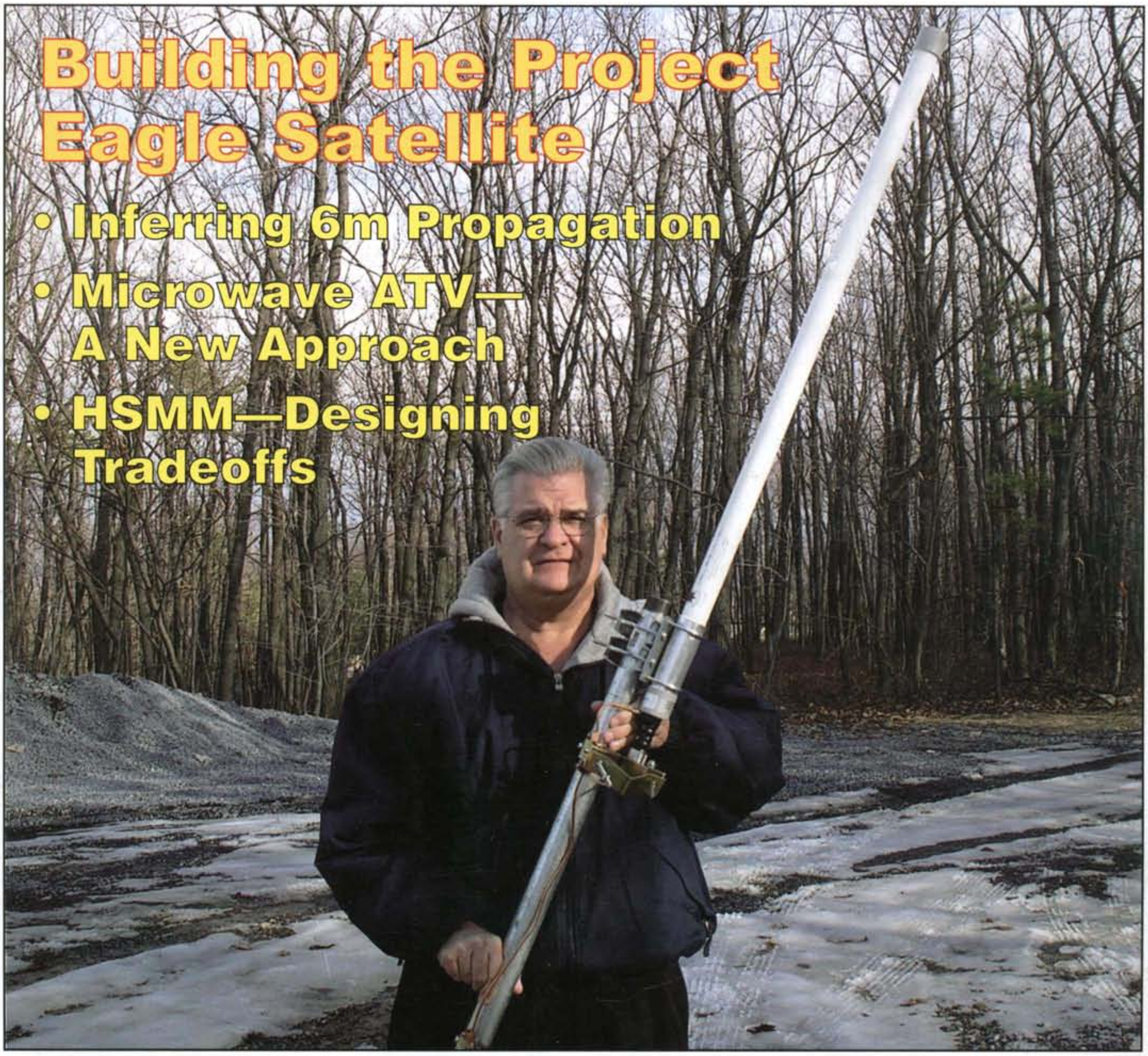
ISSN 1085-0708

CQ VHF Ham Radio Above 50 MHz

www.cq-vhf.com

Winter 2007

$6.50



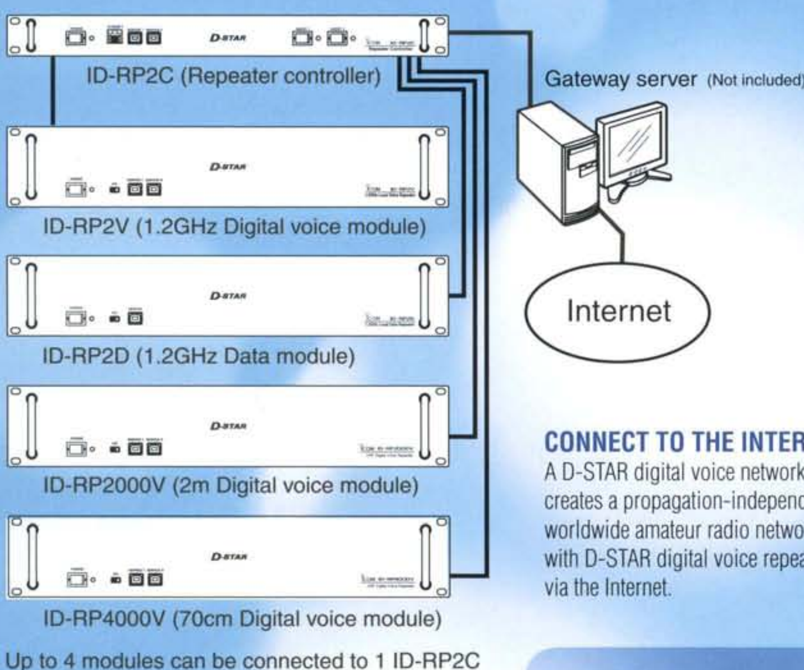
Building the Project Eagle Satellite

- Inferring 6m Propagation
- Microwave ATV—A New Approach
- HSMM—Designing Tradeoffs

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

Go digital! D-STAR repeaters! Now in 23cm, 70cm and 2m

D-STAR REPEATER SYSTEM



CONNECT TO THE INTERNET

A D-STAR digital voice network creates a propagation-independent worldwide amateur radio network with D-STAR digital voice repeaters via the Internet.

ID-RP2C

REPEATER CONTROLLER

The cornerstone of the D-STAR repeater system. Handles up to four RF modules. Basic in-band or crossband operation. Linking capabilities through the internet and future 10GHz backbone products.

ID-RP2V

23CM DIGITAL VOICE MODULE

ID-RP2D

23CM DIGITAL DATA MODULE

Access point with a data rate of 128kbps. Depending on the system setup, set up an email and/or file server for EmComm support. Perfect for web applications or support via internet connection.

ID-RP2000V

2M DIGITAL VOICE MODULE

Finally, commercially available crossband repeaters! With proper callsign programming in any D-STAR compatible mobile or portable, the Icom D-STAR repeaters will automatically route your signal to any other RF module connected to a common RP2. With simple repeater commands, you can direct your communications through any of the RF modules or across the world via the gateway.

ID-RP4000V

70CM DIGITAL VOICE MODULE

DIGITAL

Meet the future of amateur radio, today. D-STAR repeater systems are coming to more locations around the the country. Jump in! Visit your favorite authorized dealer today.
D-STAR forum: www.icomamerica.com/support/forums

COMPATIBILITY CHART WITH ICOM DIGITAL TRANSCEIVERS

	IC-91AD or IC-91A with UT-121	ID-800H	IC-2200H + UT-118	IC-V82 + UT-118	IC-U82 + UT-118	ID-1 (1.2GHz)
ID-RP2000V	✓	✓	✓	✓	--	--
ID-RP4000V	✓	✓	--	--	✓	--
ID-RP2V/2D	--	--	--	--	--	✓
Analog Repeaters	✓	✓	✓	✓	✓	✓

AMATEUR | AVIONIC | LAND MOBILE | MARINE | RECEIVERS | SYSTEM | WWW.ICOMAMERICA.COM

ICOM

A publication of

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

Offices: 25 Newbridge Road, Hicksville, New York 11801. Telephone: (516) 681-2922. FAX: (516) 681-2926. E-mail: cq-vhf@cq-vhf.com. Website: http://www.cq-vhf.com. CQ VHF (ISSN 1085-0708) is published quarterly (4 times a year) by CQ Communications, Inc. Periodical postage paid at Hicksville, NY and additional offices. Subscription prices (all in U.S. dollars): Domestic—one year $25.00, two years $50.00, three years 75.00; Canada/Mexico—one year $37.00, two years $74.00, three years 111.00; Foreign—one year $48.00, two years $96.00, three years 144.00. Government Agencies: Subscriptions to CQ VHF are available to agencies of the United States government, including military services, only on a cash with order basis. Requests for quotations, bids, contracts, etc., will be refused and will not be returned or processed. Allow six weeks for change of address.

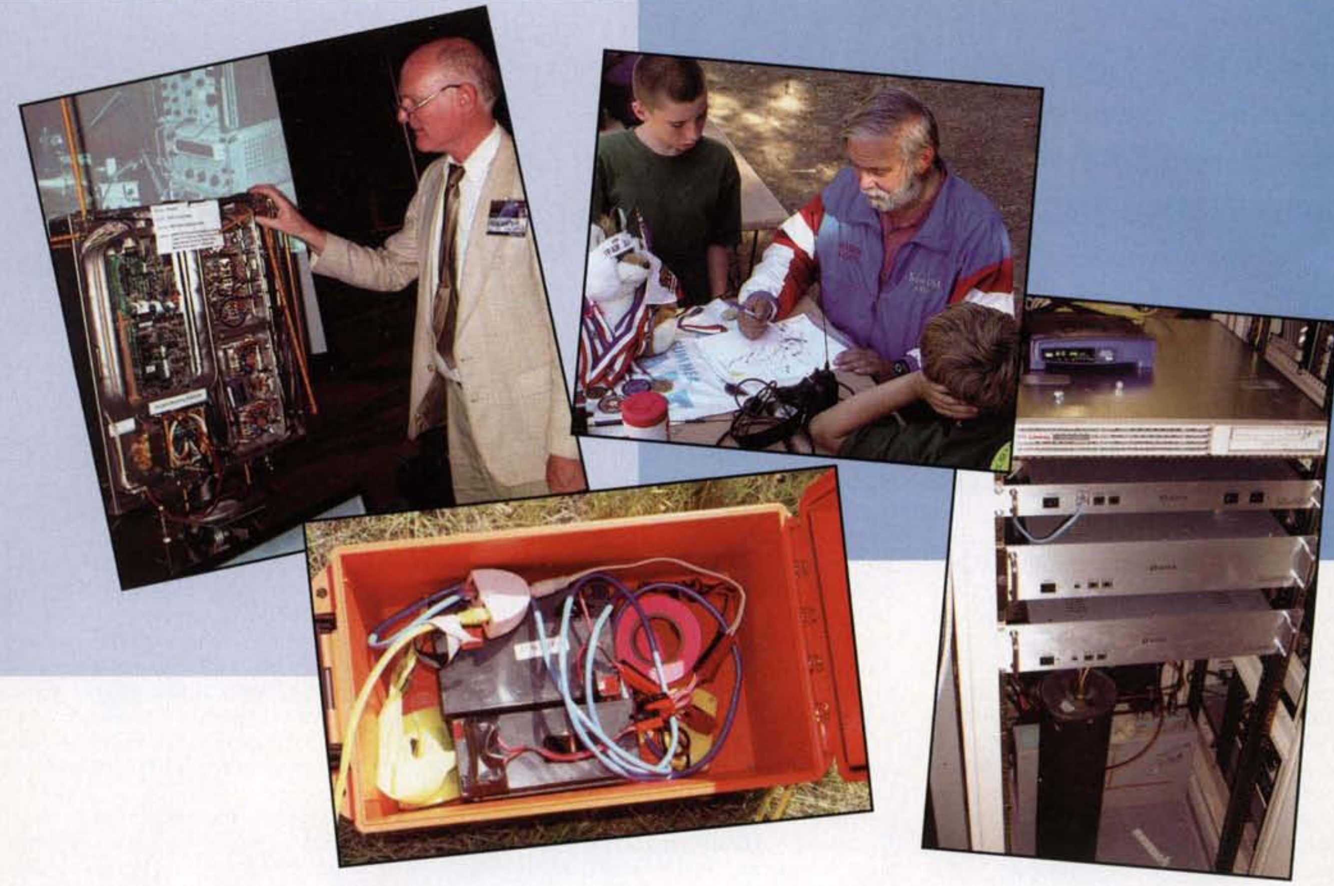
Printed in the United States of America.

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

contents

Winter 2007
Vol. 9 No. 4

FEATURES



COLUMNS

DEPARTMENTS

On The Cover: The South Mountain Repeater Assn. is operating a microwave repeater. The project leader, Gary Blacksmith, WA3CPO, is shown here holding a 23-cm omni antenna. For details, see the article by W3HMS on p. 22. *(Photo by John Jaminet, W3HMS)*

CQ VHF Ham Radio Above 50 MHz

LINE OF SIGHT

A Message from the Editor

The Eagle Has Landed

I lead off this issue's editorial by using the statement that astronaut Neal Armstrong made the moment that he and his fellow astronaut, Buzz Aldrin, landed the lunar module called *Eagle* in the Sea of Tranquility on the Moon on July 20, 1969. I use this reference to space exploration that is so much a part of our history as a literary device to write about Project *Eagle,* AMSAT-NA's major amateur satellite, because in many ways Project *Eagle* has landed in our midst as amateur radio operators—particularly those of us who specialize in communication on the VHF-plus ham bands.

With much fanfare and enthusiasm, Project *Eagle* was rolled out for the public to see last October at the AMSAT-NA Symposium in San Francisco. At that symposium the president of AMSAT stood side-by-side with the project manager as each spoke with hope and enthusiasm while describing the importance of the Project *Eagle* satellite to the future of amateur satellite communications.

While it means a lot to the future of AMSAT because it represents a way for AMSAT to have a do-over after what happened to AO-40, it also represents so much more to the future of amateur radio as a hobby. First, however, let's spend a moment on the do-over part.

It has been a long and difficult six-year journey for officials at AMSAT following the November 16, 2000 launch of AO-40 and its subsequent failures. It has been a time of trying to figure out what went wrong and what can be done in the future to prevent another failure. Perhaps the most difficult part of the journey has been the need to assess the failures without pointing the finger at who was at fault for them. The leadership at AMSAT-NA has carried out that responsibility with integrity and class.

In an effort to publicly discuss the failure, AMSAT-NA posted an extensive post-mortem assessment of AO-40 on its website. It can be found at: <http://www.amsat.org/amsat-new/satellites/satInfo.php?satID=15&retURL=satellites/all_oscars.php>. As one can read from that posting, part of the assessment of what went wrong is speculative, because barring recovery of the satellite and a post-mortem examination of its components, it will be impossible to completely say what went wrong and caused the two failures. Even so, one can ask a couple of legitimate questions regarding the plugged valve vent on the 400 N motor: "Who forgot to pull the plug?" and "Why was it possible for someone to forget to pull the plug?" From AMSAT there will be no official answers to those questions, and that is as it should be, because assessing blame is never productive. In fact, it may even be counterproductive. What is more important is what has been implemented in the aftermath of these failures—that being a peer review process.

Beginning on page 14 of this issue, Project *Eagle* Manager Jim Sanford, WB4GCS, writes of the project in terms of getting it right—both in avoiding repeating the past failure of AO-40 and also in describing what will be inside the *Eagle* satellite. In reading Jim's article, one can get a glimpse of what is inside the heart of AMSAT-NA at this time. There is deep introspective thinking taking place at all levels. There is also visioning of what the designers want to see inside the satellite and visioning of what new technology has to be developed for all of the components.

In order for the project to be successful, AMSAT-NA is drawing upon great talent from within and outside the amateur radio community. This latter outreach is particularly important, because it gives those outside our amateur radio community a whole new insight into what we are all about.

One major outreach is in securing a new facility for AMSAT-NA research and development. Described both in Jim's article and in Keith Pugh, W5IU's "Satellites" column (which begins on page 64) is the agreement that AMSAT-NA has signed with the University of Maryland Eastern Shore (UMES) and its affiliate, the Maryland Hawk Corporation, to co-locate its Satellite Integration Lab with the Hawk Institute for Space Sciences. This new laboratory space is in Pocomoke City, Maryland, which is very near NASA's facilities at Wallops Island, Virginia.

What is significant about the university connection is contained in one of the memorandum of understandings signed between AMSAT-NA and UMES . From the AMSAT-NA press release (which is reprinted in full in Pugh's column) is the following:

> The agreement with UMES calls for AMSAT-NA to work collaboratively with UMES to identify opportunities to work together on satellite and related technology projects as well as to work with their students and faculty to enhance hands-on studies and dissertation research. The possibility also exists for AMSAT-NA scientists and engineers to receive Adjunct status at the UMES.

The heart of the above quote brings me to my second point in this editorial, that being the importance that the Project *Eagle* satellite means to the future of amateur satellite communications. The education component means a great deal to the future of amateur radio. Granted, later this year at the Dayton Hamvention® we all will bear witness to a spike in interest in amateur radio because of the elimination of the Morse code requirement for licensing. However, as with other incentive licensing blips, it will be short-lived and will have minimal residual effects to the overall future of our hobby.

What has to happen to refill our dwindling ranks with quality members is education. Having the education connection to the new lab is absolutely critical for our future. This education component will provide for the exposure of amateur radio to students in the University of Maryland. Hopefully, some of these students will become inspired to become a part of our hobby for the long term. Perhaps something that one of these students develops will be absolutely critical for a future satellite project. Perhaps something developed from that lab will be used on a future NASA mission to Mars. Who knows? Only time and dedication will tell.

Another point I want to make in this editorial is about stewardship. Last December Oprah Winfrey broke ground for her Leadership Academy for Girls in South Africa. In her press release concerning her vision for it and the students who will attend it she was quoted as saying, "I believe that one of the world's most important resources is its young people, and I believe education gives young people a greater voice in their own lives, and helps them to create a brighter future for themselves and their communities." I agree with her and I am happy for the girls in South Africa who will benefit from her endowment.

As she indicated by way of her contribution to that girls academy, nothing comes without a price tag. In the case of AMSAT-NA's development of Project *Eagle,* several million dollars will be needed to bring this project to fruition. It will take persons with deep pockets, such as the type that Oprah has, to bring about such major investment in the future of the education aspect of our hobby. Therefore, I urge those who have the wherewithal to consider the underwriting of AMSAT-NA and its efforts. As you can read from the pages of this magazine, the leadership is on track to do great things for the future of the hobby.

I conclude this editorial with another literary device, that being the allegory of launching a vehicle in space. All that is needed to get Project *Eagle* off the ground is the necessary thrust energy—and that energy comes from those who have the wherewithal to make a major investment in the project. I urge each person who can do so to seriously consider making such an investment.

Until the next issue…

73 de Joe, N6CL

Hams Help with 2006 Wild Ride Bike Rally

The following article demonstrates seamless integration of a number of wireless components, including ICOM D-STAR equipment, for the purpose of providing digital communications for a community special event. The article originally appeared in the August 2006 issue of "The Chawed Rag" (Volume 36, issue 8), the monthly newsletter of the Richardson (Texas) Wireless Klub. It appears here courtesy of the club and the author.

By Doug Kilgore,* KD5OUG

The 2006 Wild Ride bike rally was held on May 20, 2006 to benefit the Richardson (Texas) Regional Cancer Center. More than 1300 riders participated in the rally, completing courses of 11, 16, 40 or 64 miles. Routes started at Gallatyn Park in Richardson, and the longest one passed through Plano, Murphy, Wylie, Garland, Lavon, Nevada, and Josephine, with five rest stops that were manned by volunteers.

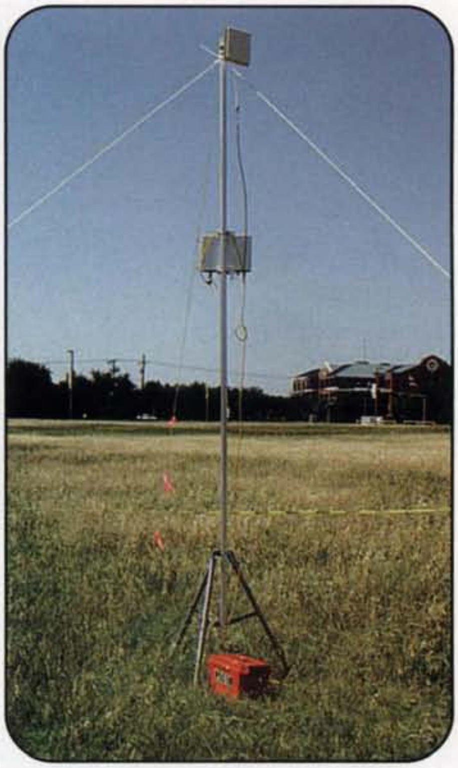
**1317 Glen Cove, Richardson, TX 75080*
e-mail: <kd5ouv@arrl.net>

Ham radio operators provided communications support for logistics and operations during the rally. Thirty-eight hams worked various positions during the rally. In addition to the use of 2-meter and 440-MHz repeaters for voice communications, the rally provided an opportunity to try out new digital capabilities to simulate EMCOMM conditions. Four rest stops were connected to the internet, allowing the transmission of digital photos taken during the rally. The photos may be viewed online at <http://www.k5rwk. org/wr>.

Net control for the event was located in an air-conditioned fifth-wheel trailer owned by the communications coordinator, Doug Kilgore, KD5OUG. The trailer was situated in the Start/Finish area with 120-VAC power provided by a 4-KW generator furnished by Jay Pinkerton, KE5FMS. Net control operators

The Wild Ride ham command post with an HSMM internet bridge mounted on the back. From left to right: Stan Liljeckvist, K5SRL, and Kevin Sims, Jr., KD5PQA. (Photo by KD5OUG)

The net control station with internet provided over HSMM. From left to right: Doug Kilgore, KD5OUG; Stan Liljekvist, K5SRL; and John Galvin, N5TIM. (Photo by N5NOT)



Battery-powered WRT54G repeating between an internet source and the 2006 Wild Ride command post. (Photo by KD5OUG)

were Stan Liljekvist, K5SRL, and John Galvin, N5TIM.

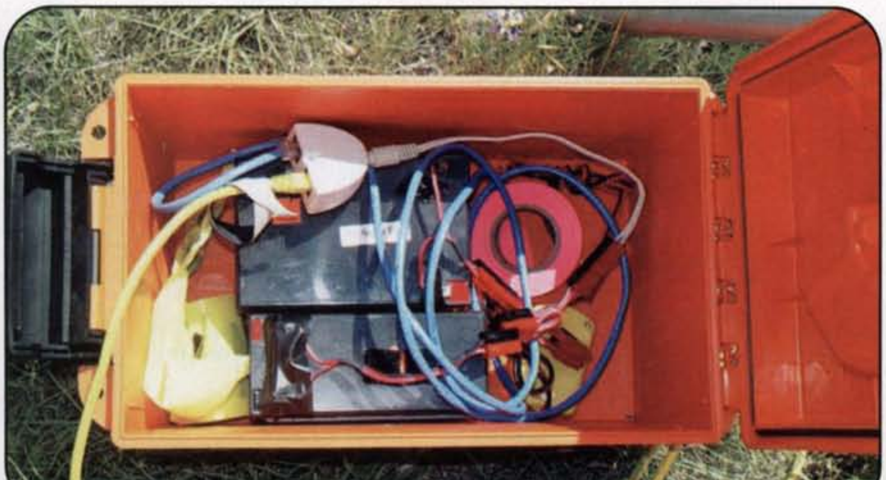
The goal of the digital operations in this event was to exercise capabilities that would be useful in an EMCOMM situation. Rest stops numbers 1 through 4 were connected to the internet to allow sending and receiving e-mail messages and sending digital still pictures to a website that could be viewed by net control and anyone on the internet.

An internet feed to the net control trailer was provided by the City of Richardson (COR). Kevin Sims, KD5YVL, who is the COR network manager, activated an 802.11b access point that was installed by hams last year at the Eisemann Center. The 2.4-GHz signal only had to travel 1/2 mile, but the trailer location was not in line-of-sight. Therefore, a battery-operated 802.11b bridge provided by John Beadles, N5OOM, was placed on a tripod out in a field in line-of-sight of Eisemann Center to relay the digital signals to the trailer. The internet feed allowed net control operators full high-speed access to send and receive e-mails and pictures from the rest stops.

Rest stop number 1 was located in a cul-de-sac in a residential area in Wylie. The connection to the internet was made with the use of a Sprint PCS Broadband card installed in a laptop computer. While its speed was not as fast as an 802.11b connection, the card allowed Kevin Sims, Jr., KD5PQA, to use this arrangement to upload digital still pictures.

Rest stop number 2, at Lake Lavon, was a challenge. Its location near the lake level was not line-of-sight to the local Wireless Independent Service Provider (WISP) in Lavon. Last year an 802.11b bridge installed on a 160-foot Corps of Engineers tower located at the dam was used to send the signal to the rest stop. The tower is now leased by the City of Wylie for their communications purposes and was unavailable.

The new ICOM D-STAR radio was used to overcome this challenge. John Beadles, N5OOM, used an ID-1, provided by Jim McClellan N5MIJ, with a homebrew 8-element Yagi for 1296 MHz. With this antenna John was able to link to the internet-connected D-STAR repeater located in downtown Dallas on one of the tall buildings—a distance of about 27 miles. The D-STAR's 128-kbps Ethernet output was connected to the input of a Linksys WRT54G access point to provide a 802.11 signal to the rest-stop digital operator, John Barrett, KE5CRP. While the speed was very slow compared to an 802.11b wireless signal, it got the



Lead-acid batteries powering a WRT54G repeater. The power is transmitted to the radio over the attached ethernet cable injector. (Photo by KD5OUG)

The Wild Ride command post. The radio is mounted in the steel enclosure and powered over the ethernet cable. (Photo by KD5OUG)

A closer look at the battery-powered WRT54G. (Photo by KD5OUG)

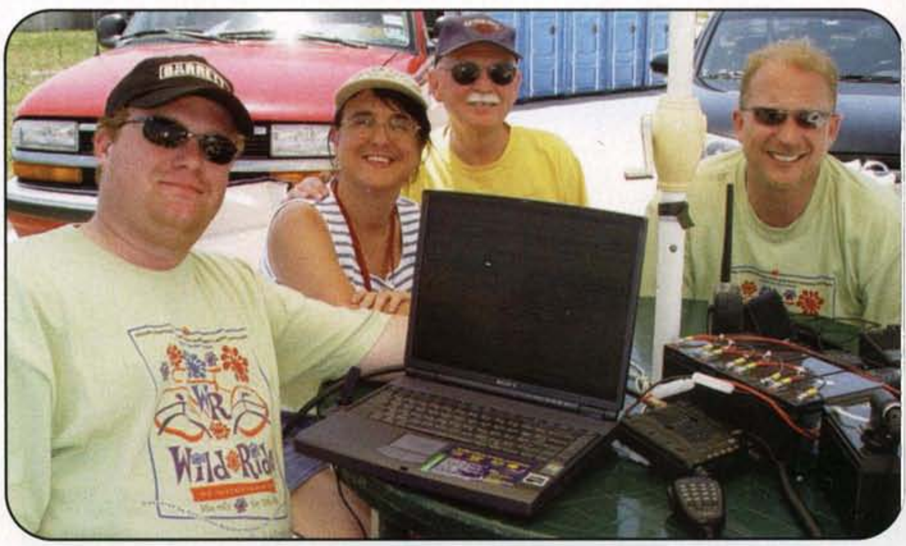
job done. E-mail was sent and received using Winlink2000.

Rest stop number 3 also used a D-STAR ID-1, provided by Deb Varian, KA5HQY, and Fred Varian, WD5ERD, for internet connection. A ridge just 300 feet from the rest stop has a view of downtown Dallas about 30 miles away. A Diamond NR2000NA tri-band mobile antenna was mounted on a pole attached to a fence post. The Ethernet output of the D-STAR again was connected to an 802.11 access point to send the signal 300 feet to the digital operators, Amelia Shultz, KD5TXQ, and Jim Shultz, W5OMG.

Rest stop number 4 was located in northeast Richardson in the parking lot of Miller Elementary School. Internet connection was made through a DSL connection of a homeowner 200 feet across the street and used by Robert Schafer, W5IUA. The 802.11b access point was set up two days before the rally. On Saturday morning all the homeowner had to do was connect the Ethernet cable to the DSL modem and plug in the access-point power transformer. The homeowner was a retired engineer and was so interested in what we were doing that he canceled his morning plans and visited the rest stop.

One medical emergency was handled quickly, with the bike of the hospitalized rider taken back to the Start/Finish area and locked up until rally officials could take care of it. Emphasis was placed on keeping track of the riders who were carried by the SAG vehicles.

The following is a list of all the hams who helped with the 2006 Wild Ride: John Barrett, KE5CRP; Richard Bartlett, KE6LOU; Ray Battalora, K5RFF; John Beadles, N5OOM; Dave Best, KD5RYM; Todd Blackmon, KC5KYP; John Bodie, KE5HSL; Don Bowen, K5LHO; Tony Campbell, W5ADC; John Carlson, K9SQ; Bruce Dingman, N5BYL; Andy Duckworth, K5BAD; Bill Dyer, KE5BTZ; Joshua Elson, KD5ZBD; Harry Fasick, K3EYL; Dan Ferree, N5NOT; Earl Foster, KE5HDN; John Galvin, N5TIM; George Grant, KA5QDI, Em. Mgr; Valli Hoski, N8QVT; Vern Kilburn, KE5HXT; Doug Kilgore, KD5OUG; Stan Liljekvist, K5SRL; Joe Martin, KM5CW; Richard Phillips, KB5YBQ; Jay Pinkerton, KE5FMS; Larry Randall, WA5BEN; Robert Schafer, W5IUA; Clarence Sebesta, K5YO; Amelia Shultz, KD5TXQ; Jim Shultz, W5OMG; Kevin Sims, Jr., KD5PQA; Kevin Sims, Sr., KD5VYL; Jesse Staab, NØISX; Chad Stelzl, KD5UMO; Christina Stelzl, KE5BYS; David Sward, KD5VYH; and Travis Willingham, KD5ZKV. ■



Hams at rest stop 1 of the 2006 Wild Ride. Internet service was provided by commercial EVDO service. From left to right: Kevin Sims, Jr., KD5PQA; Valli Hoske, N8QVT; Harry Fasick, N3EYL; and Jon Bodie, K1HSL. (Photo by KD5OUG)

Inferring 6-meter Propagation Modes from E_s and F_2 Probabilities

Not infrequently, when a long-distance QSO takes place the question is asked, "Is the propagation multi-hop sporadic-*E* or is it F_2?" Here K9LA looks at the evidence for a series of QSOs between J68AS and Europe to determine the answer to this question.

By Carl Luetzelschwab,* K9LA

In the summer of 2005, Scott, N9AG, operated as J68AS from St. Lucia. From June 23 through July 2 he made 382 QSOs with Europe on 6 meters. He said almost everyone believed this to be propagation via three- or four-hop E_s (sporadic-*E*). Let's try to confirm this with our knowledge of the statistical pattern of E_s. If we don't succeed, we'll look at other possibilities.

QSO Data

The most productive day was June 29 with almost 40% of the QSOs made on that date. The second most productive day was July 1 with almost 20% of the QSOs made that day. July 2 took third place with just over 10% of the QSOs made on that day.

Figure 1 is a plot of the 6-meter EU QSOs for all the days when J68AS was active. In essence, figure 1 is a probability distribution, with the highest probability of 6-meter J6-to-EU QSOs centered on 1900 UTC for the late June through early July 2005 time period. (The individual days cited in the previous paragraph follow the same general pattern as figure 1.) The question we'll try to answer is "Does the statistical pattern of E_s between J6 and EU match the statistical pattern of the actual QSOs?"

E_s Methodology

To determine the statistical pattern of E_s propagation between J6 and EU, we'll use the plot of 50-MHz E_s probabilities from the *USAF Handbook of Geophysics*.[1] Figure 2 shows this plot.

*1227 Pion Rd., Fort Wayne, IN 46845
e-mail: <k9la@gte.net>*

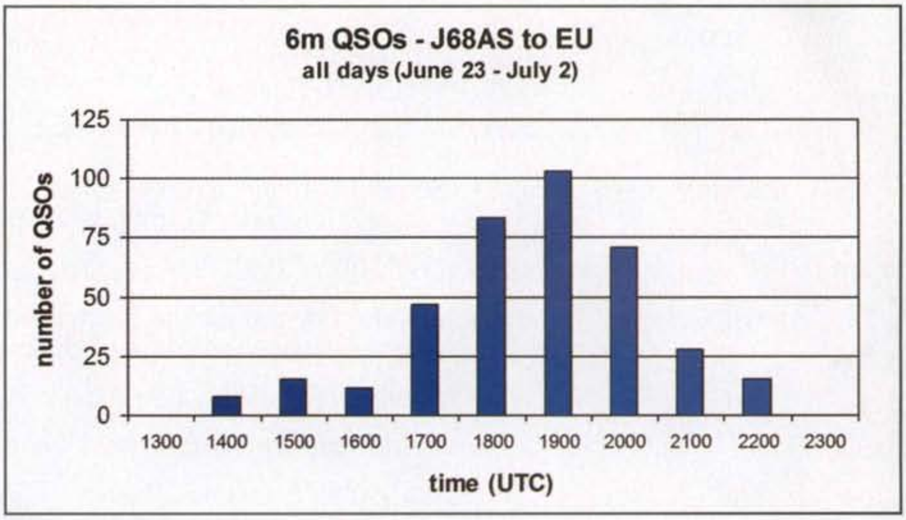


Figure 1. J68AS 6-meter EU QSOs versus time of day.

The plot gives the probability of 50-MHz E_s for all months versus local time over a two-year period and is applicable to mid latitudes (roughly 30 to 60 degrees). The contour lines are percentages. For example, using the left-most data, the probability of 50-MHz E_s at the beginning of June at 1 PM local time is about 45 percent. The term *local time* refers to the midpoint of the path. Thus, we need to know the local time of the mid-point of each hop along the J6-to-EU path.

E_s Analysis

For the analysis, we'll use a path between J6 and HB (7283 km). We'll assume this is a four-hop path (each hop is 1820 km). This defines where the apogees (and mid-points) of the four hops encountered E_s clouds: at 55°W longitude, at 41°W longitude, at 24°W longitude, and at 4°W longitude. Next the local times at these four encounter points were determined, and the left-most data of figure 2 for the 1400 to 2200 UTC period was used for probabilities. The results of this exercise are in Table 1.

Assuming that the probability of each E_s cloud at each encounter is independent (in other words, a huge E_s patch did not occur along the entire path from J6 to EU), the four probabilities were multiplied together to give the overall probability of a four-hop E_s path (the last column in Table 1). This probability is plotted in figure 3,[2] which also includes the actual QSO data from figure 1.

It is quite obvious that the four-hop E_s probability appears to be out of phase with the actual QSO data.[3] This suggests that the J68AS 6-meter QSOs with Europe may have involved more than just E_s modes. The obvious next step is to look at F_2 modes to see if there's a bet-

UTC	55°W local time	55°W prob	41°W local time	41°W prob	24°W local time	24°W prob	4°W local time	4°W prob	overall prob (decimal)
1400Z	10 AM	40%	11 AM	42%	Noon	42%	2 PM	35%	.0247
1500Z	11 AM	42%	Noon	42%	1 PM	42%	3 PM	27%	.0200
1600Z	Noon	42%	1 PM	42%	2 PM	35%	4 PM	21%	.0130
1700Z	1 PM	42%	2 PM	35%	3 PM	27%	5 PM	20%	.0079
1800Z	2 PM	35%	3 PM	27%	4 PM	21%	6 PM	31%	.0062
1900Z	3 PM	27%	4 PM	21%	5 PM	20%	7 PM	42%	.0048
2000Z	4 PM	21%	5 PM	20%	6 PM	31%	8 PM	42%	.0055
2100Z	5 PM	20%	6 PM	31%	7 PM	42%	9 PM	42%	.0109
2200Z	6 PM	31%	7 PM	42%	8 PM	42%	10 PM	40%	.0219

Table 1. Probabilities for four E_s hops.

ter fit between the distribution of actual QSOs and F_2 probabilities.

A Look at F_2

To see if we're on the right track with an F_2 mode, we'll look at the median MUF (maximum usable frequency) for a 3000-km F_2 hop out of J6 towards EU. We'll do this using the worldwide MUF maps that can be generated in Proplab Pro (Solar Terrestrial Dispatch). Figure 4 shows the median MUF data at an effective smoothed sunspot number (SSNe) of 45 (from <www.nwra-az.com/spawx/ssne.html>) centered on June 29—the midpoint of N9AG's DXpedition.

This data is very encouraging. It shows that for a 3000-km path from J6 towards EU the F_2 region maximizes around the time of the QSOs.[4] However, it's obvious that we have a problem—and that is the median MUF is not close enough to 50 MHz to predict any probability of propagation on 6 meters. Does this mean F_2 wasn't possible? Not necessarily. We need to consider three mechanisms that can increase the MUF.

Increasing the F_2 MUF

The first mechanism that may increase the F_2 region MUF is a hop longer than 3000 km. As the hop length increases the MUF increases, because the wave needs to encounter the electron density at more of a grazing angle for a longer hop. A single F_2 region hop on 6 meters longer than 4000 km (the accepted limit for HF propagation) may be possible. In fact, parabolic layer theory predicts this.[5] The caveat is that radiation at an extremely low launch angle is needed, which shouldn't be a problem on 6 meters due to typical antenna heights in terms of an electrical wavelength.

The second mechanism involves help from the underlying E region. The MUF for the F_2 region is a function of the electron density (measured in terms of the critical frequency f_oF_2) and the angle at which the electromagnetic wave encounters the F_2 region (which in turn is dependent on the height of the layer). Due to the spherical Earth-ionosphere geometry, the lowest angle at which a wave launched at a 0-degree elevation angle can normally encounter the F_2 region is around 20 degrees. This limits the MUF to approximately three times the f_oF_2 value (from one over the sine of the angle). To achieve a higher MUF, more of a grazing angle on the F_2 region is needed, which may be possible with some refraction help from the underlying E region.

The third mechanism is over-the-MUF propagation. Often signals are received at frequencies above the standard MUF (even taking into account the upper statistical bound of the median MUF). The F_2 region can be regarded as a number of separate patches of ionization with differing maximum electron densities, so that each patch has its own MUF.[6] An over-the-MUF mode introduces more loss, but 6 meters is more tolerant of loss than the HF bands.

Applying estimates for these mechanisms to the data in figure 4 for 1900 UTC still results in a median MUF too low (just

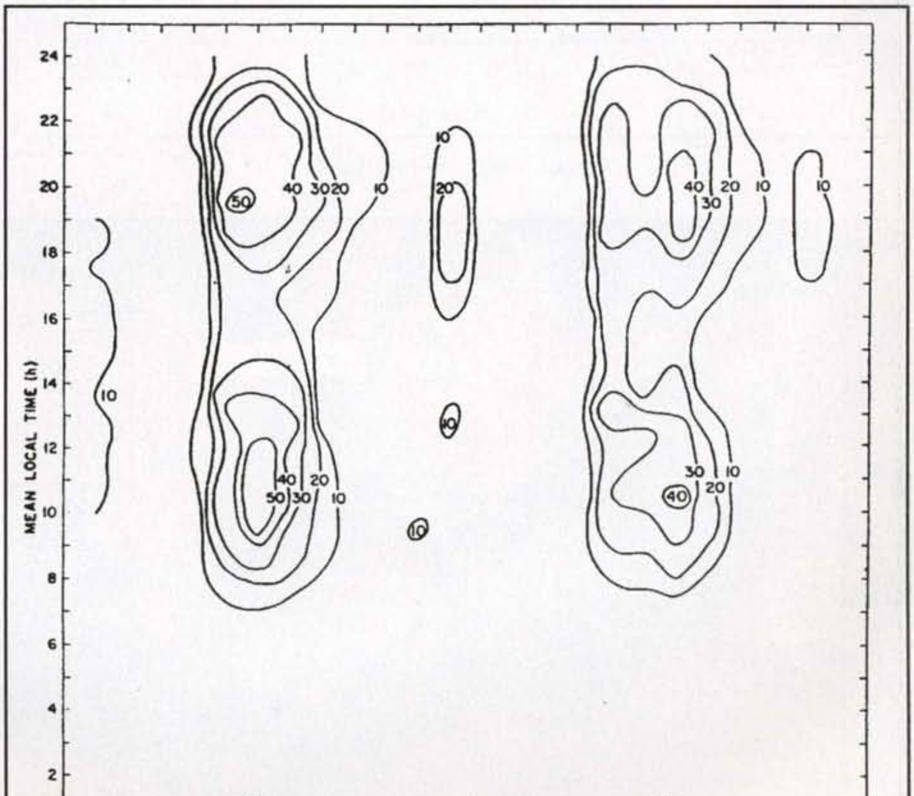


Figure 2. 50-MHz E_s probabilities.

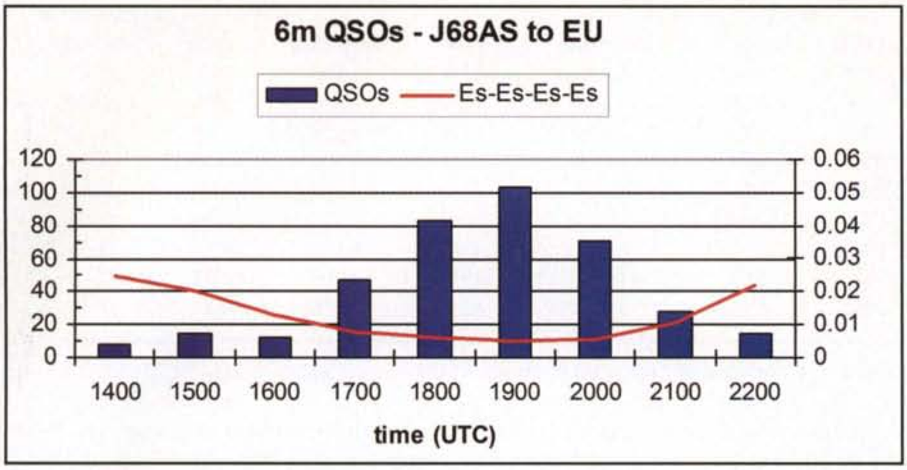


Figure 3. Comparison of E_s-E_s-E_s-E_s probability with QSO data.

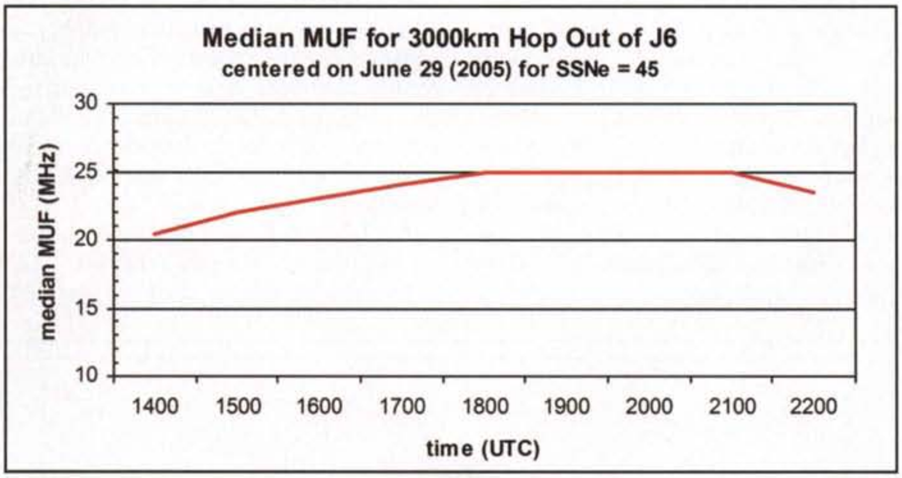


Figure 4. Predicted 3000-km median MUF.

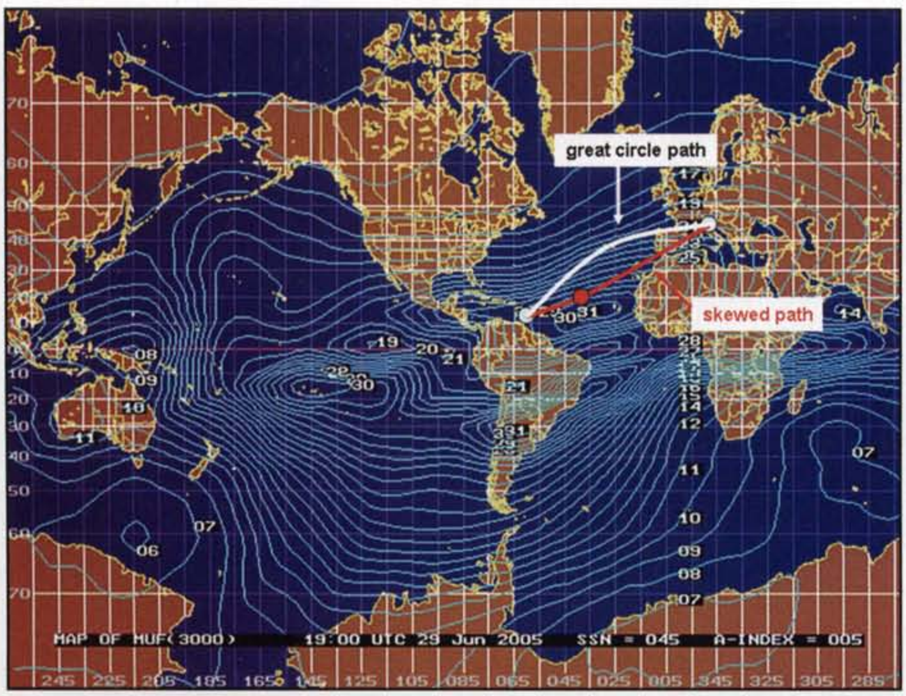


Figure 5. Worldwide map of 3000-km MUF.

under 40 MHz) to predict any probability of propagation on 6 meters. For the detailed analysis of the three mechanisms that can increase the MUF, visit <http://mysite.verizon.net/k9la> and click on the file "Increasing the F_2 MUF." Are we dead in the water? No, not yet. It looks as if we just need some help from the equatorial ionosphere.

A Skewed Path Hypothesis

The equatorial ionosphere is the most robust portion of the ionosphere in the world. Even at solar minimum, the MUFs at the crests of the equatorial ionosphere on either side of the geomagnetic equator can reach 30 MHz at certain times of day during certain months. Figure 5 shows contours of median 3000-km MUFs centered on June 29 (2005) at 1900 UTC at an SSNe of 45.

The thick white line in figure 5 is the true great-circle path from J6 to HB (this is where the data in figure 4 comes from). Also shown is a skewed path from J6 to the high MUFs of the northern extremity of the northern crest of the equatorial ionosphere and then into HB (the thick red line, with the red dot representing the skew point). The azimuth difference between the true great-circle path and the skewed path on the J6 end of the path is 27 degrees, and it is 14 degrees on the HB end. This suggests that a skewed path could occur without the necessity of moving antennas on each end of the path off the true great-circle path. In other words, N9AG and the operators in Europe may not have known a skewed path was occurring.

This skewed path is the hypothesis for how these QSOs occurred—a long F_2 hop on the J6 end with refraction from the high MUFs at the northern crest of the equatorial ionosphere (the red dot), coupled with two E_s hops to get to HB. Note that the ionization gradient of the northern crest in the area is going the right way for this skewed path to happen (an electromagnetic wave refracts away from a higher electron density).

F_2 Analysis

Going through a similar analysis to what was done for the 4-hop E_s mode in Table 1 and using the estimates in the previous "Increasing the MUF" section gives the results in figure 6.

The shape of the F_2-E_s-E_s probabilities agrees much more closely with the actual QSO data than the E_s-E_s-E_s-E_s results. To reiterate, the values of the probabilities are my best-guess estimate.

(I will readily admit that the analysis is crude, but it is the best I can do.) Although the values are estimates, the *shape* of the statistical pattern versus time should be accurate.

Summary

A comparison of estimated E_s and F_2 probabilities to actual QSO data suggests that the F_2 region had more to do with the J6-to-EU QSOs experienced by Scott, N9AG, in late June 2005 than originally thought. I doubt if we'll ever know for sure what really happened, but it is interesting to estimate F_2 and E_s probabilities and compare them to QSO data to try to understand the propagation mode.

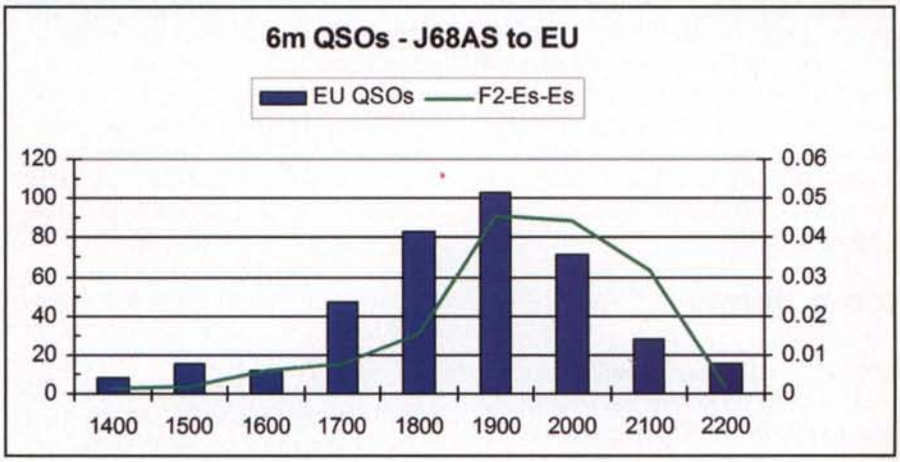


Figure 6. Comparison of F_2-E_s-E_s probability with QSO data.

Notes

1. Although the data is from 1957 and 1958, compares favorably with more recent data such as that presented by Wu, et al, in a paper entitled "Sporadic E morphology from GPS-CHAMP radio occultation" published in the *Journal of Geophysical Research*, January 2005.

2. Since figure 2 is for latitudes between roughly 30 and 60 degrees, the probabilities on the J6 end of the path are a bit optimistic, since the encounter with the E_s patch on the J6 end of the path is around 20 degrees. Correcting the first-hop probability for this issue still results in the E_s probability being out of phase with the QSO data.

3. The exercise in Table 1 was also done for a three-hop E_s mode, with the same results: The three-hop E_s probability appears to be out of phase with the actual QSO data.

4. The normal *E* region, being under direct solar control, maximizes around noon local time. The F_2 region, although relying on solar illumination for ionization, maximizes later in the day due to the influence of additional factors such as slower recombination at the higher F_2 region altitudes and diffusion of plasma due to winds.

5. See figure 6.15 on page 175 in *Ionospheric Radio* (Davies, 1990). It shows one-hop F_2 region propagation out to 6000 km.

6. See section 6.5 starting on page 5 of *Propagation at Frequencies Above the Basic MUF* (Report ITU-R P. 2011-1, International Telecommunications Union, 1997–1999). It discusses over-the-MUF modes. VOACAP uses an over-the-MUF algorithm in its assessment of F_2 region propagation. ■

Building the Eagle Satellite

WB4GCS, the *Eagle* project manager, describes AMSAT's latest project, its innovations, and the efforts to "get it right."

By James A. (Jim) Sanford, PE,* WB4GCS

Welcome to AMSAT *Eagle,* the next major project of the Radio Amateur Satellite Corporation. *Eagle* is one component that will help fulfill the AMSAT strategic vision: "Our Vision is to deploy high earth orbit satellite systems that offer daily coverage by 2009 and continuous coverage by 2012..." We hope that AMSAT-DL's P3E will be the first, *Eagle* the second, and a descendant of *Eagle* the third, ultimately leading to 24/7 DX coverage by satellite.

This is not a technical article. Rather, it is a project management article describing the things we are doing to actually deliver this satellite. In this article, I will describe *Eagle,* how we got where we are today, and what we're doing to build it—and to make *sure* it *works.* I appreciate the enthusiasm of Joe Lynch, N6CL, for what AMSAT is doing with *Eagle* and his support of this article.

Some History

First, some history. At the 2000 AMSAT Symposium in Portland, Maine, Dick Jansson, WD4FAB, proposed a successor to P3D/AO-40 in a paper entitled "So, you want to build a satellite." The features and principles in this paper guided AMSAT for several years. Coincidentally, Matt Ettus, N2MJI, also proposed a digital transponder for the International Space Station (ISS), and more on this later. Alas, not a lot of progress was made for a while, despite a very good design meeting in Denver, Colorado. In July 2004, the AMSAT leadership convened a meeting in Orlando, Florida. This is where *Eagle* functionality was refined, and incidentally, where I joined the *Eagle* team. An AMSAT life member since 1995, I'd been interested in contributing to AMSAT, but it just was not practical. By the 2004 meeting, I had some time and was looking for a way to contribute. When the meeting was over, I was the *Eagle* Project Manager (gulp!). Working closely with brilliant legends whom I have admired for many years is an honor and a privilege.

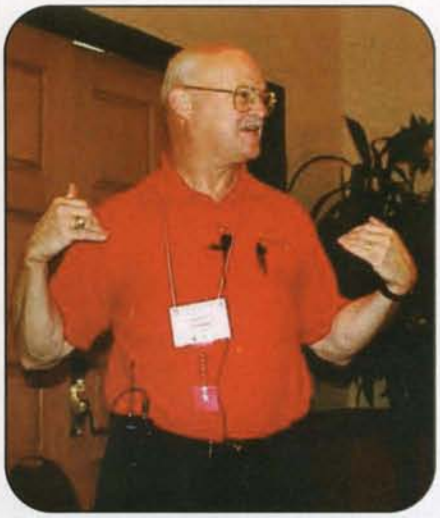
The next year brought some progress with *Eagle,* but we were still more of a meandering mob than a productive team. In the fall of 2005, things started to come together, and we planned an *Eagle* design meeting in Lafayette, Louisiana, in conjunction with the annual symposium. We all know about hurricane Katrina; a less well-known consequence of the storm was the decision by AMSAT leadership, regretfully, to cancel the annual symposium. After a lot of scrambling, the AMSAT Board of Directors meeting and the *Eagle* design meeting were held in Pittsburgh, Pennsylvania. At the *Eagle* meeting, the team started to focus, concrete information exchange began, the requirements defined in Orlando a year prior were refined and task assignments made, leading to some real progress. As we embraced electronic connectivity, our teamwork and productivity soared.

Over the years, Tom Clark, W3IWI (now K3IO), had proposed an in-band C-band (5.8 GHz) analog transponder, which then became a digital transponder. This transponder proposal was known as "CC-rider." The objectives of this package were to do something innovative with digital communications and to put a stake in the ground for one of our microwave bands. Matt's digital transponder proposal re-emerged and complemented Tom's ideas.

Over the next few months, operating procedures were developed and open source fundamentals articulated and implemented. As Bdale Garbee, KBØG, said at the Pittsburgh meeting, "Our legacy may very well be our documentation." The *Eagle* team began periodic electronic communications. The modern internet has given us collaborative abilities AMSAT had never used before. We exchange information daily by e-mail, we use the web to store and collaborate on information, and we meet for monthly tele-conferences on TeamSpeak, an internet conferencing client/server freeware product. These facilities have allowed us to keep things moving in a new, exciting way. We can even have impromptu ad-hoc meetings, enhancing our productivity in huge ways. I am extremely grateful to Eric Ellison, AA4SW, for making the TeamSpeak server available to us. His recent award from AMSAT only scratches the surface in recognizing the significance of how he has helped AMSAT and *Eagle.*

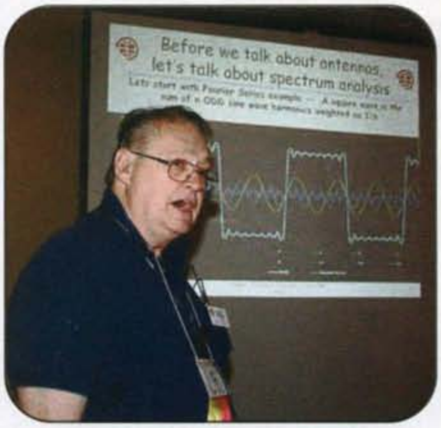
As time went on, it became clear that we needed a focused meeting to refine the

**10 Sugar Run Rd., Eighty Four, PA 15330*
e-mail: <wb4gcs@amsat.org>



AMSAT Project Eagle Manager Jim Sanford, WB4GCS. (Photos by Rick Lindquist, N1RL, and courtesy of the ARRL Letter*)*

AMSAT-NA President Rick Hambly, W2GPS, addresses the 2006 AMSAT Symposium attendees.



Ham radio satellite guru Tom Clark, K3IO.

digital package. This meeting was held in June 2006 at Qualcomm headquarters in San Diego, thanks to Franklin Antonio, N6NKF, and Phil Karn, KA9Q. We refined our thinking in terms of *services* to be provided our users, and we did some hard link analyses. At the end of this meeting, we had quantitative analysis that told us the C-C package is just not possible in a satellite that AMSAT can afford to fly. Given that conclusion, we used the link budget calculations to determine the bands to be used for the various services. We also calculated a preliminary power budget. This helped us come to grips with the fact that the spacecraft structure we'd been dealing with for over a year didn't allow enough area for adequate power generation or antennas.

The Work Continues

This conclusion initiated a rethinking of the spacecraft structure, which is ongoing. We now have a preliminary redesign, but more work is needed and is continuing.

In October 2006, AMSAT met in San Francisco for the annual Board of Directors meeting, the AMSAT General Meeting, and the Space Symposium. At this meeting the AMSAT Board approved:

An SSB/CW (etc.) transponder with uplink on U-band and downlink on V-band. System design has a goal that it be usable over 75% of the orbit by an AO-13 or AO-40 capable ground station.

• An SSB/CW (etc.) transponder with uplink on L-band and downlink on S1-band (2.4 GHz). An AO-13 or AO-40 capable ground station will be able to use this payload.

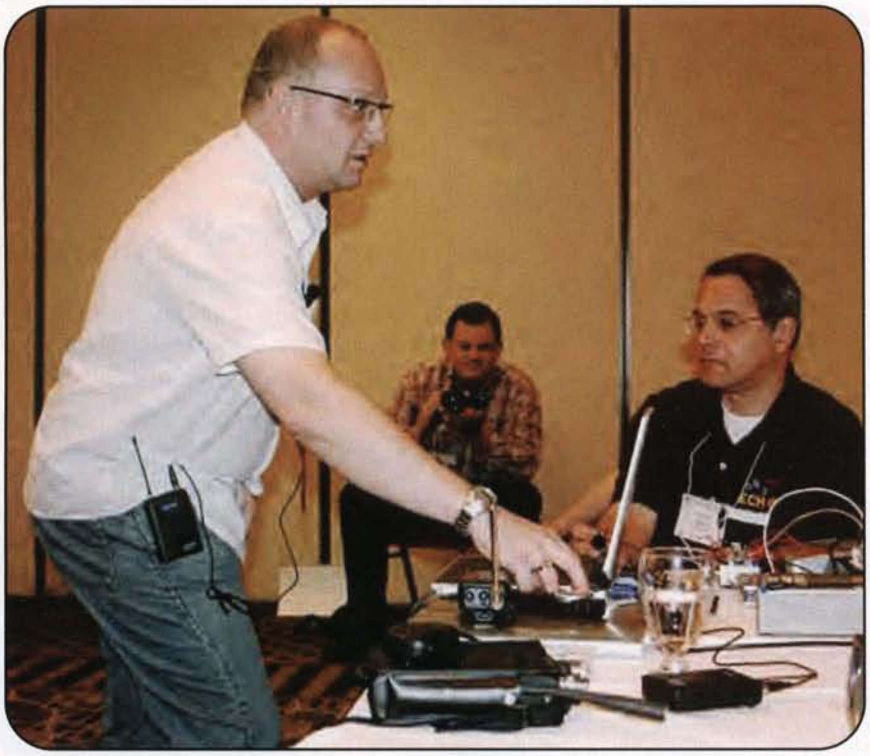
• A low-rate text-message system, such as SMS. It will operate on U/V-bands and be usable over 75% of the orbit by a small terminal on the ground.

• These transponders will be implemented using Software Defined Transponders (SDX).

Eagle will also carry an advanced communications payload (ACP). Using advanced signal processing and RF techniques, the ACP will allow:

• Voice communications on S2-band (3.4 GHz) uplink and C-band (5.8 GHz) downlink using a single 60-cm dish. The satellite antennas will be electrically steered to reduce spin modulation and allow use over 75% of the orbit.

• An additional fix-pointed uplink will be available at L-band. This L-band uplink will require a separate uplink antenna at the ground station. The L-band uplink is intended to allow users in Region 1, where 3.4 GHz is not current-



Howard Long, G6LVB, demonstrates a prototype SDX.

ly allocated to the Amateur Satellite Service, to use the ACP legally, by transmitting on L-band.

• High-rate data communications, such as streaming video, using a 2-meter dish on S2/C bands.

• AMSAT will develop and make available an affordable ground segment for the ACP system.

Although to the user the traditional transponders will look very much like those in earlier satellites, their implementation using Software Defined Transponders will yield significantly improved performance. An SDX was demonstrated in 2006 at the Dayton Hamvention®, and many users commented on how "clean" it sounded compared to previous transponders. SDX will also allow much more efficient transmitters than we've ever seen before, which means a louder signal on the downlink for the same battery and solar-array power. Even better, SDX allows a very effective "alligator killer." Nicknamed "Stella" in one implementation, it is a per-signal automatic gain control (AGC); no single uplink signal can capture the satellite AGC to the detriment of all other users. This feature was also demonstrated at Dayton and is documented on the AMSAT website.

The symposium had several *Eagle*-related presentations. The *Proceedings* are well worth purchasing and reading.

At the AMSAT General Meeting, the question was asked, "It's nice that you guys are designing this satellite with all these neat, new features, but what are you doing to make sure the thing *just works*?"

This question goes to the heart of how we're managing this project. First, let me point out that project managers talk about the "triple constraint"—cost, schedule, quality. Usually you can pick any two, unless you have infinite resources. For now, the *Eagle* project is focusing on quality and cost, in that order. By all accounts that I've heard, AMSAT historically has done whatever it takes to meet a launch date. *Eagle* is different, as we don't yet have a launch date. Therefore, we are working on getting it right and keeping it affordable. When we have a launch, we'll adjust, but quality will remain a priority.

Getting It Right

What are we doing to "get it right"? Many things, and these are worth sharing here. First, we're recruiting new members. The *Eagle* team has many AMSAT stalwarts, but we have actively recruited new members with significant microwave RF or space experience in industry, some embedded system designers, and most important, some *young* people. We have developed some formal processes and exploited easy communications. We make the design open, and use a *wiki* to share information and allow comment. (Go to the AMSAT website and the *Eagle* pages to get connected to *EaglePedia*, which is our public *wiki*.)

Just adding duplication and redundancy is not a solution, as this actually introduces additional complexity and its own set of vulnerabilities. See Tom Clark's paper on complexity versus numbers at <http://mysite.verizon.net/w3iwi/curmudgeon.ppt>.

We review and incorporate lessons learned from earlier AMSAT projects and other aerospace-related events. (For example, I have studied both the *Challenger* and *Columbia* reports in detail, and we have reports of other amateur satellite or NASA failures and problems on the website as well.)

We have introduced a formal peer review process. We are making refinements to our processes as we go along, which will only improve them and, ultimately, the eventual product.

We commit to full testing and characterization of all components. We commit to test possible, but unintended, operational modes—no surprises on-orbit.

Where possible, we will design out any single-point failures. Sometimes this is not possible (such as explosion or splash of the launch vehicle); we will know what those situations are, what the risks are, and how we can mitigate or at least deal with them. To that end, we will test everything, and publish the results. You will be able to ask, "What is the noise figure of the *whatever*-band receiver; how much uplink ERP do I need?" and get an answer. We will fully, and publicly, characterize *Eagle*.

The object of all this up-front effort is that, as much as humanly possible, there will be no single failures that compromise the entire mission. We will understand, either through analysis or testing, the consequences of any single failure that we can anticipate. Where possible, we will apply mitigations to minimize the consequences of any single failure.

Where *Eagle* Stands Now

Where does *Eagle* stand now? We have scrapped a structure that we worked with for several years in favor of a larger, more capable one. This decision was made based on hard analysis: links, power budgets, and a realistic estimate of antenna space needed. We have made final decisions, ratified by AMSAT leadership, on transponder payloads, including operating modes and uplink/downlink frequencies.

We have a prototype Internal Housekeeping Unit (IHU, the "brain" of the satellite) design. The IHU has been tested and it works. We will initiate a peer review on the hardware and software in the next few months. We have refined the spacecraft CAN bus, which will communicate between the IHU and payload modules. We are evaluating a fault-resistant implementation of the CAN bus.

We have a near-final, peer-reviewed design for the U-band receiver and expect to be testing a prototype soon. The formal acceptance test plan will be peer reviewed and published, as will the test results. This receiver will be more robust than any we have ever flown. In particular, it is designed to perform under predictable conditions of very strong in-band interference. We have a similar L-band receiver design in progress. We have been given access to a state-of-the-art antenna test facility for our microwave phased-array antennas. These results will also be published.

We are exploring an energy storage topology which will break the historical paradigm of a single failed cell in the battery compromising the entire battery. Look for more information on this as design and prototype testing progress.

Some very exciting news about the *Eagle* project recently was reported in the *AMSAT Journal.* AMSAT has entered into agreements with the University of Maryland Eastern Shore and the Hawk Institute for Space Sciences, which bodes well for *Eagle*. These agreements provide us with a first-class laboratory and integration facility, access to modern communications facilities, and access to motivated and technically qualified volunteers. We have an excellent place to build *Eagle,* a great team to design it, and the potential to assemble an excellent team to build and test it. In addition, we have a relationship with the Embry-Riddle Aeronautic University in Daytona Beach, Florida. They recently fabricated for evaluation some heatsinks in an aluminum alloy that has a high thermal conductivity—and is very difficult to work with.

More About *Eagle*

To learn more about *Eagle,* check out the AMSAT website and *EaglePedia.* Join AMSAT and receive the weekly news bulletins and the bi-monthly *AMSAT Journal,* where I update *Eagle* status. You'll find that many members of the *Eagle* team publish details of their work in the *Journal.*

The 2007 AMSAT Symposium will be in Pittsburgh. The *Eagle* team will have much to say and demonstrate. Come to Pittsburgh and see what we're up to. Observe our hardware demonstrations. Ask us questions—*difficult* questions.

The *Eagle* team is working hard to deliver a capable, reliable satellite, and we're eager to tell you about it.

Acknowledgements

Finally, some acknowledgments. First, I thank the *Eagle* team for accommodating this newcomer. They truly are the most brilliant, dedicated group of intellects I have ever encountered in my life. Thanks also to Joe Lynch for his support of AMSAT and for allowing me to expound in these pages. ■

About Jim, WN4GCS

Jim was first licensed as WN4GCS in 1967. Even before becoming a ham, he was fascinated with VHF and microwaves, largely from reading about the first 1296 EME QSOs in old *QST*s that someone gave him. Jim grew up in Florida with *Mercury, Gemini,* and *Apollo* and has been a member of AMSAT since the early 1990s. A 1976 Electrical Engineering graduate of the United States Naval Academy, Jim's professional career was with the U. S. Navy until 2003. He now works in industry. He is a Professional Engineer and Senior Member of the IEEE, and can be reached at: <wb4gcs @amsat.org>.

CQ VHF Visits:

West Mountain Radio

The second in a series of factory tours, this time WB6NOA takes us to West Mountain Radio, which offers weak-signal operators accessories for VHF and UHF.

By Gordon West,* WB6NOA

West Mountain Radio, in Norwalk, Connecticut, offers weak-signal operators compact accessories for VHF and UHF operating stations. Field Day is just a few months away, so it's time to be thinking about Anderson PowerPole connections, where everyone is assured of the same type and polarity, DC power input, and output plug.

Dan Gravereaux, N1ZZ, and Del Schier, K1UHF, joined forces to form West Mountain Radio, combining their own engineering companies. Dan was an engineering director of CBS Laboratories and then struck out on his own, making audio amplifiers for the New York Transit Authority subway cars. Del owned and ran an exclusive, high-end home-entertainment specialty store in Greenwich, Connecticut. The combination of Dan's and Del's experience gave them plenty of engineering background to make West Mountain Radio an instant success.

On our factory tour, we saw the first product that emerged from their technical backgrounds—RIGblaster. Del, an accomplished VHF/UHF weak-signal operator and contester, now had an interface to use contesting software with a voice keyer function, ideal for EME (Earth-Moon-Earth) and meteor-scatter operating.

"Our design goals for the RIGblaster were to make it universally compatible with most weak-signal radios, including high-frequency radios, and compatible with all ham software and almost any computer," commented Dan, N1ZZ.

"We called our first RIGblaster the M8, for the 8-pin round mic connector," said Del, K1UHF. "Now we have four different models of RIGblaster, from the most basic "nomic" model (no microphone) to the RIGblaster PRO, which will do anything you can do with a computer and a radio," added Del.

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

The West Mountain Radio staff (left to right): David, KB1LTW; Elena; John, N1OLO; Kathy; Dan, N1ZZ; Ned, KA1CVV; Del, K1UHF; and Ed, K3EIN.

The Rigblaster "nomic" and the PRO are microphone-jack interfaces, which make them universally compatible with any VHF/UHF radio and all HF radios. Interfacing the audio and PTT (push to talk) always works correctly with any radio, provided the mic connector is either RJ 45 or 8-pin round.

For 4-pin round-connector radios, such as the old Kenwood rigs, and 6-wire RJ 22, we also offer adapter kits "covering over 2000 different radios as supplied," said Del, smiling. Dan and Del were quick to realize that hams like getting everything in the box, making it simple to get on the air. They say that all RIGblasters now come with everything included in the box to get on the air with sound-card software.

They recently introduced the RIGblaster data-jack plug-and-play model with a built-in USB interface. Unlike the

John, N1OLO, hamfest and public-relations director for West Mountain Radio.

other RIGblasters, a data-jack interface is not universally compatible and cannot provide automatic switching between a microphone and a computer. This new USB model is easy to set up, provided the radio has a properly designed data or auxiliary jack, and the radio operator doesn't mind manually switching between his mic and the computer. Even though each and every one of the over 100 sound programs require a serial port for PTT, FSK, or CW, many new computers do not have an RS-232 serial port. Today, all RIGblasters come with a USB interface cable that properly converts this USB connector to function as a virtual serial port.

There are over 100 ham radio soundcard programs that support operating on over 25 distinctively different modes, and switching between these modes is as simple as clicking your mouse and setting your radio to an appropriate frequency," commented West Mountain Radio. Del, K1UHF, has a favorite use for his RIGblaster—to operate with K1JT's WSJT weak-signal program. WSJT is a free program, written by Joe Taylor, K1JT, holder of a Nobel Prize for his work in radio astronomy.

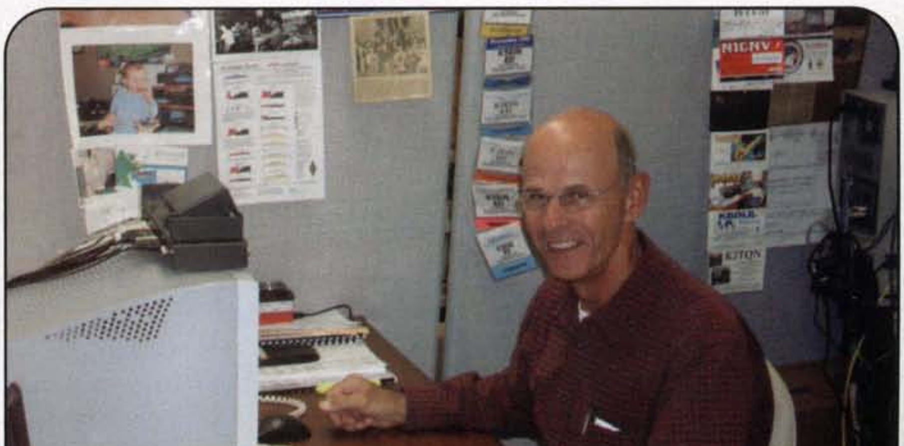
WSJT allows two hams with only a *single* long Yagi and 100 watts on 2 meters to work the ultimate DX—"over 500,000 miles to the moon and back!" said Del. WSJT also supports nearly 24 /7 meteor scatter, and it is far and away one of the most sophisticated programs available for ham radio communications.

Another use of the RIGblaster is for Echolink. Del calls Echolink "a very long mic cord" connected to the radio by passing audio back and forth over the internet with VoIP (Voice over Internet Protocol). Rigblasters are great for PSK-31, slow-scan television, RTTY, and many other keyboard-to-keyboard chat modes. CW can also be received and transmitted with a computer connected to a radio with a RIGblaster. I also discovered that West Mountain Radio offers CAT and CI-V rig controls, plus RIGtalk, with a stand-alone USB version, for the ICOM CT-17 or Yaesu FIF-232C. This is a tiny USB dongle device that allows logging software to exchange frequency and band information with a radio, with many control options.

Many hams know about the popular West Mountain Radio 80-amp (40 each side) distribution strip, with 12 outputs, each one individually fused. Unlike other "look alike" Anderson Powerpole distribution strips, the RIGrunner 8012 also includes a blown-fuse indicator plus audible and visual alarms for over- and under-voltage conditions. I suggested to Dan and Del to lower the pitch of the audible alarm for us older hams, and I very much like what MFJ has included with its look-alike panel, and that is a simple needle expanded volt meter—expanded meaning 9 volts to 15 volts DC.

There are five different models of the popular RIGrunner, plus two PWR gate back power systems designed specifically to allow a ham station to operate on batteries, such as during an emergency. This would be ideal for mountaintop repeater applications as well.

By the way, how is your repeater mountaintop battery doing? West Mountain offers a computerized battery analyzer, the CBA, which does a constant



Ed, K3EIN, technical support, at the service desk.

current discharge and then measures and graphically charts the voltage, to be saved at the end of a capacity test. This testing provides accurate and easily interpreted data, showing the "character" of the battery. "Any ham who provides emergency communications with a battery needs this product," commented Dan.

"The CBA was designed primarily for the RC [radio control] model market, as modern RC models are critically powered with a specific battery voltage," said Del, indicating the thousands of hours of laboratory analysis of hardware, firmware, and software that went into this product.

Finally, PWRbrite is a white LED tube light, ideal for Field Day, drawing minimal current for exceptional brightness from 11 volts to 24 volts. I used PWRbrite on my recent trip to Christmas Island, where there were several medical clinics that had no lights at all. The PWRbrite light was put to good use several times during critical medical situations. One Christmas Island doctor claimed the light was just like sunlight in intensity, and I left the lights behind when I left the island because they couldn't go back to regular flashlight power after using these!

West Mountain Radio gets its name from Del's superb VHF QTH on the top of—you guessed it—West Mountain, 1000 feet above sea level, 100 miles in from the shore of the Atlantic Ocean, with VHF/UHF DX directions from Florida to Maine!

Everything is put together at the Norwalk, Connecticut facility. The hams I met who work at West Mountain Radio are Ed, K3EIN, Technical Support; Ned, KA1CVV, Production Manager; John, N1OLO, Hamfest and PR Director; and David, KV1TW, Circuit Board Assembly. There are other non-ham employees, and most of them plan to get a ham license very soon.

West Mountain Radio has a contest club, callsign K1WMR, and it was a sponsor of the ARRL RTTY Roundup this year and will be next year. Everything Dan and Del do within the company is inspired by their regular on-the-air operating. It was a pleasure to be with this group and catch the enthusiasm for West Mountain Radio products.

West Mountain Radio is located at 12 Sheehan Ave., Norwalk, CT 06854; web: <http://www.westmountainradio.com>; phone (888) 937-8686. ■

QUARTERLY CALENDAR OF EVENTS

Current Contests

European Worldwide EME Contest 2007: Sponsored by DUBUS and REF. The EU WW EME contest is intended to encourage worldwide activity on moonbounce. Multipliers are DXCC countries plus all W/VK/VE states. The contest dates and bands are as follows: First weekend: 50, 144, 432, and 1296 MHz, 24–25 February, 0000 to 2400 UTC, digital only. Second weekend: 432 MHz and 5.7 GHz and up, CW/SSB, 24–25 March, 0000 to 2400 UTC. Third weekend: 144 MHz and 2.3 and 3.4 GHz, CW/SSB, 21–22 April, 0000 to 2400 UTC. Fourth weekend: 1296 MHz CW/SSB, 19–20 May, 0000 to 2400 UTC. Sections and Awards include the following: QRP 144 MHz <100 KW EIRP, 432 MHz <400 KW EIRP, 1296 MHz <600 KW EIRP, but no separate QRP/QRO categories.

Complete rules can be found at: <http://www.marsport.demon.co.uk/EMEcont2007.pdf.> Questions: <info@dubus.de>.

Spring Sprints: These short-duration (usually four hours) VHF+ contests are held on various dates (for each band) during the months of April and May. This year's dates and times were not available at press time. It is assumed based on last year's dates that they will be as follows: 144 MHz, April 2, 7–11 PM local time; 222 MHz, April 10, 7–11PM local time; 432 MHz, April 18, 7–11 PM local time; Microwave, May 5, 6 AM to 1 PM local time; and 50 MHz, May 12–13, 2300 UTC Saturday until 0300 UTC Sunday. Contact information: Jeff Baker, WU4O, 2012 Hinds Creek Road, Heiskell, Tennessee 37754; e-mail: <springsprints@etdxa.org>. Sponsored by the East Tennessee Valley DX Association. The up-to-date information on these contests can be found at <http://www.etdxa.org>. At this URL, click on the VHF/UHF link to get to the contest information.

2 GHz and Up World Wide Club Contest: The following is unofficial and is developed from assumptions based on last year's contest. Sponsored by the San Bernardino Microwave Society, this contest should run from 6AM on May 5 to 11 midnight on May 6 (36 hours). The object is for worldwide club groups of amateurs work as many amateur stations in as many different locations as possible in the world on bands from 2 GHz through Light. Rules are available at the following URL: <http://www.ham-radio.com/sbms>.

Conference and Convention

Southeast VHF Society: The 11th annual conference will be hosted in Atlanta, Georgia, April 27 and 28, 2007. Hotel registration information was not available at press time. Please check the website <http://www.svhfs.org/> for the registration forms.

Dayton Hamvention®: The Dayton Hamvention® will be held as usual at the Hara Arena in Dayton, Ohio, May 18–20. For more info, go to: <http://www.hamvention.org>.

Quarterly Calendar

Feb. 2	Full Moon
Feb. 4	Moderate EME conditions
Feb. 7	Moon Apogee
Feb. 10	Last Quarter Moon
Feb. 11	Very poor EME conditions
Feb. 17	New Moon
Feb. 18	Good EME conditions
Feb. 19	Moon Perigee
Feb. 24	First Quarter Moon
Feb. 25	Poor EME conditions
Mar. 3	Full Moon & Total Lunar Eclipse, Americas, Europe, Africa, and Asia
Mar. 4	Moderate EME conditions
Mar. 7	Moon Apogee
Mar. 11	Very poor EME conditions
Mar. 12	Last Quarter Moon
Mar. 18	Good EME conditions
Mar. 19	New Moon & Moon Perigee & Partial Solar Eclipse, most of Asia and Alaska
Mar. 21	Vernal Equinox
Mar. 25	First Quarter Moon. Poor EME conditions
Apr. 1	Moderate EME conditions
Apr. 2	Full Moon
Apr. 3	Moon Apogee
Apr. 8	Very poor EME conditions
Apr. 10	Last Quarter Moon
Apr. 15	Very good EME conditions
Apr. 17	New Moon and Moon Perigee
Apr. 22	*Lyrids* Meteor Shower Peak; poor EME conditions
Apr. 24	First Quarter Moon
Apr. 29	Moderate EME conditions
Apr. 30	Moon Apogee
May 2	Full Moon
May 5	*Eta Aquarids* Meteor Shower Peak
May 6	Very poor EME conditions
May 10	Last Quarter Moon
May 13	Good EME conditions
May 15	Moon Perigee
May 16	New Moon
May 20	Moderate EME conditions
May 23	First Quarter Moon
May 27	Moon Apogee; poor EME conditions
June 1	Full Moon
June 3	Very poor EME conditions
June 8	Last Quarter Moon
June 10	Good EME conditions
June 12	Moon Perigee
June 15	New Moon
June 17	Moderate EME conditions
June 21	Summer Solstice
June 22	First Quarter Moon
June 24	Moon Apogee; poor EME conditions
June 30	Full Moon

—EME conditions courtesy W5LUU.

Calls for Papers

Calls for papers are issued in advance of forthcoming conferences either for presenters to be speakers, or for papers to be published in the conferences' *Proceedings*, or both. For more information, questions about format, media, hardcopy, e-mail, etc., please contact the person listed with the announcement. The following organization or conference organizer has announced a call for papers for its forthcoming conference:

Southeast VHF Society (see conference dates announcement above): The deadline for the submission of papers and presentations is March 2, 2007. All submissions should be in Microsoft Word (.doc) or alternatively Adobe Acrobat (.pdf) files. Pages are 8 and 1/2 by 11 inches with a 1 inch margin on the bottom and 3/4 inch margin on the other three sides. All text, drawings, photos, etc,. must be black and white only. Please indicate when you submit your paper or presentation if you plan to attend the conference and present there or if you are submitting just for publication. Papers and presentations will be published in bound proceedings by the ARRL. Send all questions, comments, and submissions to the technical program chair, Jim Worsham, W4KXY at <w4kxy@bellsouth.net>. For further conference information: <http:// www.svhfs.org>.

Central States VHF Society Conference: The Central States VHF Society is soliciting papers, presentations, and poster/table-top displays for the 40th Annual CSVHFS Conference to be held in San Antonio, Texas on July 26–28. Papers, presentations, and posters on all aspects of weak-signal VHF and above amateur radio are requested. Deadline for submissions: For the *Proceedings*, May 7, 2007; for presentations at the conference and for notifying the group you will have a poster to be displayed at the conference, July 2. Further information is available at the CSVHFS website: <http://www.csvhfs.org/conference/callforpapers.html>. Contacts: Lloyd Crawford, N5GDB, e-mail: <N5GDB @austin.rr.net>. Alternate: Thomas Visel, NX1N, e-mail: <Thomas@neuric.com>. Snail mail: RMG, P.O. Box 91058, Austin, TX 78709-1058.

Meteor Showers

The *a-Centaurids* meteor shower is expected to peak on February 8 at 1100 UTC. The γ-*Normids* shower is expected to peak on March 14 and again on March 17. Other February and March minor showers include the following and their possible radio peaks: *Capricornids/Sagittarids,* February 1 at 2000 UTC; andthe χ-*Capricornids,* February 13 at 2200 UTC.

The *Lyrids* meteor shower will be active during April 16–25. It is predicted to peak around 2230 UTC on April 22. This is a north-south shower, producing at its peak around 10–15 meteors per hour, with the possibility of upwards of 90 per hour.

A minor shower and its predicted peak is *pi-Puppids* (peak on April 23). Other April and May minor showers include the following and their possible radio peaks: April *Piscids,* April 20, at 2100 UTC; δ-*Piscids,* April 24 at 2100 UTC; η-*Aquarids,* May 9 at 2000 UTC; ε-*Arietids,* May 9 at 2000 UTC; May *Arietids,* May 16 at 2100 UTC; and *o-Cetids,* May 20 at 2000 UTC. June *Arietids,* June 7 at 2300 UTC; *zeta-Perseids,* June 9 at 2200 UTC; and β-*Taurids,* June 28 at 2100 UTC. For more information, see NW7US's Propagation column on page 77. Also visit the IMO's website: <http://www.imo.net>.

Microwave ATV – A New Approach!

This article was originally presented as a paper at the 2006 Microwave Update in Dayton, Ohio and published in the *Proceedings*. In it W3HMS challenges the reader to consider other frequencies, such as 3480 MHz and 10 GHz, as possible alternatives for ATV use.

By John Jaminet,* W3HMS

Amateur Television (ATV) has, since its inception in the 1950s, used the 420–450 MHz band for both simplex and in- band AM repeaters. This was necessary in the early days as little equipment operated well above 2 meters and reception was often accomplished using converted UHF TV tuners with poor sensitivity. The pictures were often marginal, with rolling, without color, and without sub-carrier sound. Those close to repeaters will argue differently, but in the fringe area where I found myself, the best pictures were rather pathetic by the commercial color and sound standards of the day. Sound was often transmitted on 2 meters, which did offer two-way discussion of the picture on the screen. Sub-carrier sound as the broadcasters did it was the exception rather than the rule, and sound-on-carrier required an additional receiver. The transmitters classically used crystal signals doubled and tripled to the output frequency, often 439.25 MHz, using cathode AM modulation.

ATV picture at the author's QTH.

A Visit to Switzerland

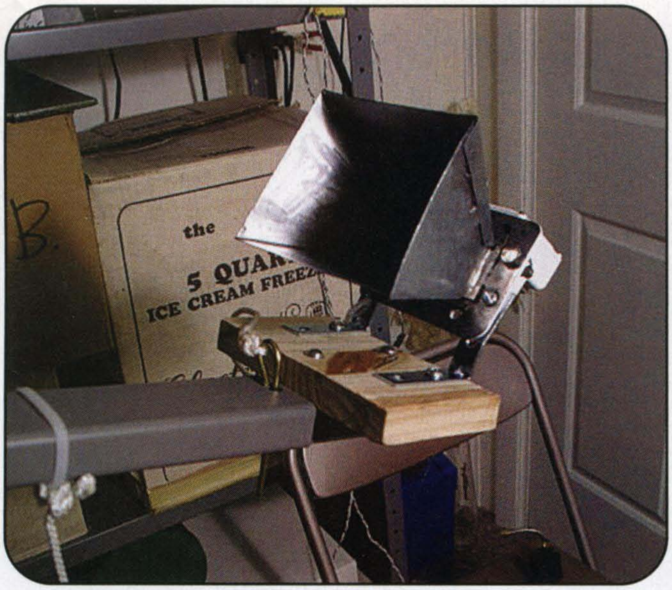
In the fall of 1997 I found myself at the QTH of Michel, HB9AFO, near Lausanne. During one evening in his shack I had the pleasure of seeing a rock-solid 1255-MHz FM ATV picture at 18 miles between Switzerland and France. It was great—like a painting on the wall—except for the plume of smoke from his pipe coming across Lake Geneva in France! This was the day that I knew there must be a better way . . . and there is! It is FM and the microwave bands.

Another reason why I visited HB9AFO was to see his world-class 10-GHz ATV equipment. He and his partner then held the

**912 Robert St., Mechanicsburg, PA 17055*
e-mail: <W3HMS@aol.com>

The author in front of his ATV ham station.

The KU-band LNB (low noise block) for 10 GHz ready to be resealed.

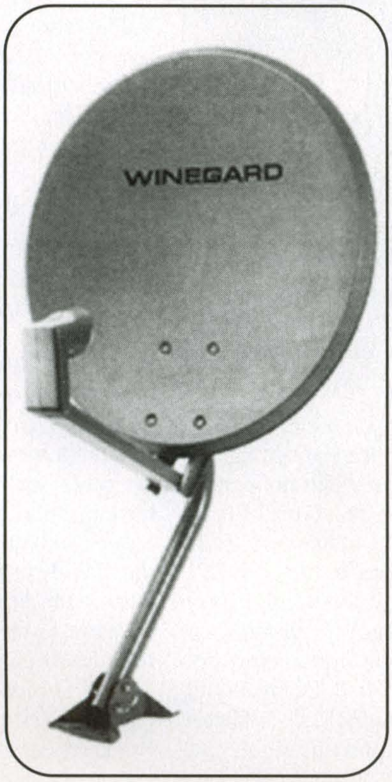


A 3.4-GHz offset dish feed.

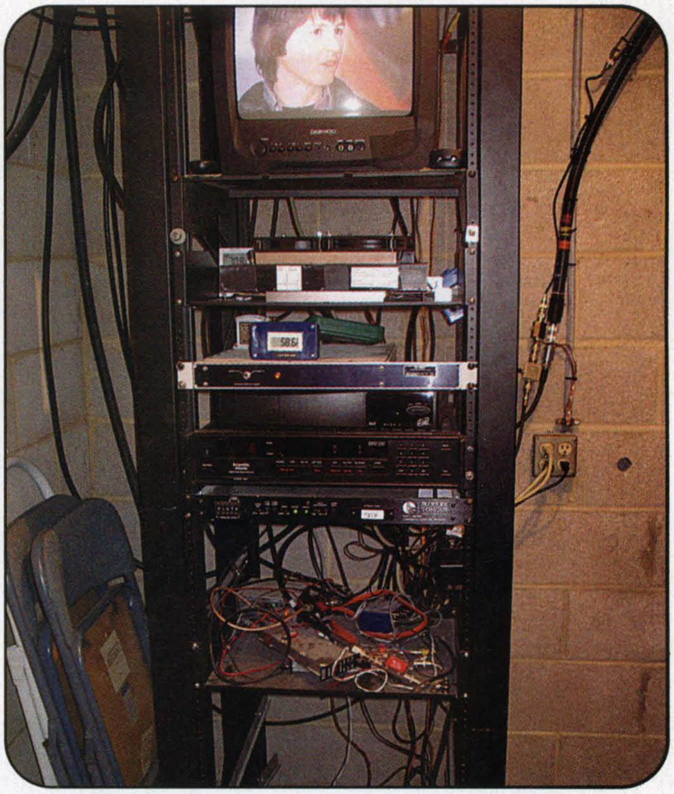
world DX record at about 410 miles. I was impressed by the use he and colleagues made of Ku-band satellite components such as LNBs and antennas. Indeed, F6IWF had developed a modification for a popular LNB that brought all the power of engineering and production for a mass-produced item and gave hams a super-performing LNB for relatively low cost. The same was true for 60 cm and larger offset dishes.

My 10-GHz Work

I had always wanted to work 10 GHz with a Gunnplexor in sound and in video. Therefore, I obtained an LNA from F6IWF and two LNAs with 9-GHz oscillators from the U.K. These were put into service with hamfest-grade U.S.-style satellite receivers which tune 950–1450 MHz and 18-inch offset dishes using feeds designed from the W1GHZ HDL.ant PC program. For video transmitted on 10,300 MHz, the IF is 1300 MHz. I ran periodic tests with Joe, WA3PTV, and we gradually extended our personal DX records in ATV to 51.6 miles using only 10 milliwatts on one leg of the QSO. The other leg used just 250 mw and a 24-inch dish. In both cases we had



A 24-inch offset dish. →



The White Rock ATV repeater as of January 31, 2006.

P5—that is, broadcast-level pictures—in full color. Our 10-GHz efforts then turned to CW/SSB and contesting.

FM vs. AM Video Modulation

With respect to modulation, FM offers considerable advantages over AM with respect to picture quality, just as it does for audio quality when compared to AM, particularly in a fine music environment. To me this is clearly evident in the snow-free pictures received with a signal level of AM P3, which appears as P5+ in FM.

Microwave ATV

For an ATV repeater, the 9-cm band at 3300–3500 MHz offers the possibility of using modern, high-quality components designed for the mass market without modification for transmitting commercial-grade pictures in FM. Additionally, to the best of our knowledge this band has no competition from data communication or other unlicensed devices. With an input on another band, the user can see his own pictures at the same quality level as other viewers see it. In addition, the use of 2200-MHz separation permits the LNB and the transmitting antenna to be close on the same station tower without QRM, and it eliminates filters at the repeater and at QTH stations. Hams have found that filters are always costly, bulky, and difficult to tune and, it seems, become untuned from time to time. Thus the absence of filters is a real plus.

SMRA Microwave ATV Repeater

In the Carlisle/Harrisburg, Pennsylvania area the South Mountain Repeater Association is now operating a dual-band repeater using 1280-MHz FM input and 3480-MHz FM out-

The White Rock 3480-MHz repeater site view at 100 feet.

Gary Blacksmith, WA3CPO, holding the 23-cm omni antenna. It is designed to be well protected from intruding insects.

put. We are currently repeating NASA shuttle audio and video when no signals are in the 1280-MHz receiver. Local reception provides an outstanding, full-color, snow-free picture. In fact, our DX record is 63 miles with this kind of picture. It is perfectly legal to rebroadcast NASA video, which most viewers receive with a 24-inch dish, Dishnet type LNB, and a Free to Air MPEG-2 Traxis DBS-2800 receiver purchased on the internet. The beacon/repeater is on full time—that is, 24 hours per day 7 days per week—for months at a time between shutdowns!

The project leader for this most ambitious project is Gary Blacksmith, MD, WA3CPO, who has obtained an excellent site with a 100-foot tower and 7/8-inch hardline cable from the transmitter to the antenna. Our transmitting antenna is a vertically polarized omni on 3480 MHz with a gain of 11 dBd made by Stella-Dorus in Ireland.

We are using a commercial-grade exciter with 1 milliwatt output to the Toshiba 40-watt amplifier. This exciter is very small, about the size of a commemorative postage stamp, but its performance characteristics are superb. The amplifiers, which need only 1 mw of drive, are often used by 9-cm weak-signal operators, of which I am one. The transmission antenna is either a panel antenna with about 135-degree coverage or a commercially made omni with 11 dBd gain. We use vertical polarization on both reception and transmission, as omnidirectional antennas for this polarization are more readily available than horizontal antennas. To improve the picture quality of all input signals, we use a Time Base Corrector, a model ATV-8710. The video/audio controller is the model ATVC-4 Plus by Intuitive Circuits.

Sound

The sound subcarrier input to the repeater on 1280 MHz is 5.5 MHz. The sound subcarrier output on 3480 MHz is 6.8 MHz. Both frequencies are quite common in the world of satellite TV.

Toshiba 40-watt Amplifiers

We have found that the Toshiba 40-watt amplifiers get *very hot* in the summer months with 24/7 use, and they require a *large* heat sink with the fins pointing up. By large, we mean about 2.5 times the surface area of the amp. This large heat sink is cooled by two 5 inches across blowers in parallel, so if one fails the other will continue. In addition, we have installed thermometers designed for indoor and outdoor use on the amps with the outside probe mounted on the hottest part of the heat sink. The summer temperature difference between chassis and the hottest part of the heat sink is often 20–30° F. Since this rework, we have had excellent service for the primary White Rock repeater and the new 3420-MHz beacon mounted at the WITF-TV Ch-33 site north of Harrisburg, both of which transmit NASA 24/7. A detailed check list for putting this Toshiba amp on the air in ATV, CW, and SSB service was developed by me, dated January 6, 2006. It will be sent to anyone who sends an e-mail asking for it to me at <W3HMS @aol.com>.

Reception of the Input Signal on 1280 MHz

The receiving antenna is a Comet Model GP-21 of 14.9 dBi gain at 100 feet feeding a filter that heavily attenuates below 1240 MHz for elimination of cell-phone and paging QRM. It was designed, built, and donated to us by Founder/ Owner Jerry Buckwalter of Alpha Components of Mechanicsburg, PA.

The preamp is a Kuhne Electronics (DB6NT) LNA Model MKU 132A feeding a Holland model HR 120 satellite receiver with audio and video outputs to the controller.

Reception on 3480 MHz

LNBs for reception on 3420 or 3480 MHz are standard, out-of-the-box, C-band satellite types that cover 3700–4200 MHz but will also work just fine on 3480 MHz when followed by a satellite receiver tuned as an IF to 1670 MHz. For 3420 MHz, it is a 1730-MHz IF. American-style satellite receivers do not cover 1670 MHz, but European receivers do cover to at least 1750 MHz and most to 2150 MHz. The latest C-band LNB we have found is actually an LNBF (LNB with feed) made by DMS International and it covers 3400–4200 MHz. It has an incredible 13° Kelvin noise factor, and it comes complete with a scalar ring feed and two LNAs, one for vertical polarization and the other for horizontal polarization. In commercial service, the satellite receiver selects between these amplifiers by use of +18 VDC or +13 VDC. In amateur service, we just mount them for vertical polarization with +18 VDC on the line and orient for best picture. We buy these LNBFs in the below $30 range on the Internet (Google DMS International).

The DMS International C-Band LNBF (low-noise block with feed).

For 3480-MHz reception we have found that the best reception is obtained with a C-band LNBF on a 24-inch offset dish

The Blonder Tongue satellite receiver model BT 66 mounted below the monitor.

The Blonder Tongue satellite receiver and the Traxis digital satellite receiver.

now available for about $30. For regular LNBs, a feed horn, designed by Paul Wade's program HDL2000, also on a 24-inch offset dish, works quite well. We use vertical polarization on both reception and transmission, as omni-directional antennas for this polarization are more readily available than horizontal antennas.

Now a weak-signal operator well could ask if these LNAs could be converted for 3456-MHz use. We haven't tried it, but I have opened up an LNB and observed the two probes and the two LNAs. Thus, at about $10 per LNA, experimentation should not "break your bank"—hi!

The cable-TV operators around the U.S. are replacing analog satellite receivers with digital receivers. As these analog receivers do not contain any circuitry for frequency or orientation memorization, there is no market for them except for ATVers. Therefore, the companies that buy all the equipment at a satellite site are quite happy to sell it at a very low price or give it to ATVers, as their other option is to pay the "crushers" to haul them away.

Satellite Receivers

We have found that several Blonder-Tongue, PICO, and Holland satellite receivers offer excellent pictures, and they cover at least 950–1750 MHz. The Scientific Atlanta model 9660 is an excellent performer, *but* the video must be inverted. We have perfected a low-cost, easy to scratch-build circuit. The models that we did find to work well are as follows, although we did *not* test all satellite receivers: Blonder-Tongue Model BT-6166 and Model 6185A (not 6185!), PICO Model PR-4200, Holland Model HR-120, and Scientific Atlanta Model 9660.

WA3CPO has found sources of ex-commercial satellite-system analog receivers, and he has obtained a limited supply to sell to members of the SMRA, our supporting club. These receivers are excellent in all aspects and they require no conversion. Some operators (me, for instance) like to add an AC power switch, LED, and front-panel audio and video RCA jacks.

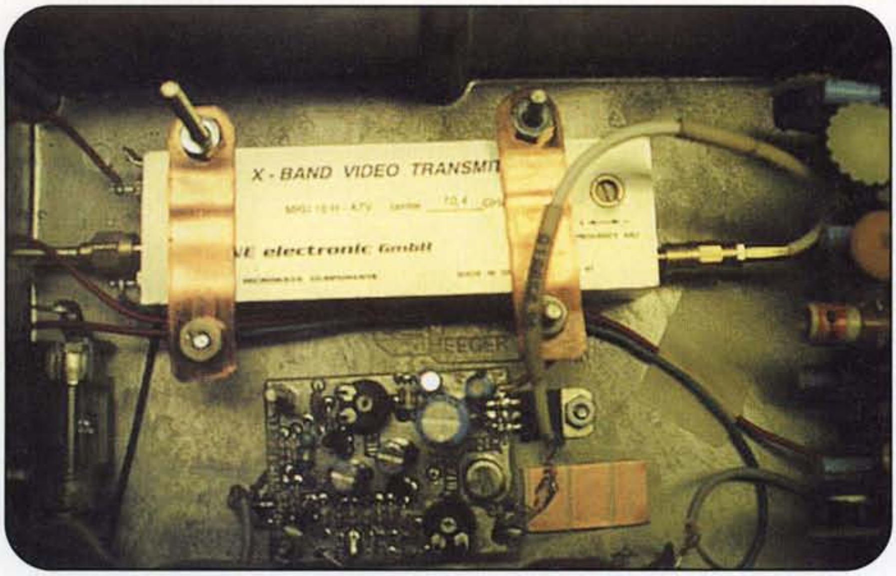
If you can find one, a European analog Pansat (Microtek) receiver at about $130, which works on 117 VAC, is an excellent performer. These and other models can often be found on eBay in the under $50 range.

The Internet to the Buying Rescue

Judicious use of the internet in the search for equipment has unearthed some incredible equipment buys: low-noise LNBs; dual-polarization 13° Kelvin LNBFs in the $20 range; 24-inch steel offset satellite dishes in the $30 range; and ex-cable-TV commercial-grade satellite receivers for under $100, and on one occasion zero dollars, as we saved the seller the labor of getting the receivers to the "crushers"!

10-GHz Repeater Linking

The use of 10 GHz for ATV is by no means dead. Indeed, we have purchased the excellent 1-watt DRO ATV transmitter made by Kuhne Electronics (DB6NT) in Germany. The transmitter is sold with the understanding that a base-band unit is required for operation with proper video, sound, and color. We have been attempting to obtain an RSE BBA unit

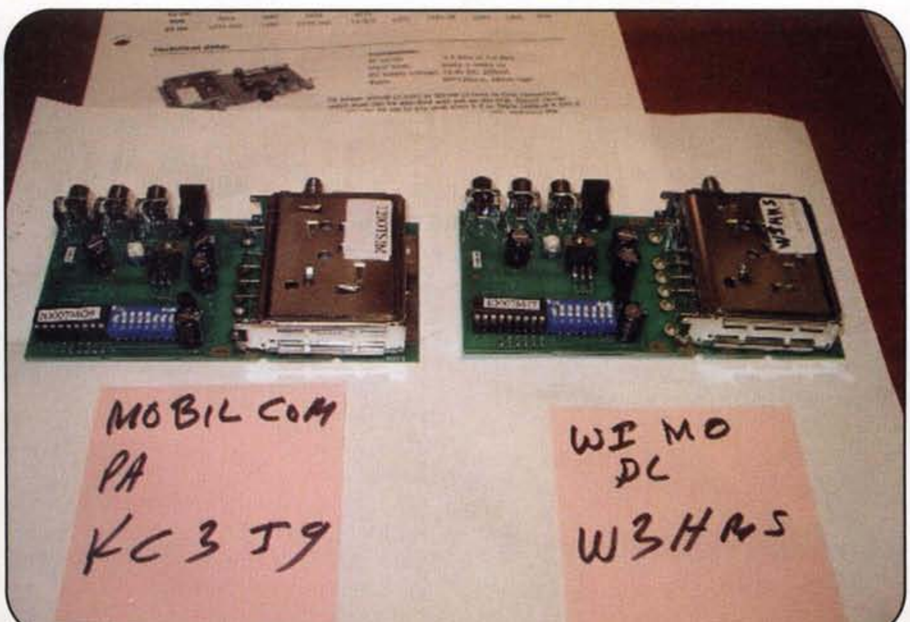


The DB6NT 10-GHz video transmitter.

from Belgium with no luck, despite a three-month effort! We envision mounting the power supply and BBA unit in a rack in the repeater building. We plan to run two RG-6 cables to the 10-GHz transmitter mounted on the arm of a 24-inch offset dish. The feed was converted from an inexpensive ($20 class) Ku-band LNB. It will operate on 10.4 GHz. The receiving capability will also use a 24-inch offset with a "Bob Platts" 9-GHz LO LNB from the U.K. feeding a U.S. satellite receiver at 1400 MHz. We will use this to link two repeater sites over a distance of about 60 miles with broadcast-level-quality video, sound, and color.

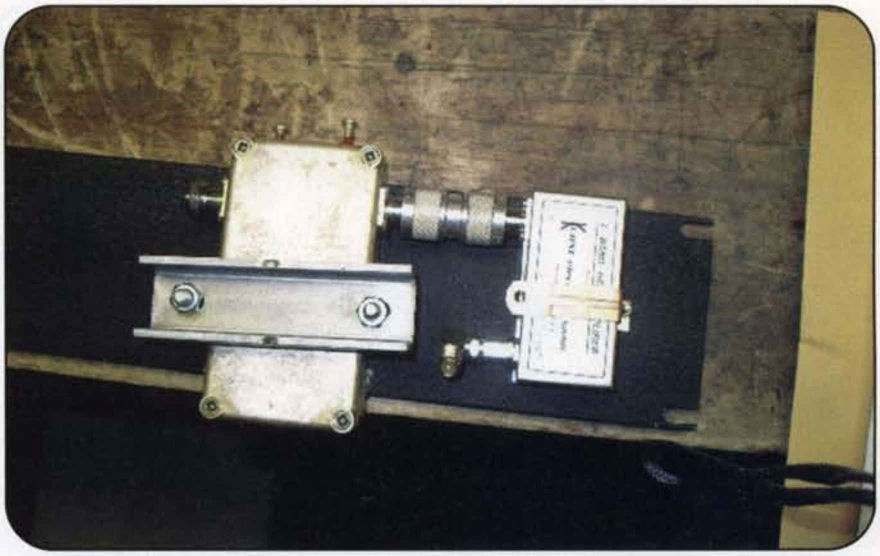
1280-MHz FM Transmission Into the Repeater

For 1280-MHz transmission our tests have confirmed that the Videolynx Z23B with 2 watts output produces broadcast-quality video, as may other units in the marketplace—if you can find them! The sound deviation from this transmitter is much less than the 200 kHz needed for a satellite TV receiver, but the designer/



23-cm ATV transmitters.

A 23-cm can antenna.



A 1280-MHz filter and preamp.

builder has developed a solution. This transmitter needs line-level audio input, not microphone level, and 1-volt p-p video input. A common camcorder is useful with a *modified* Z23B transmitter.

We envision that stations close to the repeater can use a neat little #10 food-can antenna with probe on 1280 MHz, as employed by F4DAY at his QTH and by others in the U.S. I am using this antenna at my QTH with 30 watts in the station and low-loss LMR coax to the can antenna. Other stations can use higher gain antennas based on signal needs/distance. For additional power, several of us use the 30-watt DEMI linear amplifier, which is equipped with a large heat sink. It is ideal for long transmissions, and I find that I have often transmitted for 30 to 40 minutes without generating excess heat. It needs only about 20 milliwatts of drive.

We recently tested the WIMO (Germany) 23-cm, ATV-Sender, 50-mw output, FM ATV transmitter, and the TVHAM.com 23-cm transmitter with 50 mw output. It is sold in the U.K. and available on that website. It seems to have the same appearance and specs, save for the frequency range, the settings, and the key IC. Both units offer much promise and are low cost, at $70–102. Both units will accept camcorder video and audio output and fully modulate the carrier as viewed on a TV set and a waveform monitor.

The Videolynx Z23B with 2 watts output does offer slightly better video. The sound sub-carrier is not fully modulated for proper recovery of the sound in a satellite receiver of the types cited above without a conversion developed by the designer/builder. Regrettably, over many months it has been extremely difficult to obtain replies to communications about conversions from the designer/builder. Thus, we have chosen to search for other transmitters, particularly when the cost can be reduced, as is the case with the WIMO and TVHAM models. We have not yet finished our testing of these two rigs in terms of the sound conversion to 5.5 MHz and their ability to access the repeater with an amplifier of at least 2 watts in the circuit.

Repeater Inputs

We have expanded reception to include linking of two other local repeaters into our controller. Our inputs in priority sequence are:

1. 1280-MHz FM repeater input
2. York 439.25-MHz AM repeater input
3. York 23-cm FM video input or Baltimore 23-cm/9-cm input.
4. NASA video input
5. A local tone-select camera

This linking has permitted the accomplishment of a long-standing local goal—that of actual ATV linking among the users of two repeaters to exchange very high-quality P5 color pictures. We know that, far above normal ham use, this ATV capability could well serve local emergency organizations.

Lightning Protection

One could ask the question: Does a 100-foot tower on the top of a tall hill attract lightning? At least twice we have suffered damage this way. As such, we have installed Polyphaser units at each end of the transmit and receive cables. Several receiving stations have installed the JVF Surchargers for use on RG-6 cables between the LNB and the satellite receiver.

Accomplishing a Long-Term, Complex Project

We have found that you need the following to accomplish a long-term, complex project:

1. Motivation
2. Money
3. Repeater site
4. Technical skills
5. Time

Of all of these, motivation seems to be the most critical factor. With it, it seems the others can be found. Without it, the others are never within reach; only excuses are found!

Future Projects

We see these projects for the future:

1. The development of a video-inverter PCB and kit to make available to about 45 buyers of the Scientific Atlanta Model 9660 satellite receiver.
2. The ability to receive and retransmit the 3480-MHz signal while simultaneously transmitting the picture on 3420 MHz.
3. The installation of the 10-GHz link, and the conversion of our 3420-MHz beacon to a fully functioning repeater. ■

Tradeoffs in Designing Digital Communication Systems

There are a number of tradeoffs to be made in the design of wireless digital communication systems. This document provides a short overview of the problems and some solutions.

By John B. Stephensen,* KD6OZH

With analog voice communication, we can use the speech recognition capabilities of our brains to compensate for signal degradation in the transmission channel. For digital communication, the processing power of a computer must be used. This requires making tradeoffs to minimize both the amount of energy that must be radiated by the transmitter and the complexity of the signal processing required at the receiver. These tradeoffs tend to fall into four categories:

1. Power versus Bandwidth
2. Transmission Channel Limitations
3. Frequency Selection
4. Limited Spectrum Availability

Claude Shannon enumerated the power versus bandwidth tradeoff in 1948. For a given bandwidth, using more power can increase the rate of information transmission. Conversely, for a given information rate, using a wider bandwidth can decrease the amount of power required. Table 1 shows the theoretical signal-to-noise ratio (SNR) required with a perfect demodulator for various forms of modulation for a 10^{-5} symbol error rate in an additive white Gaussian noise (AWGN) channel. This is a channel where the only source of interference is the thermal noise generated by the random motions of charged particles in atoms and molecules when they are at a temperature above 0°K. The amount of electromagnetic energy radiated is proportional to the temperature and has constant power spectral density over a wide frequency range. Thus, when it is viewed at optical frequencies, it appears white.

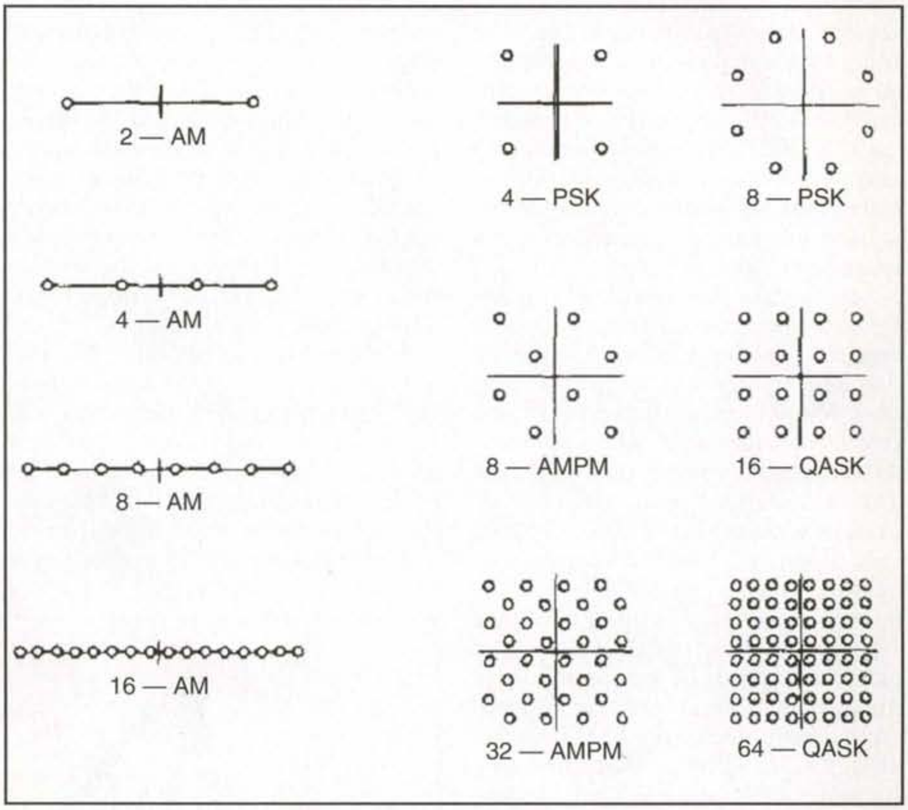


Figure 1. Signal constellations.

As the data rate (in bits/Hz) increases, the amount of power required increases dramatically. Doubling the data rate from 1 to 2 bits per Hertz requires doubling the transmitter power. However, doubling the data rate gets progressively harder; going from 4 to 8 bits per Hertz requires increasing transmitter power by a factor of 16. This is because the power required increases with the number of states of the symbol (the signal constellation size) rather than the number of bits transmitted. Increasing the number of states in a phase-shift-keyed (PSK) or amplitude-shift-keyed (ASK) signal uses only one dimension and ultimately requires almost four times more power for each doubling. If both phase and amplitude information can be utilized, as in quadrature amplitude modulation (QAM), the power increase can be limited to a factor of 2, as two dimensions are utilized as shown in figure 1.

*3064 E. Brown Ave., Fresno, CA 93703
e-mail: <kd6ozh@amsat.org>

Symbol States		2	4	8	16	32	64	256
Bits per Hertz		1	2	3	4	5	6	8
	ASK	10	17	24	30	36	—	—
SNR	PSK	10	13	18	24	30	36	47
(dB)	DPSK	11	15	21	27	33	39	51
	QAM	—	13	—	20	—	26	32
	DQAM	—	15	—	23	—	29	35

Table 1. Required SNR for data rates greater than the signaling rate.

Note that the QAM signal can be arranged in different ways with each point in the constellation representing one possible value of the symbol being transmitted. AMPM (combined amplitude modulation and phase modulation) and QASK (quadrature amplitude shift keying) are two possibilities. The value being transmitted can also be represented as the difference between adjacent symbols as in differential phase shift keying (DPSK) or differential quadrature amplitude modulation (DQAM). Differential signaling requires more power but is more immune to variations in signal propagation, such as fading.

Adding redundancy to the transmitted signal can decrease the amount of power required at the transmitter. The information-bearing signal is spread out over time. Multiple copies of the signal will correlate but the noise will not correlate, so the signal-to-noise ratio is increased. This is performed most efficiently by using an error-correcting code. A rate $^1/_2$ code doubles the bandwidth occupied by the transmitted signal but decreases the power required by a factor of 2 to 4 at a 10^{-5} symbol error rate. The amount of reduction depends on the complexity of the decoder. A bandwidth expansion of 16 can reduce the power level by a factor of 25. The effect is similar to analog frequency modulation (FM): Increasing signal redundancy increases the error rate at low SNRs and decreases it at high SNRs. Large signal constellations and coding can be combined to produce high data rates at reasonable power levels.

In outer space, this is all that we need to contend with. The thermal noise level is 2.7 Kelvin (K) between 2 GHz and 50 GHz and signals need to be a certain level above that noise. Below 2 GHz the noise level increases at 6 dB per octave due to the black hole at the center of our galaxy. Above 50 GHz the noise level increases at 6 dB per octave due to quantitization noise because the energy required per photon increases with frequency.

On Earth, the situation is more complex. First, the average temperature is 290°K, so the thermal noise level is about 100 times higher and transmitter power must be 100 times higher for the same path loss. Second, there are lots of objects that absorb, diffract, and reflect electromagnetic radiation, as shown in figure 2. This includes solid objects, such as mountains and buildings, and gasses, such as the atmosphere and the ionosphere. These do two things to the signal. They cause the received signal to arrive via multiple paths, spreading the energy out over time. In addition, these objects move, causing Doppler shift that spreads the energy over a band of frequencies. There are two general cases.

Between 3 kHz and 30 MHz, the electric charge density of the ionosphere is high enough to reflect signals back to Earth by continuous refraction. Not only are desired signals reflected, but so is the energy from all of the thunderstorms throughout the world. This raises the ambient noise level by 20 to 40 dB over the thermal noise level, so transmitter power must be increased to compensate. Below 3 MHz, the properties of the ionosphere are fairly stable, except for a diurnal variation that causes instability at sunrise and sunset. However, between 3 and 30 MHz, its characteristics are extremely variable. The Doppler shift varies between 0.1 and 1 Hz, and the multi-path spread varies between 1 and 10 ms. Propagation via auroral paths is even worse.

Between 30 MHz and 300 GHz, propagation conditions are more stable. Figure 3 shows the multi-path spread for a 2.3-km long path in an urban area at 910 MHz. The multi-path delay spread increases over longer paths.

The Doppler shift is generally less than 10 Hz up to 30 GHz, and the multi-path spread is usually between 0.4 and 20 μs. Rural areas have less multi-path propagation and urban areas have more multipath propagation. Shorter paths have shorter spreads and longer paths have longer spreads. When information is transmitted serially, the effect is to smear one transmitted symbol into the next transmitted symbol, causing inter-symbol interference (ISI) and a much higher error rate. There are two approaches to alleviate this problem and the effectiveness depends on the environment.

If the spread is a small fraction of the symbol period, the receiver can perform equalization. An algorithm that determines the delays of the two or three highest amplitude rays and inserts a compensating delay at the receiver accomplishes

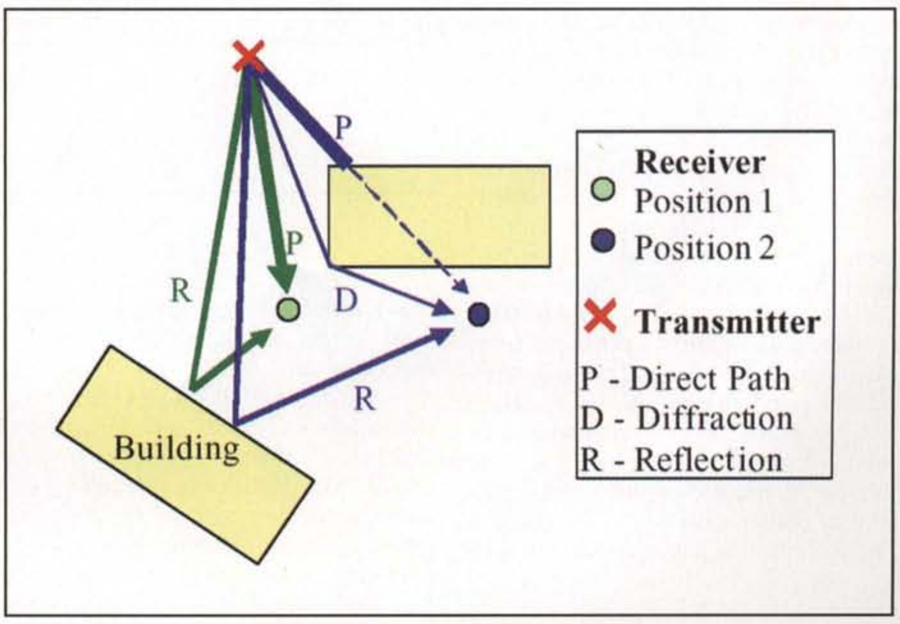


Figure 2. Signal propagation with obstacles.

New from West Mountain Radio

RIGblaster plug & play

The fastest and easiest to hookup RIGblaster ever, with the minimum time to the first QSO! Built in USB interface provides rig control, CW keying plus carrier detect for Echolink operation. Unlike other RIGblasters the plug & play works only with a radio's data or aux jacks, not a mic jack and may be ordered for your particular radio. The plug & play is the only USB sound card interface that has fully isolated audio and keying circuits for a clean, hum free signal.

Operation on all modes and bands with mic. muting is only possible if your radio's back panel jack supports this.

CBA Amplifier 10X

The CBA is the easy and inexpensive way to accurately measure the health of any size or type of battery.

A CBA can test any battery at up to a 100 watt continuous discharge rate but with the new CBA Amplifier accessory connected to a CBA you can test at 500 watts continuously!

Intended for lab or commercial use in emergency communications, aerospace and medical applications the CBA amplifier is the solution.

RIGrunner 8012

80 amp total continuous operation, 40 amps on each side's 6 outputs to run a total of 12 pieces of equipment. Supplied with a permanently attached six foot 8-gauge power cord. Blown fuse indicators and unambiguous over and undervoltage audible and visual alarms.

PWRbrite LED1

Super efficient blue white LED tube light for your ham station, especially QRP. Dynamically regulated steady light even with CW operation. Full brightness from 11 to 24 volts with almost indefinite life.

RIGtalk RT1

For the first time you can control your radio with a computer's USB. port. The USB RIGtalk CAT/CI-V rig control interface allows your radio to share frequency mode and band information with your logging software without tying up a serial port.

West Mountain Radio www.westmountainradio.com

18 Sheehan Ave., Norwalk, CT 06854

TOLL FREE order line (888) 937-8686

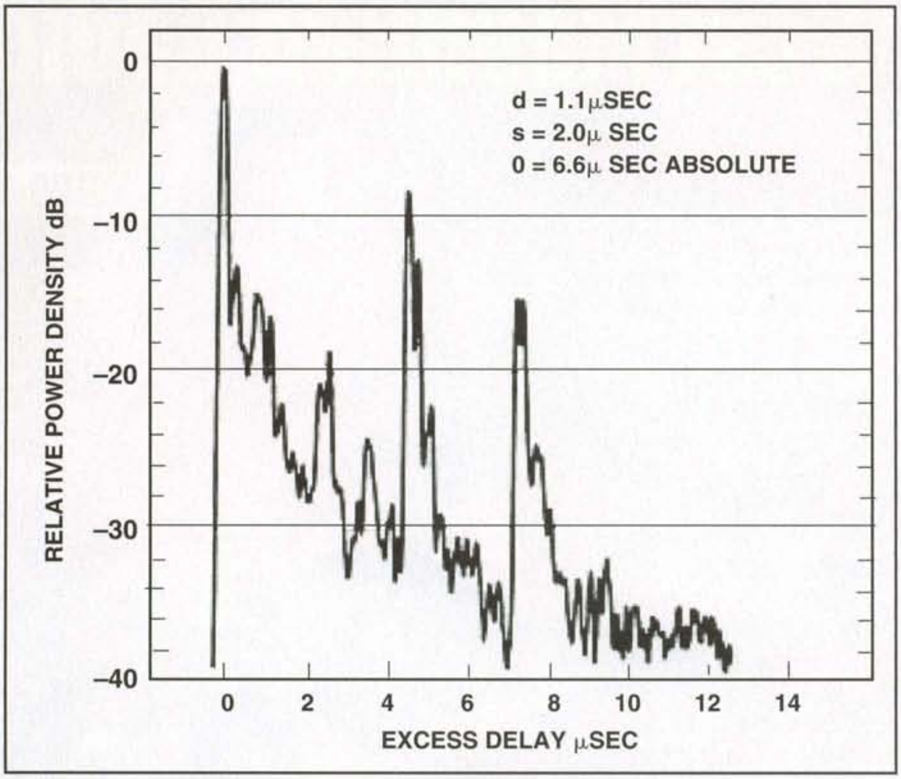


Figure 3. Multi-path spread for 2.4-km path at 910 MHz.

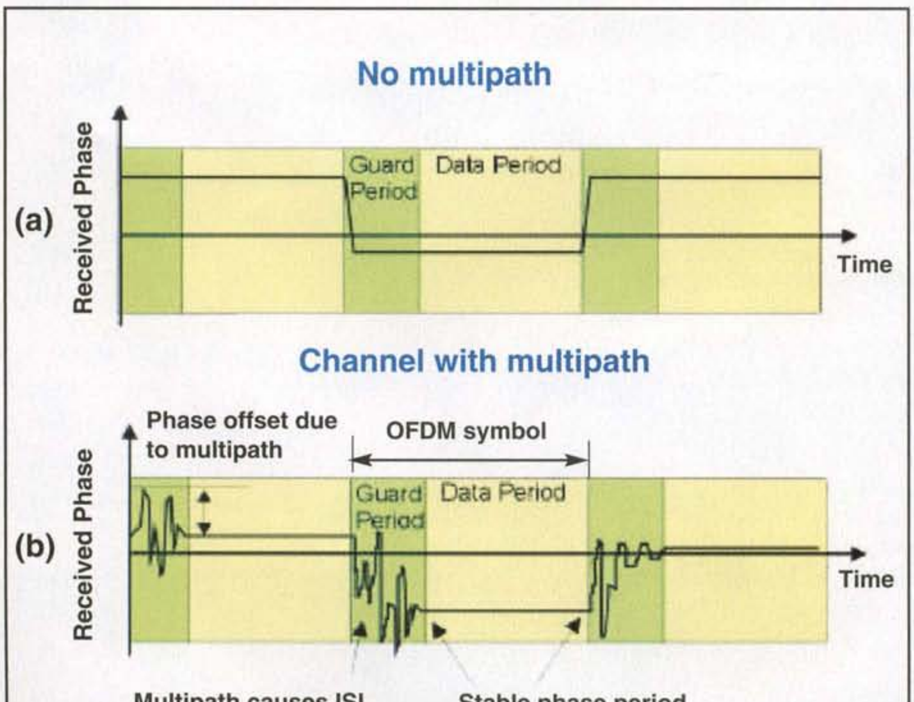


Figure 4. Guard interval and multi-path mitigation.

this. The energy from all rays is then combined to increase the SNR. This can work well until the spread becomes larger than 1/2 of the symbol period. Thus, the symbol rates accommodated could extend to between 25 and 1,250 kBaud, depending on the local environment. The D-STAR system uses this approach with GMSK modulation at 128 kBaud for a throughput of 128 KBPS. The advantage is that the RF amplifier can be non-linear so that a PA module made for an analog FM transceiver can be re-used.

An approach that works at higher data rates is orthogonal frequency division multiplexing, or OFDM. This method divides the communications channel into smaller and smaller frequency bands until the multi-path spread is a fraction of the symbol rate. Multiple carriers are then transmitted with many bits in parallel. If the carrier spacing is the inverse of the symbol period, the sidebands of each carrier do not interfere with each other and orthogonality is maintained.

A gap between received symbols is inserted that is longer than the expected multi-path spread (figure 4). At the transmitter, this is filled with a copy of the end of the next transmitted symbol. The receiver never sees the multi-path interference. The cost of this is the extra energy transmitted to fill the gap. If the gap is less than 25% of the symbol rate, the loss is less than 1 dB. In the UHF- and VHF-range path length is limited and the delay spread rarely exceeds 90 µs. A symbol rate of 4800 baud allows a gap of 41.7 µs, which removes most ISI in the 30-MHz to 30-GHz range. For 3–30 MHz the optimum symbol rate is 25–50 baud, as large delay spreads are caused by multiple reflection from the ionosphere. OFDM required linear power amplifiers, so they are somewhat less efficient. However, the overall power efficiency is improved.

In either case, there is a limit on the length of the received symbol if two-dimensional modulation is to be used. The Doppler spread rotates the received signal constellation at a rate of 360° per second per Hz, causing errors. The amount of rotation in one symbol period should be less than 1/4 of the distance between symbol states. Thus, for a 10-Hz Doppler spread, received symbols should be less than 12.5 ms in width for BPSK and less than 1.56 ms in width for 256 QAM. This puts a lower limit on the symbol rate of about 500 baud for the 30-MHz to 30-GHz range. For HF, the 1-Hz Doppler spread and 12-baud symbol rate limit the complexity of the signal constellation to DQPSK.

The path loss varies as the incoming rays enforce each other or cancel. For fixed stations, this is a slow variation, but for mobile stations the rate increases with velocity. Signal redundancy over time is used to combat fading. Codes that combat thermal noise are not the best for fading. Generally, an additional error-correcting code that is optimized for correcting bursts of errors, such as a Reed-Solomon code, is used to combat fading. These codes generally have a rate of 80–95% and can decrease the required power level by a factor of 10 by allowing the bits received during a null to be lost. Two rays will generally cancel completely for only a short period of time, as shown in figure 5.

OFDM increases the effectiveness of error correction during fading, as the fading channel has a narrow bandwidth. This ensures that the fade is flat and not frequency selective. When a signal occupies a wide bandwidth, the fading can generate a notch in the frequency spectrum that sweeps across the signal. This results in extreme levels of distortion and high error rates that persist over an extended period of time.

For moving vehicles, the maximum frequency that can be used with phase modulation is determined by the Doppler shift. For example, the UHF OFDM modem standard created by the ARRL HSMM (High-Speed Multi-Media) working group uses a carrier spacing of 1.5 kHz up to 450 MHz and 6 kHz up to 2.4 GHz. The reason is as follows: For automobiles operating at 75 MPH, the Doppler shift is 0.112 PPM or 270 Hz at 2.4 GHz and 51 Hz at 450 MHz. This causes the signal constellation to rotate by 16° per symbol period at 2.4 GHz and 12° per symbol period at 450 MHz. Since the minimum difference between symbols is 45° for D8PSK modulation, these are near the maximum frequencies that should be utilized with the specified carrier spacing. Fixed stations could use more complex signal constellations.

When Doppler shift cannot be avoided and cannot be compensated for, amplitude shift keying must be used and the amount of power required increases dramatically.

Path loss, for antennas of a given gain, varies with the square of the frequency. When omnidirectional coverage is desired, there are limits on the range of frequencies that can be used. To achieve high data rates, we need to operate above 30 MHz and avoid ionospheric propagation. The minimum antenna length for efficient generation of electromagnetic waves is 1/4 wavelength. At 50 MHz, a 1/4-wavelength antenna is 5 feet long, has a gain of 2 dBi, and fits on any vehicle.

If we are willing to forgo communication with aircraft, the antenna pattern can be compressed in elevation and remain omnidirectional in azimuth. However, the pattern cannot be compressed to less than 6°, as this would compromise communication between stations at different altitudes. This antenna has a gain of 16 dBi and would be approximately 5 feet long at 2.4 GHz. The difference in total path loss is:

+34 Increase in path loss from 50 MHz to 2.4 GHz

–14 Additional antenna gain at 2.4 GHz vs. 50 MHz

–12 Reduction in noise level from 50 MHz to 2.4 GHz, equals:

8 dB increase in power required at 2.4 GHz vs. 50 MHz

Therefore, the frequency allocations for the Amateur Radio Service that are below 1.3 GHz are preferred, as they require four times less power for a given data rate.

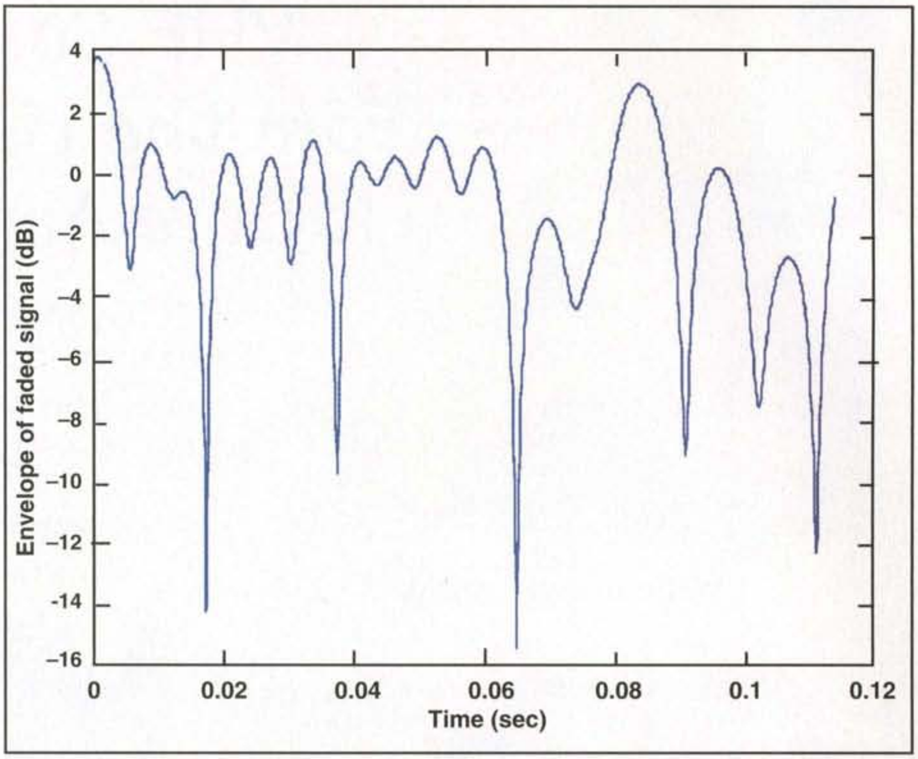


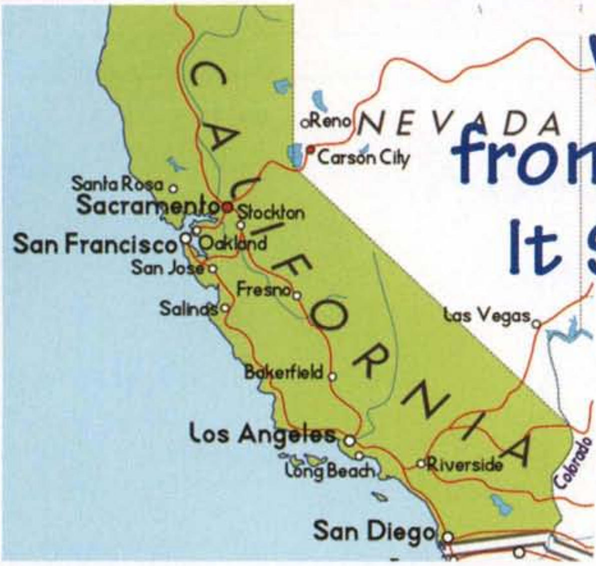
Figure 5. Amplitude of fading signal over time.

The final consideration is spectrum availability. Above 902 MHz there are no FCC limits on data rate. With 384 data carriers at 6-kHz spacing, D8PSK modulation with rate 2/3 coding and a guard interval of 1/4 and 768 bits per symbol, a data rate of 3.6864 MBPS can be achieved for land-mobile and maritime-mobile operation.

In the 219–220 and 420–450 MHz bands, the FCC limits data communication to a 100 kHz occupied bandwidth. With 96 data carriers spaced at 750 Hz, D8PSK modulation with rate 2/3 coding and a guard interval of 1/8, a data rate of 128 KBPS is possible.

The 50–54, 144–148, and 222–225 MHz bands have a 20-kHz maximum occupied bandwidth limit for data transmission. This limits the data rate to about 30 KBPS with a reasonable SNR. With a rules change, 256 KBPS would be practical in a 200-kHz wide channel with a SNR of 15 dB or less. This would allow medium-resolution compressed video transmissions in bands where propagation is better than the UHF bands.

Current regulations limit data transmission to a 100-kHz bandwidth in the 420–450 MHz band, but multi-megabit data rates are allowed if the content is digitized video. A rules change would make this possible for all modes. ■



VHF Contesting from the Heartland . . . It Sure Ain't Like L.A.!

What happens when a southern California ham operates in a VHF contest from the Midwest? W6AQ describes his experience.

By Dave Bell,* W6AQ

For an ARRL September VHF QSO Party several years ago, I found myself back at W8JJO's Michigan lakeshore hideaway, ostensibly helping him winterize his antennas, which consisted mainly of cranking down and tilting over his very, very old 55-foot EZ-Way tower and "nesting" the fiberglass elements of his 3-element SteppIR rotary beam (4 elements on 6 meters).

Before that happened, however, there was the weekend of the QSO party. Would I be able to get all of the winterizing done on Monday and Tuesday, my last days on the lake before flying back to Los Angeles? Would it rain? Should I risk foul weather and operate the contest on the weekend? One guess. . .

Brad's radio is an IC-746, which has both 6 and 2 meters. While I think he has never used it, he has an M^2 7-element Yagi underneath the SteppIR at about 55 feet. That was the station—4 elements on 6 meters and 7 elements on 2, low power.

In the proud tradition of my departed pal Lew McCoy, W1ICP, allow me a small digression. I'm not a demon contester, although I enjoy it and have been low-band contesting off and on for probably 30 years or more. I've just recently gotten into VHF/UHF contesting. I've participated in maybe a dozen of them, all from my home station in the hills of Hollywood.

I started my ham career in the late 1940s with an SCR 522 (if you don't know what that classic old VHF rig is, you're not really an old-timer), chatting with a pal of mine (now W8CY) in my quaint old hometown, Andover, Ohio. Up until a few years ago I hadn't been on VHF since then except for some now and then HT activity. I'd been thinking about expanding my HF horizons for several years before I ran across a brand-new Yaesu FT-736R at the TRW swapmeet. It was clear that the great ham radio spirit in the sky was telling me that now was the time, so I bought the rig. When I got home that day my wife asked me if I had found the coax connectors I'd gone for, and of course I said that I had, omitting the fact that they were on the back panel of the FT-736R.

Pretty soon I was checking into nets run by the Western States Weak Signal Society, which, depending on frequency, had anywhere from a dozen to 50 check-ins. While looking at the WA7BNM website for upcoming contests, I read that a VHF contest was imminent, and, never having been in one, I thought it would give the rig, the op, and the antennas a good workout. I figured that given the number of net check-ins, there would be lots of activity in the contest.

*5700 Hill Oak Drive, Hollywood, CA 90068
e-mail: <dbellw6aq@aol.com>

Well, there was . . . and there wasn't. What I discovered was a huge pile-up on 144.200, the calling frequency. The rest of 2 meters had a few—a couple really—stations calling CQ, but easily three quarters of the contesters were parked on the calling frequency, now and then to be driven off that prime spot by a KW calling "CQ North" or otherwise locking up the frequency. Then, and only then, did some campers move off the calling frequency for the empty quiet of virtually anywhere else on the band.

I quickly discovered the wisdom of asking your contact if he/she has "other bands" and popping up to 220, 440, or 1296 MHz. Some West Coasters have 900 as well, and a few venture regularly above 1296, but not me (yet), and not many. What frequency is usually suggested for the move elsewhere? Why, that band's calling frequency, of course. There are exceptions to that rule, but a casual observer could be forgiven for coming to the conclusion that a lot of VHF rigs in southern California are crystal controlled. Many VHFers in California complain about the calling frequency pile-ups, but for whatever reason, the pile-ups linger like halitosis after a night on the town.

Thus, imagine my surprise when I fired up W8JJO's IC-746 on 144.200 and heard . . . nothing. Absolutely *nothing*! Did I have the wrong date or time for the contest? I double-checked *QST*. No, now was the time and the date. So where was the contest? Had that deer I'd seen in Brad's front yard eaten his coax? I tuned off the calling frequency and was astounded! There was the contest, all over the place. Most of the 2-meter band was teeming with activity, but there was no one on the calling frequency. It was like the low bands. You actually had to tune to make a contact! What a concept! When I was asked to move to my other band, I was never asked to move to the calling frequency. Never!

Tuning around there on the shores of Lake Michigan I heard (I couldn't believe it) CW! Wow! Could this be 2 meters? Somebody was calling CQ on CW! And then there was another one! About the only station I ever hear calling CQ on CW in southern California is K6TSK, and by the time Ralph fires up his key, I've already worked him on phone. (Maybe it's time to count phone and CW as separate contacts in the VHF and UHF contests. Some dusty old keys would come down off the shelves.)

I'd heard that Midwesterners have a huge advantage over us West Coasters in VHF/UHF contests, and that weekend in September I learned what it is. They all don't camp on one frequency and fight to be heard. Of course, there's also the advantage that the ground is fairly flat and there are stations in every direction. Also, when there's a hill, it's not very big and it's usually surrounded by hundreds of miles of flat land. The rovers are on top of the hill. I heard a guy on both 6 and 2 meters who was running 4 watts on each band and was about 200 miles away!

This won't be the last time I operate a VHF contest at W8JJO's place in Pier Cove, Michigan. It's a great, quiet location, and from southwest to northwest it's all lake. Incidentally, don't look for Pier Cove on a map. You won't find it. The Lakeshore Drive signs letting you know you've arrived were made by the residents and look exactly like Michigan road signs, except they're square. It's about five miles south of Saugatuck, which is a really nice little tourist trap.

How do my Michigan versus L.A. scores compare? Well, I only did about one quarter as well in Michigan as I've done in L.A., but all of my contacts in Michigan were one-pointers, because those were the only bands available to me. In L.A. I have many of the money bands and some big Yagis. I suspect that if I had my L.A. station and antennas there on the shores of Lake Michigan, I'd probably double the score I usually settle for in L.A.

Next time I'm taking my Heil headset and a footswitch so I don't have to hold a hand mic while attempting to type my contest log one-handed. I'll also probably hook up my laptop to Brad's radio so I always log the right band and send slightly better CW. Other than that, no changes are necessary.

Don't be surprised to hear W6AQ from the Midwest in a future VHF contest. I like to tune for my contacts. . . . I'm old-fashioned that way. ■

International Satellite Frequency Coordination

With the growing educational interest in developing satellites that are designed for use on amateur radio frequencies, the definition of what is truly an amateur satellite has become challenged. Here ZS6AKV offers some suggestions regarding frequency coordination as a way of bringing some conformity to the proliferation of these new satellites.

By Hans van de Groenendaal,* ZS6AKV
IARU Satellite Advisor

Following the increase in the number of organizations building and launching satellites operating on frequencies allocated to the Amateur Satellite Service, various attempts were made to introduce a coordination system. This led to the appointment of the IARU Satellite Advisor, who is responsible to the IARU Administrative Council and charged with the task of working closely with AMSAT and other organizations to provide a coordination facility and a link to the IARU.

Various processes were followed, including the appointment of a Satellite Frequency Coordinator who reported to the IARU Satellite Advisor. This did not work too well, as a single person was not always able to take a world view. In addition, the volume of work had grown well beyond the ability of two volunteers to handle it.

Some years back, following recommendations by the IARU Satellite Adviser to the IARU AMSAT International Forum, held in alternate years in conjunction with the AMSAT UK Colloquium and the AMSAT NA Space Symposium, an Advisory Panel was introduced. Over the past four years this panel has developed a transparent process that has greatly enhanced the coordination of frequencies for satellites that operate on frequencies allocated to the Amateur Satellite Service. Credit is due to the unstinting amount of time and effort the panel has put into it.

**P.O. Box 90438, Garsfontein 0042, South Africa*
e-mail: <hans@intekom.co.za>

Currently the panel is as follows: Convener, Hans van de Groenendaal, ZS6AKV; Region 1, Graham Shirville, G3VZV, and Norbert Notthoff, DF5DP; Region 2, Ray Soifer, W2RS, and Art Feller, W4ART; Region 3, Jan King, VK4GEY. Panel members were chosen for their expertise and experience on recommendation from the regional IARU organizations and AMSAT groups.

Changing Environment

At one stage only satellites operating on frequencies allocated by the ITU to the Amateur Satellite Service were designed, built, and launched by AMSAT groups in various countries. Other institutions—such as universities, technical colleges, and national space agencies—are now showing a growing interest in small satellites as educational and developmental projects. Many of these satellites are "scientific birds" used for research into scientific principles that have little or nothing to do with amateur radio, or are "educational birds" primarily intended to train students in satellite engineering, yet they will operate on frequencies allocated to the Amateur Satellite Service.

Different countries have different views on how amateur frequencies may be used and many encourage educational institutions to do so. In some areas of the world, even projects that border on commercialization are licensed to operate on amateur frequencies.

This has raised the question of when a satellite is an amateur satellite. There are many different views on the subject. I, however, believe that the answer can be found in the ITU Radio Regulations. Here are the relevant definitions:

Article 1

1.56 *amateur service. A radiocommunication service* for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest.

1.57 *amateur-satellite service. A radiocommunication service* using *space stations* on earth *satellites* for the same purposes as those of the *amateur service.*

Certain other regulations are also worth noting, as they relate to the purposes for which an amateur station, satellite, or otherwise can be operated:

Article 25
Section I

25.1 Radiocommunication between amateur stations of different countries shall be permitted unless the administration of one of the countries concerned has notified that it objects to such Radiocommunications.

25.2 Transmissions between amateur stations of different countries shall be limited to communications incidental to the purposes of the amateur service, as defined in No. **1.56** and to remarks of a personal character.

25.2A Transmissions between amateur stations of different countries shall not be encoded for the purposes of obscuring their meaning, except for control signals exchanged between earth command stations and space stations in the Amateur Satellite Service.

25.3 Amateur stations may be used for transmitting international communications on behalf of third parties only in cases of emergencies or disaster relief. An administration may determine the applicability of this provision to amateur stations under its jurisdiction.

Section II

25.10 The provisions of section 1 of this article shall apply equally, as appropriate, to the Amateur Satellite Service.

It is sometimes difficult to determine whether a particular satellite that is intended to operate in the amateur satellite segments should be licensed in the Amateur Satellite Service or as an experimental station. However, that is a matter for the licensing administration. The advisory panel believes that it is appropriate that such satellites be coordinated, since the benefits of doing so outweigh the potential disadvantages.

Whether such satellites are licensed as amateur or as experimental stations is for the authorizing administration to determine. There is no point in attempting to second-guess that determination. In either case, if the satellites are operating in the amateur bands it is desirable that their operation be coordinated in order that their operation is confined to the amateur satellite allocations and is conducted so as to minimize the possibility of harmful interference to (other) amateur satellites.

The request for coordination of satellite frequencies is done by completing the coordination form that is available at <www.iaru.org/satellite>. The preamble to the form sets out the various conditions. A wealth of other information of interest to satellite builders is available on above URL.

In the panel's interaction with non-amateur organizations building small satellites that operate on amateur frequencies, it became apparent that many had limited knowledge about amateur radio and about amateur radio's involvement in satellite communications and the level of technological expertise that had been developed since the launch of OSCAR 1 in 1961.

Individual panel members are doing a great job interfacing with universities, the small satellite industry, and other interest groups, highlighting the AMSAT message: "Amateurs pioneered the small satellites, industry followed."

The Frequency Coordination Process

Prospective builders complete a form with as much detail as possible. The panel studies this. Copies of the requests are sent, for comment, to the National Society and the AMSAT organization in the country where the request originated.

The panel discusses the validity of the request and interacts with the various role-players to achieve a common understanding. Where a satellite is strictly non-amateur, every effort is made to convince the requester to seek alternative frequencies. This is, however, not always possible. The coordination process is set into action and the panel selects the best possible frequencies and proposes these to the requester.

The process is transparent and regular updates are posted on a website hosted by AMSAT UK (linked from <www.iaru.org/satellite>). The panel monitors the progress of the project and, where appropriate, offers advice.

Many educational institutions have little or no idea of how the Amateur and Amateur Satellite Services operate—how radio amateurs do band planning to ensure maximum usage of the allocated frequency spectrum and how limited the resource really is. Often the same frequency has to be coordinated for a number of satellites because there simply is not enough spectrum available. This process is carried out with lots of thought, including study of the orbit and the type of usage and ground station location.

National Society Support is Needed

Even considering the potential opportunities that educational satellite projects can provide for legitimate amateur satellite activities, as well as the role of educational institutions in training and motivating new generations of amateur radio space enthusiasts, the danger of overcrowding amateur frequencies exists. IARU member societies thus have an important role to play:

First, member societies should work with those in their country who are responsible for satellite projects intended for operation in the amateur bands to educate them about how appropriate frequency planning will benefit their projects.

Second, member societies should work with their national administration to promote the proper use of amateur frequencies in accordance with the Radio Regulations.

Third, engage with educational institutions to create an understanding of the amateur service and to encourage prospective satellite project teams to study the IARU paper "What is an Amateur Satellite."

The author welcomes comments and suggestions. ■

The Phase Modulator in NBFM Voice Communication Systems

Why is a phase modulator, rather than a frequency modulator, used in FM communication systems? WØINK discusses the reasons why this type of modulator is best for this application.

By Virgil Leenerts,* WØINK

The phase modulator has been a point of discussion as to why it, and not a frequency modulator, is used in what are called FM communication systems. This article's goal is to show why. There are a number of points regarding why phase modulators are used and they are probably valid, but this article will show that to meet technical requirements and create efficient operation with a voice response, a phase modulator is best.

Looking at the characteristics of frequency and phase modulators and coming to a conclusion that one is better than the other without considering the system technical requirements can lead to incorrect conclusions. Frequency modulators and phase modulators have different characteristics as a function of the input modulation voltage frequency response, and they need to be understood in order to come to the correct conclusion.

The explanation of why a phase modulator is the modulator of choice will be undertaken by breaking down the elements that make up the system performance. Once the elements are gone over, then the characteristics of these elements will be used to explain why the phase modulator is used in FM communication systems. The breakdown is as follows:

The FM discriminator
The voice response
The modulation index

After the above discussions, the technical requirements will be applied to sort out the reasons for using the phase modulator. Also for this discussion, the phase modulator can be either a phase modulator, or a frequency modulator preceded by a pre-emphasis or differentiator circuit, making it a phase modulator. The merits, or lack thereof, of phase modulation from a phase modulator or a frequency modulator preceded by a differentiator circuit are not within the scope of this article.

*1007 W 30th St., Loveland, CO 80538
e-mail: <w0ink@arrl.net>

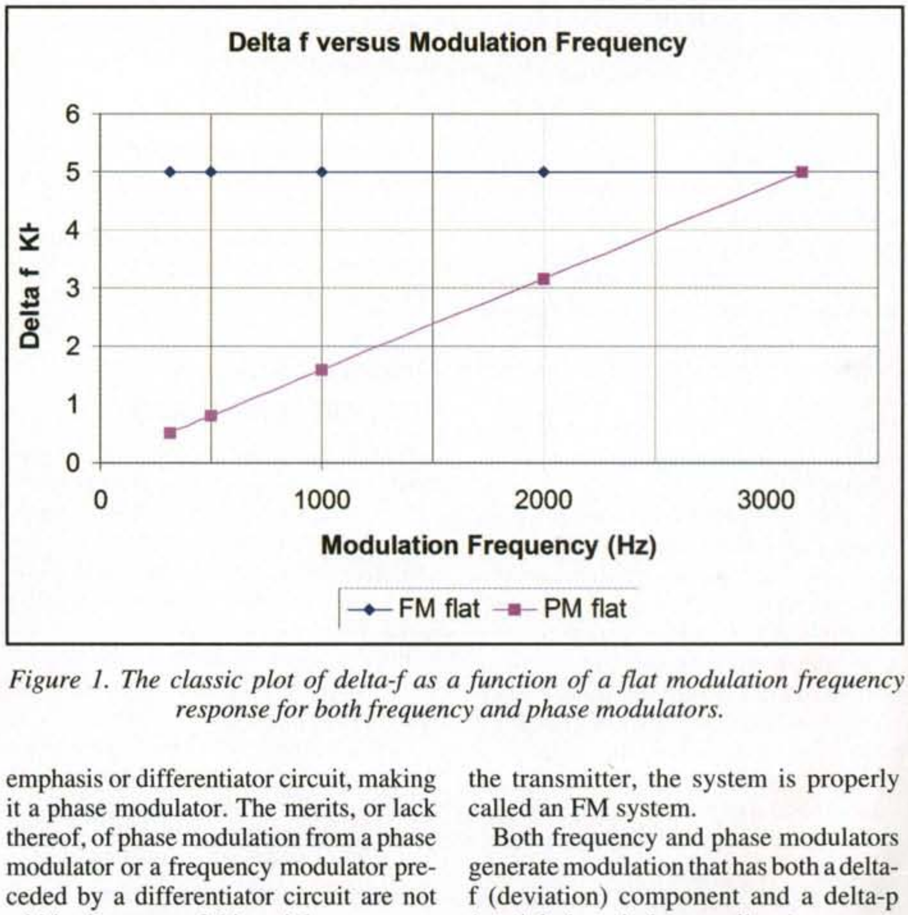


Figure 1. The classic plot of delta-f as a function of a flat modulation frequency response for both frequency and phase modulators.

The FM Discriminator

FM receivers have discriminators that convert the incoming RF signals to an audio output. Since FM discriminators demodulate only the delta frequency modulation of the modulated signal (not the phase modulation), the receiver sees only the frequency modulation of the modulated signal. Because the receiver detects only the frequency modulation of the transmitter, the system is properly called an FM system.

Both frequency and phase modulators generate modulation that has both a delta-f (deviation) component and a delta-p (modulation index—radians) component. (*Note:* delta-f and delta-p occur simultaneously and each represents a different aspect of the same thing—angle modulation). Figure 1 illustrates the classic plot, delta-f as a function of a flat modulation frequency response for both a frequency and phase modulator.

The relationship used for these plots is the classic relationship between FM and PM for a single-tone frequency. The expression is delta-p = delta-f / fm. Delta-p is more commonly recognized as the

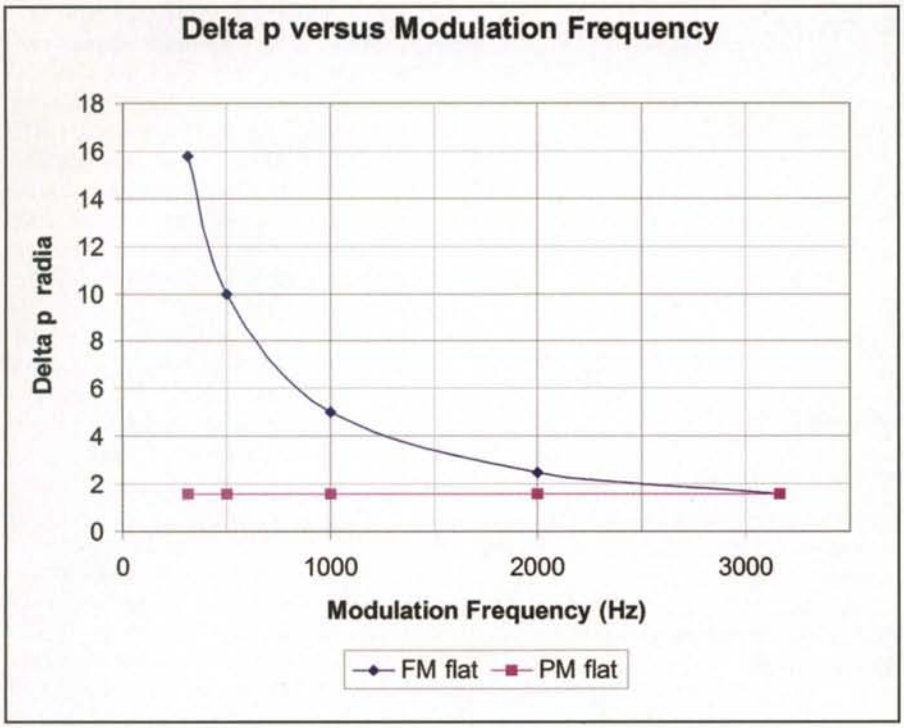


Figure 2. The not-so-often-shown plot of delta-p as a function of a flat modulation frequency response for both frequency and phase modulators.

modulation index. Note that this expression is for a sinusoid steady-state modulation frequency.

What appears in figure 2 is the not-so-often shown plot of delta-p as a function of a flat modulation frequency response for both a frequency and phase modulator. Both plots assumed a maximum deviation of 5 kHz as the reference. For the frequency modulator plots, a flat frequency deviation of 5 kHz for modulation frequencies from 316 to 3160 Hz resulted in a phase deviation from 15.8 to 1.58 radians. For the phase modulator plots, a flat phase deviation of 1.58 radians for modulation frequencies from 316 to 3160 Hz resulted in a frequency deviation from 500 to 5000 Hz, which is shown in the previous delta-f versus modulation frequency plot. For this article, deviation is assumed to be ± ( ) deviation.

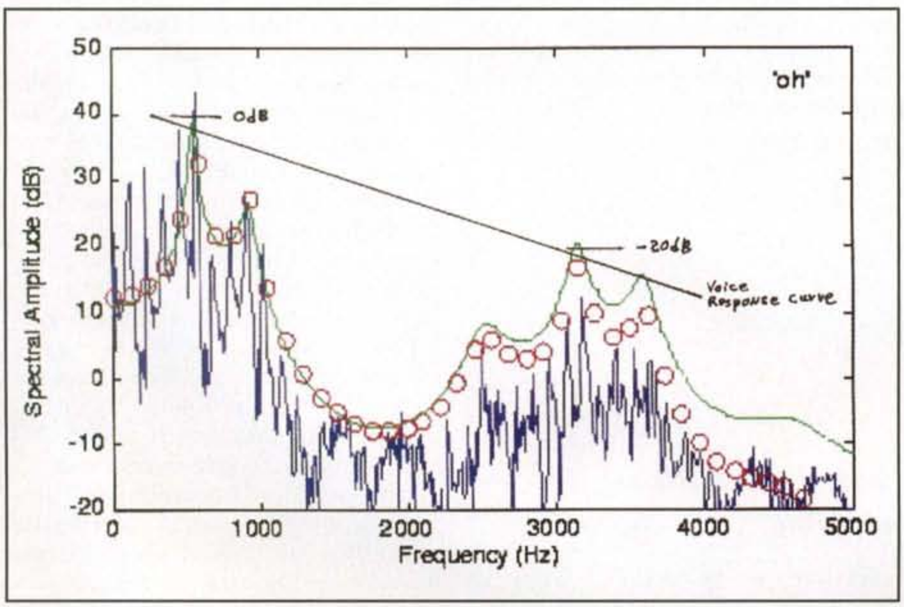


Figure 3. The plot of the voice response for the word "oh."

The Voice Response

Using the results from the flat frequency response would lead to different results and may be fine if the modulation characteristics needed to be a nominally flat response for modulation inputs such as music. However, the communications system was designed to have the human voice, and not music, as the modulation input. This requirement brings about the need to analyze the characteristics of the modulators so as to optimize the modulation for the human voice.

The voice spectrum response has characteristics that are, at best, very complex and are what gives everyone's voice a unique sound. However, a search of material for the voice spectrum reveals that the general characteristic of a voice is a sloping response of 6 dB per octave starting in the 300- to 400-Hz range. This general sloping in response is always present even though the actual spectrum components are very complex.

Figure 3 illustrates the plot of the voice

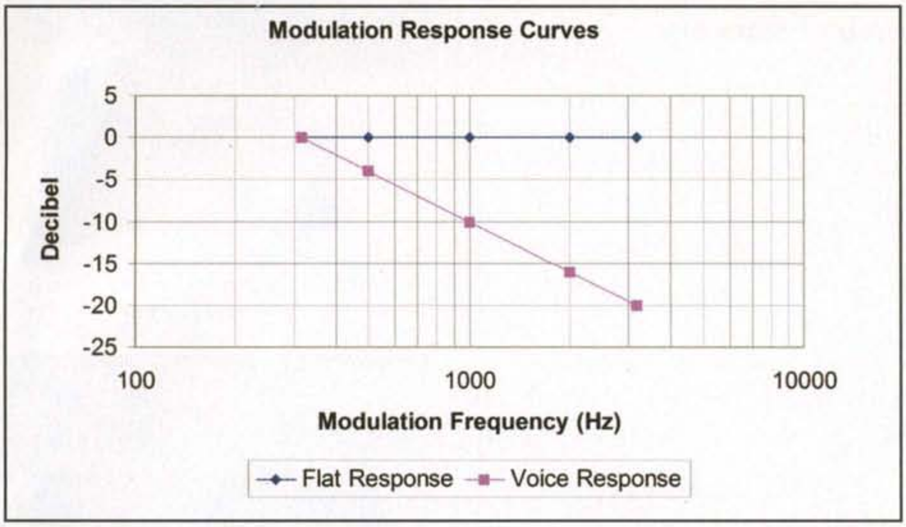


Figure 4. The response in decibels versus the log of modulation frequency for the flat and voice responses.

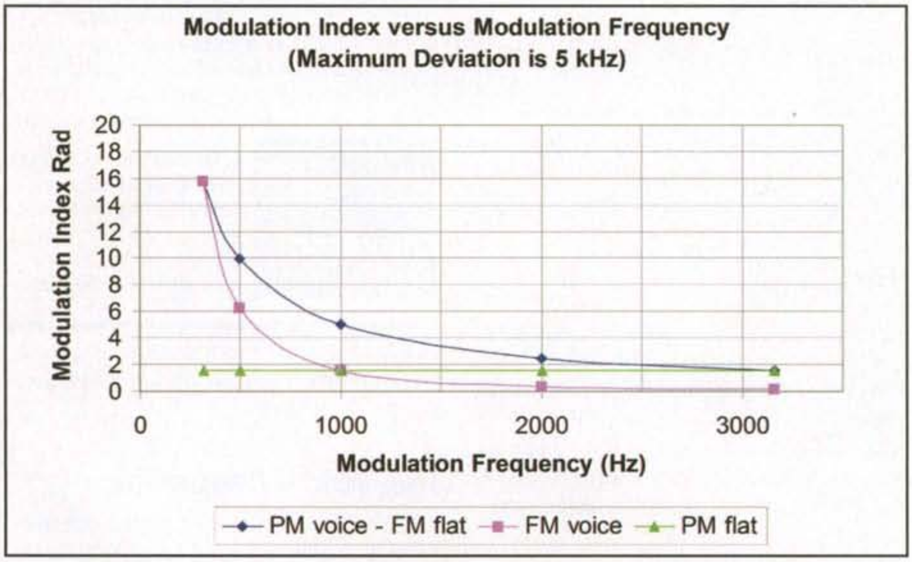


Figure 5. The plot of modulation index versus modulation frequency.

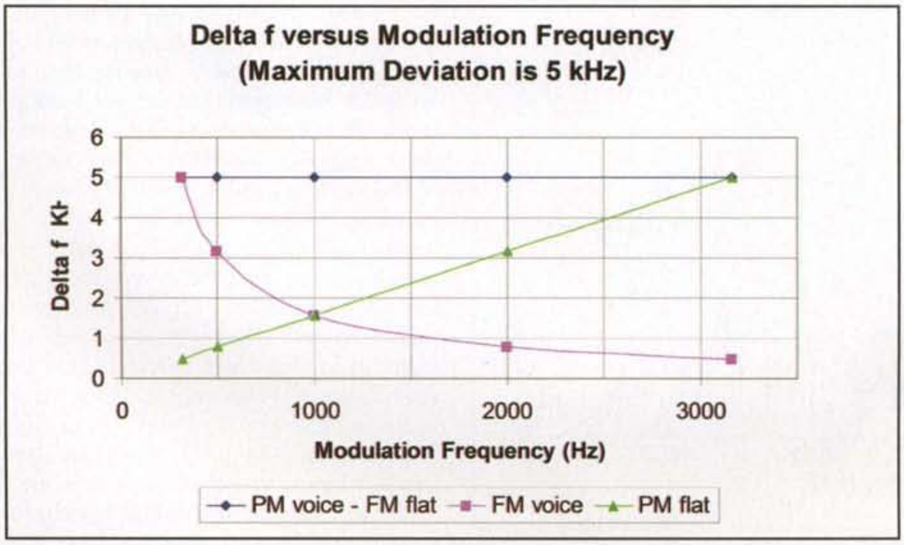


Figure 6. The plot of delta-f or deviation versus modulation frequency.

response for the word "oh," which is very typical of what the human voice spectrum components look like. Thus, for the FM communication systems, the modulation input is a voice response that has a 6-dB per octave or 20-dB per decade sloping response. An examination of the audio clipper circuit in a narrow-band FM (NBFM) transmitter will reveal that it operates on the basis that this is the expected input response.

Figure 4 illustrates the response in decibels versus the log of modulation frequency for the flat and voice responses. These are the modulation response curves used for all the other plots.

The Modulation Index

The modulation index is a parameter that is used to indicate the level of modulation relative to the carrier level. Another way to look at it is that the modulation index is how much power is in the sidebands that carry the modulation information, and as such, should be as large as possible. For AM, the modulation index is usually stated in percent, with 100 percent being the upper limit to avoid distortion. For FM or PM, the modulation index has no upper limit, but just like AM, it is advantageous to keep the modulation index as large as possible. The modulation index for FM or PM does not have the constraint of distortion like AM, but it does have a constraint of bandwidth. The modulation index for a frequency modulator is determined by the expression of deviation over modulation frequency. The deviation of a frequency modulator is proportional to the modulation amplitude. The modulation index for a phase modulator is proportional to the modulation amplitude. Conversely, the deviation of a phase modulator is proportional to the modulator amplitude and frequency. It is very important to note that the modulation index and deviation are very different for frequency and phase modulators as a function of modulation amplitude and modulation frequency.

Figure 5, which illustrates the plot of modulation index versus modulation frequency, was made with the condition that the maximum deviation is 5 kHz. Because the voice amplitude response is a maximum at low frequencies (for this plot, the low frequency is 316 Hz), the modulation index is lower as modulation frequency increases. Note that the overall modulation index for phase-modulated voice is higher than frequency-modu-

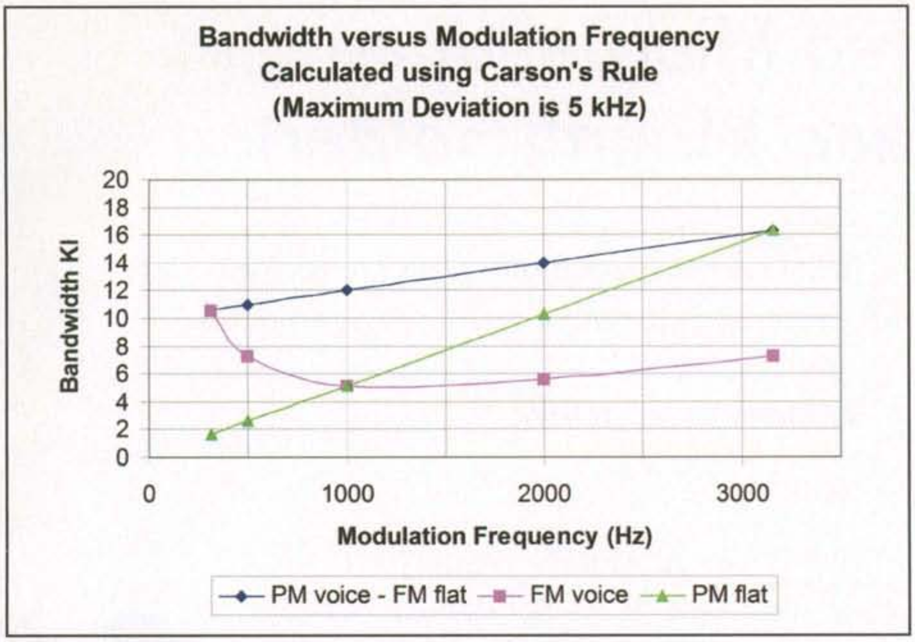


Figure 7. The bandwidth versus modulation frequency calculated using Carson's Rule of estimated bandwidth.

lated voice, and thus the phase modulator better utilizes the voice response for higher modulation efficiency.

Technical Requirements

The generally accepted technical requirement in the Amateur Radio Service for NBFM is a maximum deviation of 5 kHz and a maximum bandwidth of 15 or 20 kHz. The Amateur Radio Service Part 97.307 emissions standards list only the modulation index as a requirement. Part 97.307 (f) (1) states: "No angle-modulator emissions may have a modulation index greater than 1 at the highest modulation frequency."

Figure 6, which illustrates the plot of delta-f, or deviation versus modulation frequency, shows the classical deviation versus modulation frequency for the frequency modulator and phase modulator with a flat modulation response and the voice modulation response. Note now that the voice response greatly changes the deviation versus modulation frequency curves. With the voice response restricted to a maximum deviation of 5 kHz, the FM voice deviation lowers with increasing frequency, which accounts for the modulation index being lower. The phase-modulated voice response deviation curve now has the deviation as a constant over the modulation frequency range, and as was noted in the modulation index curve, has a higher modulation index for higher modulation efficiency.

The bandwidth of the transmitted signal is probably one of the most critical of the FCC requirements, as well as being a measure of how well a channel is being utilized. A transmitted signal that is narrower than the allowable bandwidth is poor utilization of the modulator and the channel. A signal that is wider than the allowable bandwidth is interference. Therefore, the goal is to have maximum bandwidth over the modulation frequencies, but not over the required maximum bandwidth. The bandwidth in the plot in figure 7 was calculated using Carson's Rule of estimated bandwidth. The expression for FM is $2 \times (\text{delta-f} + \text{fm})$, and for PM it is $2 \times \text{fm} \times (\text{delta-p} + 1)$. The phase-modulated voice response curve results in highest bandwidth over the modulation frequency range, with the frequency-modulated voice response curve resulting in a falling off of the bandwidth over the modulation frequency range.

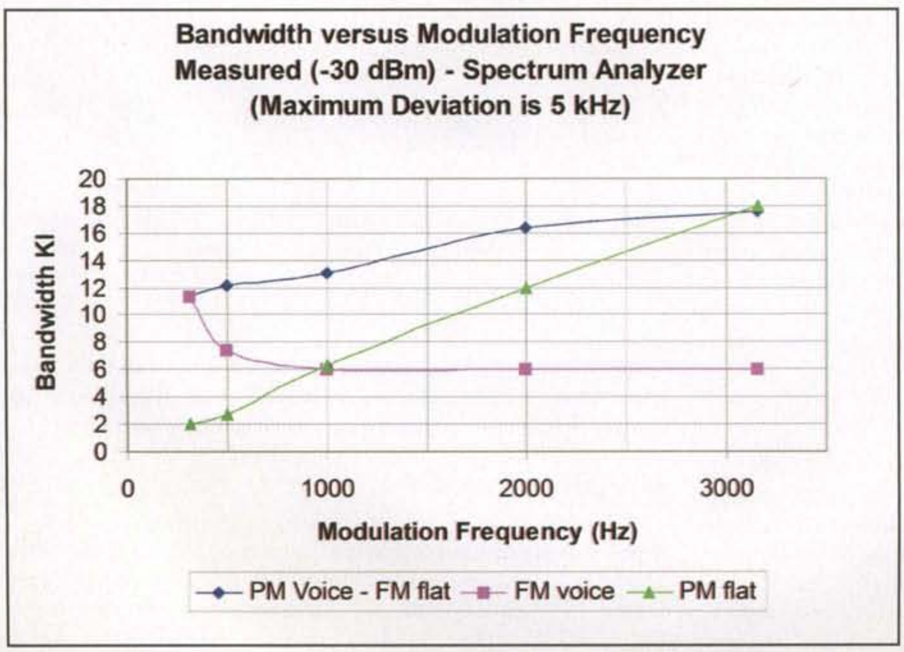


Figure 8. The bandwidth of FM and PM signals that were measured at –30 dBm below the carrier.

Conclusion

The plots of bandwidth, deviation, and modulation index as a function of modulation frequency show that the phase modulator is the best overall choice for NBFM voice communications systems. It has been used for decades and is still in use today. Note again that a phase modulator for this discussion can either be a phase modulator, or a frequency modulator proceeded with a pre-emphasis circuit, making it a phase modulator.

Appendix A

Figure 8 illustrates the bandwidth of FM and PM signals that were measured at –30 dBm below the carrier to show how close it is to calculated bandwidth using Carson's Rule.

My textbooks did not indicate what the level in dB down from the carrier is for the bandwidth that is calculated using Carson's Rule. My estimation for the bandwidth was –30 dBm below the carrier, which is what I used for my measurements. ■

Stereo Microscopes for Surface-Mount Soldering

Here are some suggestions from hams about what to consider when you want to buy a stereo microscope for your soldering projects.

By Steve Bible,* N7HPR

A frequently asked question is what one should look for when purchasing a microscope for surface-mount soldering. What follows are some suggestions from various users of stereo microscopes.

Chuck Green, NØADI

You *need* a stereo zoom microscope, magnification 10X. Most of the time I use 7X to get a wider field of view. Higher magnifications are sometimes useful for looking at suspect items, but this is rare. I never use greater than 40X, and even this is extremely unusual. Distance to focal point should be as long as possible. Remember, you need to work in this space. Mine is about 3 inches, and that is often limiting.

Get a really good light. It might be a significant portion of your total outlay. It's worth it! I have a 360-degree (goes completely around the objective lens) fluorescent light. It was pricey, but I'm glad I got it. Its only drawback is that it is a bit large and exacerbates the workspace under the microscope problem. Since I bought this, some LED lights have become available which *might* be better. I have no experience with these.

Don't get a microscope mounted on a stage. Get it mounted on a boom. The stage just gets in the way. You really want your work to only be on your anti-static mat, so the microscope needs to be able to swing out over this space. My boom is about 22 inches long and is just about right. The length that is best for you will depend on your workspace. Mine is a standard desk (5' × 30"). You want to be able to swing the microscope in and out as needed. This needs to be easy to do, as you will do it a lot. It's also nice to be able to swing the microscope completely off the surface of your workspace so you can get large objects under it.

Assi Friedman, KK7KX/4X1KX

I agree with Chuck. We have a B&L stereo zoom 4. We got it from an industrial liquidator. You can often purchase them for around $400 to $500. We have the rear illuminator (it's the cylinder in the back), which isn't as good as a circular one. However, since we tend to work on a board from the left and right sides, I rarely block the light. The boom is a must indeed, as it allows you to work on a box or a bare board. It is also convenient when you want to get it out of the way. The only nicer microscope I have seen is a stereo one that gives you a 3D image. While not a must, it is a nicer viewing experience.

*2470 W. Thompson Way, Chandler, AZ 85248
e-mail: <n7hpr@tapr.org>

The Luxo MicroLux Microscope System. (Photo courtesy of Stanley Supply and Services)

Lyle Johnson, KK7P

A couple more comments: I bought an inexpensive stage-type binocular microscope a few years ago, with a rotating (not zoom) lens system. It was helpful, but not as useful as I had hoped. Last year I bought a 7-45X binocular zoom microscope on a boom stand with a circular light system from "Precision*World," a dealer on eBay. They sell for $350 to $425 depending on, well, who knows? This is a huge improvement and I use it all the time. I bought a 0.5X Barlow lens for it, and sometimes wish I had bought a 0.25X or 0.3X instead, as the minimum magnification of 3.5X is sometimes a little too much. 7X as a minimum is definitely too much.

One problem with this microscope is that as you vary the zoom, the focal length changes. Therefore, as you zoom, you need to raise or lower the head slightly. This is not a big deal, as it is well within the adjustment range of the knob. With the Barlow lens, the focal length is about 5.5 inches. This is a comfortable working distance.

To prevent solder fumes from plating on the lens, I put a small piece of Costco plastic kitchen wrap over the lens and hold it in place with a rubber band. This seems to not distort things optically, and it means I don't have to touch the lens surface with anything to clean it, just toss the plastic wrap. Of course, I use a solder fume extraction blower when I solder under the 'scope.

Downsides of this 'scope:

1. The lamp is a little weak, or maybe my eyes are just tired. I sometimes wish for a little more brightness.

2. The variable focal length with zoom.

3. I wish the boom were longer.

4. It would be nice if the boom were grooved so that if I wish to alter its extended length, the head wouldn't rotate about the boom's long axis. In practice, this is not a problem, as I rarely need to change the extension. I see the same dealer carries a "dual arm boom" system to mitigate this. Would I buy one of these again? Yes. I haven't found a better value for the money.

John Stephensen, KD6OZH

The best that I've found is the Luxo MicroLux Microscope System. It has a 10-inch working distance with 5X magnification and will do 20X. These are available from Stanley Supply and Services (on the web: <http://www.stanleysupplyservices.com/productgroup.aspx?id=6587>). Prices are: $878 for the model with a mounting clamp and $962 for the model with a weighted base. A 0.5X Objective Reducing Lens is also available for $125.

Steve Bible, N7HPR

Finally, take a look at <http://www.microscope-store.com>. The author also goes by "windypines" on eBay. ■

By Joe Moell,* KØOV

HOMING IN

Radio Direction Finding for Fun and Public Service

RDF in the Headlines

Whether for sport or for public service, stories about RDF (radio direction finding) are of interest to the general public as well as to ham operators. Although they rarely explain the technical details, the mainstream media often present news items that include electronic signal tracking. Let's dig into some recent ones.

As I write this, there is much in the news about James Kim, a Senior Editor for CNET, who perished while seeking help for his stranded family in the mountains of Oregon after a severe snowstorm. CNET is reporting that the successful search for Kim's wife and children was greatly aided by a brief signal from his cell phone.

The very remote spot where the Kim family vehicle became snowbound was blocked from all the towers of his provider, Cingular Wireless. They could not call 911. However, two clever engineers from Edge Wireless, the regional operator, scoured the call data records and found a single "ping" from James Kim's phone at 1:30 AM to a tower near Glendale, Oregon. This brief transmission was acknowledgement of a waiting text message.

Kim drove out of that "sweet spot" before picking up the message, but the automatic transmission exchange was enough for the two Edge engineers to determine that his phone was less than 26 miles southwest of Wolf Peak in the little-used "Z" coverage sector. They then employed computer models to determine areas of mountain shadowing and combined that data with their own knowledge of the region to direct searchers toward Bear Camp Road, which is where Kim's family was found in the vehicle. Kim had driven down that road by mistake because a vandal had broken a lock and opened the gate to it.

The Kims' planned route for their Thanksgiving holiday was from Interstate 5 to Gold Beach via NF-23, but they took a wrong turn. Instead of backtracking, they continued in hopes of finding another road back to NF-23. That would have been tricky even in good weather. I remember a mobile hidden transmitter hunt in the Oregon coastal mountains back in June 1991. VHF signals constantly fluctuated in amplitude and direction due to the steep forested terrain. The poorly maintained logging roads were a confusing maze. Eventually, April and I found the hidden transmitter, and then we faced the challenge of finding the right way out.

E911 and RDF

The Kim tragedy points out how far this country is from the goal of 100% cellular coverage and accurate location of persons who call for help via cell phones. For many years, dispatchers at the approximately 10,000 PSAPs (Public Safety Answering Points) around the USA have had near-instant indication on their computers of the street addresses of landline callers to 911. In 1996, the FCC demanded in Docket 94-102 that cellular and PCS providers send the exact location of their 911 callers to dispatchers and gave them until October 1997 to start doing it.

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

This Cingular Wireless tower has three sets of directional antennas to increase channel capacity by dividing coverage into multiple sectors. The antennas do not have sufficient directivity to provide accurate angle-of-arrival information on incoming signals. (Photo by Joe Moell, KØOV)

The carriers objected, so the regulation was modified for a two-phase implementation of Wireless E911 technology, as it was called. In Phase 1, by October 1997, the location of the cell tower receiving the 911 call was to be displayed to dispatchers and a callback number presented. In Phase 2, by October 2001, the location of the caller had to be displayed to an accuracy of 100 meters 67% of the time and within 300 meters 95% of the time.

Given that the cellular/PCS industry was undergoing major changes at the time, with older transmission protocols being replaced with newer ones such as GSM (Global System For Mobile Communications), and given that FCC didn't require the benefiting public-service agencies to provide funding, that time-

Customers of Verizon and Sprint wireless services are being converted to handsets with built-in GPS so their exact locations can be transmitted to 911 dispatchers. Will GPS be built into amateur radio handi-talkies of the future?

table was completely unrealistic. Carriers tried hard, as their responses show.[1] However, technical impossibility and earnest efforts didn't deter the courts and the FCC from imposing consent decrees and million-dollar penalties on them when the original and extended deadlines weren't met. That penalty money could have been better spent on more towers in wilderness areas to help people such as the Kims.

At first, it appeared that classic RDF techniques would play a big part in Wireless E911. The antennas at most cell towers are directional, and it was thought that multiple-tower amplitude-based triangulation could locate the callers. The antennas would determine angle of arrival of handset signals and automatic attenuators would facilitate estimation of distance to them.[2]

Typical cellular tower antennas have an azimuth beamwidth of 30 to 90 degrees. That directivity made it possible to determine that the Kims were in a particular coverage sector. To get sufficient arrival-angle accuracy to meet the FCC's E911 requirements, much narrower beamwidth would be needed. Such multiple-element antenna arrays would be much larger and more complex, and would be needed at every tower. Accurate distance estimates by attenuation might be possible if users were always outdoors in the clear, but in practice, this proved unsuccessful due to unpredictable losses through walls and vehicle glass, as well as from reflections.

Traditional RDF methods showed the most promise on old analog cell systems, where time averaging could have refined the bearings on continuous-carrier handset transmissions. However, they were soon ruled out for pulsed digital systems such as TDMA (Time Division Multiple Access) and GSM. For that, engineers turned to the TDOA (time-difference-of-arrival) location method.

Just as GPS (Global Positioning System) receivers determine position and altitude by comparing the differences in signal arrival time from three or more orbiting satellites, providers such as Cingular and T-Mobile are now determining the location of 911 callers by detecting the difference in signal arrival time at multiple towers. Some writers have used the word *triangulation* to describe this method of location, but the correct term is *trilateration* if there are three sites and *multilateration* if there are more.

The FCC mandate spurred the formation of many small companies that seek to provide Wireless E911 solutions to the major carriers. New processing algorithms to improve location accuracy and reliability are being developed. Cingular has partnered with TeleCommunications Systems and more recently with TruePosition for location technologies. Cingular is also moving rapidly to convert all users to GSM phones and to shut down its analog network as part of E911 implementation.

The Verizon Wireless and Sprint Nextel networks employ CDMA (Code Division Multiple Access) transmission protocol to squeeze many users onto a single radio pair. CDMA is not compatible with TDOA positioning, so a network-based E911 solution is not possible for them. These companies have turned to handset-based solutions. All users are being converted to phones with built-in GPS receivers. GPS chipsets have improved greatly, but still do not work in all places, particularly indoors. Nevertheless, the FCC has accepted this method of achieving E911 compliance.

After many false starts, funding squabbles, and technological challenges, Wireless E911 implementation is finally nearing completion. The next step should be to expand all networks with more towers in wilderness areas to increase coverage and improve location capabilities. After all, it's the wilderness areas where tragedies such as that of the Kim family tend to occur.

Geeks in the Woods

International-rules ARDF (Amateur Radio Direction Finding) also found its way into mainstream media in recent weeks. Dennis Moran of the Santa Barbara News-Press in California told readers of his visit to a practice event in Goleta. He did an excellent job of explaining radio-orienteering from the basics to nuances such as the importance of taking regular bearings on up to five foxes while you track down one at a time. As always, however, there were references to the esoteric nature of the sport. The first line was "Jay Hennigan came to the crossroads where electronics-geek meets athlete—and he ran right past it, antennas shaking."

Writer Moran was referring to WB6RDV, who was featured on the cover of the last *CQ VHF* magazine as he practiced in Bulgaria just before the 2006

Jay Hennigan, WB6RDV, runs to the finish line at the 2006 USA ARDF Championships in North Carolina. He was featured in a Santa Barbara News-Press article on November 17. (Photo by KØOV)

ARDF World Championships. Jay is justifiably proud of his near addiction to electronics. He's quoted in the article as saying, "I've been a geek all my life, if you will. In fact, I joke about this as being one my 'geeks running through the woods' activities."

Thanks to Marvin Johnston, KE6HTS, of Santa Barbara for arranging this coverage of ARDF in his home city. Marvin is familiar to regular readers of this column because he has been one of USA's foxtailing pioneers. He was on the small team that represented the USA for the first time at the ARDF World Championships back in 1998. Since then, he has served twice on the international jury at the World Championships.

In 2004, KE6HTS led Santa Barbara Amateur Radio Club's sponsorship of the USA ARDF Championships at sites northeast of Los Angeles.[3] Now he's preparing to do it again. Marvin is chair of the SBARC committee that will put on the 2007 USA ARDF Championships (see sidebar).

Months before, transmitter hunting was featured in the "Outdoors" section of *The Los Angeles Times* under the title "Signal Stalkers" and the subhead "Obsessions." The writer gave an excellent description of his experiences at a radio-orienteering event in Griffith Park and a mobile T-hunt in the land of freeways. He quoted one mobile hunter as saying, "It's an addiction, but at least it's not drugs."

The results of transmitter hunts are nearly always unexpected, and the results of inviting a reporter to an RDF event are equally unpredictable. *The Los Angeles Times* photographer wanted to follow a Griffith Park on-foot hunter and one of the experienced ones volunteered. Unfortunately, he was first to go out and last to return that day, so the photographer missed the opportunity to snap photos of many other competitors, including some young people, in the interim.

I have learned the hard way that you can't stack the deck in a situation like this. When a Fullerton newspaper reporter asked to ride with April and me on a mobile hunt a decade ago, I was concerned because recent hunts had featured very weak signals. I knew I couldn't ask the hider to "rig" this event, but I strongly requested that he not put on a weak-signal hunt that would result in the reporter sitting in the back seat with no signal to hear for most of the evening.

Big mistake! This sly fox accommodated me by putting his hidden T on a hilltop and running much more than the usual power level. Strong signals were everywhere! Thinking I had arrived, I got out of the car to "sniff" on foot several times when I was still a mile away. The reporter got lots of laughs at my expense that night.

Plan Now for USA's National ARDF Championships

Santa Barbara Amateur Radio Club and Los Angeles Orienteering Club are joining forces to host our country's next major radio-orienteering event. The Seventh USA Championships of ARDF will take place September 14–16, 2007 at South Lake Tahoe, in the Sierra Mountains near the border between California and Nevada.

The courses for this event will truly be world class. They will be in the same forests where the United States Orienteering Federation held its 2003 national championships of classic orienteering with 350 competitors. The maps are excellent and the course setter will be Bob Cooley, KF6VSE, a winner of medals in both classic and radio-orienteering.

Friday will be a practice and equipment checkout day, followed by the 2-meter contest on Saturday and the 80-meter contest on Sunday. Event headquarters will be at Camp Concord in the El Dorado National Forest. An inexpensive package including two nights of lodging in the rustic cabins and five meals will be offered to event registrants. There are other lodging and dining options nearby.

The course sites are so good that they will attract the attention of ARDF enthusiasts from around the globe as well as around the states. Inquiries about attending have already been received from Asia. As in recent odd-numbered years, the 2007 USA ARDF Championships will be combined with the ARDF championships for International Amateur Radio Union (IARU) Region 2, encompassing North and South America. Previous IARU R2 championships in the USA have drawn competitors from Australia, Canada, Czech, Bulgaria, Hungary, Japan, Kazakhstan, Russia, and Sweden.

The USA ARDF Championships are open to anyone, beginner or expert, with or without a ham radio license. More information on this event plus registration forms, when they are available, can be found at <www.homingin.com>. See you there!

Joe Moell, KØOV
ARRL ARDF Coordinator

Styrofoam in the Snow

Transmitter hunting made news in Illinois on December 7. Editor Chuck Gysi, N2DUP, of the *Macomb Journal* reported on a ham radio high-altitude balloon that landed near his town. It had been launched by the Kansas Wesleyan University Physics Club from a football field in Salina on the previous Saturday, with a ham radio package by Pete Sias, NØOY. The balloon ascended more slowly than anticipated, so it spent more than the usual amount of time in upper-level winds. Tracking teams had lost the GPS data signal by the time it got well into Missouri and were nowhere nearby when it landed.

Bill Brown, WB8ELK, who has assisted and coordinated high-altitude ham radio balloon experiments for decades, called in Mark Garrett, KA9SZX. Mark, who is Assistant Director or Technology for Tri-States Public Radio in Macomb, had done RDF for balloons before, as well as for pirate radio stations and some ham radio competitions. I contacted Mark to get all the details.

Although the APRS payload batteries were dead, NØOY had included a small metal-can oscillator on 28.322 MHz. Its antenna was resonant on the fifth harmonic at 141.610. The oscillator was keyed by a timer chip powered with a 9-volt lithium battery and regulator chip. A map from Ralph Wallio, WØRPK, showed a predicted 10-mile landing radius just north and east of Blandinsville, Illinois.

"That's about 15 miles from where I work," Mark wrote. "Monday evening I began a search pattern in hopes of hearing the package. I used my ICOM 2810 dual-band mobile radio and an MFJ dual-band low-profile antenna. I kept the squelch open and drove around listening for any change in the white noise. When I heard something, I tried to confirm the same change on the 10-meter rig.

"Since we had received nine to eleven inches of snow on Friday, it was rough going. I almost got stuck on one country road that dipped slightly below grade. I actually drove along the east side of the block that the balloon was in, but I did not hear it due to terrain.

"After giving up around 9 PM, I called WB8ELK and asked him if he could narrow up the search area. Bill was in transit and did not have any tracking pro-

Marvin Johnston, KE6HTS, got good publicity for ARDF in Santa Barbara recently. He is the primary organizer for the 2007 USA ARDF Championships in September. In this photo he is introducing two Scouts to radio-orienteering at Jamboree On The Air 2006. (Photo by KØOV)

grams with him. He also did not know what Pete had launched. I spoke with Pete later in the evening and found out that his package weighed 5 pounds and his parachute was 3.5 feet and orange in color.

"From that, Bill predicted off the cuff that the package would be east of La Harpe and southwest of Blandinsville. I left work in mid-afternoon Tuesday and searched around that area. I came upon a very weak signal that was on-off in nature and could be heard on both bands.

"I went around the country block to see if I was at the closest. I still could not hear it on the east side, only weakly on the west, barely audible on the south, and strongest on the north.

"At the strongest spot on the north side, I got out a tape measure 2-meter Yagi[4] and determined which side of the road it was on. I also tried to get an idea of how far into the open corn field it was. I didn't need an attenuator because the signal was pretty weak.

"About this time, a fellow with a 4-wheel-drive truck saw me and offered to take me into the field. I asked him if he owned the land because 'No Trespassing' signs were posted. He said he did not but directed me to a farm house. The woman there said that she did not own the land, but said it should be no problem to go in and recover the package.

"We drove into the field about a quarter mile and took a bearing. By then we were running out of light. The signal was stronger but still straight ahead. We drove until we heard it on the HT in the truck, and by the time we stopped, we had driven past the Styrofoam-covered package.

"Bill Brown's prediction was right on the money. The actual spot was east of La Harpe and north of Blandinsville by about $2^1/_2$ miles. Not bad for guessing! The package was in great shape. I measured the lithium battery on the beacon and it was down to 5.43 volts after almost 100 hours of operation. That meant there was probably a milliwatt or less being radiated on the fifth harmonic."

Congratulations to Mark for finding the balloon and for the good publicity. I'm sure that RDF for him would have been easier if the oscillator's harmonic had been closer to the 2-meter band. I remember attempting to find a signal at 152 MHz with a 2-meter Yagi. Gain and directivity were not nearly as good there, compared to in-band.

False SOS Signals and a New Video

From Digital World Tokyo comes the story of 279 false distress signals that were investigated by the Japanese Coast Guard during June and July 2006. Eighteen ships and 19 aircraft were deployed during that time in an attempt to find the source of a beacon-like signal on 243 MHz, one of the international frequencies used for aircraft ELTs (Emer-

Mark Garrett, KA9SZX, tracked a very weak 10-meter signal from the Kansas Wesleyan University balloon package to a cornfield near Blandinsville, Illinois. Pictured is Larry Bailey, who assisted in the recovery. (Photo by Mark Garrett, KA9SZX)

This high-altitude balloon payload by Pete Sias, NØOY, was launched on December 2, 2006 in Salina, Kansas and recovered three days later in Illinois. (Photo by KA9SZX)

gency Locator Transmitters). Eventually, with help from the Kanto Bureau of Telecommunications, the source was found in Chiba, a seaside suburb of Tokyo. The interference was being caused by a defective cordless telephone.

Would amateur radio operators have assisted if this case of interference had occurred in the USA? RDF-proficient hams have tracked down many sources of QRM to important radio services in recent years, including a stuck marine radiotelephone transmitter,[5] defective video surveillance camera,[6] and satellite communications modem.[7] I would like to hear your success stories of RDF for public service, as well as for fun. I also want to know how transmitter hunting has provided good public relations for our hobby in your area. My e-mail and snail-mail addresses are at the beginning of this column.

A unique form of publicity for transmitter hunting ends this edition of "Homing In." A music video that includes competitive ARDF has been released by a pop group in the Czech Republic. I don't understand the words (can someone translate?), but it appears that there's a spark of romance between a young radio-orienteer and a YL electronics assembler. What does it all mean? Download the 20 MB video at <http://www.krystof.net/ke_stazeni/krystof_rubikon.wmv> and decide for yourself.

73, Joe, KØOV

Notes

1. http://www.fcc.gov/911/enhanced/ reports/phase2-waiver.html.
2. As an example, see US Patent 4,728,959
3. http://members.aol.com/homingin/gorman04.html.
4. http://members.aol.com/homingin/equipment.html
5. Story in "Homing In," Fall 2004 *CQ VHF*.
6. Story in "Homing In," Summer 2006.
7. Story in "Homing In," Winter 2006.

By John Champa,* K8OCL

Communicating Voice, Video, and Data with Amateur Radio

Building an Amateur Radio Digital Network

New Opportunities for Radio Amateurs

This month's HSMM column is guest authored by Paul Toth, NA4AR.†

Anyone who has ever linked two or more analog voice repeaters together knows you need several key ingredients to build a network. You need spectrum diversity for the repeaters and the linking fabric, vertical real estate to mount the antennas, security to control how the links and repeaters are managed, and RF (radio frequency) systems. Building a broadband, HS (high-speed) digital network requires those same ingredients, as well as a working knowledge of a number of industry-standard networking protocols.

Now you can start building your RF network with no particular purpose or goal in mind other than maybe the experimentation factor and what I will call "pure nerd enjoyment." However, I would recommend some thought be given, up front, to how the network could or will be used once it is built. Unlike the analog voice repeater network, a digital broadband network can carry many different kinds of traffic simultaneously. You might have live data streams originating from weather sensors operating in your area. As good as APRS (Automatic Position Reporting System) on 144.39 MHz is, the bandwidth available at 1200 baud HD (half duplex) limits the amount of data you can collect and transmit. Collecting live weather data from a network of sensors every minute at 1200 baud is not practical. However, tie those sensors to a broadband RF system capable of transmission rates measured in Mbps (megabits per second) and collecting that data every minute is practical.

You might want your network to serve as a transport for live streaming video, web services, e-mail (SMTP, or Simple Mail Transport Protocol) messaging, and IM (instant messaging) chat. You might want to build this network to provide the backbone for a conventional or digital voice repeater system. Or, you might want your network to do all these things and more. IT (information technology) professionals will tell you the best way to build a network is to develop a utilization plan up front. That way, you will not be committing endless time and resources engineering and re-engineering your network.

Once you have some idea of how your completed network will be used, you can start planning your network design. Radio amateurs have long held in their back pocket a number of key, licensed spectrum allocations upon which to build a viable digital network. These include:

- 902–928 MHz (33 cm)*
- 1240–1300 MHz (23 cm)
- 2390–2450 MHz (13-cm or 2.4-GHz band)*
- 3300–3500 MHz (9 cm)
- 5650–5925 MHz (5 cm or 5.8 GHz)*
- 10.0–10.05 GHz band.

**Shared with overlapping Part 15 allocations.*

Selecting the right frequency mix is important, particularly if you are planning a digital backbone and end-user WAPs (Wireless Access Points) into the network. The 902-MHz and 2.4-GHz bands are very popular, with a wide range of low-cost end-user equipment available. Be mindful that in many geographic areas both bands are heavily populated with Part 15 operators.

A band that offers a lot of potential for development is the 5.8-GHz allocation. This band features two segments that are not shared with Part 15 operators: 5650–5700 MHz and 5850–5925 MHz. These segments offer some great opportunities for high throughput and very good signal-to-noise ratios. Signals in this band are NLOS (near line of sight). Trees in your path are not the showstoppers that they might be on the 2.4-GHz band. One note: Intelligent Transportation Systems have been granted primary use of the 5850–5925 MHz part of this band for dedicated short-range operations along major highway corridors. You will likely see some ITS activity by the end of the decade.

Another band that may be a "real treasure" for amateur radio digital networks is the 3.3–3.5 GHz allocation. This allocation is fairly pristine, with only a handful of areas seeing limited weak-signal and analog ATV activity. This band comes with two restrictions for terrestrial development. The first is for radio astronomy, which carves out two small bandwidth segments from 3.332–3.339 GHz and 3.3458–3.3525 GHz. The second restriction is observance of a satellite segment from 3.400–3.410 GHz. The AMSAT *Eagle* satellite is expected to operate a high-speed data transponder in this segment!

Low-cost digital radios and associated gear for the 5.8-GHz band are readily available now, according to Dave Anderson, KG4YZY, an engineer with the Amateur Radio Broadband Alliance (ARBA, Inc.).[1] Anderson's company, FAB Corporation (http://www.fab-corp.com), is a leading supplier of 802.11 and 802.16 wireless technology, and has also been working with manufacturers to bring to the amateur radio market some new, standards-based RF technology for the 3.3-GHz band. Anderson says he hopes to be testing these radios on working links shortly.

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

†9231 120th St. N., Seminole, FL 33772
e-mail: <NA4AR@ni4ce.org>

The Fox River Radio League D-STAR Repeater – Aurora, Illinois

By Kermit Carlson, W9XA

The Fox River Radio League (FRRL) operates wide-coverage repeaters from Aurora, Illinois, serving the Greater Chicago metropolitan area. The decision was made in September 2006 to add a complement of D-STAR systems to the list of club repeaters. A new site was chosen to allow the D-STAR systems to be developed without affecting the existing FM repeaters.

When considering building a D-STAR system, the most important considerations are similar to any other full-duplex repeater system: antenna location, high-quality feedlines ($1^5/8$-inch Heliax® was used throughout in the FRRL installation); high-quality commercial-grade antennas; high-quality duplexers; and, of course, internet access at the repeater site for gateway operation. The devil is in the details, and the total construction cost of a well-installed system will depend greatly on the cost and availability of the Heliax® feedlines and cavity duplexers. The importance of an appropriate repeater site to the success of any repeater system cannot be overstated.

It is very helpful to have a method to check the operational aspects of the antenna, feedline, and duplexers with professional test equipment, real transmitters, and receivers. The ICOM D-STAR systems have no integral RSSI (Received Signal Strength Indicator), limiter function monitoring, or AGC/S-meter readings, so good test gear is a must.

Although any Class-C amplifier will work for the 0.5GMSK (Gaussian Minimum Shift Keying) D-STAR signal, one detail that can cause problems is that the power-output of some inexpensive RF amplifiers will sag at power-on. Should instabilities in the bias or collector supplies of an external RF amp cause a sag in the output of the amplifier, a distortion of the D-STAR preamble may occur and will distort the initial portion of the transmit stream. This will result in problems, depending on the received signal strength of the system.

When it comes to activating the gateway system, a background in information technology is helpful. Training as an administrator on the gateway software is required to join the network of systems. To date all of the training has been conducted at training sessions held throughout the U.S. However, alternate means of training may become available. The details of proper gateway administration are very specific and must be followed exactly in order to successfully join the gateway network. The best advice is to designate a SysAdmin who will complete the training and become one of the registered gateway administrators. In the case of the FRRL D-STAR team we have been fortunate to be able to rely on the expertise of Pat Skerrett, W9PDS, of Chicago, Illinois, as our Gateway (Linux) SysAdmin.

There are specific technical requirements for the internet speed—greater than 750 kBaud—and requirements for the attributes of the gateway computer system with two ethernet ports, large memory, and high speed. ICOM recommends better than a 3.6-GHz Pentium!

The FRRL D-STAR team found the help and advice of existing D-STAR repeater operators to be invaluable. My personal thanks go to Jim, McClellan, N5MIJ, of the Texas Intertie Team K5TIT, in Dallas, Texas, and to Tim Barrett, K6BIV, of the K6MDD Mt. Diablo (San Francisco), California D-Star system, for their help in establishing Chicago's first D-STAR repeater system.

I hope to see you on one of the D-STAR systems soon!

73 de Kermit, W9XA
(e-mail: <w9xa@yahoo.com>)

The FRRL D-STAR rack. From top to bottom are the WRT-54G running Linux; then the Linux server running the ICOM gateway software, the ICOM RP2C Controller, and the RP-2000 2-meter repeater; and at the bottom the RV-4000 442.100-MHz repeater. Also visible at the bottom of the relay rack is the 440 duplexer and bandpass cavity. (Photo courtesy of Greg Braun, N9CHA)

The FRRL D-STAR tower. The FRRL D-STAR systems installation used 1200 feet of $1^5/8$ Andrews heliax. This required 450 stainless-steel line hangars (at $1.90 each) and 56 man-hours of professional tower-climbing time to complete. (Photo courtesy of Greg, N9CHA)

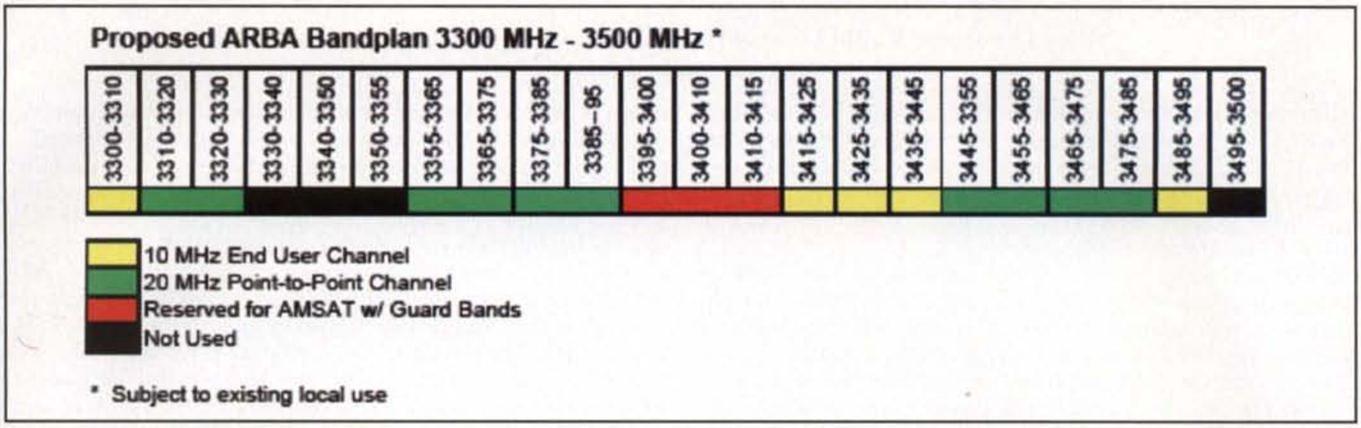


Figure 1. A graphical chart showing the channelization proposed for the 3.3-GHz ham band. This information has been forwarded to AMSAT for their input to provide them with whatever spectrum they will need for the package they have proposed for their Eagle satellite. The legend is as follows: Green channels are designed to provide 54-Mbit throughput and would be used for network backbone deployment. Yellow channels are designed for Endpoint (End User) use. Two of these channels could be combined to provide higher throughput. One green and two yellow channels could also be combined to provide 100-Mbit throughput in the backbone. What prompted the development of this proposal is the upcoming availability of a low-cost 3.3-GHz radio. This will enable licensed hams to utilize a slice of spectrum to which we have never had real access. What sweetens the pie is the lack of a Part 15 overlay on this spectrum.

Watch for more on this development in future columns.

One of the inhibitors to the development of high-speed, broadband amateur radio digital networks is security. It is still unclear whether FCC rules permit the use of security protocols on amateur radio that are built into most 802.11 and 802.16 radios. These security protocols are widely used by Part 15 operators on spectrum shared with hams to limit access to their networks and radios.

Hams do have some security tools, short of full encryption, that they can employ. One such tool is MAC filtering. Every 802.11 and 802.16 radio is assigned a unique, 15 digital address. MAC filtering allows Part 97 operators to limit access of the radio to one or more specified MAC address devices. However, a technique called "MAC Spoofing," the cloning of a MAC address, is available to almost everyone and is widely used by hackers to gain entry to wired and wireless networks.

You can also limit access to your network by turning DHCP (Dynamic Host Control Protocol) off and assigning a static IP address to your radio. Use something other than the standard Class A, B, or C network mask for your radio's IP address. For example, a mask of 255.255.255.192 will severely limit the range of IP addresses that can connect to your access point. There exists a problem with this approach, as well, in that address spoofing and "man-in-the-middle" attacks can take advantage of foxed IP addressing without encryption and assume a real user's identity.

Many access points that also double as routers have provisions for port filtering. Make sure that you open only those RVP and UDP ports that you need. Keeping all others closed can prevent unauthorized access to your network.

Use of narrow beamwidth antennas will severely limit the ability of other stations to make a connection to your radio and network. Grid parabolic antennas typically operate with a five-degree to seven-degree beam width.

Use of polarization diversity can also limit access to your radio and network and help your next node hear your signal in the clutter. The same 20-dB differential that exists at other frequencies between vertically and horizontally polarized antennas works on all these bands, too.

Finally, there is "security by obscurity." This practice will work on those bands (e.g., 3.3 GHz and 5.8 GHz) and segments not shared with Part 15 operators. However, it is neither foolproof nor something you should rely on if you are transmitting sensitive information.

A major challenge for amateur radio operators is finding vertical real estate to mount antennas and erect access points. The rooftops of high-rise buildings in metropolitan areas can provide easy access and reasonably accommodate network node equipment packages. Many rooftops have become cluttered with cellular antenna arrays and other RF and require extreme caution when working on them. Many rooftop and commercial tower owners are now requiring substantial liability insurance coverage (up to $5,000,000) to gain access to these sites. Some rooftops and towers are still accessible. Look around your town for other opportunities, including water towers and natural structures (e.g., hills and mountains).

Broadband digital networks have many emergency communications applications, including shelter operations, the transmission of weather and other sensor data, access to weather radar and lightning-detection data, point-to-point linking, high-speed messaging (e-mail and instant messaging), and video linking. Broadband networks can also be used to transport multi-circuit telephony services, something that will be in demand when normal infrastructure is down. This is the future of amateur radio and amateur radio emergency communications.

Want to know more about 802.11, 802.16, OFDM, SIP, IPv6, QoS, OSPF, WPA, and all the other protocols and technologies you can use on your digital broadband network? Just open your internet browser, go to your favorite search engine, and start typing away. The internet is an almost limitless source of useful information. Many communities also have local Linux user groups and IT networking groups that may be able to provide technical insight. And while you are there, you might even be able to recruit a few new hams.

73, Paul, NA4AR

Note

1. ARBA, Inc. was established out of a need to continue to supply amateur HSMM radio (digital radio >56 kbps) emerging technologies. It is a nationwide organization of amateur radio operators who have turned their energies to bringing forth technology that makes a positive, dramatic impact on the world community. This corporation was organized for the purpose of promoting amateur radio in the public interest that is beneficial to society as a whole through the establishment and operation of emergency communications facilities; providing educational programs in amateur radio communications techniques; conducting scientific experimentation in emerging HSMM radio technologies with potential applicability to amateur radio practice; and promoting cooperation with disaster and emergency response organizations involved with the protection of the public during times of emergency, including the Department of Homeland Security and other national defense organizations. ARBA is sponsored and supported by the Academy for Advanced Telecommunications at Texas A&M University, College Station, Texas (http://academy.tamu.edu).

By Del Schier,* K1UHF

AIRBORNE RADIO

Using Amateur Radio to Control Model Aircraft

Batteries: Care and Feeding

This column is primarily about electric-powered model airplanes. Electric-powered model airplanes depend on batteries. With the availability of nickel-cadmium batteries, electric-powered models became a reality. NiCad batteries still perform well, but they are rapidly becoming unavailable due to the environmental hazards of cadmium and have pretty much been replaced with nickel metal hydride, NiMh. Either type of nickel battery is still a good source of power, but they now are quickly being replaced by lithium. We will discuss how batteries are used and how they should be cared for. I will confine this discussion to NiCad, NiMh, and lithium batteries. Most of the following information applies to rechargeable batteries that are not only used in airplanes, but also in amateur radio stations.

Standard lithium ion (Li Ion) batteries used to power a laptop computer are not normally used in a model airplane. The Lithium-polymer (LiPo) type is the battery of choice for a model airplane. You may be familiar with this type of cell, as they are commonly found in cell phones disguised inside a plastic case. LiPo cells have a soft poly bag over the interior and are relatively fragile when that interior is exposed. When made into packs for a model, they are usually wrapped with fiberglass tape and covered with heavy shrink tubing for lightweight protection. Li Ion cells are in metal tubes, which are more subject to explosion but otherwise are more durable. LiPo batteries are very similar in chemistry and characteristics to Li Ion and there are variations of this chemistry to include lithium manganese and lithium nano potassium.

Most of us are familiar with the average rating of dry cell batteries, that being 1.5 volts. This is not the case of the cells being discussed in this column. Because of their composition, each of the type of cells being discussed has its unique rating. For example, nickel cells are rated at 1.2 volts. However, this is the average voltage over a complete discharge cycle.

*e-mail: <k1uhf@westmountainradio.com>

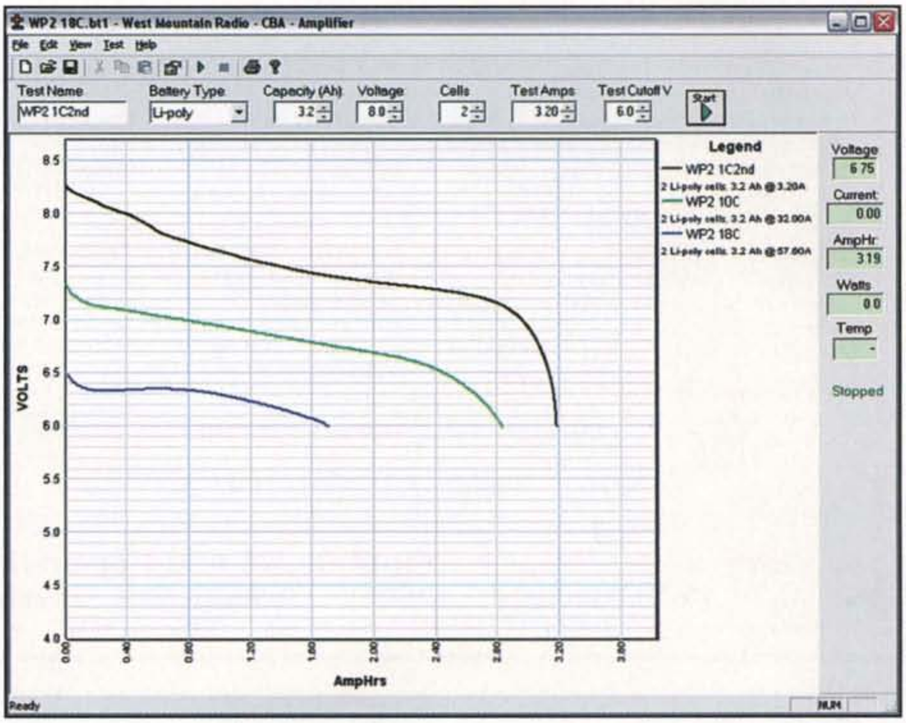


Figure 1. A two-cell LiPo 3.2-Ahr pack tested at 1C, 10C, and 18C: 3.2 A, 32 A, and 57.6 A, respectively. Notice the severe drop in voltage and capacity at the higher rates. This test shows higher internal resistance than the latest technology.

Typically, they are 1.55 volts after resting from a full charge and .9 volts at full discharge. Lithium cells are rated at 3.7 volts average, and are exactly 4.2 volts at full charge and 3.0 volts at full discharge. Lithium nano potassium are 3.6 volts at full charge and 2.0 volts at full discharge.

The voltage of a battery is only one important characteristic. The most important rating is capacity—how much energy the battery will store. Capacity for batteries is rated in amps over time, Ahr or mAhr. Capacity may also be rated in watt hours or some other unit of energy storage. Another important rating is the battery's internal impedance or resistance.

Model airplane motors generally draw high current and a battery must be of a size to do the job. The average current draw cannot cause the battery to overheat, and it must produce enough voltage to get the desired power from the motor. The capacity of the battery should also be chosen to provide a reasonable flight time. The problem is that you cannot just put a larger battery in an airplane if you expect it to get off the ground. Lead-acid batteries are a good choice in some applications, but not to power an airplane. Nickel batteries work well because you can draw extremely high currents from them and they are very durable. Lithium packs are far and away the lightest for a given capacity, about one third the weight of nickel chemistries.

The current capability is a direct function of the internal resistance. The lower the internal resistance, the higher the voltage and the cooler the battery operates under load. Most model airplane batteries have manufacturer recommended C ratings. A 10 C rating for a 1 Ahr battery means that it can safely be discharged at 10 amps. Nickel cells can be discharged at 50 C or higher; 50 C is a full discharge in 1/50th of an hour, the Ahr capacity rating times 50. The best lithium cells are rated at 30 C intermittently with 10 C or 15 C continuous. These ratings are some-

Photo 1. A LiPo pack showing the individual cell charging connector and also the standard discharge connection.

Photo 2. A West Mountain Radio CBA is the only easy way to do a lab test of any size or type battery.

times overstated, which has been my experience with using these batteries, both in my airplanes, as well as testing batteries with the West Mountain Radio Computerized Battery Analyzer, CBA. The safe temperature limit for a LiPo cell is about 145° F. Any higher temperature may damage them. At 180° F they may ignite or be destroyed.

A good LiPo battery will take several hundred 10 C discharges with only 10 or 20% loss in capacity, but one discharge to 160° F may do severe damage. Heat is the enemy of a battery. Therefore, if you expect to use the batteries for a long time, you must keep them cool. They should be mounted inside an airplane with provision for air flow around the pack.

Furthermore, these batteries must be operated at a conservative average current. Average current will depend greatly on how the throttle control is used to fly the airplane. With a motor glider that needs to quickly climb to altitude and then have the motor shut off a few seconds later, the battery will not have time to get hot. However, with a pylon racer that is flown the entire flight at full throttle, it is a different story.

Selecting and sizing a battery for an electric-powered model airplane is a matter of considering several factors and starting with the recommendation of a good dealer as to what battery to use with a given power system. One thing to consider once you have picked an appropriate power system is whether or not a battery will physically fit with its weight and location for the correct aircraft center of gravity. Other considerations will be the desired flight times and whether or not the voltage is correct. The size of the battery and current-draw heating will determine if you will have a good cycle life. If you plan the current draw carefully, you will be close. If you are a bit high or low, you can fix that problem by selecting a different propeller.

Test your system before flight. Both the AstroFlight Whattmeter and the Medusa Power Analyzer are intended for this purpose. These handy meters plug in between a battery and the motor speed control. These meters simultaneously measure volts and amps and then calculate and display watts, amp hours, and watt hours. A quick static run at full power will tell you whether or not you are within safe limits for the battery, motor, and speed control.

You should make sure the power system operates at or below the peak ratings

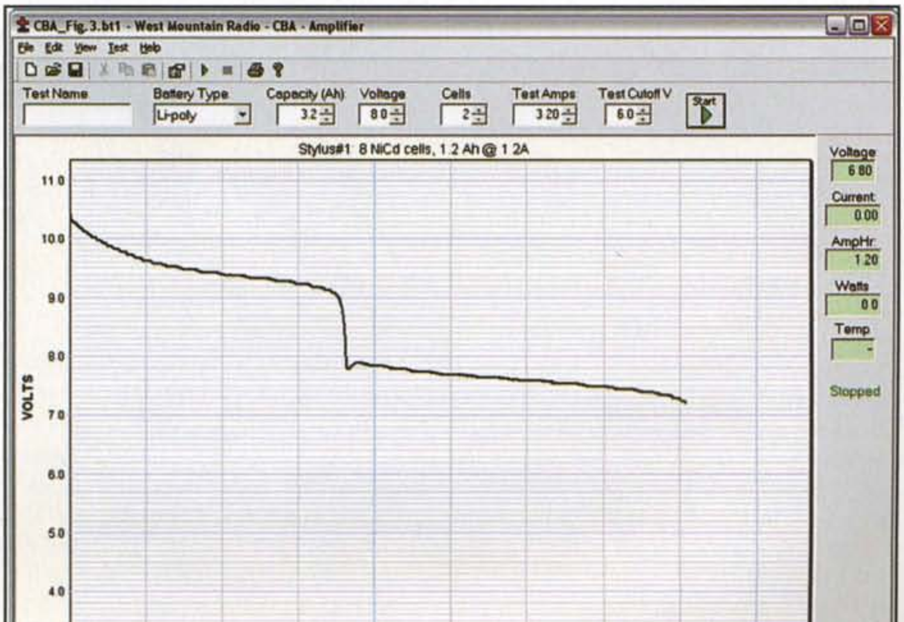


Figure 2. An 8-cell NiCad pack showing a step in the discharge indicating that there is one bad cell in the pack with much lower capacity than the other seven cells.

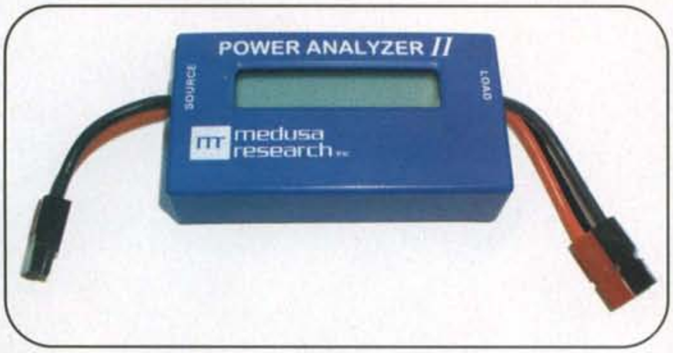


Photo 3. The Medusa Power Analyzer lets you measure an aircraft's power draw by plugging it in between the battery and the power system.

Photo 4. An AstroFlight Whattmeter is another way to measure power when connected between a battery and the load.

of the equipment if used in an airplane with intermittent full-throttle operation. For an airplane flown most of the time near full throttle, you should check that you are under the continuous ratings. An IR (infrared) temperature gun is a handy tool for checking for heating of the battery and motor. You also may want to do a static run with a partially discharged battery to check the low-voltage cutoff operation of the speed control. To fine-tune the system's power draw, you may need to change the prop size and then check the power again.

It can be a disappointment or a disaster if you have a problem with a battery. In any application where batteries are critical, it is good to periodically maintain and test your packs. With nickel packs there is the infamous memory effect. NASA studied memory effect, but for all intents and purposes it is not detectable to anyone under normal use. Memory effect is a reduction in capacity for a battery that is repeatedly partially cycled.

You will notice that a pack degrades with use. This is not memory effect; it is a pack with imbalanced cells. Cells do not charge or discharge evenly within a pack, and after time a pack becomes imbalanced. The cure for pack imbalance is to charge each cell individually, which is impossible to do without taking apart the pack. The practical way to balance and restore a pack is to repeatedly discharge the pack and then charge the pack back up slowly over 10 hours or more—the slower the better. Although convenient, fast charging is bad for a battery. Nickel batteries should only be fast charged with a peak detecting charger at a maximum 3 C rate. A 0.1 C 10-hour charge is

Photo 5. The AstroFlight Blinky 109 Lithium charger will charge up to a nine-cell lithium pack at up to 8 amps but doesn't balance the pack.

much better to get full capacity and life span from a battery. Even so, never leave a simple slow charger connected for a long period of time.

If you have questionable batteries, you should test and maintain them. The only good way to test a pack is with a West Mountain Radio CBA, Computerized Battery Analyzer. A CBA measures the true capacity of a battery by doing a constant current discharge and recording the voltage over time. With a graph of the discharge characteristics of a battery, a CBA shows you the exact condition of a pack. You will know if you have low capacity or if the pack is out of balance. A severely out-of-balance pack will show staircase steps toward the end of the discharge curve. See figure 1 for an illustration of this effect.

Nickel cells may be discharged to 0 volts without damage, but this can only be done with individual cells. A battery pack of nickel cells should never be taken close to zero, as cells within the pack may reverse in polarity and the pack will be severely damaged if quickly charged.

Lithium cells will be damaged if they are taken much below 3 volts. Leaving them in an over-discharged state is particularly bad. The same is true for lead-acid chemistry. However, the minimum for a lead-acid cell is 1.6 volts. If you do accidentally over discharge a LiPo pack, you should immediately bring each cell back up to over 3 volts with a balancing charger.

LiPo battery packs are more easily damaged by letting a pack go out of balance. To remedy this problem, most modern RC packs have a balancing connector to tap into each cell. Modern chargers use this connector to individually charge each cell to within 0.05 volt or closer. There are also balancers to balance a pack before use.

Nickel chargers stop when detecting a small peak in the pack voltage. If a nickel charger is used on a LiPo battery, it will not see a peak and keep charging and destroy the battery or start a fire. To charge them never use anything but a charger specifically designed for lithium batteries. LiPo chargers charge at a constant current and then taper off to exactly 4.2 volts per cell at completion. LiPo chargers can be fully automatic, setting themselves to the proper charge rate and cell-count voltage, or individually charging each cell through a battery's balance charge connector.

Note: Batteries of any type are dangerous, just like cans of gasoline. A nickel cell two thirds the size of an AA cell will put

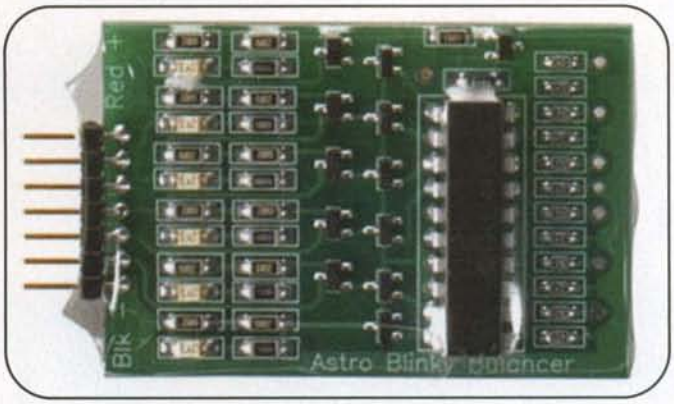


Photo 6. The AstroFlight Blinky will balance each cell of up to a six-cell lithium pack for maximum life span and pack performance.

Photo 7. An FMA Cellpro lithium charger charges each cell individually through a pack's balancing connector and displays the charge rate and charge condition of each cell with completely automatic operation.

out over 85 amps. A C-size nickel cell will melt a ten-penny nail! Lithium batteries can and will explode with a violent fire. Always be extremely careful not to short out a battery; care should always be taken. Any battery will get hot—or make the wires connecting it hot—if it is discharged too rapidly or charged incorrectly. Even though batteries are designed to be safe, they will explode, and most lithium cells will ignite with a violent fire. Improper charging of lithium batteries should be carefully avoided. *(For more information, see "Are Li-Ion batteries Safe?" in the February 2007 issue of CQ.—ed.)*

In conclusion, properly cared for and used rechargeable nickel and lithium batteries can be recharged hundreds of times with little loss of capacity and provide many hours of flight time for a model airplane. Happy flying! 73, Del, K1UHF

Related Links

AstroFlight: <http://www.astroflight.com>
FMA: <http://www.fmadirect.com>
Medusa Research: <http://www.medusaproducts.com>
West Mountain Radio: <http://www.westmountainradio.com>

By Dr. H. Paul Shuch,* N6TX

THE ORBITAL CLASSROOM

Furthering AMSAT's Mission Through Education

Reinventing the Cube

In a previous column (Summer 2006 issue of *CQ VHF*), we introduced CubeSats, the cheap and easy way to involve students in the design, construction, launch, and operation of ham satellites. In case you missed that minor opus, a CubeSat is a 1-kg picosat in a standardized cubic form factor, 10 cm on a side, designed for cluster launch from a wide range of boosters into any orbit of convenience. So far the cubes all have ended up in Low Earth Orbit (LEO), where minimal path loss makes their signals simple to copy with modest 2-meter or 70-cm equipment.

This time we will introduce a unique science mission that lends itself perfectly to CubeSat support. If your 1-kg picosat project is a solution in search of a problem, have we got a deal for you!

Although the world's navies are in fact involved in satellite technology, it should surprise no one that their primary mission involves ocean-going vessels. They also engage in oceanographic research. In addition to training the next generation of naval officers, the US Naval Academy in Annapolis, Maryland is involved in such research, and much of it makes use of satellite technology.

One of the projects in which Annapolis midshipmen participate is the deployment of ocean-going buoys for monitoring ocean levels, currents, temperatures, salinity, and composition. Once built and cast adrift on the sea, these buoys have to transmit their data to . . . somewhere. That's where CubeSats can come in.

Bob Bruninga, WB4APR, showing off the US Naval Academy's PCSAT2 engineering prototype at Space Day at the National Air and Space Museum in May 2006. (N6TX photo)

Bob Bruninga, WB4APR, heads up the US Naval Academy Satellite Lab. He is also well known to the amateur radio community as the father of APRS® (Automatic Position Reporting System), a technology that marries packet radio digipeaters to GPS for the purpose of tracking moving vehicles (including your mobile 2-meter station). Why not, suggests Bob, use APRS and CubeSats together to keep track of his students' ocean buoys, and perhaps to collect their scientific data via store-and-forward packet technology?

"For CubeSat missions looking for a neat project," writes Bruninga, "remember, we welcome more low-duty-cycle packet digital devices on the global satellite packet uplink frequency of 145.825 MHz. The more small satellites providing a bent-pipe relay on this frequency, the better the connectivity for other student school projects, such as ocean buoys, environmental sensors, arctic weather stations, and wilderness explorers using APRS."

I floated Bob's suggestion (OK, guilty as charged...) at a recent CubeSat workshop at the California Polytechnic University to a generally favorable response. Most enthusiastic, not surprisingly, were those radio amateurs at the workshop who see packet satellites as a useful augmentation to their own amateur radio pursuits. This is altogether appropriate, but let's not lose sight of the educational opportunity with which the proposal presents us. The students building the buoys may have no particular interest in ham radio, let alone APRS, as an end unto itself. Is there an opportunity here to turn them on to amateur radio, amateur satellites, and AMSAT? Before we dismiss as non-ham these scientific or educational projects of our fellow radio amateurs, we should

*Director of Education, AMSAT
e-mail: <n6tx@amsat.org>
<www.AMSAT.org>

remember that broadening the appeal of amateur radio benefits us all.

Of course, the proposed satellites, and their global satellite data channel, are not limited to ocean buoys. Once operational, they can be used by any remote environmental sensor (or any other remote amateur radio device) that needs to have low-duty-cycle communications. Those interested in learning more about US Naval Academy buoys, and related projects, may wish to browse WB4APR's web page at <http://www.ew.usna.edu/~bruninga/buoy.html>. If you are involved with a CubeSat project, as a faculty advisor, mentor, or student, you might wish to consider reinventing your cube in support of these worthy efforts.

PCSAT2

CubeSats are not the only birds proposed for packet digipeating applications, nor are they the only such options being supported at the US Naval Academy. Bob Bruninga's students were also responsible for the deployment of PCSAT2, a 145.825-MHz AX.25 digipeater attached to the International Space Station (ISS). Although never assigned an OSCAR designation because it is an appendage on another spacecraft (the ISS), similar payloads can easily be made stand-alone (fly-alone?) in the future, and would thus be eligible to become true OSCAR satellites. Imagine a sky full of orbital 2-meter digipeaters just waiting to relay your packets around the world, and you'll get some idea of where this Naval Academy initiative might someday take us.

Both the packet transponder on PCSAT2 and the ARISS (Amateur Radio aboard the ISS) ham radio on the ISS can already relay some of these data experiments, and they both are visible on the web via the following links: <http://www.ariss.net> and <http://www.findu.com/cgi-bin/pcsat2.cgi>.

If you're new to CubeSats and want to learn more, you should take a look at the CubeSat website hosted by Cal Poly at <http://www.cubesat.org>. There you'll find the CubeSat electrical and mechanical specifications, information about many of the existing and planned cube projects, and a good overview of using satellites in education.

To copy a CubeSat, take a look at the satellite database on the AMSAT website. It lists operational status, frequencies, and modes for all those cubes that have been granted OSCAR designations. Several of the cubes downlink easily copyable CW telemetry in the 435–438 MHz satellite downlink band. You'll be amazed at how loud 1/2 watt of RF can be from LEO, even into an omnidirectional antenna.

A few cubes transmit FM voice or SSTV and are equally easy to copy. Other cubes transmit 1200-baud or 9600-baud ASCII. These modes take a bit more link margin to decode, generally requiring a small beam. The popular Arrow 2-meter/70-cm Yagi combo works quite well on these birds, as it does on our various other Mode B or Mode J LEO ham satellites. Two line Keplerian elements, available from all the usual sources, will let you track CubeSats with your favorite AMSAT software.

There's no denying that talking to other hams via a relay satellite is an important part of ham radio. However, don't overlook the simple pleasures of intercepting these abundant signals from space. This is a good way to introduce students, civic groups, and your next-door neighbor to the joys of amateur radio. Many's the new ham who got his or her start by looking up and listening. ■

By Keith Pugh,* W5IU

SATELLITES

Artificially Propagating Signals Through Space

2006 AMSAT BoD Meeting & Space Symposium & ARISS International Meeting

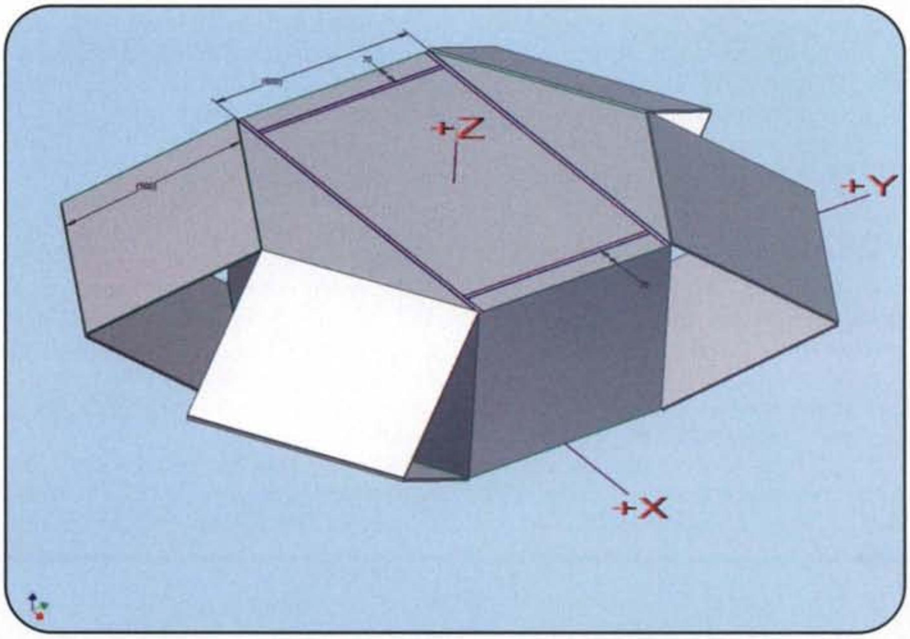
A series of important meetings were held in the San Francisco Bay area in October 2006. The AMSAT Board of Directors Meeting was held on October 5–6, the AMSAT Space Symposium on October 6–8, and the ARISS International Meeting on October 9–10. As promised in my last column, I will provide a full report of these meetings; however, much has already been said in other publications about them, so I will limit it to my observations and impressions.

AMSAT BoD Meeting

President Rick Hambly, W2GPS, introduced the new slate of AMSAT Board of Directors members with the only changes being between the active and runner-up positions in a couple of cases. Next a new slate of officers was elected/appointed. Major changes were the election of Bob McGwier, N4HY, as VP of Engineering, the election of Drew Glassbranner, KO4MA, as VP of Operations, and the appointment of Barry Baines, WD4ASW, as Corporate Secretary and VP of Special Projects. The position of VP of Marketing, formerly held by Barry Baines, was left open for the time being. Reports were given by all of the officers and functional leads on their activities over the last year and plans for the future. Bob McGwier discussed major engineering efforts in support of AO-51, the original PacSats, Phase III E, and ARISS. Budget concerns/corrections were addressed along with the reports. Major items of discussion were fund raising, definition of the modes and functions of Project Eagle, and re-location of the AMSAT Lab. These topics are treated separately below.

Two presentations were made by groups seeking to host the meetings in 2007. Pittsburgh, PA, was selected. The meeting concluded after the usual "atta boys and atta girls."

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



This is a working-concept drawing of what the Project Eagle satellite may look like. (Drawing courtesy AMSAT-NA)

Fund Raising

Gunther Meisse, W8GSM, AMSAT Treasurer, opened the discussion and introduced a professional consultant who has been retained by AMSAT to help define the effort needed to raise the funds necessary for Project Eagle, Phase III E, Educational Outreach, and other ongoing projects. General goals were established, but details of the consultant's report were discussed in a closed session due to the proprietary nature of the report. Details of the effort will be made public when finalized. Look for a comprehensive plan that will encompass an effort for establishing funding for the long-term goals of AMSAT.

Definition of the Modes and Functions of Project Eagle

Jim Sanford, WB4GCS, Eagle Project Manager, reported on the progress of Project Eagle to date along with the meetings and discussions held over the last year. Bob McGwier, N4HY, VP of Engineering; Tom Clark, K3IO; Rick Hambly, W2GPS; and other Project Eagle Team Members participated. Of particular importance were the findings of the meeting held in San Diego in June of 2006 and discussions since then regarding activity within the frequency bands over the projected life of the satellite. A lot of this discussion centered on discussions and membership comments made over the internet during the summer. After due consideration, a list of modes and functions was proposed by the team for further consideration by the BoD and adoption. After a thorough review and some modification, a consensus was reached and a vote was taken to proceed with the Eagle design utilizing this approved list as a basis for the modes and functions. This agreement is

AMSAT-NA Signs Agreements to Build Eagle at a UMES Facility

November 21, 2006: AMSAT-NA has accepted an offer to co-locate its Satellite Integration Lab with the Hawk Institute for Space Sciences (HISS), a division of the Maryland Hawk Corporation, which is a 501(c)(3) non-profit educational organization affiliated with the University of Maryland Eastern Shore (UMES). The HISS facilities, currently under construction, are in the Mid-Atlantic Institute for Space and Technology (MIST) building in Pocomoke City, MD, on the Maryland Eastern Shore of the Chesapeake Bay. Maryland Hawk is a member of MIST. HISS is a division/unit of Maryland Hawk. Pocomoke City is about a three-hour drive southeast of the Baltimore-Washington International airport.

AMSAT-NA has been actively searching for a suitable location for the past two years, as AMSAT's most recent lab at the municipal airport in Orlando, FL was condemned due to damage by Hurricane Charley on August 13, 2004. With the unanimous approval of the AMSAT-NA Board of Directors, AMSAT-NA has executed two Memoranda of Understanding, one with the University of Maryland Eastern Shore and the other with Maryland Hawk Corporation, formalizing the relationship. These MOUs give AMSAT-NA essentially no-cost access to the HISS facility in return for sharing its equipment and ideas with HISS. In addition, the agreement with UMES calls for AMSAT-NA to work collaboratively with UMES to identify opportunities to work together on satellite and related technology projects as well as to work with their students and faculty to enhance hands-on studies and dissertation research. The possibility also exists for AMSAT-NA scientists and engineers to receive Adjunct status at the UMES.

AMSAT's VP Engineering, Bob McGwier N4HY, commented "I consider these happenings to be a serious beginning of the activities towards a real spacecraft." AMSAT's lead mechanical engineer, Bob Davis, KF4KSS, is also an employee of HISS, resulting in AMSAT having a representative on site at all times. Bob Davis was AMSAT's mechanical design expert in the Orlando lab during the AO-40 satellite campaign.

HISS is currently constructing the interior walls for its new 8,000-square-foot facility. It is being designed around AMSAT's dual clean room, which was used for AO-40 and is in storage at Florida Space Institute. AMSAT will move the clean room and the parts and equipment currently in storage in the Orlando area to the new lab in the next few months. The facility will also include adequate meeting and office space for visiting AMSAT personnel. The agreement with HISS also provides AMSAT limited access to NASA Wallops Flight Facility with its environmental testing, machine shop, rocket manufacturing, and launch facilities.

AMSAT members Bob Davis, KF4KSS; Rick Hambly, W2GPS; Tom Clark, K3IO; Jim Sanford, WB4GCS; and Bob McGwier, N4HY; have worked very hard on this project. AMSAT members are encouraged to volunteer to work in the new lab, come by and visit (call first), and donate to the P3E and Eagle satellite funds.

a major milestone in the Eagle design and has permitted the Eagle Team to move forward with the design and construction. Some prototyping had already been accomplished, but now the effort can proceed "full steam ahead" within the constraints of available funding. The full list is available on the AMSAT web page and within Eaglepedia (online documentation of the Eagle design).

Relocation of the AMSAT Laboratory

Since the start of construction of AO-40, AMSAT has maintained a laboratory in Orlando, FL. This facility served the program well and has also served several other programs, including manned space efforts, since that time. As an economy move, some of the rented space was released and equipment was moved into less expensive quarters. In recent years, hurricane damage to the quarters has necessitated a search for better quarters. Some of the equipment has been loaned out to schools within the area with a plan of reclaiming the equipment when new permanent quarters can be obtained. Initial search efforts were in the Orlando area.

Within the last year a new laboratory space has been found in Pocomoke City, Maryland (which is near NASA's facilities at Wallops Island, VA), within a new facility being built by the University of Maryland. Upon investigation, this facility offers several advantages:

1. Minimal cost—provided rent-free.

2. Close to the NASA facilities at Wallops Island, VA.

3. Can be used for educational outreach with the University of Maryland branch in the local area.

4. Bob Davis, KF4KSS, already lives and works within the area and has agreed to assume the position of Lab Director and leader of the mechanical design effort. Bob obtained extensive experience with the AO-40 project while it was in Orlando.

5. While not in a major metropolitan area, it is close enough to the Baltimore-Washington area (it is about a three-hour drive southeast of the Baltimore-Washington International Airport) to share some of its advantages without incurring the high housing and food expenses associated with the Baltimore-Washington metro area.

6. The facility is large enough to house all of the efforts associated with Eagle and other known AMSAT efforts.

The BOD directed that efforts to secure an agreement with the owners of this facility proceed as soon as possible. As of this date, the agreement has been reached and AMSAT is proceeding with all possible haste to relocate the AMSAT Lab from Orlando, FL to this new facility near Wallops Island, VA. Please see the accompanying sidebar for the official announcement of AMSAT's agreement.

AMSAT Space Symposium

The AMSAT Space Symposium started on October 6 and ran through October 8. A full agenda of papers kept everyone busy on Friday afternoon, all day Saturday, and Sunday morning. Other "break-out sessions" were held on Friday evening, in addition to the President's Club Reception. Saturday evening included an Attitude Adjustment Hour and the Annual Banquet. Sunday afternoon a tour of the NASA Ames Facility was made available. Prize drawings were held throughout the meeting at the end of each paper preentation to avoid a long prize- drawing session at the banquet.

Papers were presented on topics ranging from Ground Station Design to Space Craft Design, with ample representation of satellite operation, satellites in education, and manned space efforts mixed in. A series of presentations by the Eagle Team on Project Eagle were the highlights of the show. For variety, Gordon Hardman, WØRUN, provided an excellent show on the Peter I DXpedition and the satellite efforts within this DXpedition. Tony Montinero, AA2TX, presented his annual imaginative antenna article.

The featured Saturday evening banquet speaker, Bill McArthur, KC5ACR, Commander of Expedition 12 to the ISS (International Space Station), gave an outstanding presentation of all of his amateur radio activity while he was on board the ISS.

ARISS International Meeting

Once again the annual ARISS International Meeting was held in conjunction with the AMSAT meetings. This one took place on October 9–10. Representatives from all regions, with the exception of Europe, were in attendance. At the appropriate time the European representative attended via Telecon. All officers agreed to serve another year and were re-elected by acclimation. Reports on the activities of each region were presented. Cynthia (Mrs. Bill) McArthur gave an excellent report on the activities of the NASA Education Office.

The "hottest topic" this year was SuitSat-1 and its successor, SuitSat-2. A full report on the successes and problems with SuitSat-1 was presented. A breakout meeting was held to finalize the conceptual design of SuitSat-2. This design was presented to the full meeting for approval and authorization to proceed. Much of the preliminary design has already been done. The design presented for approval includes: solar panels, expanded processor capabilities, a software-defined transponder, and expanded video capabilities. Once again the "fuse is short," with a planned launch from ISS in the fall of 2007. Even though its life will be short, SuitSat-2 will be a full-featured amateur radio satellite.

(Left to right) Astronaut Bill McArthur, KC5ACR; Cosmonaut Sergy Samburov, RV3DR, the Russian ARISS representative; and Frank Bauer, KA3HDO, ARISS International Chairman and AMSAT VP of Manned Spaceflight, at the 2006 AMSAT Symposium banquet just before Sergy is about to make a presentation related to his time onboard the Russian Soyuz spacecraft. (N6CL photo)

One of the last items of discussion was dteremining a host for the 2007 meeting. Sergy Samburov, RV3DR, the ARISS Russia representative, presented a formal invitation to a meeting hosted by ARISS Russia in conjunction with the 50th anniversary of the launch of Sputnik-1 on October 4, 1957. A full six-day agenda is planned, including visits to the home of the Father of Russian Space Activities, Energia, and several other well-known attractions. All present enthusiastically received the invitation and plans are under way for this meeting.

Frank Bauer, KA3HDO, ARISS International Chairman and AMSAT VP of Manned Space Flight, finished out the activity with a report on the direction in which NASA is headed for manned space flight for the future and a challenge for ARISS to become involved early on.

Summary

Once again these meetings proved interesting and useful. Plan to attend the meetings in Pittsburgh in October 2007 and be a part of this activity. It's hard to describe the feelings one has attending one of these meetings, so experience it yourself. There is always something for everyone who is even remotely interested in amateur radio satellites. Support your area hamfests, and by all means, support the efforts of AMSAT to build our new projects—P3-E and Eagle.

73, Keith, W5IU

LDG Electronics

Recently Introduced Specialty Items

The LDG RCA-14 breakout box.

LDG Electronics, the St. Leonard, Maryland based ham radio equipment manufacturer, recently introduced two ham accessories, the RCA-14 breakout box and the Multi-DC power supply.

"The RCA-14 is a breakout box for the accessory jacks on most popular transceivers."

The RCA-14 is a breakout box for the accessory jacks on most popular transceivers. It comes with cables with the right DIN plugs, and all the outputs are simple RCA jacks. Simply plug the RCA-14 into your radio's accessory jacks, and all your ports are right there at your fingertips; just plug and play, one function or all of them. Also, you can change things around as often as you like; it's as simple as swapping out an RCA plug.

The Multi-DC is a simple DC distribution box with one 12-VDC input and six outputs. The provided cables have the right coaxial DC power plug to connect

LDG's Multi-DC distribution box.

"The Multi-DC is a simple DC distribution box with one 12-VDC input and six outputs.

to all LDG products. The Multi-DC can source up to three amps; each of the six outputs can provide up to .5 amps to LDG accessories. The Multi-DC comes with an input cable and six output cables, each 3 feet long.

"These two products solve two distinct ham problems," said Dwayne Kincaid, LDG's Chief Engineer, "The RCA-14 solves your cable problems and the Multi-DC solves your power problems. We continue to innovate with an eye toward solving the problems and annoyances hams encounter every day."

These two products continue a trend started in 2005 when LDG released the TW-1 talking wattmeter. "LDG is more than an autotuner company. We will continue to look for opportunities to develop innovative ham accessories in addition to state-of-the-art autotuners," added Kincaid.

"These two products solve two distinct ham problems," said Dwayne Kincaid, LDG's Chief Engineer, "The RCA-14 solves your cable problems and the Multi-DC solves your power problems."

The RCA-14 and Multi-DC were just several new products by LDG for 2006. Other products introduced were the FT Meter for Yaezu FT-857 and FT-897 radios; the AT-200PC, the first autotuner designed specifically for PC controlled radios; and the AT-7000, a simple-to-use autotuner for the ICOM IC-7000.

Contact information: Dwayne Kincaid LDG Electronics, Inc., 1445 Parran Rd., St. Leonard, MD 20685 (phone 410-586-2177; fax 410-586-8475; e-mail: <ldg@ ldgelectronics.com>; on the web: <www.ldgelectronics.com> ■

By Chuck Houghton,* WB6IGP

MICROWAVE

Above and Beyond, 1296 MHz and Up

Tricks of the Trade Construction Methods

There are many tricks that can be used in the construction of microwave equipment, and quite a few of them are related to support equipment. We all would like to have milled out blocks of aluminum to use for our devices. However, the reality is that it is better to use simple, inexpensive, readily available containers in which to construct our power supplies and then assemble related switching equipment on a simple substrate. For heavy component parts, mounting the parts and equipment on an aluminum plate is most desirable. The aluminum might not be available at a reasonable price, though.

A suitable alternative that is reasonable in price is a new, blank, copper printed circuit board, which can serve almost as well as an aluminum plate. The copper board can be used for mounting small circircuitry assembled in the old, traditional "dead bug style." With this method the component parts are attached by their ground leads for connection to the copper PC board top section ground, usually the top foil. This ground foil is used to connect the devices to common ground, and it works well. It is also easy to attach additional shields of copper material for high-gain circuits to prevent feedback paths. It's easy to experiment to see just where feedback/oscillations on the PC board are taking place, and then add bits of copper foil pieces in the right spots to stop the feedback paths. Additional cuts in the ground foil can be made with a section of metal or a scrap section of PC board material used as a straight edge. Making these cuts in the ground foil material produces a variety of isolated islands to suit circuit connections. These isolated islands now add signal paths so other portions of components can use connectivity similar to the grounded foil by soldering these other portions of components to the now isolated copper foil.

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

The bottom of my 1296-MHz rig showing components attached by the RTV sealant method. The wiring of devices is done by tying one end only, making the other end ready to run to the other leads. When the back lead is soldered, the wiring routing will have a neat appearance on the bottom of the chassis. The case is from a Qualcomm computer assembly. I took out the computer control devices and installed the 1296-MHz amps, mixers, and power-supply components. I was able to obtain five cases and use them for 1296, 2304, 3456, and 5760 MHz, and 10 GHz.

When assembling small power supplies and types of circuits with few parts, this method works well. The same "dead bug" method of construction can be used when mounting larger components, but with a little twist.

When mounting somewhat larger components, such as DC-to-DC switching power supply devices, stack two or three of the small DC switching power supplies to the copper plate. Here is where the mounting of these power supplies and other component devices that have a flat surface can be easy. Most of these devices have connection leads on one side and a flat surface on the other side, making attachment with nuts and bolts one solution for things such as microwave mixers, amplifiers, and coax relays of the SMA type.

There are, however, no mounting lugs or holes on the DC supplies. The solution to this problem is quite inexpensive and simple. For the DC supplies, or other devices with a similar mounting structure, lay the supplies or other circuitry dead-bug style on the copper or aluminum plate and mark out the area to which the device is to be attached. Draw out the mounting area with a pencil. Then take a small tube of RTV silicon caulking and deposit a suitable amount of it on the bottom of the DC supply. Place the supply on the mounting area you marked out on the bottom plate and let the RTV dry. It will set overnight. The RTV I recommend comes in a blue, large toothpaste-like tube and can be obtained in most auto supply stores. As an added bonus, using RTV, the DC supply can be pried off the plate with a screwdriver for use in other projects.

I have used this technique for mounting microwave mixers, coax switching relays, as well as DC-to-DC switching power supplies that were used to increase the DC voltage to power 24-volt coax relays. A 12-volt main DC supply was increased to just over 24 volts by stacking a few 5- to 9-volt miniature DC switching supplies. These miniature switching supplies are the size of three to four postage stamps, making them very versatile.

These are just a few of the simple projects that can be accomplished using RTV to mount components.

The above having been achieved, now all you have to do is locate a suitable container into which to place the device. Local swap meets can be a great source of aluminum boxes (chassis). They can come from similar-size defective test equipment, such as Hewlett Packard 432 power meters for small projects. Older HP 431 power meters are good for slightly larger projects, and other rack-mounted test equipment works for large projects. These shells often can be obtained for a song and make very nice microwave converter chassis. The price is usually quite inexpensive compared to commercial cabinets. A suitable chassis, let's say from a Hewlett Packard piece of equipment, will give you a look very similar to other microwave converters.

Erector Sets – A New Use

While I was writing this column, another useful chassis construction aid was discovered. I was watching the Discovery channel, and a program featured an engineering mockup of California Adventure, the latest ride at Disneyland. Engineers at Disneyland had used material from a child's Erector Set to visualize the new ride rather than use a paper blueprint drawing. It was a quite versatile tool for a mock-up, and it would be good, too, as a mounting aid for various components in a microwave converter project.

My next project will incorporate some of the Erector Set parts—that is, if I can get permission from my two grandchildren, who just constructed a ferris wheel from parts of the three Erector Sets we bought many years ago. All of this goes to show that a good junk box, as well as some unexpected other bits and pieces, can help out in assembling many different projects.

Heat Guns

Well, back to circuit boards and using components recovered from used PC boards for other projects.

Desoldering components from surplus boards can be a rough job. It can be tough even with a quality, grounded, temperature-controlled soldering iron and an Xacto™ knife (allowing room to use the Xacto™ knife to heat and pry the component off the PC board).

Another technique can be used with simplicity. The solution is to purchase a heat gun, which is much like a hair dryer. The heat gun can be obtained at a hardware store in the form of a paint-removal heat gun. The one I have is MFG by Super Stripper. It has two power levels, low and high, with the high power level being 1500 watts. The heat gun will desolder components on a PC board in just under 2½ minutes. When the parts start to come loose on the PC board, use a pair of tweezers to remove the components desired. If you want to remove a large quantity of components, place a piece of paper on the work bench and prop up the PC board vertically. Tap the rear of the board while heating the front of the board, which will release the heated components, and then they will fall onto the paper.

I modified my heat gun by using a copper plumbing reduction fitting to limit the area that could be blown on (heated). This prevents the gun's large opening from blowing unwanted parts off the board, and the paper from being blown onto the floor. The heat gun I have has a main opening of 2 inches. Selecting a 2-inch to ½-inch copper pipe adapter fitting made the heat gun more manageable. It will still blow parts off the board being desoldered, but it is more controllable with the fitting. To make the adapter a tight fit to the heat gun, jam-fit a few wraps of tin foil to hold the adapter tight on the end of the heat gun.

Remember, as with anything that is hot and/or shoots flames, use safety glasses and work with one component at a time for maximum safety.

This time we presented a few construction tips that can be used quite easily. Do you have a technique that you would like to share with others? If so, please send it to me for this column. I would appreciate any input you have. As always, too, I will be glad to answer any questions.

73, Chuck, WB6IGP

CQ's 6 Meter and Satellite WAZ Awards

(As of January 1, 2007)

By Floyd Gerald,* N5FG, CQ WAZ Award Manager

6 Meter Worked All Zones

No.	Callsign	Zones needed to have all 40 confirmed
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	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	1,2,3,6,10,12,18,19,23,32
26	W1AIM	16,17,18,19,20,21,22,23,24,26,28,29,30,34
27	K1LPS	16,17,18,19,21,22,23,24,26,27,28,29,30,34,37
28	W3NZL	17,18,19,21,22,23,24,26,27,28,29,34
29	K1AE	2,16,17,18,19,21,22,23,24,25,26,28,29,30,34,36
30	IW9CER	1,2,6,18,19,23,26,29,32
31	IT9IPQ	1,2,3,6,18,19,23,26,29,32
32	G4BWP	1,2,3,6,12,18,19,22,23,24,30,31,32
33	LZ2CC	1
34	K6MIO/KH6	16,17,18,19,23,26,34,35,37,40
35	K3KYR	17,18,19,21,22,23,24,25,26,28,29,30,34
36	YV1DIG	1,2,17,18,19,21,23,24,26,27,29,34,40
37	KØAZ	16,17,18,19,21,22,23,24,26,28,29,34,39
38	WB8XX	17,18,19,21,22,23,24,26,28,29,34,37,39
39	K1MS	2,17,18,19,21,22,23,24,25,26,28,29,30,34
40	ES2RJ	1,2,3,10,12,13,19,23,32,39
41	NW5E	17,18,19,21,22,23,24,26,27,28,29,30,34,37,39
42	ON4AOI	1,18,19,23,32
43	N3DB	17,18,19,21,22,23,24,25,26,27,28,29,30,34,36
44	K4ZOO	2,16,17,18,19,21,22,23,24,25,26,27,28,29,34
45	G3VOF	1,3,12,18,19,23,28,29,31,32
46	ES2WX	1,2,3,10,12,13,19,31,32,39
47	IW2CAM	1,2,3,6,9,10,12,18,19,22,23,27,28,29,32
48	OE4WHG	1,2,3,6,7,10,12,13,18,19,23,28,32,40
49	TI5KD	2,17,18,19,21,22,23,26,27,34,35,37,38,39
50	W9RPM	2,17,18,19,21,22,23,24,26,29,34,37
51	N8KOL	17,18,19,21,22,23,24,26,28,29,30,34,35,39
52	K2YOF	17,18,19,21,22,23,24,25,26,28,29,30,32,34
53	WA1ECF	17,18,19,21,23,24,25,26,27,28,29,30,34,36
54	W4TJ	17,18,19,21,22,23,24,25,26,27,28,29,34,39
55	JM1SZY	2,18,34,40
56	SM6FHZ	1,2,3,6,12,18,19,23,31,32
57	N6KK	15,16,17,18,19,20,21,22,23,24,34,35,37,38,40
58	NH7RO	1,2,17,18,19,21,22,23,28,34,35,37,38,39,40
59	OK1MP	1,2,3,10,13,18,19,23,28,32
60	W9JUV	2,17,18,19,21,22,23,24,26,28,29,30,34
61	K9AB	2,16,17,18,19,21,22,23,24,26,28,29,30,34
62	W2MPK	2,12,17,18,19,21,22,23,24,26,28,29,30,34,36
63	K3XA	17,18,19,21,22,23,24,25,26,27,28,29,30,34,36
64	KB4CRT	2,17,18,19,21,22,23,24,26,28,29,34,36,37,39
65	JH7IFR	2,5,9,10,18,23,34,36,38,40
66	KØSQ	16,17,18,19,20,21,22,23,24,26,28,29,34
67	W3TC	17,18,19,21,22,23,24,26,28,29,30,34
68	IKØPEA	1,2,3,6,7,10,18,19,22,23,26,28,29,31,32
69	W4UDH	16,17,18,19,21,22,23,24,26,27,28,29,30,34,39
70	VR2XMT	2,5,6,9,18,23,40
71	EH9IB	1,2,3,6,10,17,18,19,23,27,28
72	K4MQG	17,18,19,21,22,23,24,25,26,28,29,30,34,39
73	JF6EZY	2,4,5,6,9,19,34,35,36,40
74	VE1YX	17,18,19,23,24,26,28,29,30,34
75	OK1VBN	1,2,3,6,7,10,12,18,19,22,23,24,32,34
76	UT7QF	1,2,3,6,10,12,13,19,24,26,30,31
77	K5NA	16,17,18,19,21,22,23,24,26,28,29,33,37,39
78	I4EAT	1,2,6,10,18,19,23,32
79	W3BTX	17,18,19,22,23,26,34,37,38
80	JH1HHC	2,5,7,9,18,34,35,37,40.

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
23	VR2XMT	01 May 06	2,5,8,9,10,11,12,13,23,34,40

CQ offers the Satellite Work All Zones award for stations who confirm a minimum of 25 zones worked via amateur radio satellite. In 2001 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>.

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

By Bob Witte,* KØNR

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

Basic Frequency Modulation Theory

The concept of frequency modulation in radio communications was first described by Armstrong back in 1936.[1] FM continues to be a very popular mode with radio amateurs, especially on the 144-, 222-, and 440-MHz bands. Despite the widespread use of FM, some of its characteristics are not well understood. This article is a review of the basics of FM theory and is based heavily on an article I wrote that was originally published in *QST*.[2]

Modulation Techniques

A review of the common analog modulation techniques will help put FM into perspective. Mathematically, we can represent a radio signal as a sinusoid:

$$v(t) = A\cos(2\pi ft + \theta)$$

where

A is the peak amplitude of the signal
θ is the relative phase of the signal
f is the carrier frequency
t is time

If we keep the amplitude A and the phase θ constant, we have an unmodulated carrier or continuous wave (CW). If we keep the phase constant but modulate the amplitude, amplitude modulation is produced. Similarly, we can adjust the phase of the carrier with the modulating to produce phase or frequency modulation.

Phase modulation (PM) and frequency modulation (FM) are closely related and together are called *angle modulation.* Generally, PM and FM can be derived from each other by filtering the modulating signal, often referred to as adding *pre-emphasis* or *de-emphasis* to the audio signal. Phase modulation is, in fact, the industry standard.[3] However, since the conventional ham radio terminology is "frequency modulation," I will use that terminology here. I am not going to cover pre-emphasis and de-emphasis in this article. Maintaining a flat audio response in FM repeater systems does require some understanding and care. Refer to the article by Jeff Stouffer, K6JSI, in the Winter 2005 issue of *CQ VHF* for more insight on how to keep your repeater audio sounding great.[4]

*21060 Capella Drive, Monument, CO 80132
e-mail: <bob@k0nr.com>

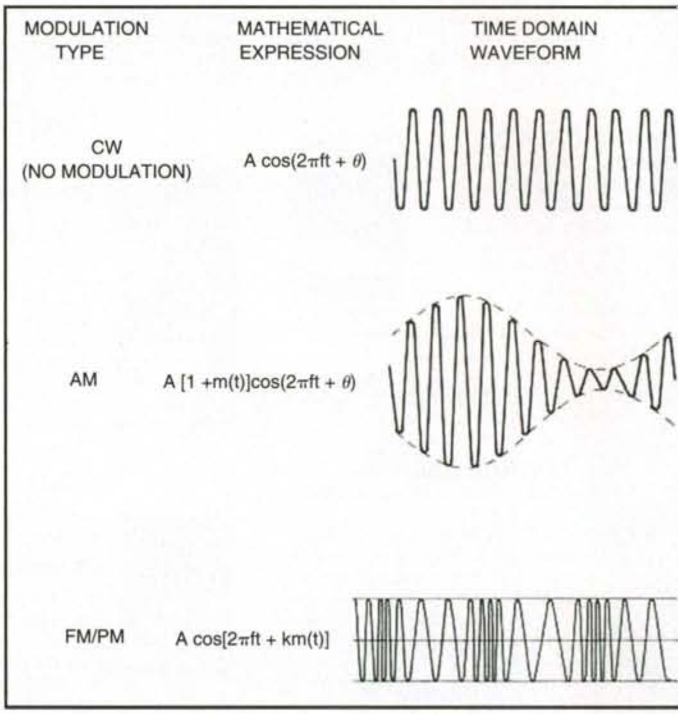


Figure 1. Comparison of common modulation techniques.

The mathematical expression for CW, AM, and FM/PM and the waveform of each signal is shown in figure 1. Single-sideband modulation is the most common form used on the HF bands. It is a version of AM that increases the efficiency of the system by eliminating the power in the carrier and one of the sidebands.[5] Since the RF spectrum of an SSB signal is just a frequency-shifted version of the modulating signal, the bandwidths of the two signals are the same. Our focus in this article is on FM, but SSB provides an important standard of comparison. Figure 2 shows the spectrum of the modulating signal and

β	Carrier	1st SB	2nd SB	3rd SB	4th SB	5th SB	6th SB	7th SB	8th SB
0.1	0.997	0.050	—	—	—	—	—	—	—
0.2	0.990	0.100	—	—	—	—	—	—	—
0.5	0.938	0.242	0.031	—	—	—	—	—	—
1.0	0.765	0.440	0.115	0.020	—	—	—	—	—
2.0	0.224	0.577	0.353	0.129	0.034	—	—	—	—
5.0	-0.178	-0.328	0.047	0.365	0.391	0.261	0.131	0.053	0.018

Table 1. FM sidebands with sinusoidal modulation. Values shown are the amplitude relative to an unmodulated carrier and are for both upper and lower sidebands. Odd-numbered lower sidebands are 180 degrees out of phase with the upper sideband. Negative values indicate 180-degree phase shift.

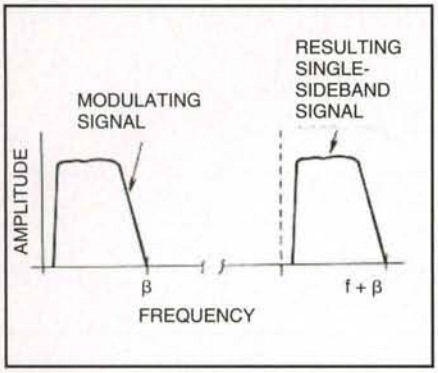


Figure 2. For single-sideband modulation, the bandwidth of the modulating signal and the resulting RF signal are the same.

that of the resulting SSB signal (in this case, upper sideband).

Frequency Modulation

When we frequency modulate a signal, we instantaneously adjust the carrier's frequency according to the modulating signal. An FM signal is described by its *frequency deviation,* which is the instantaneous change away from the carrier frequency, and by the *modulation index,* which is defined as:

Modulation index (β) =
freq. deviation/modulation freq.

Since voice modulation is a complex signal that varies dramatically in amplitude, we usually focus on the *maximum frequency deviation,* the frequency deviation that occurs at the peaks of the modulating signal. Analysis of FM signals is difficult in the general case, but is manageable for sinusoidal modulation. For sinusoidal modulation, these sidebands behave according to a class of mathematical functions called *Bessel functions.* Table 1 lists the relative amplitude of values associated with each sideband, depending on the modulation index. The sidebands are spaced at integral multiples of the modulating frequency away from the carrier. Unlike AM/SSB signals, FM signals theoretically have an unlimited number of sidebands. Sideband values less than 0.01 (corresponding to sideband amplitudes that are 40 dB below the carrier)[6] are not shown in Table 1. FM has upper and lower sidebands that are equal in amplitude but may be 180 degrees out of phase (shown with a negative sign in Table 1). Note that the amplitude of the carrier changes with the modulation index as the energy in the carrier is distributed across the sidebands. In fact, for β of 2.4, the carrier amplitude is zero. Figure 3A shows the spectrum of a typical FM signal with a modulation index of 1.0.

FM Bandwidth

We often refer to FM as either *narrowband* or *wideband.* In communication theory, narrowband FM is usually defined as an FM signal that occupies the same bandwidth as an AM signal with the same modulation applied.[7] Recall that the bandwidth of an AM signal is twice the modulating signal bandwidth. Since the signal shown in figure 3A has several significant sidebands, it is clearly not a narrowband signal. Given the nature of FM sidebands, the specific dividing line between wideband and narrowband is a bit fuzzy. It depends on what level of sidebands is ignored, but narrowband is usually taken as less than 0.2 to 0.5 (see Schwartz, note 7). The spectrum and performance of narrowband FM is identical to AM except that the lower sideband of narrowband PM is 180 degrees out of phase with respect to its AM counterpart, as shown in figure 3B.

The terms wideband and narrowband get tossed around in the amateur world to mean a variety of things. Let's start with broadcast FM, which in the U.S. has a frequency deviation of 75 kHz and a maximum modulating frequency of 15 kHz, resulting in β = 75 kHz/15 kHz = 5. From Table 1, we see that this signal has roughly eight significant sidebands on each side of the carrier. Clearly, this is a wideband signal. Modern ham transceivers may include the ability to receive FM broadcast signals, calling this feature *wideband FM receive.*

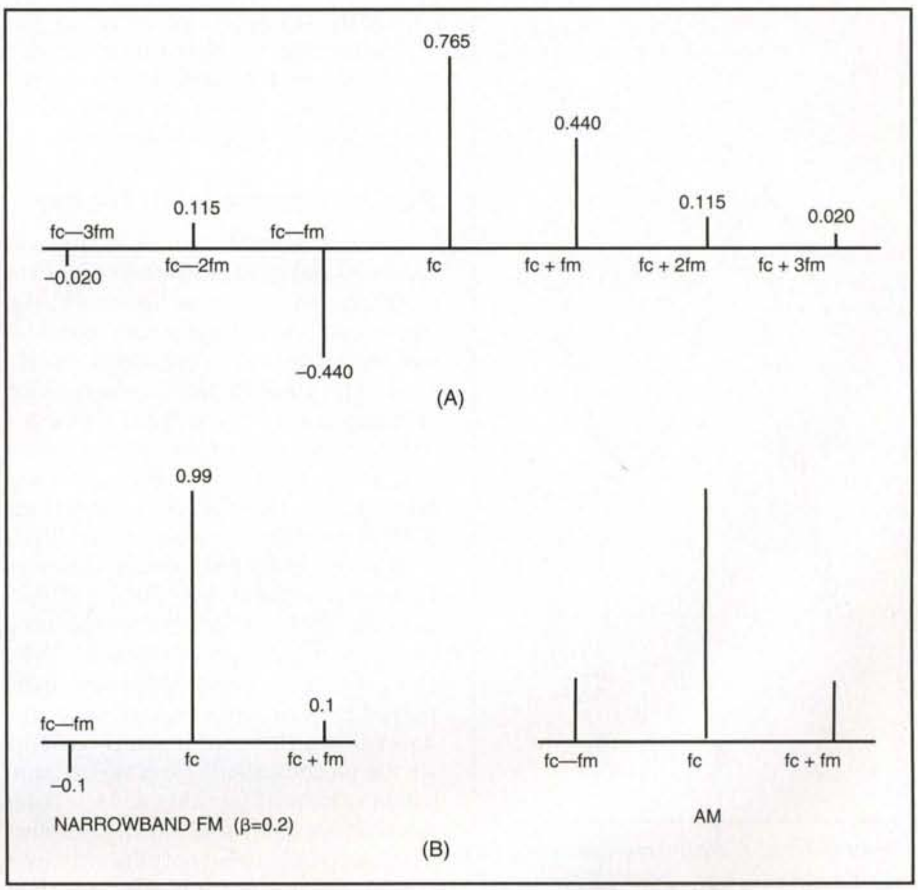


Figure 3. (A) A wideband FM signal with sinusoidal modulation, with modulation index of 1.0. (B) True narrowband FM and AM spectrums are alike, but with the lower sideband of the FM signal 180 degrees out of phase (indicated by the minus sign).

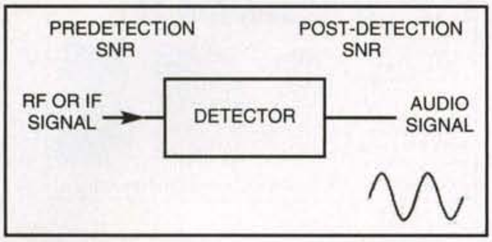


Figure 4. The SNR into the detector determines the SNR out of the detector.

Most FM operation on the ham bands has a maximum frequency deviation of 5 kHz. There was a time when 15-kHz deviation was common, so hams used to refer to 15-kHz deviation as wideband and 5-kHz deviation as narrowband. Just to make things even more confusing, some modern FM transceivers can drop their maximum frequency deviation in half to 2.5 kHz, creating an even narrowerband FM.

Focusing just on the 5-kHz deviation FM, for a maximum modulation frequency of 3 kHz, $\beta = 5 \text{ kHz}/3 \text{ kHz} = 1.67$. This clearly is *not* narrowband, as defined by communications theory. Keep in mind that for any particular frequency, the modulation index may be even higher. For example, for a modulating frequency of 1 kHz, $\beta = 5 \text{ kHz}/1 \text{ kHz} = 5$. This may seem like trivial nomenclature, but it is important, because there are certain characteristics associated with wideband or narrowband FM, and improper use of the terms confuses the situation.

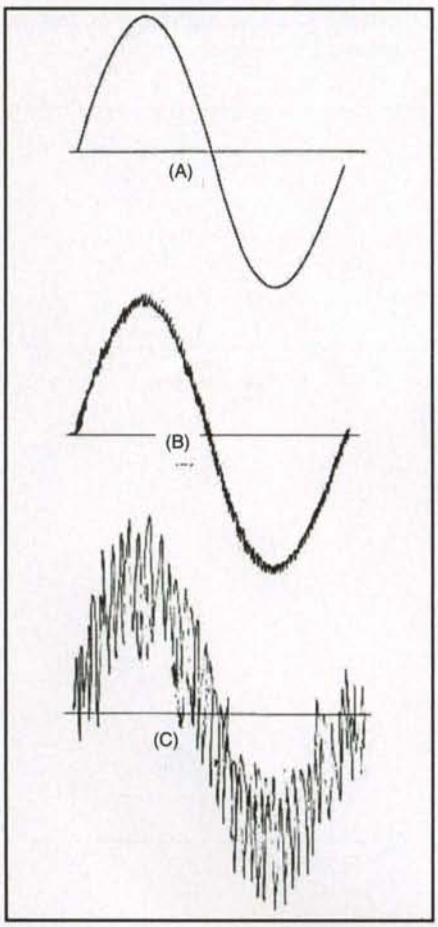


Figure 5. (A) A noise-free sine wave. (B) A sine wave with noise added (zero crossings are easy to determine). (C) A sine wave with a large amount of noise, causes the zero crossings to be difficult to detect.

Table 1 is applicable for simple sinusoidal modulation and does not represent the more common case of complex, multi-frequency modulation. For typical communication signals, Carson's Rule[8] is used to estimate the signal bandwidth:

FM bandwidth = 2 (deviation + modulating-signal bandwidth)

For 5-kHz amateur radio FM, this results in a bandwidth of:

FM bandwidth = 2 (5 kHz + 3 kHz) = 16 kHz

Note that for very large deviations, the FM bandwidth is approximately twice the deviation; for small deviations, the FM bandwidth is approximately twice the modulating signal bandwidth.

Performance with Noise

In a real communications system, noise is present and must be taken into account to determine system performance. An important figure of merit for a modulation technique is a comparison of the signal-to-noise ratio (SNR) into the detector (predetection SNR), and the signal-to-noise ratio out of the detector (post-detection SNR) (see figure 4). Because of the linear nature of SSB, the predetection SNR is equal to the post-detection SNR.

In a wideband FM system, the relationship is not so simple. For a high predetection SNR, an FM detector produces an even higher post-detection SNR. However, for a low-predetection SNR, the FM detector performs poorly and produces an even lower post-detection SNR. As the predetection SNR is varied from a high value to a low value, at some point the post-detection SNR rapidly decreases. This point is commonly known as the *noise threshold,* and this effect is called the *threshold effect.*

FM noise performance and threshold effect can be viewed graphically as shown in figure 5. The frequency of a sine-wave carrier (figure 5A) is determined by how many times the waveform crosses zero in one second. With a noise-free signal, this is easy to do, both visually by the reader as well as electronically by an FM detector. Usually, the FM signal is passed through a limiter that removes any amplitude variation, and then into a circuit that converts the frequency into a voltage. Figure 5B shows a sine wave plus noise, but with a relatively high SNR. The zero crossings of this signal are still easy to determine, because the signal dominates the noise. A signal with a low SNR (figure 5C), however, has zero crossings that are less obvious for the reader, and are harder for an FM receiver to detect. Thus, with a high SNR, the frequency of a signal is easily determined, and any FM can be detected. However, with a low SNR, the frequency is difficult to determine, and attempts to extract the modulating signal will result in a noisy signal.

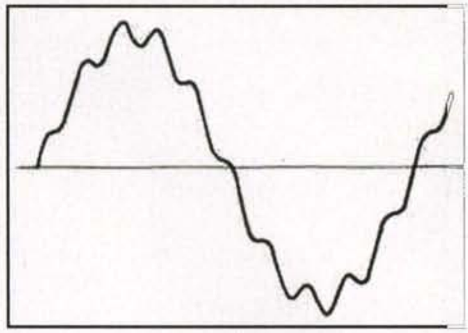


Figure 6. Two sinusoids, one much larger than the other, are combined into one waveform. The larger of the two sinusoids determines the zero crossings (and the frequency).

Like many wideband-modulation techniques, FM offers the potential of trading increased signal bandwidth for increased post-detection SNR, as long as the detector is operating above the noise threshold. As the FM deviation is increased, the SNR increases. FM broadcast stations use wideband FM to transmit high-quality audio signals. The deviation cannot be made arbitrarily high, because the increased bandwidth in the receiver lets in increased noise, which eventually causes the detector to operate below the noise threshold. Also, the higher the deviation, the more pronounced the threshold effect.

Capture Effect

SSB signals tend to add linearly, according to their relative amplitudes.

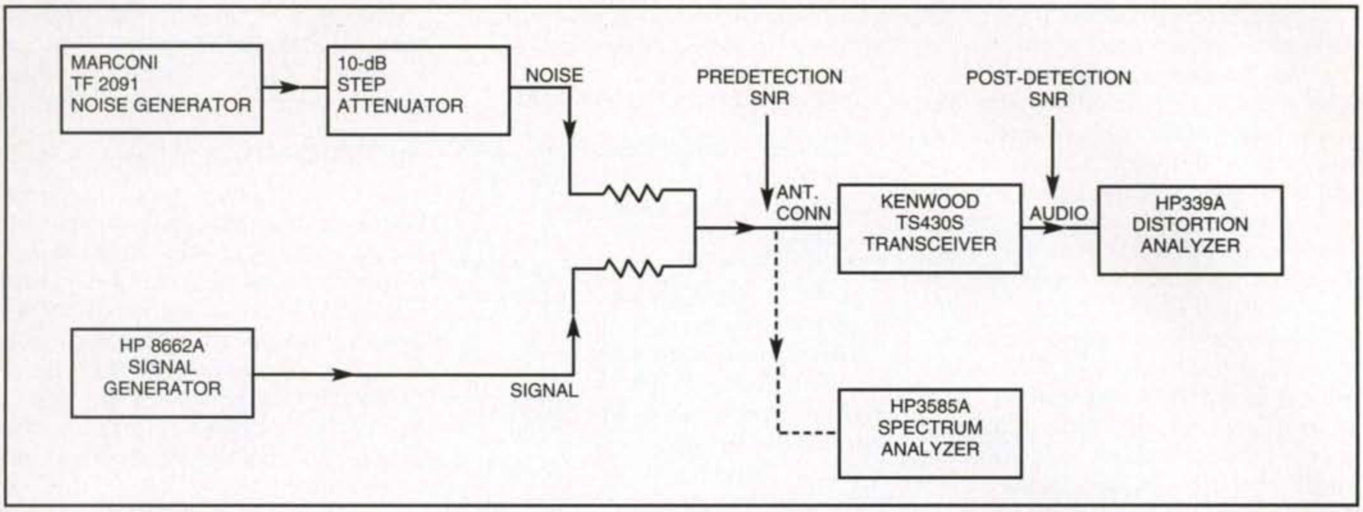


Figure 7. The test setup for measuring post-detection SNR versus pre-detection SNR for the Kenwood TS-430S transceiver.

Thus, two stations transmitting at the same time may both be heard. This is not usually true for wideband FM. The stronger of two FM signals will be heard clearly, often completely overriding the weaker signal. This is known as the *capture effect,* as the larger signal is said to "capture" the receiver. This is similar to the threshold effect: A large FM signal has the ability to overcome smaller perturbations, such as other signals or noise.

Figure 6 shows two signals, one much larger than the other, added together. For clarity, the smaller waveform is shown as having a much higher frequency than the larger waveform. Note that the larger waveform dominates and will determine when the combined waveform will cross zero. Therefore, a frequency detector will tend to respond to the larger signal and ignore the smaller signal.

FM vs. SSB

It is interesting to compare the characteristics of FM and SSB, since SSB is considered the most efficient analog voice modulation technique, commonly used on HF and the VHF bands. This comparison has been done in a variety of papers and textbooks for the general case[9], but here we will compare amateur radio FM and SSB signals. Amateur FM is assumed to have a 5-kHz deviation and be modulated with audio that is band-limited to 3 kHz. SSB has no equivalent modulation parameter, but again the audio signal is assumed to be band-limited to 3 kHz.

Since an SSB signal has the same bandwidth as the modulating signal, the SSB bandwidth is 3 kHz. Again, since an FM signal has potentially infinite bandwidth, the practical bandwidth depends on how small the sidebands have to be before they can be ignored. One source gives the bandwidth of an amateur FM signal with a 5-kHz deviation as 22 kHz (ignoring sidebands that are less than 1 percent of the original carrier).[10] Carson's Rule gives the bandwidth to be 16 kHz. Both of these estimates show why the 15-kHz channel spacing used in many parts of the U.S. on 2 meters may be a little too tight unless geographic separation is used between stations on adjacent channels. This also explains why FM is used only on the wider amateur bands, as it uses much more of the spectrum than SSB.

One might ask, "What performance difference would be noticed if the modulation was switched from SSB to FM on a modern ham transceiver?" The performance of a Kenwood TS-430S multimode HF transceiver (with FM option installed) was measured using the test setup of figure 7. The signal generator output and the noise generator output mix to produce a known SNR at the input of the transceiver. All measurements were made at 29 MHz, but similar results would be expected if conducted at VHF or UHF, since this is a test of the IF /detector portion of the transceiver. The noise level at the input of the transceiver was set to a level consistent with typical atmospheric noise.

The signal level was varied to produce different SNRs at the input of the transceiver. For SSB testing, a pure sine wave

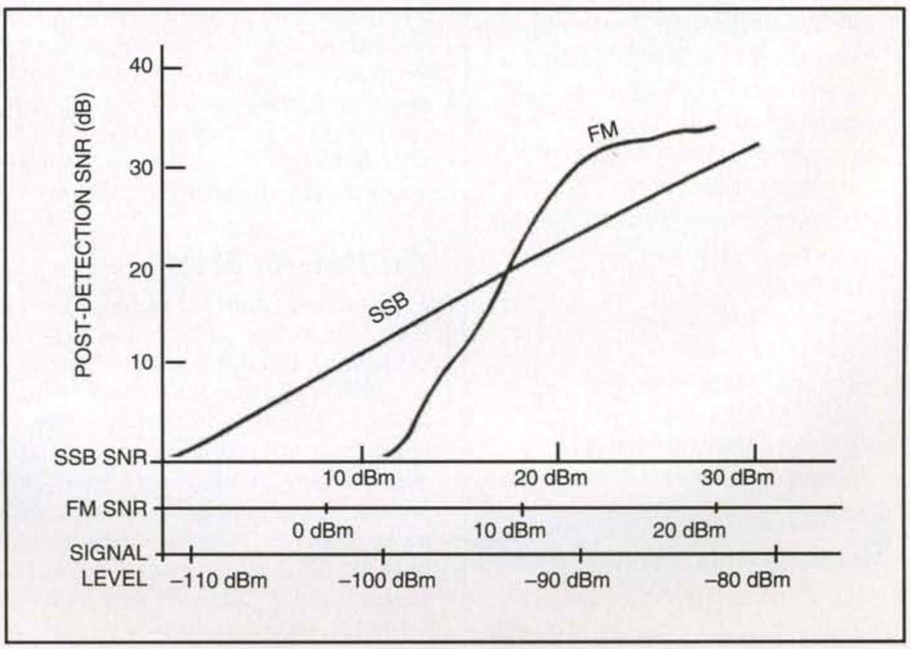


Figure 8. Measured data for the Kenwood TS-430S transceiver.

was used, set to produce a 1-kHz audio tone in the transceiver. For FM, the carrier was frequency-modulated with a 1-kHz signal at a deviation of 5 kHz. The audio output of the transceiver was connected to the distortion analyzer. It compares the power in the signal with the power in the signal after the audio test frequency has been notched out. This results in a SINAD measurement, which was converted to SNR.[11]

The results (figure 8) show the expected straight-line behavior of SSB, and the roll off of post-detection SNR for FM at a low predetection SNR. Changing modes between FM and SSB will result in different IF bandwidths, and hence different SNRs. The horizontal axis shows SSB SNR and FM SNR, which differ by 8 dB. This offset is found by taking the ratio of the two nominal receiver bandwidths in decibels. The offset is:

$$10 \log (15 \text{ kHz}/2.4 \text{ kHz}) = 8 \text{ dB}$$

an approximation, since nominal bandwidth instead of noise equivalent bandwidth is used. Thus, for any given signal level, the SSB SNR is different from the FM SNR (by 8 dB). The plot is representative of actual operation, because the noise level is held constant.

The two modulation schemes are equal at an SSB SNR of 17 dB. The FM threshold (the level at which the FM performance starts degrading rapidly) is around 10–12 dB. This is consistent with the theoretical predictions (see Schwartz, note 7). The horizontal-scale signal level is included to emphasize the comparison of FM and SSB at a constant *signal* level (as opposed to a constant SNR). The absolute value of the signal level is not significant, since the SNR depends on the original choice of noise level.

To highlight the performance differences, consider the case where the SSB SNR is 10 dB. This is a very usable signal, easy to copy, by typical weak-signal operating standards. At this same signal level, the recovered FM signal has crashed into the noise, producing something less than 0-dB SNR. This is due to the threshold effect found in wideband FM *and* the wider IF bandwidth of the FM signal letting in more noise.

The TS-430S generates about 100 watts of RF power output in the SSB mode and 50 watts in the FM mode. This would add 3 dB in favor of SSB if two TS-430s were in QSO, but this is left for the reader to assess. A check of more recent multimode HF/VHF transceivers' (the FT-897, IC-746Pro, TS-570, TS-480) datasheets shows that the rated RF output power is the same for SSB and FM.

On-the-Air Tests

Theoretical analysis combined with bench tests is great, but it is also useful to see how the theory plays out in practice. In 1999, my daughter Sara Witte, KCØAMO, performed a ham radio experiment for a regional science fair and the results were published in *CQ VHF*.[12] This experiment used on-the-air signal reports to characterize the relative performance of FM and SSB, using a Yaesu FT-847 on the 2-meter band. As expected, with high signal levels, FM was generally superior to SSB in terms of readability. With decreasing signal level, the experiment confirmed that the weak-signal performance of SSB faded away slowly, while the FM performance experienced a dramatic drop associated with the threshold effect.

Summary

This article gave a tour through the basics of frequency modulation. We looked at the bandwidth of FM signals and noted that the terms narrowband and wideband FM can mean a number of different things in ham radio. Using the strict definition of narrowband FM (same bandwidth as an equivalent AM signal), amateur FM is wideband. This means that amateur FM exhibits the threshold and capture effects.

Comparing FM with SSB, we see that SSB is superior at low signal levels, but FM is usable on HF and VHF as long as the signal levels are high enough. FM has the advantage of better overall audio quality, as long as the signals are strong enough to stay above the threshold effect.

That's all for this issue. Let me know what you are doing with FM VHF by sending me an e-mail or dropping by my weblog: <http://www.k0nr.com/blog/>.

Notes

1. Edwin H. Armstrong, "A Method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation," published in May 1936 by the Institute of Radio Engineers (IRE).

2. Robert A. Witte KBØCY, "A Close Look at Frequency Modulation," *QST*, September 1985 (used with permission).

3. Cobb, "Modulation Standards for VHF FM," *Ham Radio*, June 1970.

4. Jeff Stouffer, K6JSI, "Flat Audio," *CQ VHF*, Winter 2005.

5. Ziemer and Tranter, *Principles of Communications* (Boston: Houghton Mifflin Co., 1976).

6. dBc = 20 log (0.01) = –40 dB

7. Schwartz, *Information Transmission, Modulation and Noise* (New York: McGraw-Hill Book Co., 1980).

8. Schwartz, *Information Transmission, Modulation and Noise* (New York: McGraw-Hill Book Co., 1980).

9. Crosby, "Frequency Modulation Noise Characteristics," *Proceedings of the Institute of Radio Engineers*, April 1937.

10. Maylott, "Close Look at Amateur FM," *Ham Radio*, August 1979.

11. SINAD is the ratio of total signal power (Signal + Noise + Distortion) to unwanted signal power (Noise + Distortion). For our purposes, distortion is lumped with the noise, so SNR = SINAD – 1

12. Sara Witte, KCØAMO, and Bob Witte, KBØCY, "Which is Really Better? AM, FM or SSB?" *CQ VHF*, September 1999.

By Tomas Hood,* NW7US/AAA0WA

PROPAGATION

The Science of Predicting VHF-and-Above Radio Conditions

A Call to Action

You will know from past editions of this column that I believe in you. In your care you have the future of amateur radio and the potential to impact the world of communication. In addition, you have the chance to make a positive difference in the lives of people around the world. It is true. The radio amateur has traditionally brought new technology, methods, and skills into the light of the modern day. It was an amateur scientist who became an amateur radio pioneer and ushered in the era of radio: Guglielmo Marconi.

Guglielmo Marconi, a self-taught 21-year-old from Bologna, Italy, was convinced through his experiments that it was possible to send signals by using electromagnetic waves. His first "DX" attempt was over a very short distance—100 meters between his house and the end of his garden. Excited with that success, he demonstrated that these waves could propagate through the ether between two points separated by an obstacle.

At the time, 1895, the general view held by scientists and other experts was that electromagnetic waves could only be propagated in a straight line and then only if there was nothing in the way. Moreover, this common view held that the main obstacle to these waves was the curvature of the Earth's surface.

Marconi was a true pioneer and never allowed the tide of popular scientific opinions to deter him from his love of amateur science. Like every self-taught amateur scientist and hobbyist, he was more interested in pragmatic application and experimentation than pure theory. Armed with resolve and deep investigative dedication, he continued to improve his experimental equipment and pushed every limit he could think of. He placed his transmitter near his house and the receiver 3 kilometers away, behind a hill.

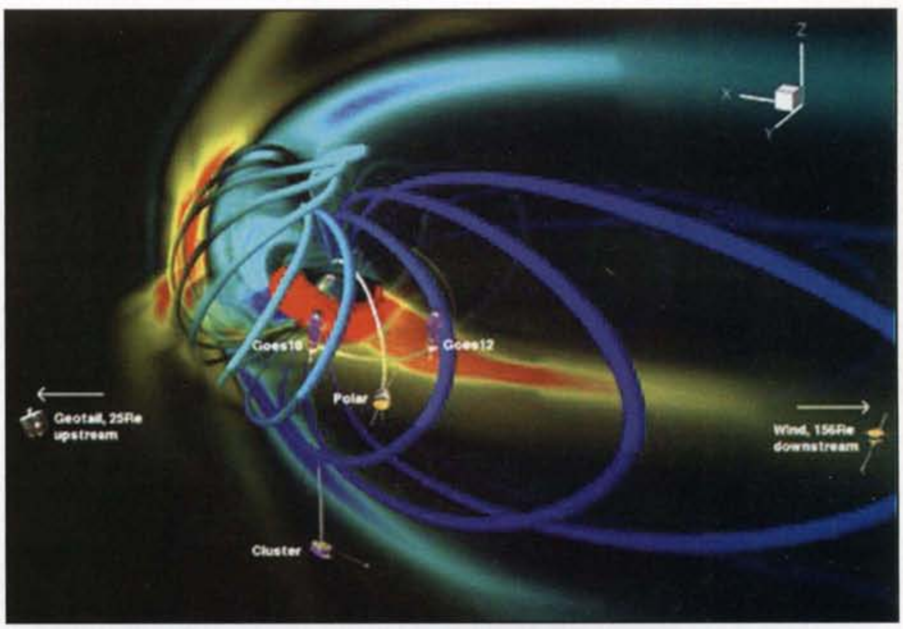
Marconi's aide, Mignani, whose only duty consisted of firing a rifle shot when the signal was received, waited by the receiver, out of sight of Marconi. When Marconi "sent" his three-dot Morse coded "S" transmission, Mignani fired his gun. For the first time in history, Morse code, and thereby the first communication, had travelled through space.

That's the power of the amateur radio scientist, too. You are among the ranks of potential pioneers, improvers, and implementers who will move radio technology and electronics forward into new territory. All it takes is your dedication to do more than turn on an appliance and settle for the bare minimum.

In prior columns I've shared online resources and communities where you can plug in and participate. In addition to getting on the air and communicating, experimenting, and pushing the limits of non-HF radio, the amateur scientist must document, share, compare, and challenge the raw data of real-world experience.

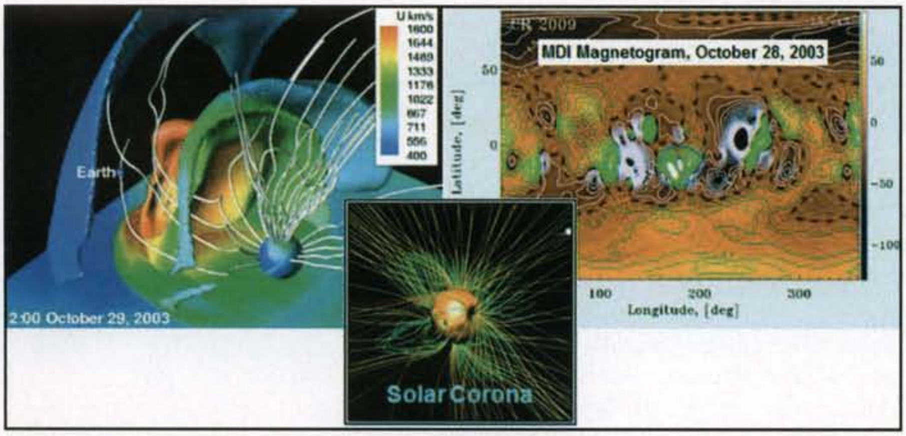
To that end, I want to open up this column to more of your feedback and involvement. What new ideas are you exploring and experimenting with? What are your results? What has your group accomplished, and what does it reveal about the science of radio-wave propagation? Please don't hesitate to share your VHF-and-above knowledge with the rest of the community. This magazine is one

Guglielmo Marconi, the developer of the first successful radio, appears on the Italian 2000 Lire note. As a dedicated, passionate amateur scientist, he eventually changed the course of history, and he is honored on this currency. Are you one of the new radio amateur pioneers? Be an active part of the science of radio and explore new ideas and technologies.



An artist's conceptualization of the space environment around Earth, and the sensing craft (satellites and space probes) used to monitor and forecast space weather. With ever-increasingly sophisticated instruments and technologies, space weather is becoming more and more understood and predictable. (Source: Center for Space Environment Modeling [CSEM])

*P.O. Box 213, Brinnon, WA 98320-0213
e-mail: <nw7us@hfradio.org>



New Global Sun-to-earth physics-based models are maturing. These three slides follow the Halloween 2003 solar storm in the Space Weather Modeling Framework on the NASA Columbia supercomputer in real time. Taking readings and images in real time and applying the advanced models from the Center for Integrated Space Weather Modeling, simulations such as this example aid solar scientists in accurately forecasting and timing the arrival of significant space weather. Amateur radio operators are able to tap into this incredible resource to predict VHF aurora-mode propagation and other propagation modes. (Source: Center for Integrated Space Weather Modeling, <http://www.bu.edu/cism/>, and Space Weather Modeling Framework, <http://csem.engin.umich.edu/>)

resource serving the amateur radio scientific community. Take advantage of it.

Winter 2007

As explained in the Fall 2006 *CQ VHF* column, we have two seasons each year when any adverse space weather has a greater influence in causing geomagnetic disturbances: The first is known as the Spring Equinoctial season and the second is known as the Autumnal Equinoctial season. The Spring Equinoctial season peaks between March and April of each year. During this year's equinoctial season there is moderate chance of geomagnetic activity combined with space weather to trigger small to medium aurora events.

What is the Aurora?

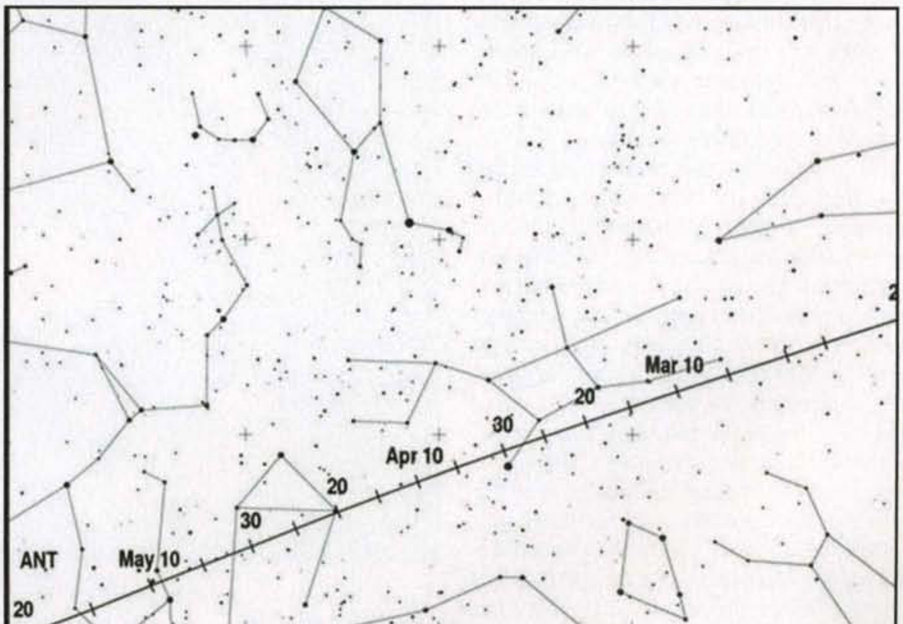
Aurora is a direct result of solar plasma interacting with gasses in the upper atmosphere. It is common to see aurora during active to severe geomagnetic storms. The magnetosphere is filled with electrons and protons that normally are trapped by lines of magnetic force that prevent them from escaping to space or descending to the planet below. The influence of solar wind that's been enhanced by coronal holes can cause some of those trapped particles to break loose, causing them to rain down on the atmosphere. Gases in the atmosphere start to glow under the impact of these particles. Different gases give out various colors. Think of a neon sign and how the plasma inside the glass tube, when excited, glows with a bright color. These precipitating particles mostly follow the magnetic field lines that run from Earth's magnetic poles, and are concentrated in circular regions around the magnetic poles called *auroral ovals.* These bands expand away from the poles during magnetic storms. The stronger the storm, the more these ovals will expand. Sometimes they grow so large that people at middle latitudes, such as in California, can see these "Northern Lights."

When you see the solar wind speed increase to over 500 kilometers per second, and the *Bz* remains mostly negative (when the Interplanetary Magnetic Flux [IMF] is oriented mostly southward), expect an increase in geomagnetic activity, as revealed by the planetary *K*-index (*Kp*).

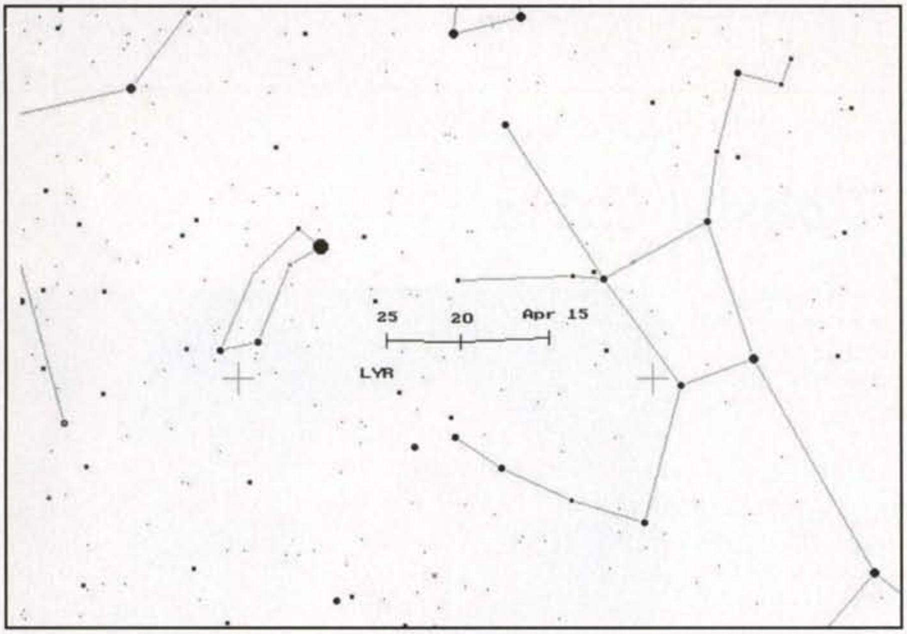
When the *Kp* rises above 4, look for aurora-mode propagation. The higher the *Kp* index, and the longer the geomagnetic storminess lasts, the more likely we'll have strong *Au* openings. You don't have to see them to hear their influence on propagation. Listen for stations from over the poles that sound raspy or fluttery. Look for VHF DX. Sometimes it will enhance a path at certain frequencies, while other times it will degrade the signals. Sometimes signals will fade quickly and then come back with great strength. The reason for this is that the radio signal is being refracted off the more highly ionized areas that are lit up. These ionized areas ebb and flow, so the ability to refract changes, and sometimes quickly. I've observed the effect of aurora and associated geomagnetic storminess even on lower HF frequencies.

Radio Aurora

If there are enough solar particles flowing down the Earth's magnetic field lines



The Lyrids radiant, 2007. (Source: IMO)



Another Lyrids radiant image. (Source: IMO)

and colliding with atmospheric atoms and molecules, ionization occurs. This ionization may be sufficient to reflect VHF and lower UHF radio waves, generally between 25 and 500 MHz. This usually occurs in conjunction with visual aurora, but the mechanism is a bit different and it is possible to have one (visual or radio) without the other.

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

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

The *K*-index is a good indicator of the expansion of the auroral oval and the possible intensity of the aurora. When the *K*-index is higher than 5, most inhabitants of the northern states and Canada can expect favorable aurora conditions. If the *K*-index reaches 8 or 9, it is highly possible for radio aurora to be worked by stations as far south as California and Florida. Your magnetic latitude can be found using the map at <http://www.sec.noaa.gov/Aurora/globeNW.html>.

Meteors

While there are no major meteor showers during February and March, April has one major meteor shower, the *Lyrids,* active from about April 16 through April 25, peaking on April 22 at 2230 UTC. While this shower peaks at about 18 meteors per hour, or about one per every 5 minutes on average, radio bursts occur more often. Also, we might see the meteor rate reach as high as 90 per hour.

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

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

For more information about the meteor showers in 2007, see the IMO website: <http://www.imo.net/calendar/2007>.

The Solar Cycle Pulse

The observed sunspot numbers from October through December 2006 are 10.4, 21.5, and 13.6. The smoothed sunspot counts for April through June 2006 are 17.1, 17.3, and 16.3.

The monthly 10.7-cm (preliminary) numbers from October through December 2006 are 74.3, 86.4, and 84.3. This is a slight rise in activity over the previous three-month period. The smoothed 10.7-cm radio flux levels for April through June 2006 are 80.9, 80.8, and 80.6.

The smoothed planetary *A*-index (*Ap*) numbers from April through June 2006 are 7.9, 7.9, and 8.3. The monthly readings from October through December 2006 are 8, 9, and 14, with December being the month with the highest smoothed *Ap* since May 2005, and the stormiest (geomagnetically) month of 2006.

The smoothed monthly sunspot numbers forecast for February through April 2007 are 10.0, 9.9, and 10.1, while the smoothed monthly 10.7 cm is predicted to be 74.4, 74.0, and 73.9 for the same period. Give or take about 12 points for all predictions. Notice how this forecast reveals the expectation of the solar minimum occurring between March and July, 2007. Clearly, solar Cycle 23 is at the end of its life and Cycle 24 is ready to take off.

(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. You are also 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/> and via cell phone at <http://wap.hfradio.org/>.

Until the next issue, happy weak-signal DXing. 73, Tomas, NW7US

By Kent Britain,* WA5VJB

ANTENNAS

Connecting the Radio to the Sky

Coaxial Cable

This time we will covering odds and ends concerning coaxial cable. You might be surprised as you read about one of the most necessary pieces of your amateur radio station. We also feature a couple of Cheap Yagis, one at N7BHC's QTH, while the other belongs to your columnist.

Coax Maximum Frequency

From Brian we received a question from the last column, where we talked about using TV station antennas. I had said that the coax the TV station was using had a maximum frequency of about 1 GHz. Maximum frequency for coax? Yes, if you look up the loss charts for a sepcific coax, such as 7/8-inch hardline, the loss line will go up to about 6 GHz and just stop. In photo A you see a section of coax and a section of 10-GHz waveguide. The coax is a *lot* bigger than the waveguide. If you tried to send a 10-GHz signal down the coax, the signal would have trouble deciding if it was going down coax or waveguide. This mixed mode of propagation means that sometimes the waves add, and sometimes they cancel when they get to the other end. In short, the output is a mess. In figure 1 we see a typical plot of coax loss to frequency on the left. If the chart continued, then it would look something like the plot on the right. Like I said: A mess!

At 6 GHz, the 7/8-inch coax shield starts to act like waveguide. Therefore, instead of being coax, it tries to become like waveguide. The connectors are not designed for this use and the coax line gets very lossy. Microwavers make coax of different sizes without the center conductor. This is called elliptical waveguide—just coax without the center wire, squished a bit, and different connectors. It is a nice long tube.

Elliptical waveguide is fairly common on the surplus market, but the connectors are not so common and are usually expensive. Figure 2 shows a mod I first saw used by Eric Ericson, KØKE. Eric drilled a hole for a connector, mounted an SMA connector with a probe on the end, and then closed off the open end of the waveguide. He simply modified the end of the elliptical waveguide into a coax to waveguide transition. You have to be careful not to put too much stress on the coax connector. Even so, this is a simple, low-cost, low-loss way to avoid needing those big, expensive waveguide flanges.

In photo B I show that there is another way to use elliptical waveguide. Find some short sections of brass waveguide that will just fit into the elliptical waveguide. You really want a brass or copper waveguide, since the last step is to solder it in. Cut off a section of waveguide and, with a big file or bench grinder, round off the outside of the corners as much as practical. Now hammer it into the elliptical waveguide as best you can, bend the copper back flush with the rectangular waveguide, and solder. I have used this with 5.7-, 10-, and 24-GHz elliptical waveguide with good results. It has a few tenths of a dB more loss than the proper waveguide flanges, but this way is 20 dB cheaper!

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

Photo A. Big coax vs. small waveguide.

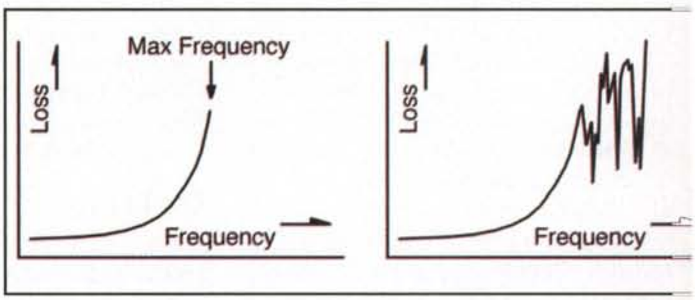


Figure 1. Coax loss vs. frequency.

Life Expectancy of Coax

The photo of some contaminated RG-8 took quite a bit of scrounging (photo C). You see, there is only one section of RG-8 actually used in my station. Furthermore, it has terminals crimped on each end, and I use the RG-8 as a ground strap on one of my towers.

The last time I rebuilt all my stations, I took all my runs of coax and loss tested each one at 450 MHz. My runs of double-shielded RG-214 were still within a few tenths of a dB of factory loss specs, and these runs are over 40 years old! My RG-213 runs are not quite that old, but again within a few tenths of a dB of factory specs. However, the RG-8 was a very different story.

In photo C the piece of 40+-year-old RG-214 on the left still has clean center insulation. I used a bright white background for the photo, and it may not show up in print that well, but the center foam insulation of the RG-8 and RG-58 has a dark yellow or tan appearance. It should be bright white, but with age the insulation has darkened—long enough and it will almost turn black. Over time, plasticizer from the black outer coating works its way into the center insulator. This leaching changes the chemical composition and dielectric constant of the center insulation. Now your 50-ohm coax slowly changes to 45-ohm then 40-ohm coax. All the while the losses in the foam plastic are also going up and up. If you have any old RG-8 and the center foam is no longer bright white, find another use for it. Don't put it between your antenna and your rig!

Back to that loss testing: While the RG-214 and RG- 213 were still at factory spec, the RG-8 loss went way up. One section of RG-8 coax had a calculated loss of 4.5 dB. It measured 17 dB of loss, which is about four times higher than it should be. Now you know why I avoid RG-8. Oh yeah . . . I am using

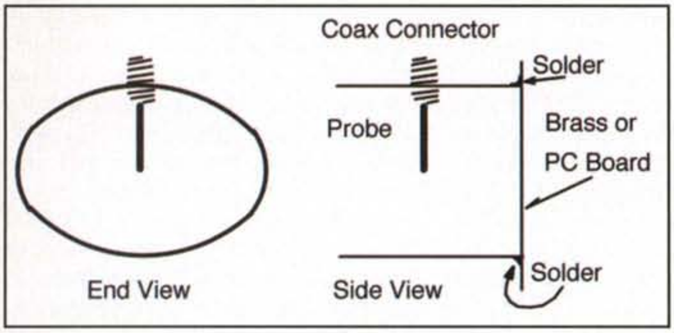


Figure 2. Homebrew coax to waveguide adapters built into the elliptical waveguide.

Photo B. Homebrew waveguide flanges for elliptical waveguide.

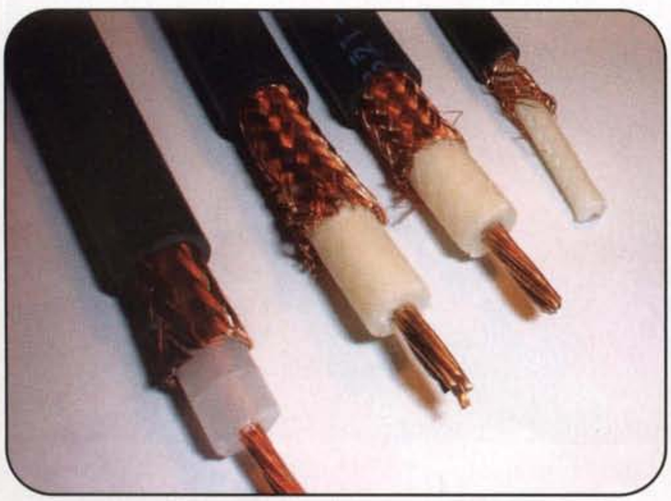


Photo C. Examples of coax and their condition.

some of that old RG-8 in my cars. I attached some big alligator clips on the ends and it makes good battery jumper cables.

Cheap Yagis

From David Pedersen, N7BHC, we have a photo of his new 1296-MHz Cheap Yagi array (photo D). Dave lives in an area that doesn't allow outdoor antennas, and thus has quite a few Cheap Yagis hiding in his attic. The antenna was built using #8 aluminum ground wire for the parasitic elements, and the center conductor was made out of some LMR-400 for the driven elements. A much better power divider is in the works, and he thinks he has enough room for a stack of eight Cheap Yagis in that attic crawl space, along with his VHF antennas.

My 2304-MHz Cheap Yagi in photo E still needs a bit more work, but I will try to have the design cleaned up by the next issue. At a recent antenna contest it came in about 4 dB under the design gain, so there is still some tweaking to do. I am also working on a Very Cheap Discone antenna. I just might be able to have one antenna for 146-, 223-, 445-, and 1290-MHz repeaters at the same time.

As always, my best ideas for columns and projects come from you, our readers. So keep those questions coming! For other antenna projects, you are welcome to visit <www.wa5vjb.com>.

73, Kent, WA5VJB

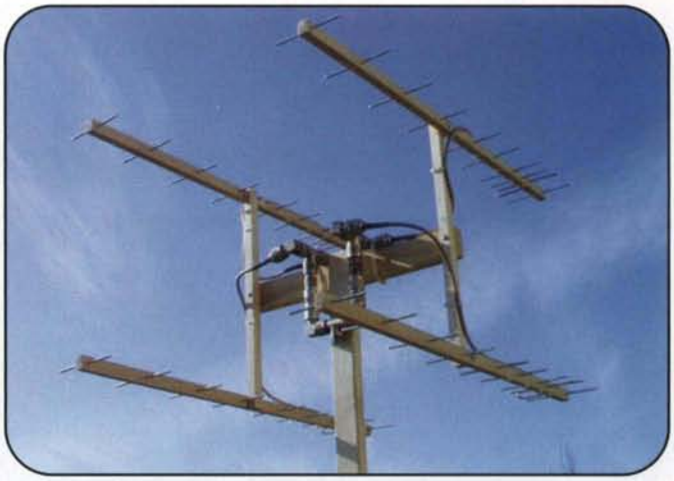


Photo D. N7BHC's array of 1296-MHz Cheap Yagis.

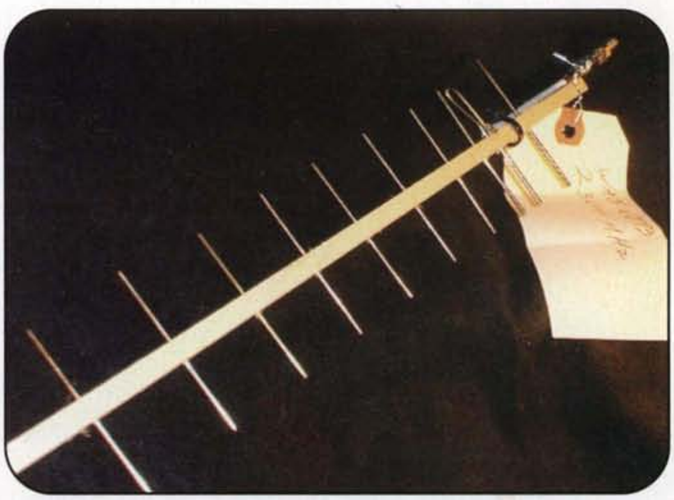


Photo E. The author's prototype 2304-MHz Cheap Yagi.

By Dr. H. Paul Shuch,* N6TX

DR. SETI'S STARSHIP

Searching For The Ultimate DX

Journalistic Exuberance

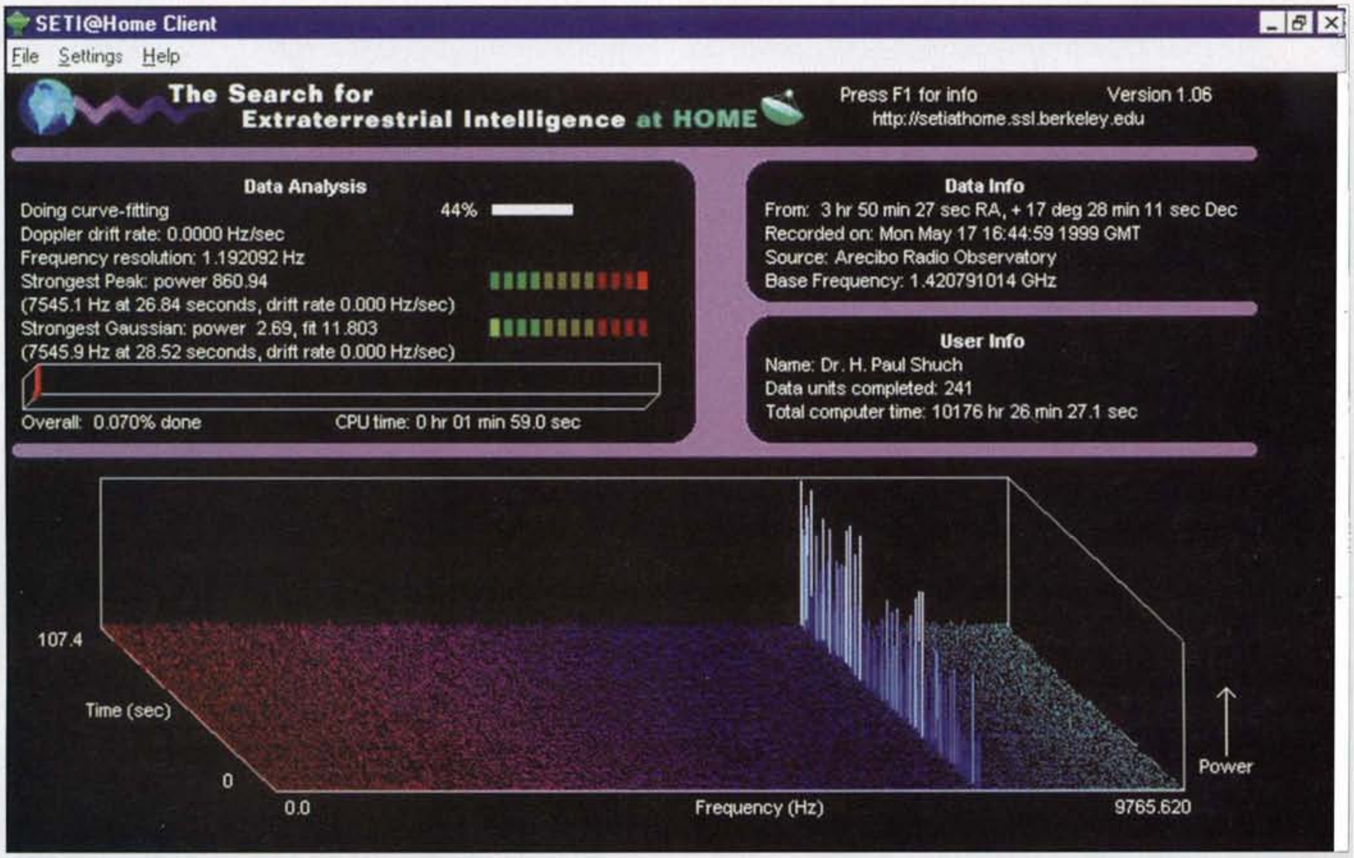
Upon my arrival at a ham convention in Boston a couple of years ago, I encountered a SETI fiction far stranger than truth. It caused us all a momentary flurry of excitement, before fading into the noise level of SETI science. I refer to claims appearing in the reputable British journal *New Scientist* of a promising detection from the SETI@home distributed computing experiment, in which I know many of you are participants. Unfortunately, these claims proved to be a classic case of journalistic exuberance.

The story in question was actually rather cautiously penned. It made no claims, beyond the assertion that at least one candidate SETI@home signal had reappeared upon follow-up examination, when SETI@home chief scientist Dan Werthimer and his team headed to the legendary Arecibo Observatory in Puerto Rico to re-examine the coordinates of a couple of hundred promising hits during the spring of 2004. The real excitement stemmed from an apparent disconnect between a responsible journalist and a headline writer who may not actually have read the story in question. The headline screamed, "Mysterious Signals from 1000 Light Years Away!"

Would that it were true! Unfortunately, the story itself reported something far more prosaic: "This radio signal, now seen on three separate occasions, is an enigma. It could be generated by a previously unknown astronomical phenomenon. Or it could be something much more mundane, maybe an artifact of the telescope itself." This is, of course, the nature of most unconfirmed SETI signal candidates, and a familiar occurrence to those of us engaged in the ongoing Search for Extra-Terrestrial Intelligence. In sort, unless ET gives his callsign and grid square, you just can't claim the contact.

Thus, from whence comes the "1000 Light Years Away" pronouncement of the headline? Back to the article itself: "SHGb02+14a seems to be coming from a point between the constellations Pisces and Aries, where there is no obvious star or planetary system within 1000 light years." It's not hard to see how this state-

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



To be considered interesting, a SETI detection (whether from Arecibo or from your back-yard dish) needs to be clearly artificial, like this one. However, it also needs to be independently verified, or repeatable. The "detection" reported in 2004 by New Scientist *was not.*

ment, carelessly read, was transmogrified into a claim far more concrete.

The late physicist and science-fiction author Dr. Robert Forward espoused a philosophy which, over the years, has become codified as Forward's Law: "Never let the facts get in the way of a good story." I respectfully suggest that what we're seeing here is an example of this corollary: "Never let the story get in the way of a good headline."

But back to Boston. Upon arrival in my hotel room, I was greeted by an avalanche of incoming e-mails. (Do 100 e-mails constitute an avalanche? I guess it all depends upon your perspective.) Many SETI League members, several interested hams, and not a few journalists wanted to know more about this claim of SETI success. Therefore, I went directly to the source, my friend and colleague (and former grad-school classmate) Dan Werthimer himself. "What about your candidate signals?" I asked. Dan replied thus, from Arecibo, where he was at that very moment preparing to put a new multifeed receiver system on the air:

> None of our candidates are very interesting. They all are consistent with noise. We will continue to observe many of the candidates over the next few years, but there's nothing on the candidate lists we are particularly excited about.
>
> A reporter from *New Scientist* read the SETI@home web pages. In particular there's a section on 'candidate signals' where we discuss how we score signals and we show the data from the 220 candidates we re-observed at Arecibo 1.5 years ago. These web pages are old, but the reporter made an exciting story about them by exaggerating their content and misquoting us and quoting us out of context, and making a press release about one of the candidates that has a bit higher score than the others.
>
> I talked to a couple of reporters today, explaining we've seen stuff like this for the last 30 years, and it's always turned out to be RFI or noise, and that there's nothing to get excited about, and that when you look at 50-trillion bytes of data, occasionally you'll find patterns that look unusual just from noise....
>
> I wish we had something in our data to get excited about.

So do I. Well, we SETIzens can't control the press, but we can be very careful not to disseminate misinformation without first checking in with the source. I only hope that when we do finally have a *real* SETI detection to announce, the press and public don't turn a deaf ear. Nobody listens to the boy who cried alien.

73, Paul, N6TX

Advertisers' Index


ANAHEIM, CA
(Near Disneyland)
933 N. Euclid St., 92801
(714) 533-7373
(800) 854-6046
Janet, KL7MF, Mgr.
anaheim@hamradio.com
BURBANK, CA
1525 W. Magnolia Blvd, 91506
(818) 842-1786
(800) 854-6046
Eric, KA6IHT, Mgr.
Magnolia between
S. Victory & Buena Vista
burbank@hamradio.com
OAKLAND, CA
2210 Livingston St., 94606
(510) 534-5757
(800) 854-6046
Mark, WI7YN, Mgr.
I-880 at 23rd Ave. ramp
oakland@hamradio.com
SAN DIEGO, CA
5375 Kearny Villa Rd., 92123
(858) 560-4900
(800) 854-6046
Tom, KM6K, Mgr.
Hwy. 163 & Claremont Mesa
sandiego@hamradio.com
SUNNYVALE, CA
510 Lawrence Exp. #102, 94085
(408) 736-9496
(800) 854-6046
Howard, W6HOC, Mgr.
So. from Hwy. 101
sunnyvale@hamradio.com
NEW CASTLE, DE
(Near Philadelphia)
1509 N. Dupont Hwy., 19720
(302) 322-7092
(800) 644-4476
Rick, K3TL, Mgr.
RT.13 1/4 mi., So. I-295
newcastle@hamradio.com
PORTLAND, OR
11705 S.W. Pacific Hwy.
97223
(503) 598-0555
(800) 854-6046
Leon, W7AD, Mgr.
Tigard-99W exit
from Hwy. 5 & 217
portland@hamradio.com
DENVER, CO
8400 E. Iliff Ave. #9, 80231
(303) 745-7373
(800) 444-9476
John, N5EHP, Mgr.
denver@hamradio.com
PHOENIX, AZ
1939 W. Dunlap Ave., 85021
(602) 242-3515
(800) 444-9476
Gary, N7GJ, Mgr.
1 mi. east of I-17
phoenix@hamradio.com
ATLANTA, GA
6071 Buford Hwy., 30340
(770) 263-0700
(800) 444-7927
Mark, KJ4VO, Mgr.
Doraville, 1 mi. no. of I-285
atlanta@hamradio.com
WOODBRIDGE, VA
(Near Washington D.C.)
14803 Build America Dr. 22191
(703) 643-1063
(800) 444-4799
Steve, W4SHG, Mgr.
Exit 161, I-95, So. to US 1
woodbridge@hamradio.com
SALEM, NH
(Near Boston)
224 N. Broadway, 03079
(603) 898-3750
(800) 444-0047
Chuck, N1UC, Mgr.
sales@hamradio.com
Exit 1, I-93;
28 mi. No. of Boston
salem@hamradio.com
12 STORE BUYING POWER
HAM RADIO OUTLET
®
WORLDWIDE DISTRIBUTION
Call for latest promotions and coupon specials
YAESU
FT-897D VHF/UHF/HF Transceiver
• HF/6M/2M/70CM • DSP Built-in
• HF 100W (20W battery)
• Optional P.S. + Tuner • TCXO Built-in
Call Now For Our Low Pricing!
FT-817ND HF/VHF/UHF TCVR
• 5W @13.8V ext DC • USB, LSB, CW, AM, FM
• Packet (1200/9600 Baud FM) • 200 mems
• built in CTCSS/DCS • TX 160-10M, 6M, 2M, 440
• Compact 5.3" x 1.5" x 6.5", 2.6 lbs
• FNB-85 NiMH battery + NC-72B included
Call Now For Low Pricing!
FT-8800R 2M/440 Mobile
• V+U/V+V/U+U operation
• V+U full duplex • Cross Band repeater function
• 50W 2M 35W UHF
• 1000+ Memory channels
• WIRES ready
Call Now For Low Pricing!
VX-2R 2M/440 HT
• World's smallest Dual-band HT w/ wide RX
• 1.5 W RF output
• WiRES compatible
• 1300 Memory channels
Call For Low Price!
FT-60R
• 2m/440 HT
• 5W Wide-band receive
• CTCSS/DCS Built-in
• Emergency Auto ID
Low Price!
NEW!
VX-7R/VX-7R Black
50/2M/220/440 HT
• Wideband RX - 900 Memories
• 5W TX (300mw 220Mhz)
• Li-Ion Battery
• Fully Submersible to 3 ft.
• Built-in CTCSS/DCS
• Internet WIRES compatible
Now available in Black!
VX-6R
2M/220/440HT
• wideband RX – 900 memories
• 5W 2/440 , 1.5W 220 MHz TX
• Li-ION Battery - EAI system
• Fully submersible to 3 ft.
• CW trainer built-in
NEW Low Price!
NEW!
VX-150
2M Handheld
• Direct Keypad Entry
• 5w output
• 209 memories
• Ultra Rugged
Call Now For Special Pricing!
FT-857D
Ultra compact HF, VHF, UHF
• 100w HF/6M, 50w 2M, 20w UHF
• DSP included • 32 color display
• 200 mems • Detachable front panel
Call for Low Price!
FT-7800R 2M/440 Mobile
• 50w 2m, 40w on 440mHz
• Weather Alert
• 1000+ Mems
• WIRES Capability
• Wideband Receiver (Cell Blocked)
Call Now For Your Low Price!
FT-2000 HF + 6M tcvr
• 100 W w/ auto tuner • built-in Power supply
• DSP filters / Voice memory recorder
• 3 Band Parametric Mic EQ • 3 IF roofing filters
Call Now For Low Pricing!
FT-8900R Quadband Transceiver
• 10M/6M/2M/70CM • Wires capable
• 800+ memories • Built-in CTCSS/DCS
• Remotable w/optional YSK-8900
Call Now For Special Pricing
AZ, CA, CO, GA, VA residents add sales tax. Prices, specifications, descriptions, subject to change without notice.
Look for the HRO Home Page on the World Wide Web
http://www.hamradio.com
COAST TO COAST
FREE SHIPPING
UPS - Most Items Over $100
Rapid Deliveries From The Store Nearest To You!


Conquer the Elements!
IPX7
Submersible 3 feet (1m) for 30 min.
5 W Heavy Duty Submersible
2 m/70 cm Dual Band FM Hand held (220 MHz: 1.5 W)
VX-6R
IPX7
Submersible 3 feet (1m) for 30 min.
6 m / 2 m / 70 cm Tri-Band
5 W Ultra-Rugged,
Submersible 6 m/2 m/70 cm
Tri-Band FM Hand held
VX-7R/VX-7RB
(220 MHz: 300 mW)
2 m / 70 cm Dual Band
5 W Heavy Duty
2 m/70 cm Dual Band
FM Hand held
FT-60R
2 m / 70 cm Dual Band
1.5 W Ultra Compact
2 m/70 cm Dual Band
FM Hand held
VX-2R
(8 key)
IPX7
Submersible 3 feet (1m) for 30 min.
(16 key)
5 W Heavy Duty Submersible
2 m FM Mono Band Hand Helds
VX-120 VX-127
2 m Mono Band
70 cm FM Mono Band Hand Helds
VX-170 VX-177
70 cm Mono Band
2 m Mono Band
Ultra-Rugged
5 W Full Featured
2 m FM Hand helds
VX-150/VX-110
A TOUGH RADIO
FOR A TOUGH WORLD!
2 m Band
50 W 2 m Ultra Rugged VHF FM Mobile
FT-1802M
QUAD BAND
DUAL RECEIVE
50 W 10 m/6 m/2 m/70 cm*
Quad Band FM Mobile
FT-8900R
*70 cm 35 W
DUAL BAND
DUAL RECEIVE
50 W 2 m/70 cm*
Dual Band FM Mobile
FT-8800R *70 cm 35 W
DUAL BAND
50 W 2 m/70 cm*
Dual Band FM Mobile
FT-7800R
*70 cm 35 W
65 W 2 m Rugged FM Mobile
FT-2800M 2 m Band
YAESU
Choice of the World's top DX'ers℠
Vertex Standard
US Headquarters
10900 Walker Street
Cypress, CA 90630 (714)827-7600
For the latest Yaesu news, visit us on the Internet:
http://www.vertexstandard.com
Specifications subject to change without notice. Some accessories and/or options may be standard in certain areas. Frequency coverage may differ in some countries. Check with your local Yaesu Dealer for specific details.

The Hottest Field Gear Anywhere!

HF/VHF/UHF Portable Operation Just Got a Lot More Powerful!

FT-897D

HF/50/144/430 MHz
100 W All Mode Transceiver
(144 MHz 50 W/430 MHz 20 W)

TCXO | DSP | 60 m Band

HF/VHF/UHF Multimode Mobile Transceiver, now Including Built-in DSP

FT-857D

HF/50/144/430 MHz
100 W All Mode Transceiver
(144 MHz 50 W/430 MHz 20 W)

DSP | 60 m Band

REAL PERFORMANCE, REALLY PORTABLE

FT-817ND

HF/50/144/430 MHz
5 W All Mode Transceiver (AM 1.5 W)

60 m Band

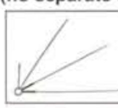
Automatic Matching for FT-897/857 Series Transceivers

FC-40
Automatic-Matching 200-Memory Antenna Tuner (160 m ~ 6 m Band)

WATERPROOF

Mobile Auto-Resonating 7~430 MHz for FT-897/857 Series Transceivers

ATAS-120A
Active Tuning Antenna System (no separate tuner required)



VHF/UHF Base RadialKit ATBK-100 for ATAS-120A.

ATAS-25
Manually-Tuned Portable Antenna

High-end HF/50 MHz Transceiver

6 meter Band included

HF/50 MHz Transceiver
FT DX 9000MP 400 W Special Order Version
Two Pairs of Meters, plus LCD Window; Data Management Unit and Flash Memory Slot Built In.
Main/Sub Receiver VRF, plus Full Dual Receive Capability,
External 50 V/24 A Switching Regulator Power Supply and Speaker with Audio Filters
Display color (Umber or Light Blue) may be selected at the time of purchase.
Modification from 400 to 200 W not possible.

HF/50 MHz Transceiver
FT DX 9000D 200 W Version
Large TFT, Data Management Unit and Flash Memory Slot Built In,
Main/Sub Receiver VRF, plus Full Dual Receive Capability,
Three µ-Tuning Modules for 160 - 20 M,
50 V/12 A Internal Switching Regulator Power Supply

HF/50 MHz Transceiver
FT DX 9000 Contest
Custom-Configurable Version
Two Pairs of Meters, plus LCD Window, VRF Input Preselector Filter, Three Key Jacks, and Dual Headphone Jacks,
50 V/12 A Internal Switching Regulator Power Supply

Display color (Umber or Light Blue) may be selected at the time of purchase. Modification from 200- to 400-Watt version not available.

HF/50 MHz Transceiver
FT-2000D
200 W Version (External Power Supply)

HF/50 MHz Transceiver
FT-2000
100 W Version (Internal Power Supply)

YAESU
Choice of the World's top DX'ers

Vertex Standard
US Headquarters
10900 Walker Street
Cypress, CA 90630 (714)827-7600

For the latest Yaesu news, visit us on the Internet:
http://www.vertexstandard.com

Specifications subject to change without notice. Some accessories and/or options may be standard in certain areas. Frequency coverage may differ in some countries. Check with your local Yaesu Dealer for specific details.