrum, while providing higher data speeds.

BPL Interference

BPL interference is a very controversial subject. Recently it has been the subject of much lobbying (read "politics") by both sides of the argument. As with all political debates, you must listen carefully and ask informed questions, hoping that you will get a straight answer.

In the USA, the ARRL has been strong in its lobbying efforts, and a great deal of information has been put on the League's web page: <http://www.arrl.org>. Unfortunately, some of the information needs to be qualified as to its relevance to the North American situation. As discussed earlier, the configuration of the power distribution grids differs greatly between Europe and North America, combined with the fact that many of the tests are old (three to five years) and reflect old BPL technology. Consequently, the results cannot be taken as conclusive proof that BPL will result in severe interference. BPL proponents cite many examples of BPL systems (Hong Kong, Spain, and France, for example) where no interference has been reported. However, the details of the deployment often are not known.

Considering that BPL is a wideband digital service, it certainly is reasonable to expect that BPL will generate wideband "noise." If you have ever tried to use a portable radio next to a modern digital computer, then the influence of digital-system noise can be appreciated. Fortunately, computer noise largely disappears with a short distance separation. Unlike narrowband analog systems, any BPL signals will tend to be wideband in nature and not generate discrete signal spurs. The BPL signal will propagate down the wires by conduction, but because of the fact that the wires are not solidly shielded or adequately balanced with close conductor spacing (in the case of two phase coupling), the signal will tend to radiate. Of course, the nature of the distribution system will greatly influence the situation. Many modern distribution systems are buried and use what are in effect shielded cables. The overhead drop wires from the transformer to the customer are severely twisted and certainly will offer some shielding effect. Last, but not least, the power level used at the injection points on BPL systems will have a direct influence on interference.

With all of these variables combined with the differences between the different possible methods of implementing BPL, it becomes very difficult to predict interference levels. Therefore, it is not reasonable to say that *all* BPL systems will generate interference . . . but certainly the potential exists. An example of European BPL interference tests shows the possible impact of BPL signals on HF amateur operations.

The test results show that the shortwave signals (narrow spikes) underneath the two undulating lines that represent the envelope of BPL signals were measured in close proximity to the BPL carrying cable (figure 4). It is clear that if the receiver's antenna is close enough to the BPL carrying conductor, interference may result.

With all the speculation and incomplete testing, it is fortunate that some good science is currently being performed by the National Telecommunications and Information Administration (NTIA). Its work to date has provided many answers (presented later on in this article), but further work is required to answer the lingering questions.

FCC BPL Proposals

The FCC in its February 2004 Notice of Proposed Rule Making (NPRM) on BPL has made it clear that it intends to make regulations that will allow BPL deployment to proceed, acknowledging that the potential for local interference may exist. It has, however, refused to increase to permitted emission limits defined under Part 15 Carrier Current System regulations and has asked that measures be put in place to ensure that interference can be managed. The FCC interference mitigation proposals include:

- Cessation of Operations Altogether: If required to resolve interference!
- Dynamic Reduction of Transmit Power: This is the ability to remotely reduce the power of a transmitter. This certainly is possible, although undesirable once a system is installed because the repeater spacing will be expected to be spaced as far as possible to minimize the installation cost.
- Avoid Operating on Specific Frequencies to Prevent Harmful Interference: This is practical with OFDM and Frequency Hopping Modems (see the notches in the modem spectra discussed earlier). This is potentially limiting of the modem's bandwidth capability, but as long as the avoided spectrum is not wideband, it can be tolerated. If the avoided spectra are wideband, such as the amateur or shortwave broadcast bands, this probably can be overcome by using additional spectrum elsewhere. Careful planning of spectrum use will be required so that BPL implementations can be smooth and simple. This type of planning was demonstrated successfully with the creation of the Homeplug standard in Europe and the USA. In fact, the ARRL participated in the interference tests and approved of these products.

Similar work has occurred recently between one BPL OFDM Modem User/Manufacturer and the ARRL. Although the ARRL is guarded in its approval of these test results, there should be some optimism that the technology can be made to work around the interference problems. Another recent trial system generated interference complaints from four amateur radio operators. Apparently, the interference was resolved, and in fact, three of the amateurs have subscribed to the service!

NTIA Interference Tests

On April 27, 2004, the NTIA issued its Phase I report, "Potential Interference from Broadband over Power Line (BPL) Systems to Federal Government Radiocommunications at 1.7–80 MHz." This report defines the interference risks to radio reception in the immediate vicinity of overhead power lines. The report looked at interference to various receiving systems including:

- a land vehicular receiver
- a shipborne receiver
- a fixed service system using a rooftop-based antenna
- an aircraft in flight

The tests indicate that high field intensities were encountered at locations well removed from the BPL devices because of discontinuities in the distribution lines.

The tests indicate that interference may occur in low- to moderate-level signals at significant distances (75 to 460 meters) from lines, and there is a frequency dependence. For a BPL implementation with a density of one system per square kilometer, there will be interference to aircraft reception of moderate to strong radio signals at an altitude of less than 6 km within 12 km of the center of the BPL deployment.

The results indicate that the measurement procedures for BPL systems need to be refined to use measurement antenna heights near the heights of the power line and that BPL emission limits should not be relaxed from existing Part 15 rules.

The report further recommends that the measures identified in the FCC NPRM be applied as needed to avoid interference (selective frequency avoidance and power reduction).

The NTIA further recommends to prospective BPL developers:

- routinely use the lowest power necessary from each BPL device
- avoidance of locally used radio frequencies
- balanced (multi-wire) injection oriented to minimize radiation
- use of filters and terminations to extinguish BPL signals where not needed
- judicious choice of frequencies to decrease radiation

A future Phase II report will address the potential interference via ionospheric propagation of BPL emissions from mature large-scale deployments of BPL networks.

Is BPL in Your Future?

As discussed earlier, all levels of government in the USA and Canada are supporting BPL deployment as another means to get service to underserved areas. BPL systems are now being deployed in many USA states, including Missouri, Virginia, North Carolina, Pennsylvania, Alabama, and New York.

In Canada, the first deployment was announced in February 2004 by PUC Telecom in Sault Ste. Marie, Ontario. Other Canadian utilities are conducting trials to evaluate the technologies and to get a first-hand knowledge of the costs as well as the issues associated with implementing BPL.

Industry Canada is intensely monitoring the situation, working with the utilities as well as with manufacturers, and will be creating its own BPL standards. ■

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By Dr. H. Paul Shuch,* N6TX

DR. SETI'S STARSHIP

Searching For The Ultimate DX

Remembering John Kraus, W8JK

I am saddened to report the death on 18 July 2004, just three weeks after his 94th birthday, of Dr. John D. Kraus, W8JK, a true renaissance man. John was Professor Emeritus at Ohio State University, where he had taught engineering, physics, and radio astronomy for nearly half a century. Long after his retirement, he was still going to the campus daily to meet with students. Ever the optimist, John had renewed his ham radio license a few days before his death—for a period of ten years.

Prof. Kraus distinguished himself as a prominent physicist, educator, antenna designer, engineer, writer, publisher, radio amateur, and philosopher. His textbooks *Radio Astronomy, Antennas, Electromagnetics,* and *Our Cosmic Universe* guided a whole generation of astronomers and engineers, including me. His two volumes of memoirs (*Big Ear* and *Big Ear Too*) inspired a whole generation of radio amateurs (again, including me). His short-lived periodical, *Cosmic Search,* was the world's first SETI magazine, its thirteen issues still cherished by those of us involved in the SETI enterprise. His designs (including the legendary Big Ear radio telescope) have expanded humanity's knowledge of the cosmos.

It was at Big Ear that the most tantalizing, elusive, and enigmatic evidence yet of extraterrestrial intelligence was collected. The legendary "Wow!" signal received there on 15 August 1977 remained the greatest mystery of John Kraus's life, a detection that fit exactly the expected profile of intercepted radiation from another intelligent civilization in the cosmos. That the anomaly was observed right around the time of his retirement must have been a disappointment to John, who would have liked to direct the hundreds of repeat observations that followed. Instead, Kraus turned over the effort to a most able lieutenant. Bob Dixon, W8ERD, had come to Ohio State as a grad student, specifically to study under the best antenna engineer of his day. He was studying there when Big Ear was being commissioned, stayed on as a faculty member, became John Kraus's deputy director, and ran the observatory during its final years.

Those final years of Big Ear came too soon, both for Dixon and for Kraus (who remained actively involved in radio astronomy and SETI well beyond his retirement). The land under the antenna's beautiful 3.5-acre ground plane had become just too valuable, and ultimately the university sold it to the developers. Big Ear, John Kraus's brainchild and one of the greatest radio telescopes of all time, was ploughed under in early 1998 to make way for a commercial golf course. Such is progress.

On a personal level, it was John Kraus who ordained me as a radio astronomer. That particular episode occurred a number of years ago at Ohio State University, when Kraus was already a Professor Emeritus. I had just presented a SETI paper to a room full of astrophysicists, and I was justifiably nervous. "After all," I told him afterward, "I'm just an electrical engineer."

*Executive Director, The SETI League, Inc.,
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Dr. John D. Kraus, W8JK, Ohio's first and foremost radio astronomer, designed and built Big Ear, the third largest radio telescope in the United States. His basic design has been duplicated at least three times around the world and is now known generically as the Kraus-type telescope. W8JK was prominent in ham circles for inventing several other important antennas, including the 8JK beam (a two-element, wire, end-fire array), the axial-mode helix, and the corner reflector. He is seen here at the site where Big Ear stood for nearly 40 years, giving its eulogy at the dedication of a state historical marker. (N6TX photo)

"Don't ever say that!" roared Kraus, with a forcefulness that belied his then eight decades. "You are a radio astronomer!"

Right there, I realized I had offended my mentor. (After all, he himself was, first and foremost, an electrical engineer.) "But John..." I started.

"But nothing!" he retorted. "As an engineer, you can very easily learn (and, in fact, have already learned) all the astronomy you need to call yourself a radio astronomer. The converse cannot be said of the physicists."

Over the years, John Kraus remained quick with his wit, frank in his criticism, generous with his praise, and ever supportive of the young upstart with his head in the clouds. I am proud to have been able to call him my friend.

The last time I saw Kraus in person was on 5 November 2000. John and 50 friends gathered on the green at the former Big Ear site to dedicate an historical marker. That ceremony was not only a memorial to Big Ear, but also a tribute to Kraus and his many accomplishments. I know that when Big Ear died, so did a part of John Kraus. That he remained among us, warm, compassionate, and mentally alert for an additional four years, was a gift to all who knew him.

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