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Summer 2011

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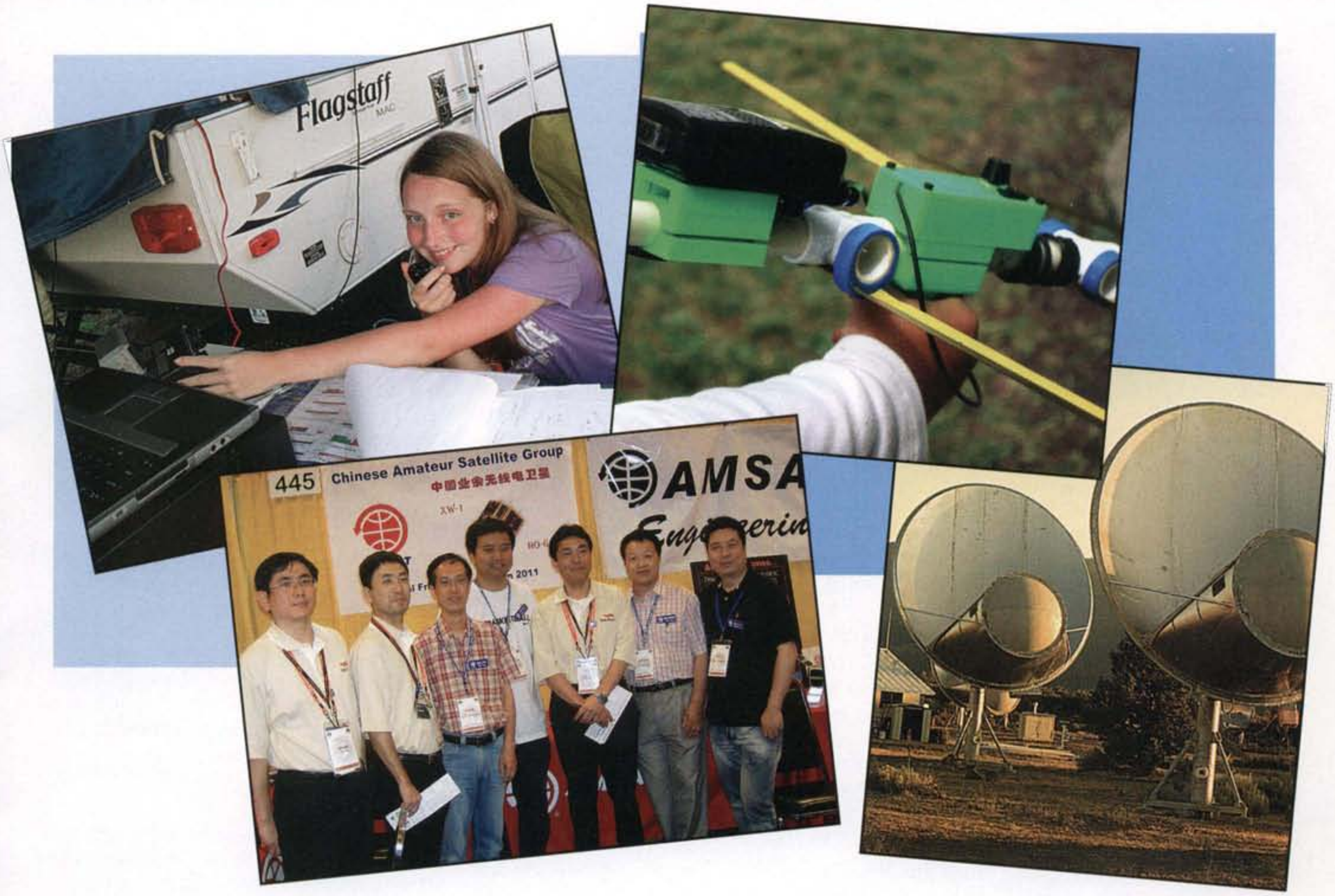
Printed in the United States of America.
Postmaster: Please send change of address to CQ VHF, 25 Newbridge Road, Hicksville, NY 11801.

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CQ VHF Ham Radio Above 50 MHz

# LINE OF SIGHT

## A Message from the Editor

# Raising Our Technical Competency

With this issue were are raising the technical competency level by publishing two quite technical articles. The first article, by Roger Harrison, VK2ZRH, originally appeared in the Volume 40, Second Quarter issue of *DUBUS* magazine. In response to my request to publish a similar article in *CQ VHF*, Harrison rewrote it so that it is better suited to the North American readership.

In his seminal work, Harrison discusses petit chordal hop and layer trapping, which he posits they "enable a dramatic increase in the MUF of an oblique propagation path." He adds: "Layer trapping has the potential to extend MUFs beyond 350 MHz. It may have been involved in the few reports of 220-MHz *Es* propagation in North America."

Are you intrigued? If so, you can read Harrison's article starting on page 14.

The second article, by James Kocsis, WA9PYH, is an extensive homebrew of an AZ/EL rotor controller. Several of us who work the satellites have struggled with how to rotate and elevate our antenna arrays as we follow a satellite across its portion of the sky. Kocsis designed and built his solution and instructs us on how we can build ours.

### EME on a Shoestring—Almost!

While Kocsis had satellite communications in mind as he designed his rotor controller, "VHF Propagation" columnist Tomas Hood, NW7US, may have unwittingly discovered another use for the controller. Hood devotes this issue's column to the new ease of EME communications. Commenting on the changes, he writes:

> Gone are the days when receivers were deaf and moonbounce required such Herculean efforts. Now, armed with the right software, a good soundcard-equipped personal computer, a modest beam antenna, and some patience along with a modern VHF transceiver, you can easily work DX via the visible Moon!

For best results, the modest beam that Hood refers to needs to be able to follow the natural satellite, the Moon. Thus, Kocsis's controller will do a nice job.

The right software that Hood describes is Joe Taylor, K1JT's JT65 program. In Hood's column he describes the different versions of JT65 and how to create a station capable of making heretofore impossible EME QSOs. I invite you to learn more by reading Hood's column beginning on page 64.

In keeping with the EME theme, "Antennas" column editor Kent Britain, WA5VJB, describes a long-boom (20-element) 432-MHz antenna that he designed for working Arecibo when that station returns to the air in a year or two. We in the EME community are collectively holding our breath in the transition to the new contractor for the mega-dish antenna. Assurances from well-placed sources that it will return cause us to breathe a bit easier and Britain to design more antennas. Look for another long-boom antenna in a future "Antennas" column.

### The Latest on ARISSat-1

Taking a bit of a gamble, "Satellites" editor Keith Pugh, W5IU, devotes considerable space in his column describing how to work the ARISSat-1 satellite once it is launched from the International Space Station. From the AMSAT website (http://www.amsat.org) Gould Smith, WA4SXM, the ARISSat-1 project manager, writes:

> The deployment date for ARISSat is still soft; a major factor is the shuttle launch. As of July 6 the EVA date is in early August. ... Since we have no firm date or time for the EVA we cannot predict where the satellite will be heard first. We will let everyone know more as we know more.

Pugh's gamble is that the launch date will slide just past the time that you will have received this issue and read his column, which begins on page 57.

### Summer's Special Propagation

The deck for Features Editor Gordon West, WB6NOA's article begins: "It happens almost every summer. Most of the time it begins during the 4th of July weekend. This year was no exception." What happens almost every summer is the tropo ducting that takes place between Hawaii and the mainland West Coast. This year's July 4th weekend proved to be another great one for the duct. West describes what happened this year and what to expect concerning future tropo-duct events, beginning on page 8.

### Other Great Reading—Including the Web

The other columns also provide great reading for your special interest in the wonderful world of the VHF Plus ham bands. I invite you to read all of them—including the Web Special article "Hope for F-Layer Propagation on 6 Meters in Cycle 24" by *CQ VHF* Features Editor Ken Neubeck, WB2AMU. To access his article, go to <http://www.cq-vhf.com> and click on the link. Unlike in the past when we have presented teasers of articles in the then-current issue, Neubeck's entire article is posted, thereby taking advantage of the resources available to us to make available even more great VHF Plus reading.

Naturally, we hope that the "tease" of a full article will encourage the website readers to sign up for a full subscription in order to read all of the content that you have at your fingertips. Therefore, if you know of someone who needs his or her copy because he or she is constantly borrowing yours and "forgetting" to return it, send that person to our website with the enticement of a bonus article online.

Concerning the web, if this concept of placing some of the content online works, then maybe we will look at placing more of the content of this, your magazine, online.

### Missing

Two regular writers are missing from this issue. Mark Morrison, WA2VVA, had to take off this issue due to family matters. Tom Dean, KB1JIJ, just graduated from West Point and is headed to Stanford to do graduate work. We should see their excellent work again in future issues of *CQ VHF*.

### Oops!

Neubeck's article "The ARRL VHF Contests" which appeared in the Spring 2011 issue contained a couple of misstatements concerning the ARRL contest rules. We regret these errors.

More important, however, was Neubeck's inclusion of a couple of snippets of a grid square map. It turns out that these snippets are part of ICOM's copyrighted grid square map. He did not realize that these were portions of ICOM's map and I failed to catch it. Ultimately, I have the responsibility to catch these copyright issues. There was no source attribution in the figure caption for the grid square map sections that Neubeck used.

I personally apologized to Ray Novak, N9JA, National Amateur Marketing Manager for ICOM America, for my mistake when I saw him at the Ham-Com convention this past June. Additionally, to him, and stated here in this editorial, I will endeavor to be more careful about such issues in the future.

### And Finally

As you can see from the Quarterly Calendar on page 6, there is plenty of VHF Plus activity to go around during the next few months. I hope to see you participating in some of these events. Until the next issue...73 de Joe, N6CL

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# QUARTERLY CALENDAR OF EVENTS

### Current Contests

**August:** There are two important contests this month. The **ARRL UHF and Above Contest** is scheduled for 6–7 August. The first weekend of the **ARRL 10 GHz** and above cumulative contest is scheduled for August 21–22.

**September:** The **ARRL September VHF QSO Party** is September 10–12. The second weekend of the **ARRL 10 GHz and Above Cumulative Contest** is September 18–19. The following are the dates for the **Fall Sprints**: The **144 MHz Fall Sprint** is September 19, 7 PM to 11 PM local time. The **222 MHz Fall Sprint** is September 27, 7 PM to 11 PM local time. The **ARRL 2.3 GHz and Above EME Contest** is September 24–25.

**October:** The **432 MHz Fall Sprint** is October 5, 7 PM to 11 PM local time. The **Microwave (902 MHz and above) Fall Sprint** is October 15, 6 AM to 12 PM local time. The **ARRL 50 MHz to 1296 MHz EME Contest** is October 22–23. The **50 MHz Fall Sprint** is October 29, 2300 UTC to October 30, 0300 UTC.

**November:** The **ARRL 50 MHz to 1296 MHz EME Contest** is November 19–20.

For ARRL contest rules, see the issue of *QST* prior to the month of the contest or the Leaque's URL: <http://www.arrl.org>. For Fall Sprint contest rules, see the Southeast VHF Society's URL: <http://www.svhfs.org>.

### Current Conferences and Conventions

**September:** The 2011 **TAPR/ARRL Digital Communications Conference** will be held September 16–18 in Baltimore, Maryland, at the Four Points by Sheraton BWI Airport, 7032 Elm Road. Reservations: 1-800-368-7764 or 1-410-859-3300. For more information, see: <http://www.tapr.org/dcc.html>.

**October:** The 2011 **Microwave Update** conference is to be held October 13–16 in Enfield, Connecticut at the Holiday Inn. Reservations (must mention Microwave Update): 1-860-741-2211. For further information, please check the Microwave Update website: <http://www.microwaveupdate.org>.

### Quarterly Calendar

*The following is a list of important dates for VHF-Plus enthusiasts:*

| | |
|---|---|
| Aug. 2 | Moon perigee |
| Aug. 6 | First quarter Moon |
| Aug. 13 | *Perseids* meteor shower and Full Moon |
| Aug. 18 | Moon apogee |
| Aug. 21 | Last quarter Moon |
| Aug. 29 | New Moon |
| Aug. 30 | Moon perigee |
| Sept. 4 | First quarter Moon |
| Sept. 12 | Full Moon |
| Sept. 15 | Moon apogee |
| Sept. 20 | Last quarter Moon |
| Sept. 27 | New Moon |
| Sept. 28 | Moon perigee |
| Oct. 4 | First quarter Moon |
| Oct. 8 | *Draconids* meteor shower |
| Oct. 12 | Full Moon |
| Oct. 12 | Moon apogee |
| Oct. 20 | Last quarter Moon |
| Oct. 21 | *Orionids* meteor shower |
| Oct. 26 | New Moon |
| Oct. 26 | Moon perigee |
| Nov. 2 | First quarter Moon |
| Nov. 8 | Moon apogee |
| Nov. 10 | Full Moon |
| Nov. 18 | *Leonids* meteor shower and Last quarter Moon |
| Nov. 23 | Moon perigee. |
| Nov. 25 | New Moon; partial eclipse of the Sun |

The 2011 **AMSAT-NA Space Symposium and Annual Meeting** is to be held November 4–5 in San Jose, California at the Windham Hotel. For more information, please see the AMSAT URL pertaining to the symposium at: <http://www.amsat.org/>.

### Calls for Papers

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

**Microwave Update:** A call for papers has been issue for the 2011 Microwave Update conference, to be held in Enfield, Connecticut. The deadline for submission is September 1. If you are interested in submitting a paper for publication in the conference *Proceedings*, please contact Paul Wade, W1GHZ, at <w1ghz@arrl.net> for additional information.

**AMSAT-NA 2011 Space Symposium:** Technical papers are solicited for the 2011 AMSAT Space Symposium and Annual Meeting to be held November 4-5 in San Jose, California. Proposals for papers, symposium presentations, and poster presentations are invited on any topic of interest to the amateur satellite program. Papers on the following topics are solicited: Students & Education, ARISS, AO-51, P3E, Eagle, and other satellite-related topics.

Camera-ready copy on paper or in electronic form will be due by the date announced on AMSAT website (http://www.amsat.org) for inclusion in the printed symposium *Proceedings*. Papers received after this date will not be included in the printed *Proceedings*. Abstracts and papers should be sent to the name listed in the symposium announcement on the website.

### Meteor Showers

**August:** Beginning around July 17 and lasting until approximately August 24, you will see activity tied to the *Perseids* meteor shower. Its predicted peak is on August 13. The *κ-Cygnids* meteor shower is expected to peak on August 18.

**September:** The *α-Aurigids* is expected to peak on September 1.

**October:** the *Draconids* is predicted to peak on October 8. The predicted ZHR (zenith hourly rate) may reach storm levels. The *Orionids* is predicted to peak on October 21.

**November:** The *Leonids* is predicted to peak around 0340 UTC on November 18. As with last year's shower, this year's peak may go largely unnoticed.

For more information on the above meteor shower predictions see Tomas Hood, NW7US's "VHF Propagation" column elsewhere in the issue of *CQ VHF*. Also visit the International Meteor Organization's website: http://www.imo.net/calendar/2011.

# Hawaii Calls!

## It happens almost every summer. Most of the time it begins during the 4th of July weekend. This year was no exception. Here WB6NOA documents the annual occurrence—and this year's beginning of tropo propagation between Hawaii and the mainland U.S.

**By Gordon West,* WB6NOA**

For over 50 continuous years, the Hawaii VHF/UHF beacon network bangs out 24/7 CW propagation beacons aimed at the United States West Coast, 2500 miles away.

"I don't think we have ever had a summer when I didn't get beacon reports from the mainland," comments Paul Lieb, KH6HME, during his every-year visit to the mainland in January.

"I remember our first Hawaii to West Coast mainland beacon, put together by Ed Tice, W6NGN, from an earlier Gonset 'Goonie bird,' keying the carrier on and off from the Island Hotel elevator roof into a 5-element beam aimed stateside," says Lieb, where no one but the US Navy realized the predictability of the every-July tropospheric duct covering this 2500-mile path.

"In the 1960s, John Chambers, W6NLZ, was well aware of the military tropospheric ducting experiments between Hawaii and San Diego, California (the Tradewinds experiment) and pulled off the first full-fledged QSO on the 220-MHz band," adds Lieb.

Chambers operated from a hill in Palos Verdes, California, and Paul indicates Chambers was quite a character: "If he didn't like you, don't drop by his shack!"

In the 1970s, Paul heard stories about television translator technicians listening to FM music coming from the mainland, at their TV translator site high atop the Mauna Loa volcano. "It was a long drive. There were so many potholes on Saddle Road that you really had to go slowly. And the volcanic road out to the corrugated metal translator shack was barely drivable!" adds Lieb, saying he went through through several Mercury station wagons during his half-century of treks to the top of the hill.

One of the first beacons up at the 8200-foot elevation site, on the side of an active volcano, was W6PJA's 432 CW system. Almost immediately, the 8200-foot site was a "tropo pipeline" into southern California, with beacon reports coming in *throughout the year,* not just in July and August.

Ten years later, the 2-meter beacon went up and the Mauna Loa volcano erupted, with the lava flow making it impossible to get to the beacon site for over half a year. Yes, the beacons stayed on the air!

"The corrugated building has been through a lot. One time a windstorm blew the roof off, but the beacons kept hammering away," laughs Lieb.

Plenty of funny things have happened up at the beacon site during band openings. "About 15 years ago, the tropospheric ducting conditions were so good—all the way up to 3456 MHz, with Chip Angle, N6CA—that I spent an entire week in the metal shack giving out contacts as far north as Washington State, throughout the west coast of Oregon and California, and even into Mexico," adds Paul, remembering that it got down to the high 40s as he slept outside in his the most recent Mercury station wagon.

"Then there was the time I drove Gordon West up to the top of the hill, and I didn't watch the gas gauge. We ran out of gas at the beacon site. We ended up siphoning gas into the car from the underground generator tanks through some open-air hardline!" says Lieb. "Hey, I wasn't worried!"

*Paul Lieb, KH6HME, during the interview at Gordo's QTH and beams aimed to Hawaii on 2 meters and 70 cm, plus 1296 MHz.*

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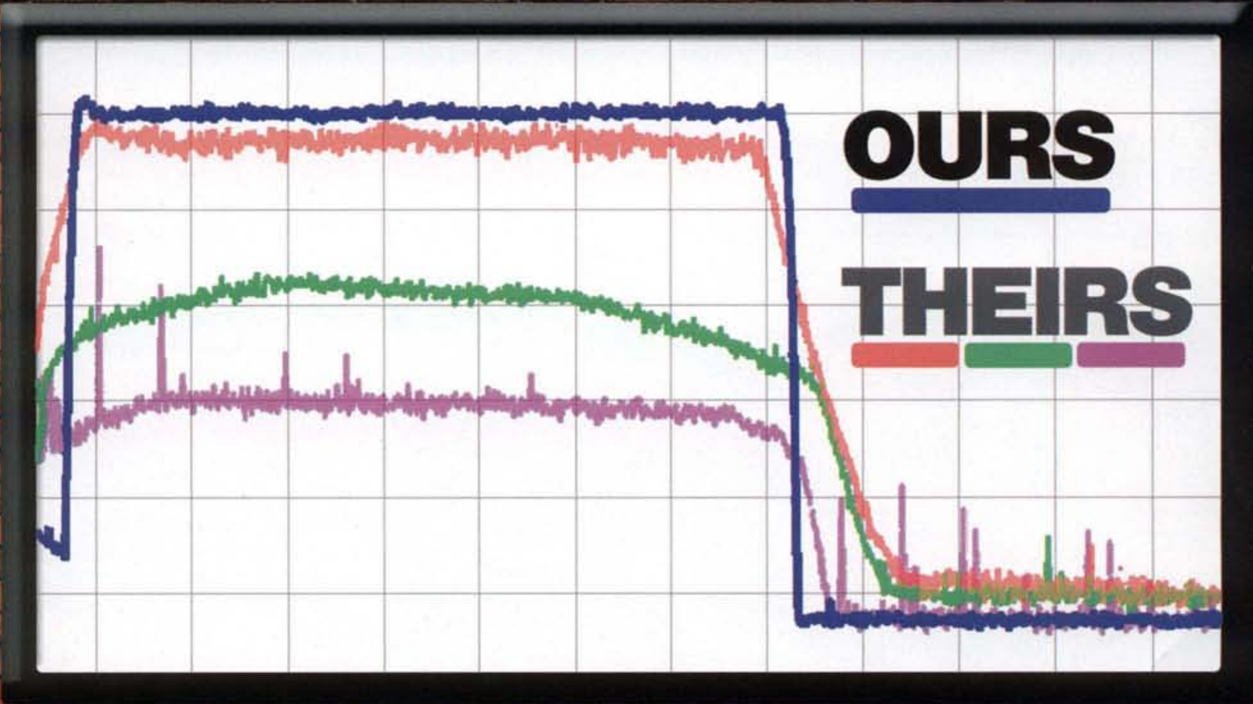
**brick wall** /brĭk - wôl/ ▪ *noun*

anything or anyone that is impenetrable, unrelenting, or unyielding

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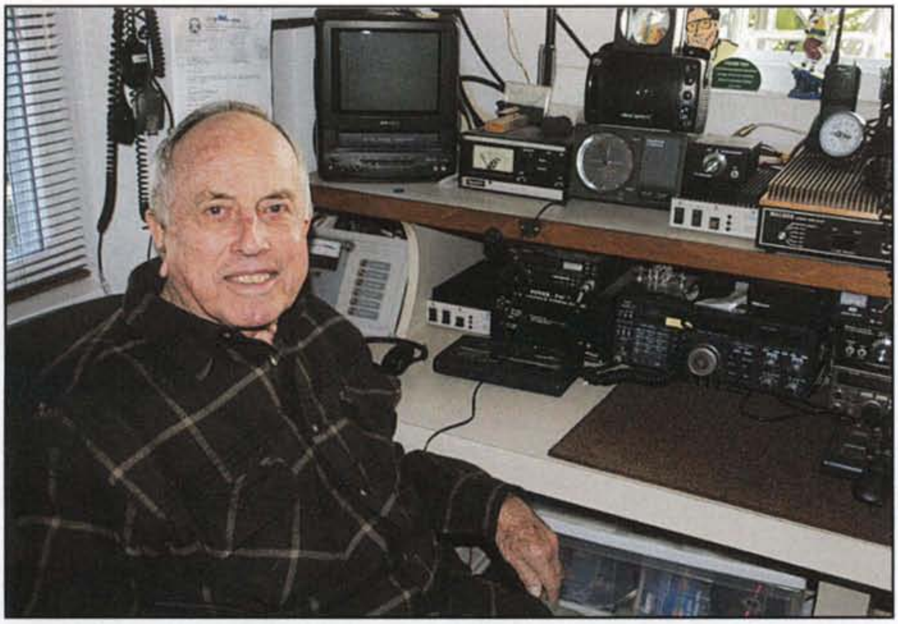
Paul's visitors to the beacon site log in on the back of a wooden door that is filled with callsigns, and until 10 years ago, the door was filling up fast.

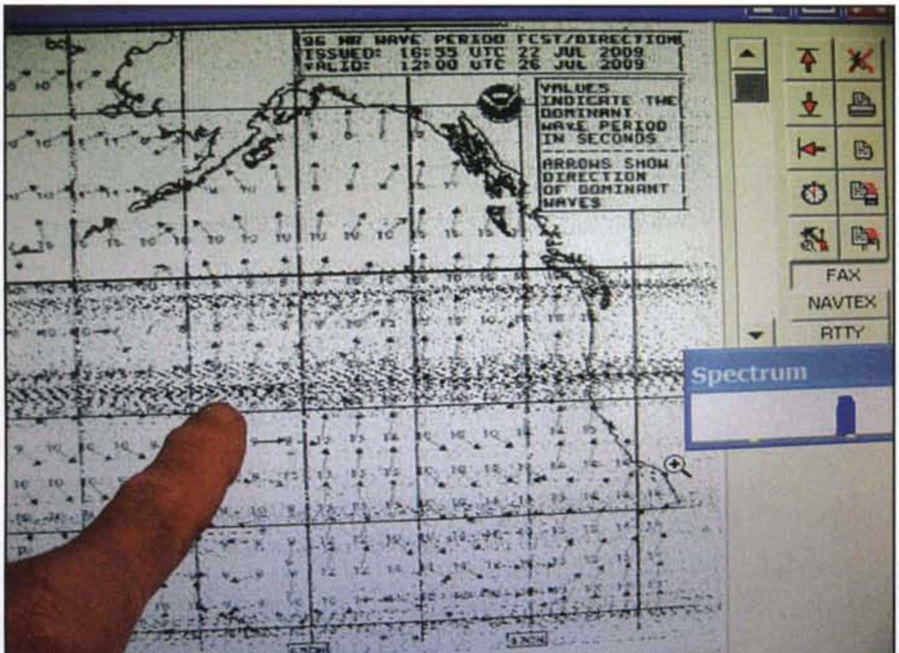
"There is also an FM inter-tie repeater system up here, but they have more repeaters than they do users," smiles Lieb, acknowledging that even weak-signal operation on 2 meters and up is significantly down from a decade ago.

Maybe it's Voice over Internet Protocol (VoIP) tied into local ham repeaters and local simplex stations that no longer create the thrill of actually talking to DX stations. What's the excitement to yak with Hawaii when all you need to do is push *2468, and you can talk to someone on the beach at Waikiki with an HT? No big deal.

"We need to make it a priority to get more hams excited about weak-signal tropospheric ducting," states Paul, tirelessly heeding the call to head up to the beacon site as soon as anyone on the mainland hears the incoming CW signals.



*KH6HME at Gordo's shack during this interview.*




*In the early years, radio fax was the only way to see high-pressure cells over the Pacific .*

July 4th *almost always* sees the "Pacific high" straddling the Pacific Ocean between Hawaii and the US West Coast. This month-long Pacific high is characterized by air aloft descending toward the ocean, called *subsidence*. This descending air stratifies at about the 1000-foot level and is squeezed by moist, dense air below it and the continued descending high-pressure air above it.

When you squeeze air, it gets warm, creating a waveguide effect for VHF and UHF and microwaves. The more narrow the tropo-duct stratified inversion layer, the more intense the signal strengths, and generally the higher the frequency of operation.

"When I see the weather service report a 10-degree increase in air temperature in air aloft, this change is usually enough to trigger a VHF/UHF band opening between my Mauna Loa beacon site to the mainland," says Lieb. Paul then shuts down the beacons, hooks up his regular transceivers, and starts calling CQ on 144.170, as well as 432.075. He sometimes QSYs up to 144.200 and 432.100 to get the attention of mainlanders whose signals he is hearing are 2500 miles away!

"My best DX is northern Washington near Seattle and the tip of Baja, California, including maritime mobile off Baja, too," comments Paul. In his 80s, with the enthusiasm of a teenager, he says he still gets excited when he approaches the beacon site and hears FM music from the mainland pouring in on his car radio!

"Get the word out. Work Hawaii on bands other than high frequency or VoIP. Work us direct on VHF and UHF, SSB and CW," finalizes Lieb, the tropo pioneer who is always there, on the top of Mauna Loa at the beacon site when the band pops open on July 4th, or almost any other time when he learns that the band is open to the mainland.

"I'll be listening!" says Paul, one of the most dedicated and nicest hams I know when Hawaii calls.

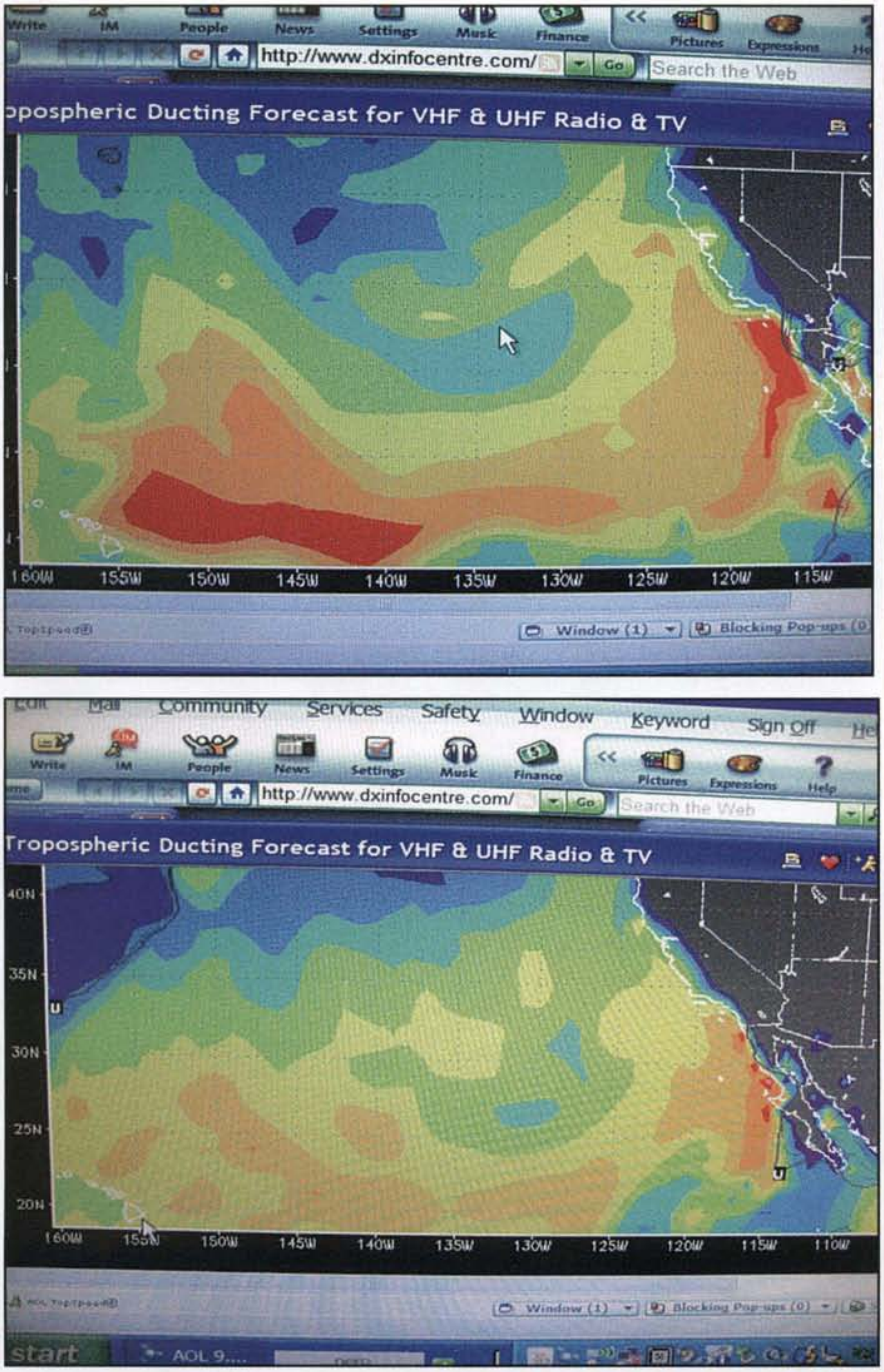
## This Year's Opening

As predicted, the Hawaiian beacon on 2 meters, 144.170 MHz, began to show up to the West Coast on June 23 this year, with a hurricane to the south, and the Pacific high moving on shore in southern California. The tropo opening lasted only a day. However, a bigger opening was looking like it would move in on the classic July 4th weekend. "Every July 4th we get openings to Hawaii," comments Tom Mackay, W6WC.

Most interesting, via the Catalina Island mountaintop repeater, 147.090 MHz, operated by Frank Shannon, KR6AL, was "Doctor Quack"(KH6DQ) in Hawaii coming over the repeater on FM and yacking up a storm over the repeater to California hams, 2500 miles away, like he was a local!

As forecasted, the Hawaii VHF/UHF beacon came out of the fireworks' smoke and noise on the 4th of July evening. Paul, KH6HME, made it to the hill the next day, July 5th, and when he shut down the beacon and lit up his transceiver, there was a pile-up to work him, from San Diego to the Bay Area!

At one point, he accommodated a request to switch over to FM, and this




*Hepburn computer analysis of tropo opening between southern California and Hawaii.*

*Chip Margelli, K7JA, preparing to listen for Hawaii down at the beach in southern California! Sometimes an on-the-water location is best for tropo.*

made him the most popular signal on the 2-meter band! Many FMers were cross-polarized, but his signal from the 8200-foot Mauna Loa active volcano was *so* strong that the copy was full quieting!

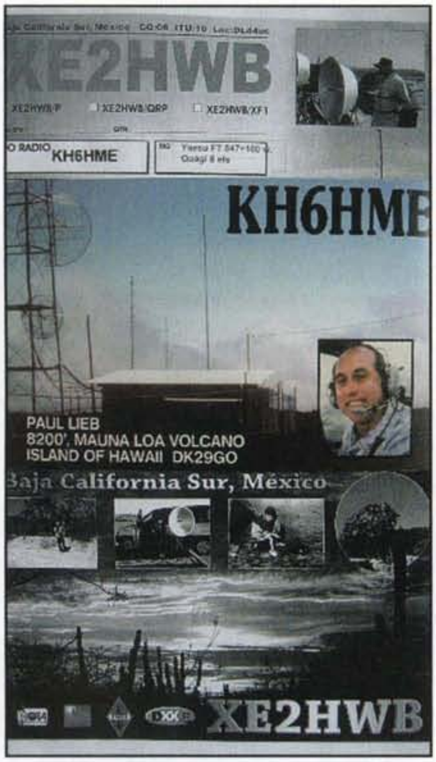
The tropo opening was classic—high pressure system between California and Hawaii, clouds just below Paul, looking to his east at the West Coast mainland.

Here in southern California, hot weather with a blanket of low clouds and fog was just sitting on the shoreline. The Hepburn report showed a favorable path between California and Hawaii on VHF/UHF.

"I could hear FM broadcast stations on my car radio on the trip up to the 8200-foot volcano—FM stations from the mainland and Mexico," comments Lieb. "Stereo, too!" he adds, "coming in to my station 5/9.

Paul was 5/9 on 432 MHz, with the 1296-MHz beacon also being heard—2500 miles away, tropo! Paul remained on the air for over six hours, but headed down the hill (a three-hour drive) to swap out a relay hanging up on his preamp. He promised to head back on the hill the next day, if we continued to hear the beacon coming in to the West Coast.

As I conclude writing this article, it is midnight now on July 5th and all three beacons on 144, 432, and 1296 MHz, are pounding into my shack near the Pacific! It looks like it will be another good year for tropo openings between the West Coast and Hawaii, on all bands from 2 meters on *up*!




*KH6HME's QSL from the record-making contact with Mexico.*


*This DSP speaker from West Mountain Radio really helps in detecting a band opening to Hawaii from the mainland .*

# On the MUF of Sporadic-E VHF Propagation

## Petit Chordal Hop and Layer Trapping

The classic model of *Es* propagation can support maximum usable frequencies (MUFs) above 144 MHz, but only rarely, and exponentially so, for 220 MHz. How, then, to explain the frequent reports, worldwide, of VHF propagation with high MUFs? This article demonstrates, for the first time, that this propagation likely occurs by means of *petit chordal hop* in a disturbed *Es* layer. Indeed, *petit chordal hop Es* may be more the norm than the exception in supporting VHF propagation from 50 MHz on up. In addition, high MUFs may be supported on some occasions by signal trapping between closely spaced *Es* layers, one above the other.

**By Roger L. Harrison,* VK2ZRH**

There has been much comment, discussion, and speculation over decades on the whys and wherefores of sporadic-*E* (*Es*) propagation at VHF. Given that it's an ionospheric mode, just how *Es* supports propagation at frequencies into the mid-VHF range and higher has puzzled amateurs and scientists alike and led to some interesting speculation on occasions.[1, 2, 3, 4, 5]

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***Editor's note:*** *The original of the following article appeared in the 2/2011 issue of DUBUS (Vol. 40, 2nd quarter). This article has been edited to better suit a North American audience. Any queries should be directed to the author at his address above.*

Sporadic-*E* contacts between amateurs on the 50-MHz band have been commonplace for many decades. More recently, contacts on 70 MHz between amateurs in countries having that band allocation have also become more or less commonplace. With the proliferation of amateurs operating on 144 MHz in countries the world over, reporting of contacts via sporadic-*E* has burgeoned over the last 20 years. It's almost 50 years since I first experienced *Es* DX on 6 and 2 meters, and 40 years since I first researched ionospheric sporadic-*E* and VHF propagation.

In my early career, during the 1970s, I worked in a senior technical position at the Australian IPS Radio and Space Services (IPS) for some seven years. I learned a lot about the

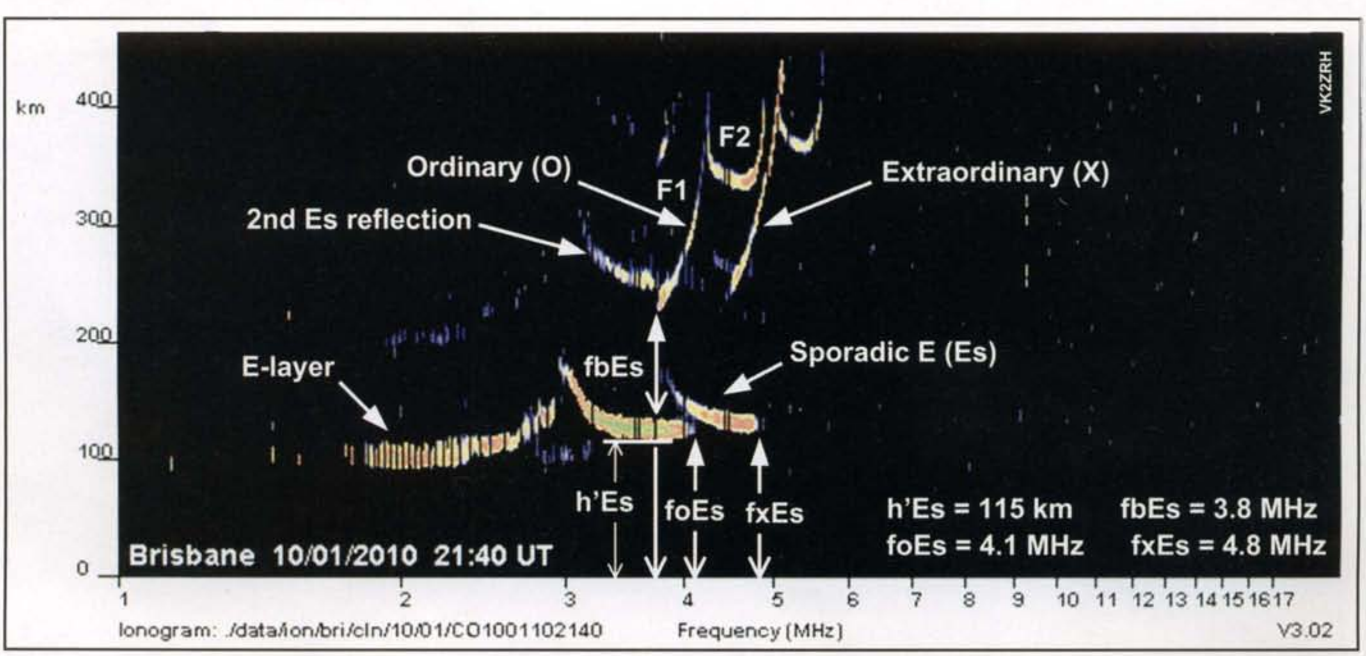



*Figure 1. Vertical incidence ionogram with various key features marked. The ordinary (O) and extraordinary (X) ray reflections are clearly seen, O to the left, X to the right. The ordinary ray penetration frequency of the Es layer, foEs, is a measure of the peak electron density. The Es layer is "blanketing" the F1 layer below 3.8 MHz (denoted as fbEs).*

ionosphere and ionospheric radio propagation. I learned to interpret and scale ionograms (read off the parameters). I worked in trans-equatorial VHF propagation research and ionosonde technology, among other things, and pursued my interest in sporadic-*E* in my own time, with the encouragement of colleagues at IPS. I have trawled through and scaled many thousands of ionograms, recorded on 35-mm and 16-mm film in that era. Sparked by studies of *Es* in North America written by Melvin Wilson, W2BOC[1] and Pat Dyer, WA5IYX[6], I researched the diurnal and seasonal morphologies of *Es* in the Southern Hemisphere, including the high latitudes[7], using both ionograms and amateur VHF-band reports. When I rekindled my interest in sporadic-*E* during the past decade, all this experience came in handy.

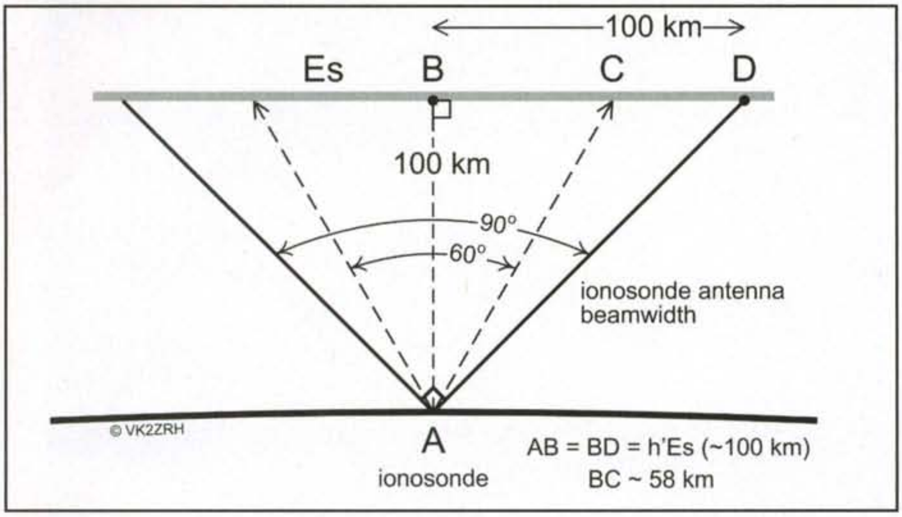



*Figure 2. Vertical elevation, showing geometry of the ionosonde "view" of a sporadic E layer (not to scale). As shown, if h'Es is 100 km, the antenna system illuminates a circle of 100 km radius (BD). If h'Es is 115 km, then the view radius is 115 km.*

*Es* propagation on the lower VHF bands of 50 and 70 MHz is generally considered to be via conventional ionospheric propagation modes—the simple geometry you learned about when studying for your license exam. But many amateurs are skeptical of or don't believe this could hold up at 144 MHz (or even at 100 MHz in the FM broadcast band), or if it did, such events would be extremely rare. However, reports of widespread 144-MHz *Es* DX over decades are now so numerous as to confound that[8] while the observations and analysis of *Es* propagation on the 88–108 MHz FM broad-

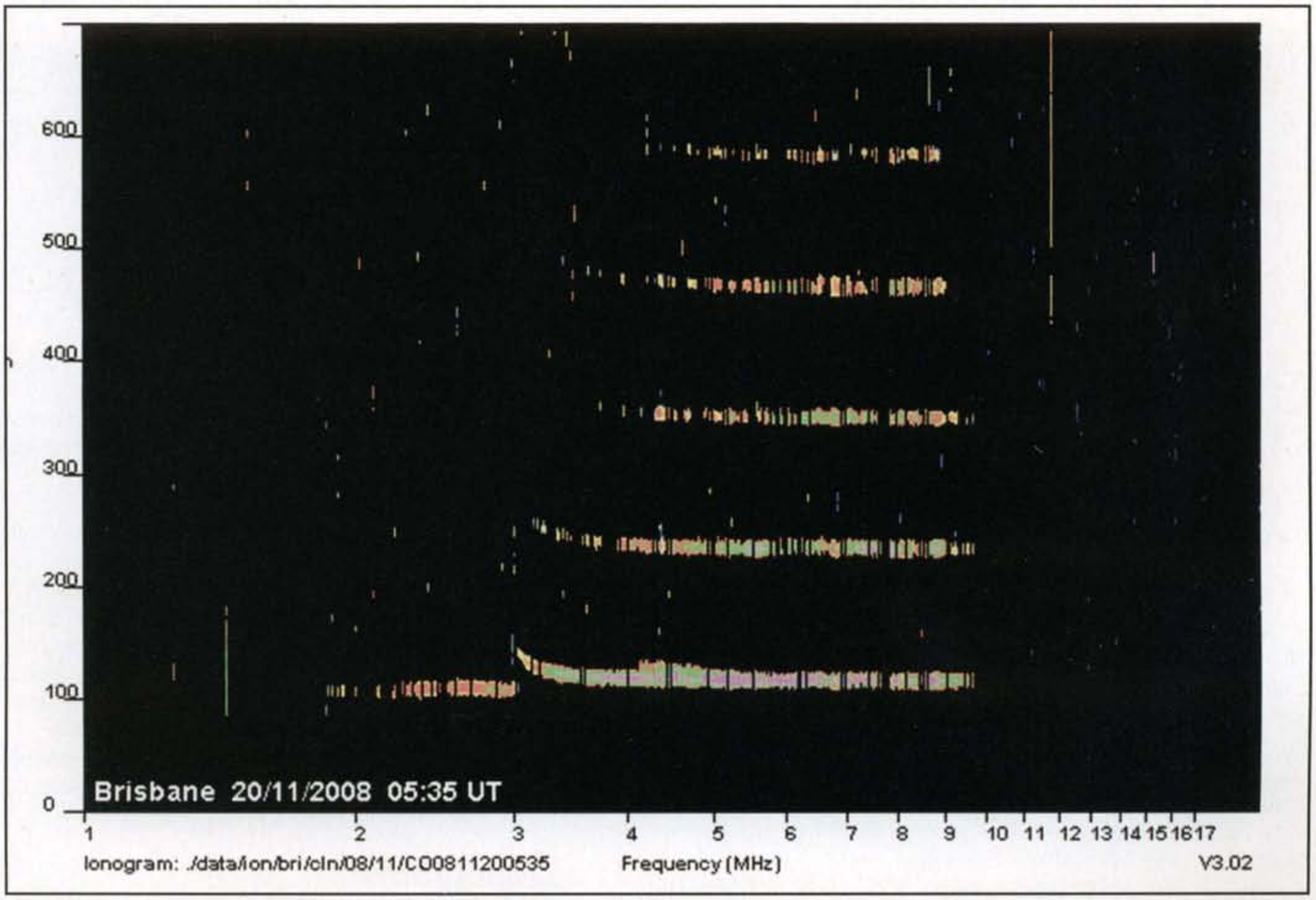



*Figure 3. Ionogram showing a dense, totally reflecting plane Es layer at 110 km, having a high value for ftEs of 9.6 MHz. Hence, foEs here is 8.9 MHz.*

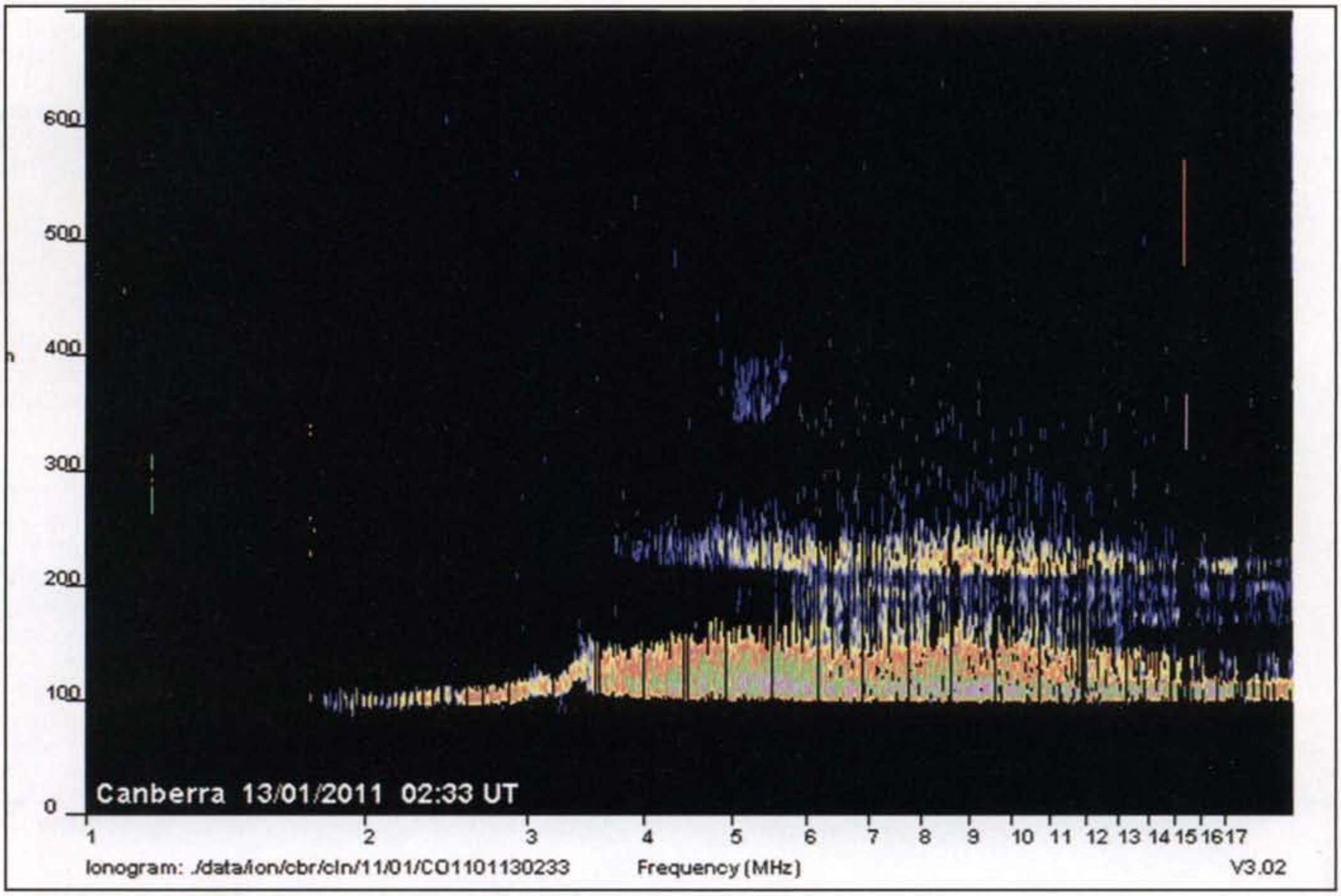



*Figure 4. An example of "spread Es." The first F-layer echo is mid-image; fbEs is 5 MHz. Lowest virtual height, h'Es, is 99 km. The top frequency is above 20 MHz, so peak electron density is very high.*

| foEs | h'Es (km) | $D_{MAX}$ | Angle (*i*) | $f_{MAX}$ |
|---|---|---|---|---|
| 9 MHz | 90 | 2141.8 | 80.43 | 54.2 |
| | 100 | 2257.6 | 79.91 | 51.5 |
| | 110 | 2367.8 | 79.43 | 49.2 |
| | 120 | 2473.1 | 78.97 | 47.2 |
| | 130 | 2574.1 | 78.52 | 45.4 |

*Table 1. Basic Es propagation parameters for the limiting case, where angle (e) = 0O. Indicative values of $f_{MAX}$ are derived for foEs of 9 MHz. Note how $D_{MAX}$ and $f_{MAX}$ vary with h'Es.*

cast band by Pocock and Dyer are legendary.[9] Thus, what's happening?

## Revisiting the Propagation Model

With the advent of the VK Logger (www.vklogger.com) for reporting VHF propagation in the Australasian region, and the availability of IPS ionograms online[10], I have been able to take advantage of the opportunity to scrutinise VHF propagation paths in Australia where the mid-points are located within "view" of an ionosonde, as this enables direct modeling of the propagation geometry and its relation to ionospheric conditions. The results have been both "as expected" and delightfully surprising!

Mid-latitude sporadic-*E* consists of thin, dense layers of ionization formed by wind shears in the *E*-region that compress long-lived metallic ions into horizontal clouds or "patches" from less than 1 km to about 5 km thick, appearing at heights ranging generally between 90 and 130 km. Patches may be only 100 m across, with clouds up to thousands of km in extent.[11, 12, 13]

I have found that VHF propagation by sporadic-*E* occurs by at least two principal modes:

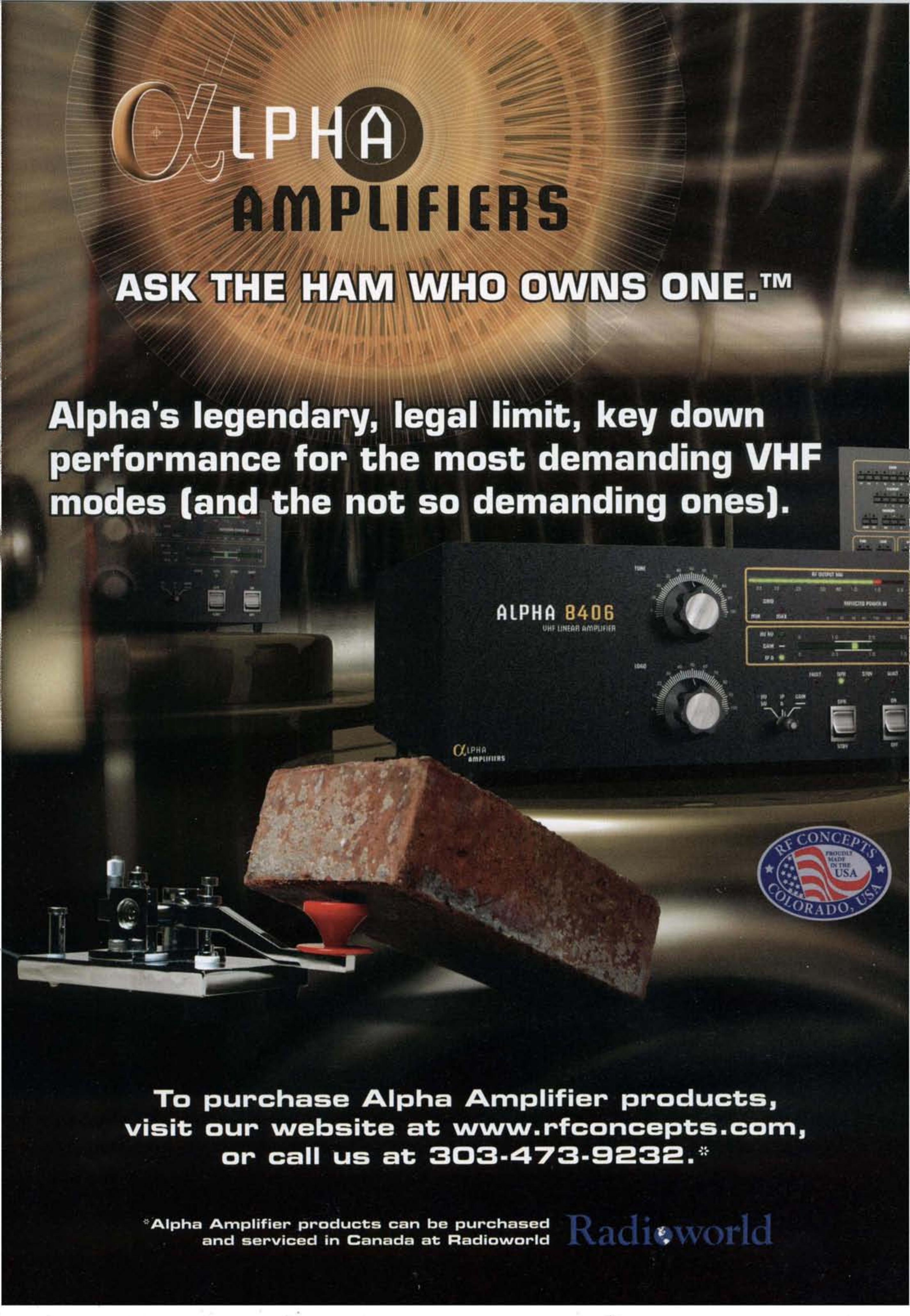
1. conventional ionospheric reflection ("classical") by a thin, "plane" *Es* layer, and
2. by successive reflections via the crests of ripples or other structures in an *Es* layer that subsequently returns the raypath to Earth—which I call *petit chordal hop*.

In each case, I can demonstrate with case studies that the well-established propagation geometry and ionospheric science can be applied to analyse and model the propagation and the maximum usable frequency (MUF) for a path. However, *there may be a third propagation mode that I have dubbed "layer trapping,"* which I discuss later in this article. Both petit chordal hop and layer trapping enable *a dramatic increase in the MUF of an oblique propagation path.*

Before going into the details of these propagation models, it is first necessary to understand something about sporadic-*E* as seen on vertical incidence (VI) ionograms.

## *Es* on Ionograms

VI ionograms are produced by swept frequency, pulsed RF HF radars with antennas pointed straight up. The echoes returned from the various regions of the ionosphere are dis-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played on a graph of height versus frequency. Figure 1 is a fairly typical summer-morning ionogram for Brisbane, Australia, showing the *E, F1,* and *F2* layers and sporadic-*E*.[14] I have marked the various features. The ordinary (O) and extraordinary (X) reflections are clearly seen, O to the left, X to the right. The "split" reflections result from the effect of the Earth's magnetic field on RF propagation in the ionosphere. The *E, F1,* and *F2* echoes curve upward to a cusp as frequency increases due to group retardation of the signal near the peak electron density. The *Es* traces do not curve up, as the layer is very thin and the ionosonde resolution is insufficient to resolve it. Note the multiple reflections. After the first return, the others are from repeated ground-ionosphere-ground echoes.

The ordinary ray penetration frequency, or *foEs*, is important because it's a measure of the layer's peak electron density. The *Es* virtual height, or *h'Es*, plays a key role in determining the propagation path distances and, in conjunction with *foEs*, the MUF of the path. The extraordinary ray penetration frequency, *fxEs*, is 0.7 MHz higher than *foEs*. The difference (called the "split") is half the gyrofrequency (fH), the natural "spin rate" of electrons in the ionosphere, which is 1.4 MHz at Brisbane.[15] Hence, *fxEs – foEs* = 0.7 MHz.

## The Ionosonde "View"

IPS ionosonde antennas are upward pointing crossed-deltas (many ionospheric stations use these antennas). They have a half-power beamwidth of about 90° through the mid-HF range, narrowing to about 60° above 10 MHz.

As illustrated in figure 2, when *Es* is present, the antenna system "illuminates" an area with a radius equal to the height of the *Es* layer (also referred to as "whole sky" illumination) and the receiver will respond to returns from within the entire area covered. If *h'Es* is 100 km, the view radius is 100 km. At the narrower beamwidth, the radius of the circle illuminated is about 58% of that for the wider beamwidth. Nevertheless, the ionosonde receiver responds to echoes across the whole area, particularly when the *Es* has ripples or other structures within it.

## Ionograms of Particular Interest

Figure 3 is an ionogram showing *Es* typical of a flat (or "plane"), thin, dense layer over Brisbane. Note the multiple reflections. No *F*-layer echoes can be seen, so the *Es* is said to be fully blanketing. The virtual height of the first return is 110 km, and it ceases at the "top" penetration frequency, denoted as *ftEs*, which is 9.6 MHz. To determine *foEs* from an ionogram like this, *ftEs* is generally assumed to be *fxEs*, and *foEs* is found by subtracting half the gyrofre-

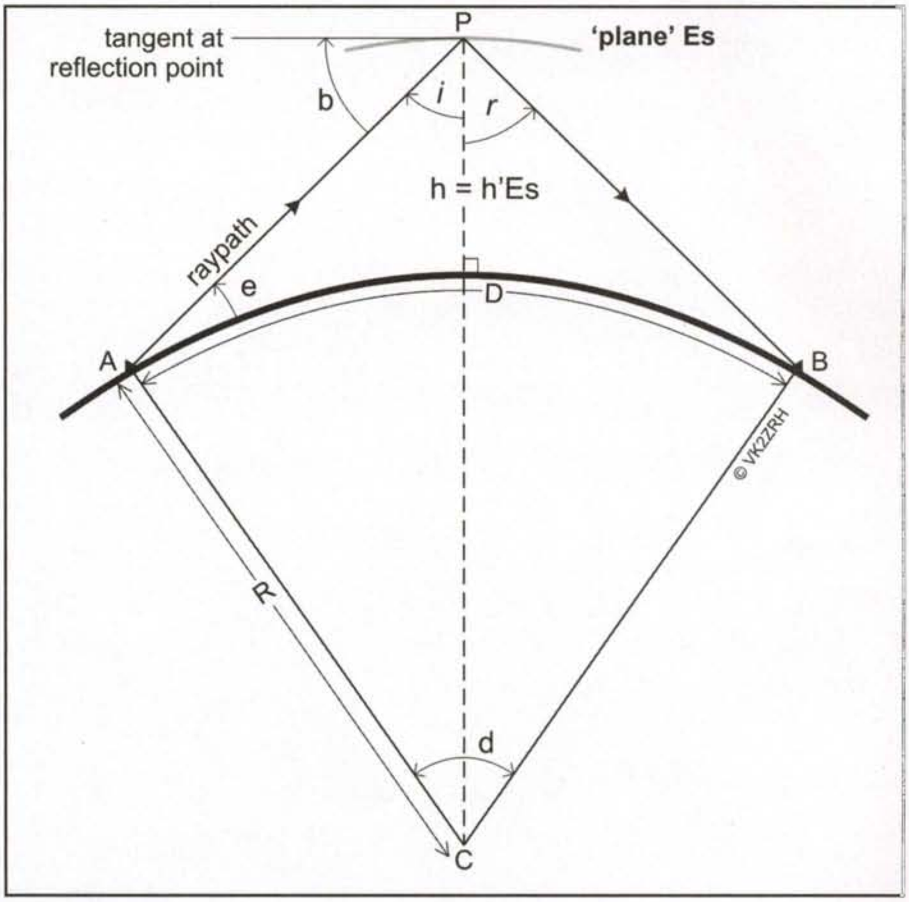


*Figure 5. Geometry of propagation via plane Es (exaggerated scale). R is the radius of the Earth. D is the distance over the Earth's surface between A and B. The line from C to P is at right angles to the Earth's surface and has a length of R + h. Angle (b) = 90 – i.*

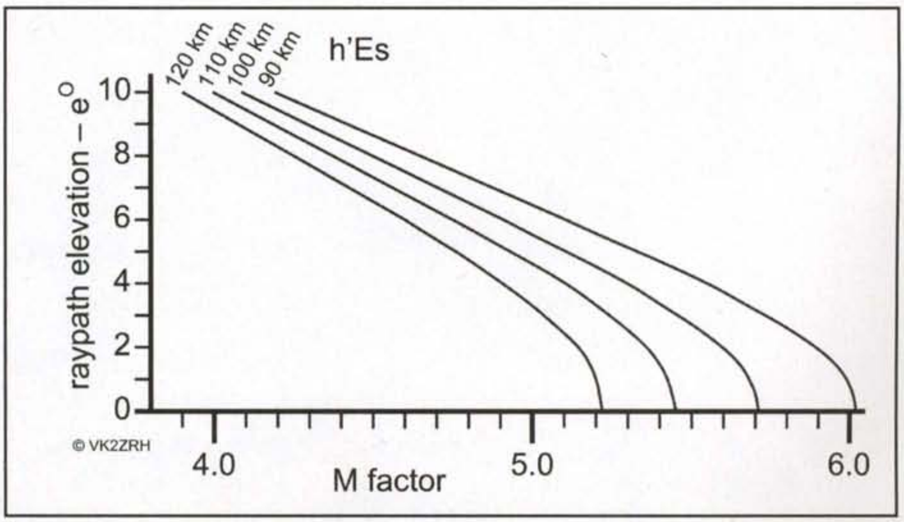


*Figure 6. How the M factor varies with the raypath elevation angle and height of a plane Es layer.*

quency. Therefore, in this instance, *ftEs* – 0.7 MHz = *foEs* = 8.9 MHz.

Figure 4 is another ionogram, this time showing "spread" *Es*. The spreading of the *Es* traces likely arises from crinkles, ripples, or other structures in the *Es* layer, which reflect the transmitter pulses from varying ranges at oblique angles, as well as from directly overhead, perhaps at different heights. Group retardation also contributes to the spreading. Note that the *Es* trace extends off-scale at 20 MHz and only partially blankets the *F*-layer. Spread *Es* is a common phenomenon.

## VHF Propagation via a Thin, "Plane" *Es* Layer

The geometry of a propagation path via plane *Es* is illustrated in figure 5. A plane *Es* layer lies parallel to the Earth's surface, not tilted across its extent or having ripples or other structures in it (no lumpy bits!).

The raypath of a signal from a transmitter at A, at an angle (e) above ground, travels towards the *Es* layer, is refracted towards the ground at P, and received at B. The common convention refers to this as reflection. Here, (*i*) is the angle between the incident raypath and the vertical line through P, while (*r*) is the angle between the vertical and the emerging raypath. Angle (*e*) is the raypath elevation angle, while angle (*b*) is that between the incident raypath and a tangent to the reflection point at P, which is a horizontal line. These angles are important in determining the MUF for a path.

In *Ionospheric Radio*[16], author Davies sets out the relationships for propagation in a thin layer in a series of very useful equations.

$$f_{op} = foEs.\sec(i) \qquad \text{Eq. 1.0}$$

where: $f_{OP}$ is the usable operating frequency, and *foEs* the measured ordinary ray vertical incidence penetration frequency at P.

This is the well-known "secant law" relationship, from which the "classical MUF" can be evaluated. The secant of an angle varies from 1.0 at 0° to infinity at 90°. So you can see immediately that the larger the incident angle, the greater the usable operating frequency for a given value of *foEs*. There is a maximum value for (*i*), which is reached when the elevation angle is tangent to the Earth—i.e., angle (e) = 0°. Triangle CAP is now a right-angle triangle. Hence, sin(*i*) = CA/CP. The length of CA is R, while CP is R+h, so we can find the maximum of angle (*i*) as follows:

$$(i)_{MAX} = \arcsin\left[\frac{R}{R+h}\right] \qquad \text{Eq. 1.1}$$

When (e) is 0°, this sets the maximum (theoretical) one-hop range or path distance, expressed as:

$$D_{MAX} = \sqrt{8Rh} \qquad \text{Eq. 1.2}$$

This situation also sets the maximum possible usable frequency, expressed as:

$$f_{MAX} = foEs\sqrt{\frac{(1+R)}{2h}} \qquad \text{Eq 1.3}$$

These three equations cover the "limiting case," where (e) = 0°. Equation 1.3 gives us the MUF for the limiting case. Clearly, the height of the *Es* layer (*h'Es* = h) is important to all these relationships, so all the critical parameters of *Es* propagation are determined by *foEs* and *h'Es*. For a given value of *foEs*, the maximum path distance and $f_{MAX}$ vary directly with the *Es* layer height, as shown in Table 1. The mean radius of the Earth used in the calculations is 6371 km.[17]

Achieving a raypath elevation of 0° is generally impractical, but many *Es* propagation paths occur at remarkably low angles, often in the range 2–3°, or occasionally below. VHF antenna radiation patterns in the vertical plane may show low responses at such angles compared to the peak gain elevation angle, but the response is not zero. Remember that aircraft-enhanced propagation on long paths occurs at angles below 1°, for example.

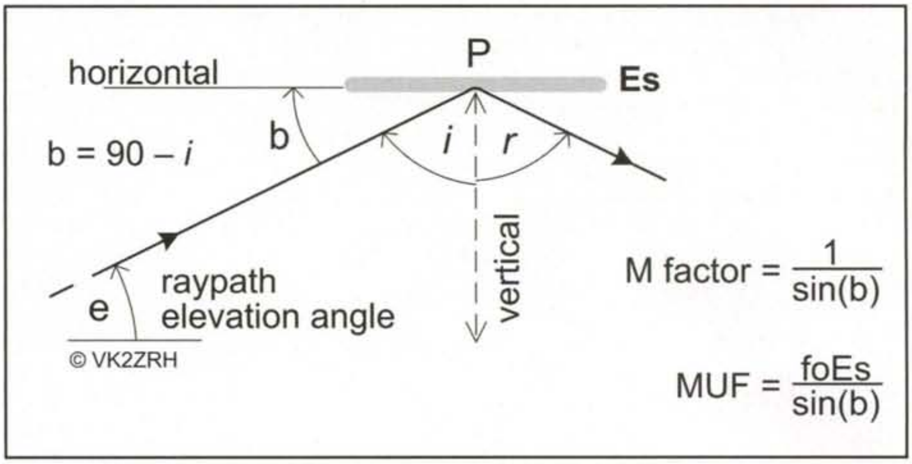


*Figure 7. Close up of the geometry for propagation via plane Es.*

For path geometries other than the limiting case—i.e. generally "usual" circumstances—a little trigonometry provides the following equations for determining (*i*) and D:

$$(i) = \arcsin\left[\frac{R}{(R+h)}\sin(90+e)\right] \qquad \text{Eq 2.1}$$

$$D = \frac{2R}{57.3}\left[(90-e)-i\right] \qquad \text{Eq 2.2}$$

The MUF is determined by the secant law:

$$MUF = foEs.\sec(i) \qquad \text{Eq 2.3}$$

Knowing *foEs* and *h'Es* at a path midpoint, and thus being able to derive angle (*i*), sec(*i*) is referred to as the "M factor" (multiplier), for obvious reasons. To make life easier in determining the MUF, it's more convenient to deal with the more familiar sine and cosine trigonometric functions, which are "standard" functions on scientific calculators and in printed tables of sin, cos and tan values. The secant of an angle is the inverse of its cosine, so 2.3 can be rewritten as:

$$MUF = \frac{foEs}{\cos(i)} \qquad \text{Eq 2.4}$$

As angle (b) is the complement of (*i*) [that is, 90 – *i*] and sine is the complement of cosine, 2.4 can be rewritten as:

$$MUF = \frac{foEs}{\sin(b)} \qquad \text{Eq 2.5}$$

Thus, the M factor can be evaluated from either 1/cos(*i*) or 1/sin(b).

$$M\ factor = \frac{1}{\cos(i)} = \frac{1}{\sin(b)} \qquad \text{Eq 2.6}$$

The relationship between the raypath elevation angle (e) and the M factor is non-linear, with a different curve for different *Es* layer heights, as illustrated in figure 6. *Es* layers at the lower heights yield a higher M factor and thus higher MUFs. A lower raypath elevation angle, with longer paths, rapidly improves the M factor, but angles below 2° experience a flattening of the M factor increase in all cases. The M factor for the limiting case, with an *Es* layer height of 90 km, is 6.03; for *Es* at 100 km, it's 5.73; at 105 km, it's 5.6 (not 5.3 or 5.4, with an assumed height of 100 or 105 km, as is often bandied about).

Table 2 illustrates the MUFs achievable for a variety of ionospheric and path parameters. The range of *h'Es* values here are commonly observed on ionograms (e.g., figures 3 and 4) and the path lengths are generally typical, at least in the Australasian-South Pacific region. For *Es* propagation at 144.5 MHz, note that *foEs* needs to be above 24 MHz for elevation angles up to 4° or 6°. I personally have observed such values of *foEs* on ionograms when 'sondes swept 1–30 MHz (1950s–1970s era). Indeed, I have seen ionograms with *Es off-scale* at 30 MHz from that era. However, while memorable, they were not common. Instances of off-scale *Es* at 20 MHz on present-era ionograms are readily found among the online displays of the IPS network stations.[14]

Figure 7 sums up the case for the geometry of VHF propagation via plane *Es*. As *Es* is very thin compared to its altitude, the trigonometry is much simpler than that employed for *F*-layer propagation and parallels optical reflection from a mirror.

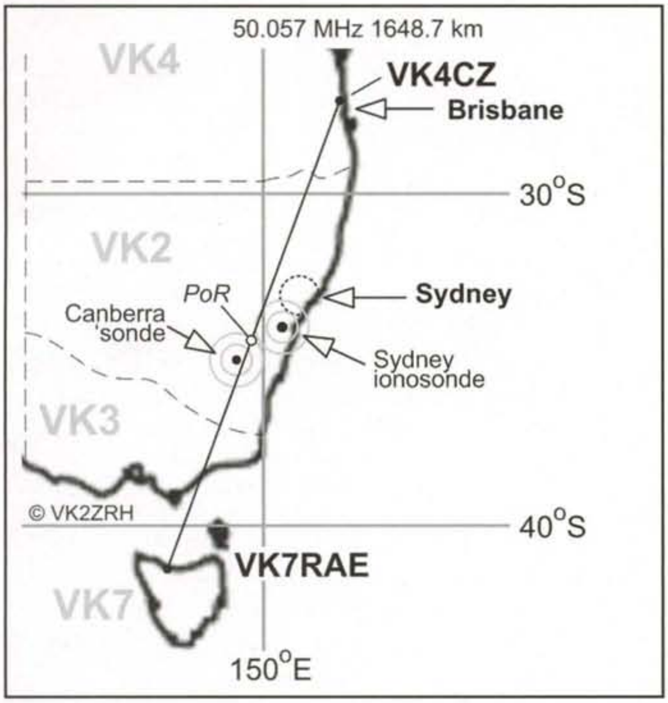


*Figure 8. The path between the VK7RAE 50.057-MHz beacon at Devenport, Tasmania, and VK4CZ on the north side of Brisbane, Queensland. The circles around the two ionosonde locations show each ionosonde's view at Es heights; they don't quite overlap.*

## A Case Study of Plane *Es* VHF Propagation

Figure 8 shows a path between VK4 (Queensland) and VK7 (Tasmania) where the path mid-point passes within the view of the Canberra ionosonde at *Es* heights. The mid-point, and likely point of reflection, is marked *PoR*. Scott, VK4CZ, frequently spots this 50.057-MHz beacon on the VK Logger with RST reports ranging from 419 through 599. Figure 9 is the ionogram nearest to the time of one such spot—2304 UT on 2 January 2009. Here, *ftEs* is 10.2 MHz. As *fH* is 1.6 MHz at Canberra[15], *foEs* would be 10.2 – 0.8 = 9.4 MHz.

As the path length is known, the elevation angle (e) is calculated to be 2.6°, and angle (*i*) to be 79.98°. Hence, angle (b)

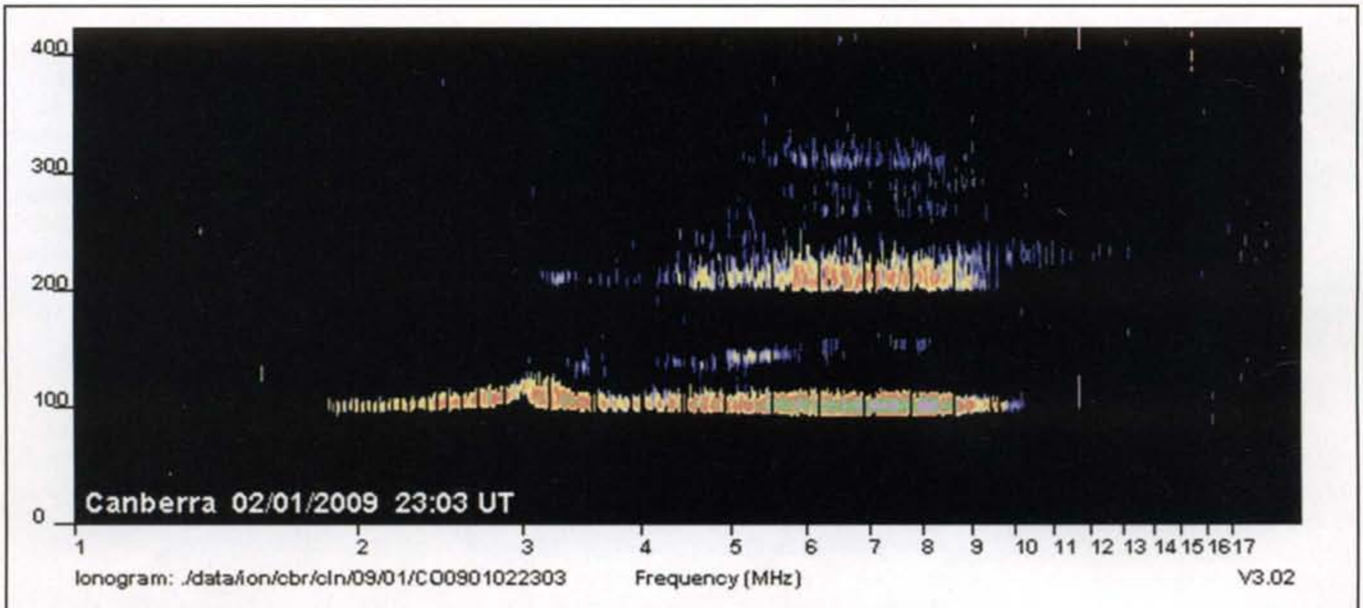


*Figure 9. Ionogram for VK4CZ-VK7RAE (beacon) spot of 2304 UT 2 Jan 2009. The beacon runs 20 W to crossed dipoles (VK Logger, Beacons page). RST was 549. h'Es is 92 km. ftEs is 10.2 MHz. An echo from another Es cloud at a large oblique angle (44°!) is evident. Path length is 1648.7 km.*

| h'Es | (e) | (i) | D (km) | M factor | MUF for foEs of | | foEs for MUF ≥ (MHz) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 9 MHz | 20 MHz | 50.5 | 70.5 | 144.5 |
| 90 km | 1 | 80.37 | 1919.1 | 5.98 | 53.82 | 119.6 | 8.5 | 11.8 | 24.2 |
| | 2 | 80.22 | 1730.1 | 5.89 | 53.01 | 117.8 | 8.6 | 12.0 | 24.6 |
| | 4 | 79.63 | 1416.5 | 5.56 | 50.04 | 111.1 | 9.1 | 12.7 | 26.0 |
| | 6 | 78.72 | 1174.1 | 5.11 | 45.99 | 102.2 | 9.9 | 13.8 | 28.3 |
| | 8 | 77.55 | 989.6 | 4.64 | 41.76 | 92.8 | 10.9 | 15.2 | >30 |
| 100 km | 1 | 79.87 | 2030.3 | 5.69 | 51.21 | 113.8 | 8.9 | 12.4 | 25.4 |
| | 2 | 79.72 | 1841.3 | 5.6 | 50.4 | 112 | 9.1 | 12.6 | 25.8 |
| | 4 | 79.16 | 1521 | 5.32 | 47.88 | 106.4 | 9.5 | 13.3 | 27.2 |
| | 6 | 78.28 | 1271.9 | 4.92 | 44.28 | 98.4 | 10.3 | 14.4 | 29.4 |
| | 8 | 77.15 | 1078.5 | 4.5 | 40.5 | 90 | 11.3 | 15.7 | >30 |
| 110 km | 1 | 79.38 | 2139.2 | 5.42 | 48.78 | 108.4 | 9.4 | 13.1 | 26.7 |
| | 2 | 79.24 | 1948 | 5.36 | 48.24 | 107.20 | 9.5 | 13.2 | 27.0 |
| | 4 | 78.71 | 1621.1 | 5.11 | 45.99 | 102.2 | 9.9 | 13.8 | 28.3 |
| | 6 | 77.86 | 1365.4 | 4.76 | 42.84 | 95.2 | 10.7 | 14.9 | >30 |
| | 8 | 76.77 | 1163 | 4.37 | 39.33 | 87.4 | 11.6 | 16.2 | >30 |

*Table 2. MUFs achievable via plane Es for common path geometry parameters and two indicative values of foEs, plus foEs values required for propagation on 6m, 4m and 2m. Note how relatively small changes in h'Es and path elevation angle (e) affects the MUF.*

is 10.02°. Thus, MUF = 9.4/sin(b) = 9.4/0.17399 = 54.026 MHz. We can be confident that it was *Es* within the Canberra 'sonde's view that supported the propagation on this occasion as the VK7RAE signal raypath to the north of the PoR passes below the *Es* layer at the latitude of the Sydney 'sonde by at least 15 km. A raypath from VK7RAE slightly lower than 2.6° would be reflected from the *Es* layer in the Sydney 'sonde's view, but make landfall some 100 km north of VK4CZ (in the sea!).

## *Petit Chordal Hop* VHF Propagation via Spread *Es*

As outlined earlier, the spreading of *Es* traces on ionograms likely arises from crinkles, ripples, or other structures in the *Es* layer which reflect the 'sonde transmitter pulses from varying ranges at oblique angles, as well as from directly overhead, perhaps at different heights. The structure of *Es* layers has been the subject of considerable scientific research and discussion over decades (e.g., notes 18, 19, 20, 21, 22, 23). It seems that wind-shear turbulence in the neutral atmosphere modulates the ionization in complex ways. While "structured" *Es* is likely to take a number of forms, From and Whitehead[19] and Bernhardt[22, 23] describe layers having "crinkles" or being "rippled," or having "clumps" of greater electron density within the cloud. Likely models of *Es* structures are illustrated in figure 10. It appears that *Es* ripples, as in example (1) and A here, are of small scale, perhaps 1-5 km crest-to-crest, with vertical amplitudes very much less than that. Other likely periodic structures include lobes on the underside of *Es* clouds, as in example (3) and B, of up to 10 km lobe-to-lobe and around 1 km deep, or elliptical structures some 5-10 km long by about 1 km deep.

The proposed principle of *petit chordal hop Es* VHF propagation is illustrated in figure 11. A raypath from a transmitter at A, at elevation angle (e), meets a ripple in the *Es* layer at a small angle (c) to a tangent with an upward tilt of the ripple at P1. If the electron density is sufficient to refract the raypath such that it emerges horizontally, it will then travel to meet the next crest of the ripple at P2, where it will be deflected in a reciprocal manner. The upward tilt of the ripple improves the raypath's obliquity to the *Es* layer and thus the path MUF. The question is, by how much?

Figure 12F shows a close-up of the refraction geometry. The incident signal will reach the *Es* layer over a range of raypath elevation angles. If one raypath strikes a ripple at a tangent such that the tilt angle (t) equals the raypath-to-tangent angle (c), the refracted raypath will be horizontal (i.e., angle (d) = 0°).

The M factor, which I have called the "$M_R$ factor", is determined by angle (c) as is the MUF, now called $M_{UFR}$. Angle (c) will be half that of angle (b), which determined the M factor and MUF in the plane *Es* case. *The impact of this is that the M factor and thus the MUF are very nearly doubled for the range of small angles involved.* For example, if angle (b) is 10° for the plane *Es* case, then angle (c) for the spread *Es* case is 5°. Sin(10) divided by sin (5) is 1.9924. The equations for the M factor and MUF now become:

$$M_R \text{ factor} = \frac{1}{\sin(c)} \qquad \text{Eq 2.7}$$

$$MUF_R = \frac{foEs}{\sin(c)} \qquad \text{Eq 2.8}$$

The geometry establishes a critical angle for the *Es* tilt angle (t) related to the raypath elevation angle (e). For a raypath elevation angle very slightly greater, it will meet a slightly smaller tilt angle (closer to the nose of the crest) and the reflected raypath will emerge at an angle below the horizontal. A raypath with (e) very slightly smaller will meet a slightly greater tilt angle (farther to the right of the crest's nose) and the reflected raypath will emerge above the horizontal.

For a raypath that strikes the right-hand crest just past the nose, the elevation angle will be lower and it will need a slightly smaller *Es* tilt angle to be reflected horizontally. Likewise, a raypath that strikes a crest to the left will be at a higher elevation angle and will find a slightly greater *Es* tilt angle to be reflected horizontally.

The array of wave-like ripples or other periodic structures in the *Es* will act on an incident wavefront in a way similar to how an optical diffraction grating affects monochromatic light. The emergent wavefront breaks into alternate areas of *constructive* and *destructive* wave interference, yielding footprints on the ground of high signal strength in some places and low strength or no signal in others. This is sometimes called the "flashlight effect." It torments operators who can hear nearby stations working DX that they can't hear! There can be a number of reasons for this effect with *Es*; the foregoing is just one.

For *petit chordal hop* via spread *Es*, the variation of the $M_R$ factor with elevation angle and *h'Es* is illustrated in figure 13. Compare this to figure 6.

One last question arises: If the ripples are shallow, will they produce the tilt angles in the *Es* required to support *petit chordal hop*? Yes! If the ripples are sinusoidal in shape (or roughly so), with a depth of at least 5% of the crest-crest distance, the tilt angle will range from 0° at the lower crest to 5.7° maximum at half depth, which is sufficient for paths having elevation angles up to 6°, 5°, 4°, and 3° when *h'Es* is, respectively, at 90, 100, 110, and 120 km. Ripples with a crest-to-crest scale of 1 km may be less than 100-meters deep; at 3 km crest-to-crest, only 150-meters deep. Greater depth/crest-crest ratios provide a greater range of angles. The range of tilt angles required for *petit chordal hop* extend from about 4.8° up to about 7.4° for *h'Es* ranging from 90 km to 120 km.

If the spread *Es* consists of structures as in figure 10 (3) and (4), their cross-sections may range from roughly circular to elliptical and thus present a suitable range of tilts facing the ground. Figure 14 illustrates an upward-looking plan view of raypaths supported by such structures. Propagation by *petit chordal hop* from wave-like ripples in *Es* would not be supported where raypaths were parallel, or nearly so, to the waves. Lobular *Es* structures will support petit chordal hop in any direction.

Table 3 (like Table 2) illustrates the MUFs achievable for a variety of ionospheric and path parameters under spread *Es* conditions. Values of *h'Es* and path lengths (D) are generally typical. For *Es* propagation at 144.5 MHz, note that the required *foEs* ranges between only 12.2 MHz and 16.7 MHz! These are values commonly found on ionograms from

*(Continued on page 68)*

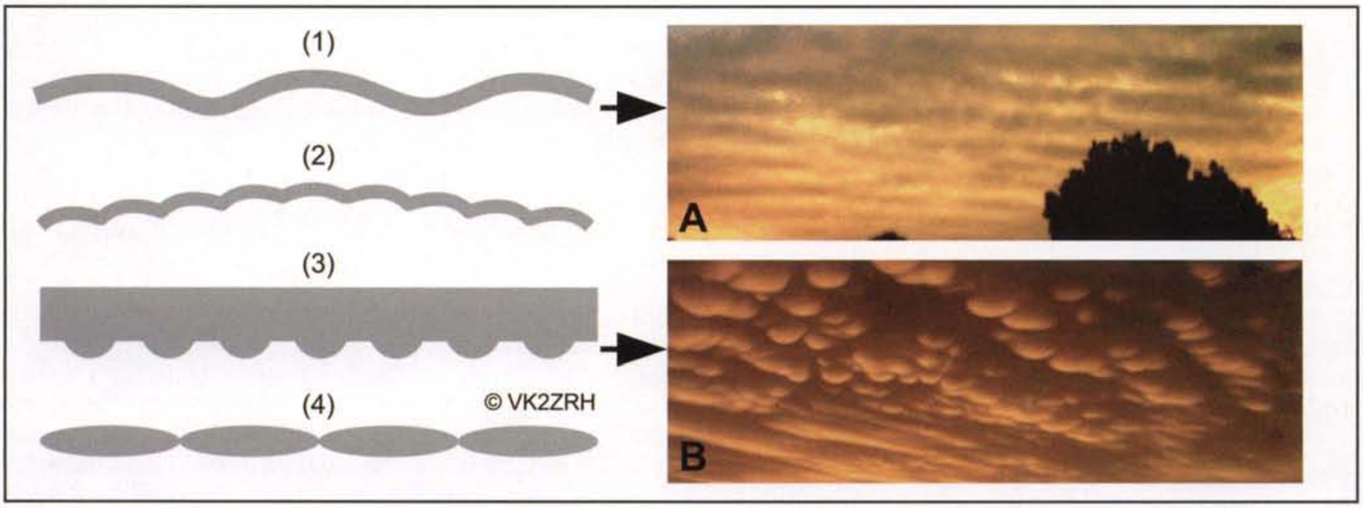


*Figure 10. At left: some likely models for Es structures (seen in profile), based on references 12, 15, and 16. Turbulent wind shear structures are the cause of spread Es on ionograms. (1) Rippled layer. (2) Ripples on a long wave. (3) Lobes on the underside of a layer. (4) Clumping produced by Kelvin-Helmholtz turbulence. At right: images of atmospheric clouds produced by wind-shear turbulence. A– rippled wave cloud formation (pic: author). B– mammatus cloud formation (pic: Wikipedia commons).*

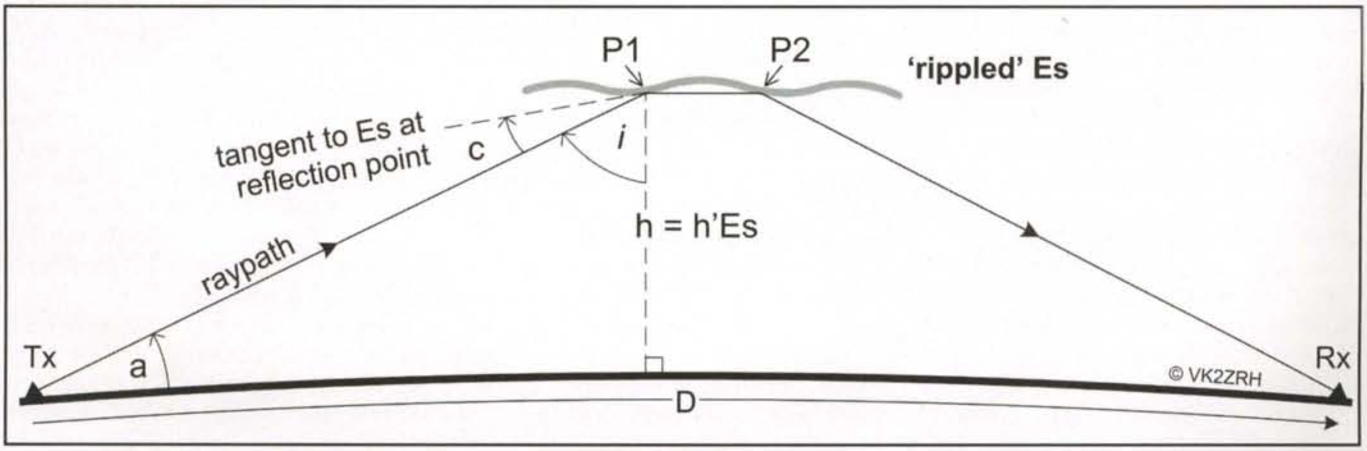


*Figure 11. The general geometry of petit chordal hop propagation via a rippled (or structured) Es layer. The raypath is refracted to the horizontal at P1 via a suitable tilt in the Es layer, then refracted back to ground at P2 via a reciprocal tilt. Path MUF rises significantly. The distance from P1 to P2 may range from 1 km to perhaps 10 km.*

# A Homebrew AZ/EL Rotor Controller

There are several solutions to AL/EZ rotation of antenna arrays, from armstrong to commercial. In this article WA9PYH describes and documents his homebrew version.

By James Kocsis,* WA9PYH

This article describes a homebrew azimuth/elevation (AZ/EL) rotator system. The system consists of a controller (the electronics) and two modified TV antenna rotators. The controller uses a very simple and elegant design by XQ2FOD to which I have added some circuitry to better suit my needs. The controller receives positional information from a program (SatPC32) running under Windows® via the PC parallel port (LPT1 or LPT2) and moves the antennas so that they point at a satellite as it moves across the sky. It indicates azimuth (AZ) and elevation (EL) position in degrees on two digital panel meters. During a satellite pass the system keeps the antennas pointed to within a few degrees of the actual satellite position, which is adequate since most antennas used for satellite work have beamwidths much greater than a few degrees.

After the introductory information, this article is divided into three sections: (I) the controller, (II) modifications to the rotators, and (III) checkout and adjustment as a system.

## Parts

The rotators are the type used to rotate TV antennas. The AZ (N, E, S, W) rotator is "bell" shaped. The EL rotator is square shaped and has an offset between the support pipe and the TV antenna mast. Make sure it is the type that has the antenna mast passing completely through the rotator body. As shown in photo 1 the EL rotator is turned on end and mounted on a flange and short piece of pipe mounted in the AZ rotator.

The best source I found for both types of rotators and the controllers is yard sales. The second best source is hamfests (since hams will know what the controllers are worth and will charge you

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*Photo 1. The two rotators showing the pipe and flange, 6-32 screw through the collar.*

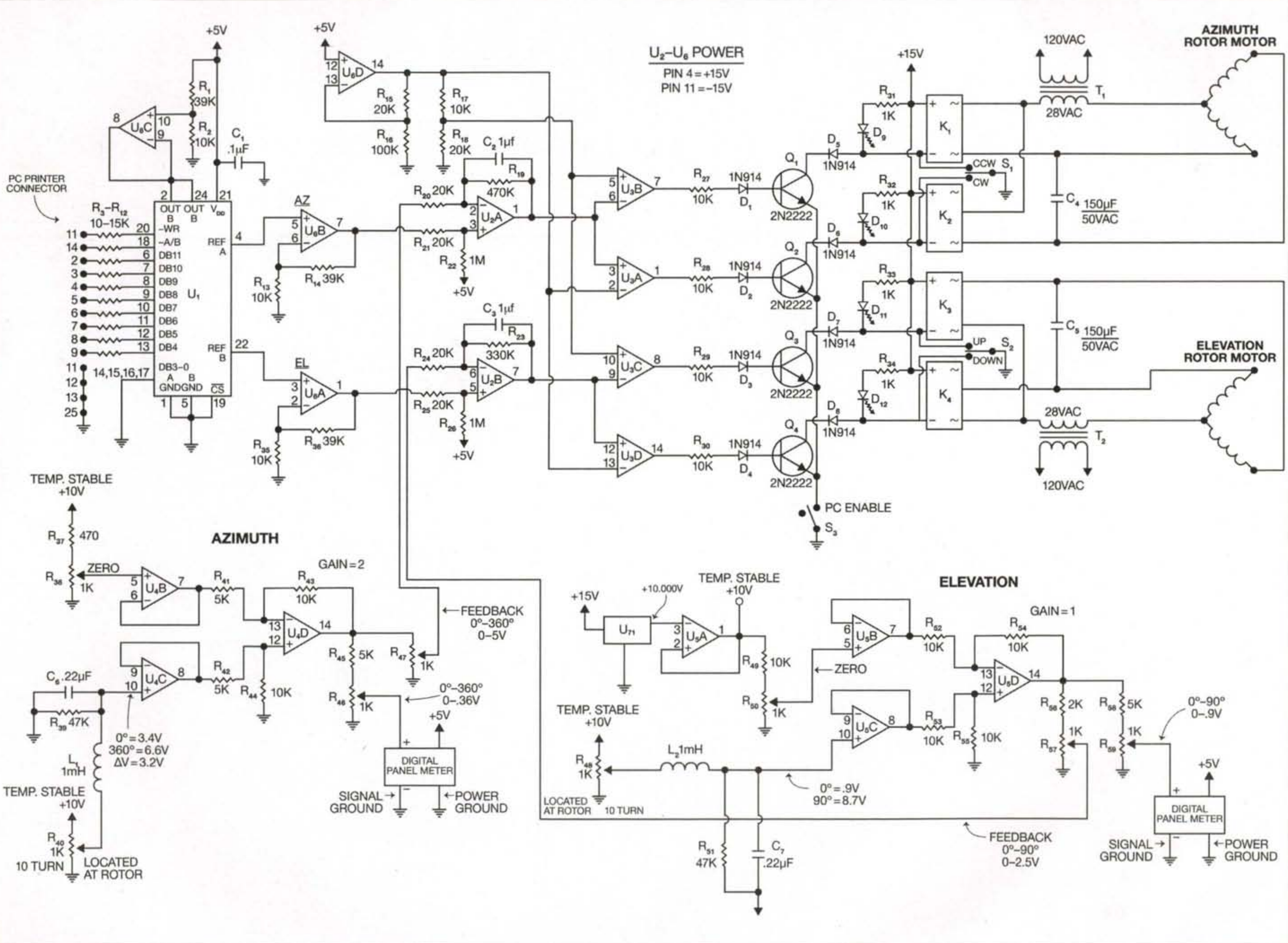



*Figure 1. The schematic of the circuit using a 12-bit D/A converter, different from the original.*

more. hi hi!). Another source is to offer to climb a neighbor's tower/roof to remove all the equipment: rotator and hopefully a large VHF antenna whose boom you can use to construct the circularly polarized Yagi antennas detailed in my companion article (*QST*, November 2008). (Don't forget to get the control box, too). With the popularity of cable and satellite TV very few people use outside antennas anymore and will be glad to have them removed at no cost.


*Photo 2. The panel meter on the left has an open-frame power transformer—bad news for the sensitive circuitry close by. Use one similar to the one on the right, as it keeps the size of the cabinet small.*

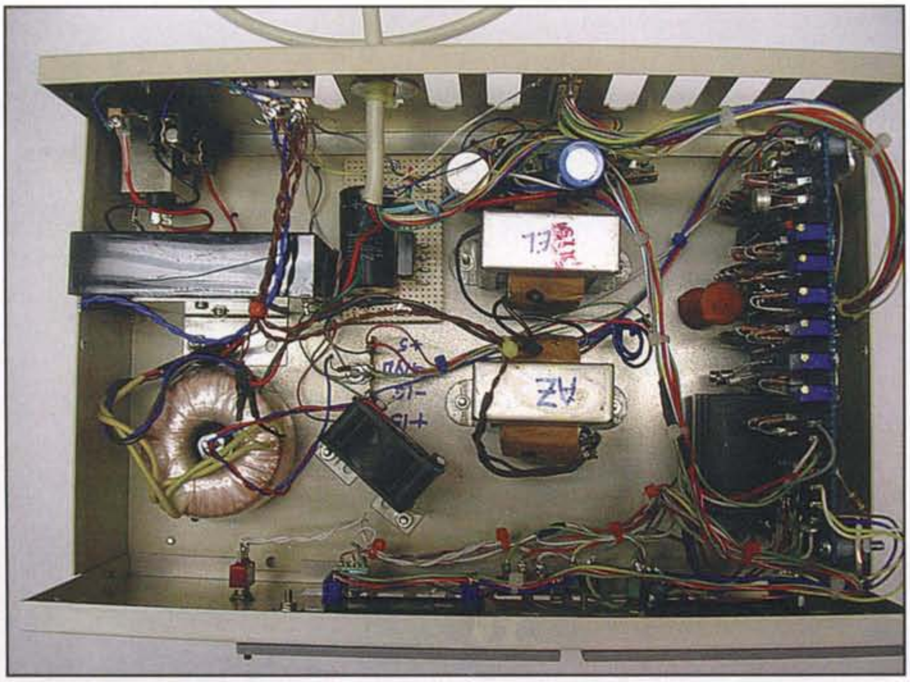



*Photo 3. The inside of the controller. Power supplies are on the left (±15V and 5V), the transformer cooling fan is mounted up and to the right of the transformers, the circuit board is on the left with potentiometers pointed up for easy adjustment, at the bottom are the digital panel meters, switches, and LEDs.*

The electronics part of this project encompasses commonly available parts except for the D/A (digital/analog converter) and toggle switches S1 and S2. The D/A specified is an 8-bit dual D/A 20-pin DIP. I had some 12-bit dual D/A 24-pin units on hand, so I grounded the four low-order bit inputs and used it as an 8-bit unit. The schematic shown in figure 1 shows the connections for the D/A that I used (DAC8221). If you use the D/A specified in the original circuit wire the D/A as shown.

Switches S1 and S2 are SPDT center-off but with a spring return to center from either side. This type of switch is needed so that when running in the manual mode you don't accidentally leave the rotator turning. It forces you to keep your finger on the switch until you reach the desired position. I know it sounds like a small issue, but the first time you leave the switch in the "on" position and the rotator runs away (out of range), it will become a big issue!

I didn't have a socket for the 24-pin D/A (DAC8221) that I used, and I didn't feel like spending the extra money on a 24-pin socket, so I installed an 8-pin and 16-pin socket beside one another and epoxied them in place. If you use the AD7528 specified in the original circuit, a 20-pin socket is needed.

The 28-volt transformers (T1 and T2) came from the original rotator controllers. Any transformer that supplies 28 VAC will work, provided it can supply the needed current.

I used LM348s for U2–U6 instead of the LM324s specified in the original circuit since I had them on hand and had a bipolar (±15V) power supply. If you have only a single power supply, you must use LM324s.

Avoid large differential parallel meters with their own power supplies. Photo 2 shows the type to avoid on the left and the recommended type on the right. The transformer in the large DPM is open frame; the windings are not shielded. I used them in an earlier version of the controller, and the 60-Hz field coupled into the circuitry and drove it crazy. To verify that they were the culprit I placed a small steel plate between them and the circuitry and suddenly it all worked properly. From the voice of experience: Use a small LED or LCD digital panel meter that is powered by 5V and you won't have any problems with noise pickup.

For the PC enable switch, S3, consider using a switch that is "locked" in position until you pull outward on the handle. This will prevent enabling PC control if the switch is hit accidently. Until the PC loads data into the D/A, the D/A can go to any position command and will try to move the rotator to that position unless you hit switch S3 in time. This affects only the EL rotator, since the AZ uses the full 0 to 5V range and the D/A can only go to 5 V. For the EL rotator, Mr. Murphy says this random antenna position will always be outside the normal operating range (2.5V/90 degrees)!

I chose SSRs (Solid State Relays) to switch power to the motor windings. SSRs are small, relatively inexpensive, produce no inductive spike such as the coil in a mechanical type, and there are no contacts to "stick" after many operations. From the voice of experience: I bought some new-looking (no scratches, clean) SSRs at a hamfest and one half of them were bad when I tested them at home, plus a few more failed during testing version 1 of the controller. I replaced them with new units and there have been no failures to date. Unless you can try them before buying, it is better to buy new units.

To keep RF out of the circuitry an LC filter should be installed on the potentiometer wiper leads going to the rotators. Shielded cable between the controller and the rotators is required to further reduce RF pickup. In the first version I used unshielded cable and no LC filters. Each time I transmitted, the RF picked up by the nearby long leads drove the controller crazy. I tried just the filters and that was not enough. My setup required shielded cable, LC filters, and a 47K resistor at U4 pin 10 and U5 pin 10 to change the very-high-input impedance (2.5 megohm) of the op amp to a lower value that is much less sensitive to RF.

Select a cabinet that will comfortably contain all parts. I used a box that originally contained other circuitry that was removed for this project. Mine came with a fuse-holder/power-receptacle, a power-line filter, on/off rocker switch, and a baked-on finish. In its former life it was an 8-port printer multiplexer that probably cost over $100. I bought it at a yard sale for $1.00. It has threaded metal inserts to hold together the four sections. It is a very robust, rugged design with all edges perfectly square, and it looks very professional. Its design is so good that I've been able to install and remove the screws many, many times and they still hold! The price of a simple aluminum box

## PARTS LIST

**Integrated Circuits**

U1: Part No. AD7528JNZ-ND; qty 1; Analog Devices/Digikey; 20-pin, dual 8-bit D/A converter; $9.36; note: 24 pin 12-bit, DAC-8221, PMI, Inc. used in authors' unit

U2–U6: Part No. LM324; qty5; quad opamp; note: can also use LM348 if using bipolar power supply

U7: Part No. LH-0070-2H; qty 1; National Semiconductor; precision 10-volt reference in author's unit; note: can also use a 12 volt regulator & voltage divider to obtain 10V

**Resistors**—all fixed values are 1/4 watt

R1, R14, R36: qty 3; 39K

R2, R13, R17, R27-R30, R35, R43, R44, R49, R52-R5: qty 15; 10K

R3-R12: qty 10; 15K; note: any value between 10K and 15K

R15, R18, R20, R21, R24, R25: qty 6; 20K

R16: qty 1; 100K

R19: qty 1; 470K; varies based on system dynamics (see text)

R22, R26: qty 2; 1M

R23: qty 1; 330K; varies based on system dynamics (see text)

R31-R34: qty 4; 1K

R37: qty 1; 470

R38, R46, R47, R50, R57, R59: qty 6; 1K, 10–25 turn, miniature potentiometer; note: Jameco p/n 853556, $1.95 each or at hamfest

R39, R51: qty 2; 47K

R40, R48: Bourns type 3500; qty 2; 1K, 10-turn potentiometer, 1/4" shaft; note: availability varies, see All Electronics, Jameco p/n 855818 5K ohm, hamfests, can use 5K with increased susceptibility to RFI

R41, R42, R45, R58: qty 4; 5K

R56: qty 1; 2K

**Diodes**

D1–D8: qty 8; 1N914 or 1N4148

D9–12: qty 4; LED

**Capacitors**

C1, C2, C3:qty 3; .1 μFd disc

C4, C5:qty 2; Holsfelt Electronics 15-930, $5.95 ea; 150 μFd, 50 VAC, non-polarized

**Inductors**

L1, L2: qty 2; All Electronics, CR-1000; 1 mHy RF choke; $0.50

**Miscellaneous**

DPM-1, DPM-2: part no. PM-122; qty 2; All Electronics; digital panel meter, 0-NNN mV.; $15.00; note: Hosfelt Electronics PM-29B, $13.95 ea.

EL rotator small gear: part no. 03125416; qty 1; <www.mscdirect.com>; 32 DP, 1" dia, 1/4" bore, 32 teeth, plastic, gear; $3.35

EL rotator large gear: part no. 03302718; qty 1; <www.mscdirect.com>; 32 DP, 2-1/4" dia, 5/16" bore, 72 teeth, plastic, gear; $7.85

AZ rotator gear: part no. 03125101; qty 1; <www.mscdirect.com>; 24 DP, 1" dia, 1/4" bore, 24 teeth gear; $3.27

S1, S2: part no. MTS-65; qty 2; All Electronics; (on)-off-(on) SPDT toggle switch; $1.25; note: Hosfelt p/n 51-219, $1.50

S3: qty 1; SPST toggle, long handle; note:optionally locked in position until pull (see text)

K1-K4: part no. SRLY-20; qty 4; All Electronics; 3-32 VDC / 3A, 120 VAC soli- state relay; $6.50; note: or equivalent

Lithium grease: qty 1; Panef Corp, Milwaukee, WI

T1, T2: qty 2; from rotator controller; 115 VAC to 28 VAC transformer

6-32, 2-56 screws, nuts, washers

1/4" × 6-32 setscrew: qty 4

Ground lug: qty 2; note: used to make EL potentiometer gear brackets

Bell-type rotator: qty 1

Square style rotator: qty 1; Alliance

Multiconductor cable, shielded: part no. 644447; qty 1; Jameco; 15 conductor, 25 feet shielded cable; $24.95; note:also available in 100-foot roll, p/n 644455, $49.95

*Table 1. Parts list for AZ/EL rotor controller.*

| PIN | Signal Name |
|---|---|
| 1 | AZ and EL potentiometer ground |
| 2 | AZ and EL transformer secondary ground |
| 3 | AZ potentiometer high |
| 4 | AZ potentiometer wiper |
| 5 | AZ motor CW winding |
| 6 | AZ motor CCW winding |
| 7 | EL potentiometer high |
| 8 | EL potentiometer wiper |
| 9 | EL motor CW winding |
| 10 | EL motor CCW winding |
| 11 | not used |

*Table 2. Connections on 11 pin connector on bulkhead.*

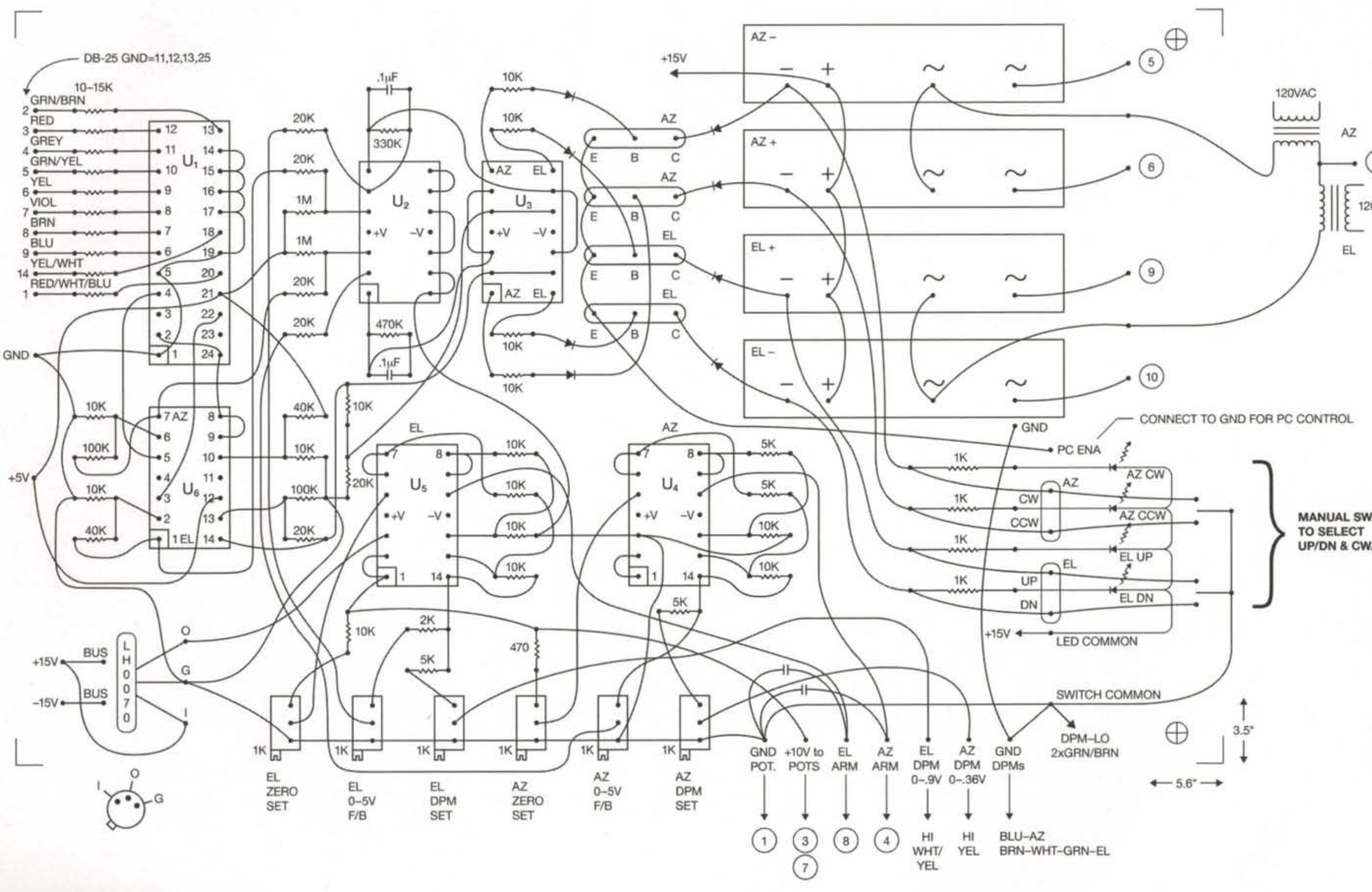



*Figure 2. A suggested layout of the parts and wiring.*

this size is over $20, the metal tapping screws that hold it together would have worn out the holes long ago, it is not painted, and it has a real "homebrew" look. The $1.00 "yard sale special" looks great in comparison.

The 150-μF 50-VAC capacitors at C4 and C5 are not commonly available. First try those that are in the existing rotator controllers to see if they are still usable even though they are old (see Table 1), but I have not tried them. The capacitors that were in my controllers work fine.

Note that in photo 3 there is a small fan aimed toward the two 28V transformers; it is mounted at a 45-degree angle. It provides cooling for the transformers. Since the transformers were intended to be powered only intermittently, I found them to get quite warm when powered continuously (15–18 minutes is required for a near overhead pass). One of the transformers in my unit has what appears to be a thermostat, but there were no shutdowns after hours of having power applied.

U7 (LH0070-2H), a 10V precision voltage source, isn't readily available. I had some in my junk box. If you can find one at a hamfest I suggest using it. A suitable alternative is to use a 12V regulator IC and resistor voltage divider to reduce the voltage to 10V.

## Construction and Layout

The IC sockets I used have relatively short stepped pins. The step usually sits on top of a PCB, but if using a perfboard as I did, you should slightly drill out each hole so that the plastic body of the socket is flush with the board and makes the full length of the pin available where two wires are connected to a pin.

While there are 12 connections between the rotators and the controller, some can be combined onto on one wire. I used a total of 10 conductors between the rotators and the controller. Table 2 shows pin versus function information. I used a bulkhead to provide a "clean break" of the controller from my antenna system. This provides lightning protection for this circuit as well as the rest of my radio equipment. (See my article in *QST* November 2008 for details.)

Keep the power supplies and transformers at one end of the box to minimize coupling 60 Hz into the circuitry.

Resist the temptation to mount the completed board in the cabinet until you have fully checked out the entire system (rotators/circuit/PC interface, and operation). Verify that it (1) is stable in operation (check for RF interference while transmitting); (2) points both rotators in the indicated direction; and (3) is stable with the antennas mounted (check for system oscillation, overshoot, and hunting for null). Test the board mounted on a breadboard so it is easy to get to the test points to make wiring changes, adjust part values (mainly in the conditioning circuits around U4 & U5 and R19 & R23), and correct mistakes during adjustment/checkout.

Leave enough lead length on wires going from the board to various points on the back and front of the cabinet so that the board can easily be moved out to allow changing components, etc. A good wiring layout is well worth the time spent. Figure 2 shows the parts layout and wiring diagram of the board in my unit.

The ranges of the DPMs should be set up to use as much of their full capability as possible to keep the signal-to-noise ratio high so that you see stable readings. Put some Scotch® +33 black electrical tape over the 1/10-degree digit; the system doesn't really have that fine a resolution and the extra digit will just confuse you. Also, if the DPM you use can suppress the display of a "+" sign, wire it up that way. However, you do want the display to show a "–" sign so that you can tell if the EL has gone below the horizon and if the AZ has gone below 0 degrees when in manual mode.

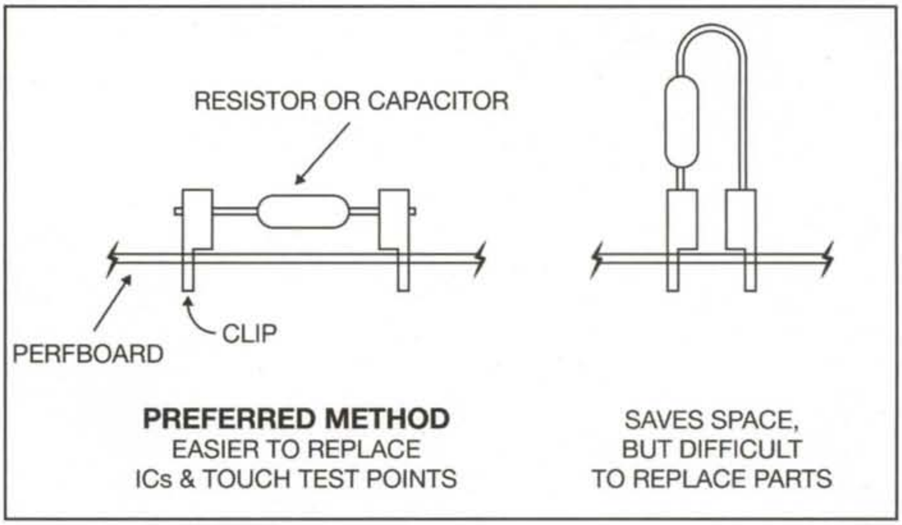



*Figure 3. The preferred method of mounting parts if using perfboard is to lay down the parts.*

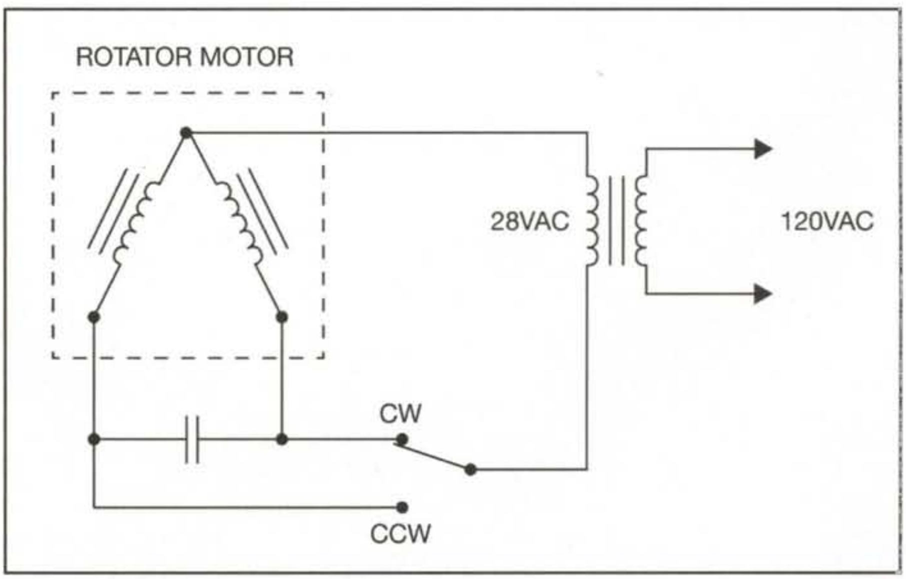



*Figure 4. Rotator motor checkout circuit.*

Photo 4. *The high-tech rain cover. This is a large-size plastic container that is used to hold cat litter.*

I was able to make all parts fit on a 4" × 6" piece of perfboard, but soldering the resistors and capacitors was difficult because all parts were so close together. I recommend a larger board and laying down the resistors instead of standing them up (see figure 3). The ICs on my board will be difficult to replace because they are lower than all other parts; it will be difficult to pry them out and hopefully they won't fail. Perhaps FAR Circuits will offer a board for this project so you won't have this problem.

## I. Controller

**Circuit Description**

The original circuit design is by XQ2FOD. A full description and schematic of his design can be found at <www.qsl.net/ve2dx/projects/fod.htm>; also see <http://ludens.cl/Electron/fodtrack/fodtrack.html>).

Each of the two channels (AZ and EL) in the circuit is a classical feedback closed-loop control circuit; a request position is input and is compared to the feedback position.

Here's a detailed description of how the EL channel (0 to 90 degrees) works: The REQUEST angle position from the program comes in the form of an 8-bit digital word that is loaded into half of the dual-channel D/A U1. The D/A produces a voltage output at pin 22 (buffered by U6A and appears at pin 1) which is proportional to the angle (0 to 2.5V for 0 to 90 degrees). The FEEDBACK angle position is generated by potentiometer R40 in the rotator and conditioned by U5a–d to produce 0 to 2.5V for 0 to 90 degrees actual position. The REQUEST voltage is compared to the FEEDBACK voltage from the rotator potentiometer in U2b. The output of U2b turns on either U3c or U3d, which turns on Q3 or Q4, and through some steering diodes turns on relays K3 or K4 and LEDs D11 or D12. K3 and K4 apply power to the rotator motor to move it until feedback equals request plus/minus a small deadband. The deadband is set by R23 and C3.

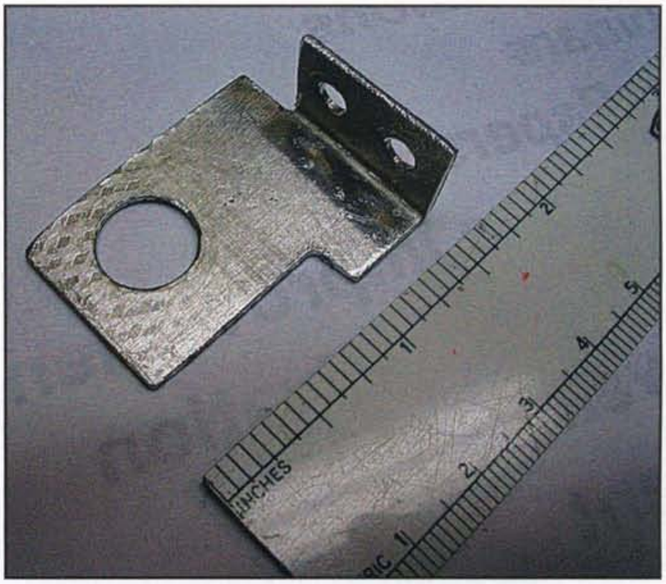


Photo 5. *This is the bracket that holds the potentiometer and gear in the EL rotator.*

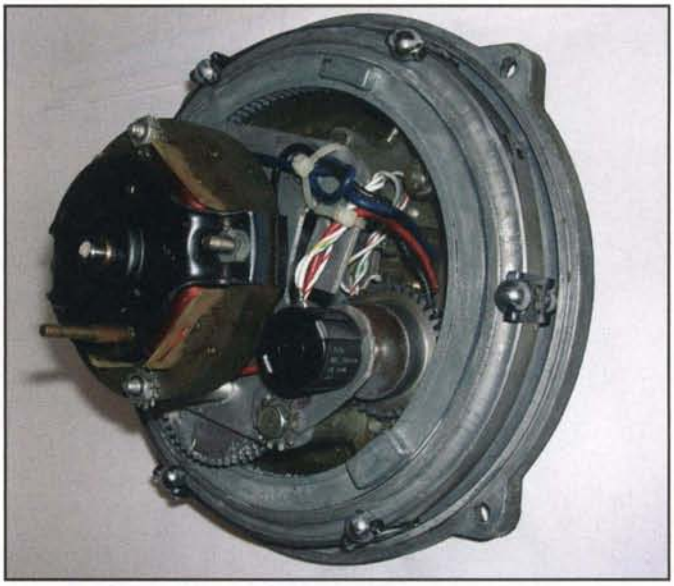


Photo 6. *The AZ rotator with all modifications. Note that the potentiometer has been removed. The new 10-turn potentiometer, bracket, and gear have been added. Secure all the new wiring with cable ties to keep it away from moving parts.*

Circuitry that I added includes: a digital display of actual position on two small panel meters, LEDs to indicate which direction the rotators are being commanded to turn, SSRs to send power to the motors, signal conditioning (gain and offset) to get the feedback signal into the range needed by the circuit (0–5V for 0–360 degrees AZ and 0–2.5V for 0 to 90 degrees EL), and a stable 10V source to provide excitation for the potentiometers.

*(Continued on page 75)*

# CQ's 6 Meter and Satellite WAZ Awards

**(As of July 1, 2011)**

**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 | 16,17,18,19,21,22,23,24,25,26,28,29,34,39 |
| 11 | GØLCS | 1,6,7,12,18,19,22,23,28,31 |
| 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. |
| 81 | PY2RO | 1,2,17,184OM,19,21,22,23,26,28,29,30,38,39,40 |
| 82 | W4UM | 18,19,21,22,23,24,26,27,28,29,34,37,39 |
| 83 | I5KG | 1,2,3,6,10,18,19,23,27,29,32. |
| 84 | DF3CB | 1,2,12,18,19,32 |
| 85 | K4PI | 17,18,19,21,22,23,24,26,28,29,30,34,37,38,39. |
| 86 | WB8TGY | 16,17,18,19,21,22,23,24,26,28.29,30,34,36,39 |
| 87 | MU0FAL | 1,2,12,18,19,22,23,24,26,27,28,29,30,31,32 |
| 88 | PY2BW | 1,2,17,18,19,22,23,26,28,29,30,38,39,40. |
| 89 | K4OM | 17,18,19,21,22,23,24,26,28,29,32,34,36,38,39. |
| 90 | JHØBBE | 2,33,34,40 |
| 91 | K6QXY | 17,18,19,21,22,23,34,37,39 |
| 92 | JA8ISU | 2,7,8,9,19,33,34,36,37,38,39,40 |
| 93 | YO9HP | 1,2,6,7,11,12,13,18,19,23,28,29,30,31,40 |
| 94 | SV8CS | 1,2,6,7,18,19,23,26,28,29 |
| 95 | SM3NRY | 1,6,10,12,13,19,23,25,26,29,30,31,32,39 |
| 96 | VK3OT | 2,10,11,12,16,34,35,37,39,40 |
| 97 | UY1HY | 1,2,3,6,7,9,12,18,19,23,26.28,31,32,36 |
| 98 | JA7QVI | 2,40 |
| 99 | K1HTV | 17,18,19,21,22,23,24,26,28,29,34 |
| 100 | OK1RD | 2,6,7,8,9,11,12,13,18,19,21,22,28,39,40 |
| 101 | S51DI | 1,2,6,18,19 |
| 102 | S59Z | 1,2,6,7,10,12,17,18,19,22,23,24,26,31,32 |
| 103 | UY5ZZ | 1,2,3,6,7,10,11,12,13,18,19,29,31,32,39 |
| 104 | UX0FF | 1,2,6,7,10,12,13,18,19,22,28,29,31,32 |
| 105 | EI3IO | 1,3,12,18,19,23,29,30,31,32 |

## Satellite Worked All Zones

| No. | Callsign | Issue date | Zones Needed to have all 40 confirmed |
|---|---|---|---|
| 1 | KL7GRF | 8 Mar. 93 | None |
| 2 | VE6LQ | 31 Mar. 93 | None |
| 3 | KD6PY | 1 June 93 | None |
| 4 | OH5LK | 23 June 93 | None |
| 5 | AA6PJ | 21 July 93 | None |
| 6 | K7HDK | 9 Sept. 93 | None |
| 7 | W1NU | 13 Oct. 93 | None |
| 8 | DC8TS | 29 Oct. 93 | None |
| 9 | DG2SBW | 12 Jan. 94 | None |
| 10 | N4SU | 20 Jan. 94 | None |
| 11 | PAØAND | 17 Feb. 94 | None |
| 12 | VE3NPC | 16 Mar. 94 | None |
| 13 | WB4MLE | 31 Mar. 94 | None |
| 14 | OE3JIS | 28 Feb. 95 | None |
| 15 | JA1BLC | 10 Apr. 97 | None |
| 16 | F5ETM | 30 Oct. 97 | None |
| 17 | KE4SCY | 15 Apr. 01 | 10,18,19,22,23, 24,26,27,28, 29,34,35,37,39 |
| 18 | N6KK | 15 Dec. 02 | None |
| 19 | DL2AYK | 7 May 03 | 2,10,19,29,34 |
| 20 | N1HOQ | 31 Jan. 04 | 10,13,18,19,23, 24,26,27,28,29, 33,34,36,37,39 |
| 21 | AA6NP | 12 Feb. 04 | None |
| 22 | 9V1XE | 14 Aug. 04 | 2,5,7,8,9,10,12,13, 23,34,35,36,37,40 |
| 23 | VR2XMT | 01 May 06 | 2,5,8,9,10,11,12,13,23,34,40 |
| 24 | XE1MEX | 19 Mar. 09 | 2,17,18,21,22,23,26,34,37,40 |
| 25 | KCØTO | 17 Mar. 11 | None |

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.

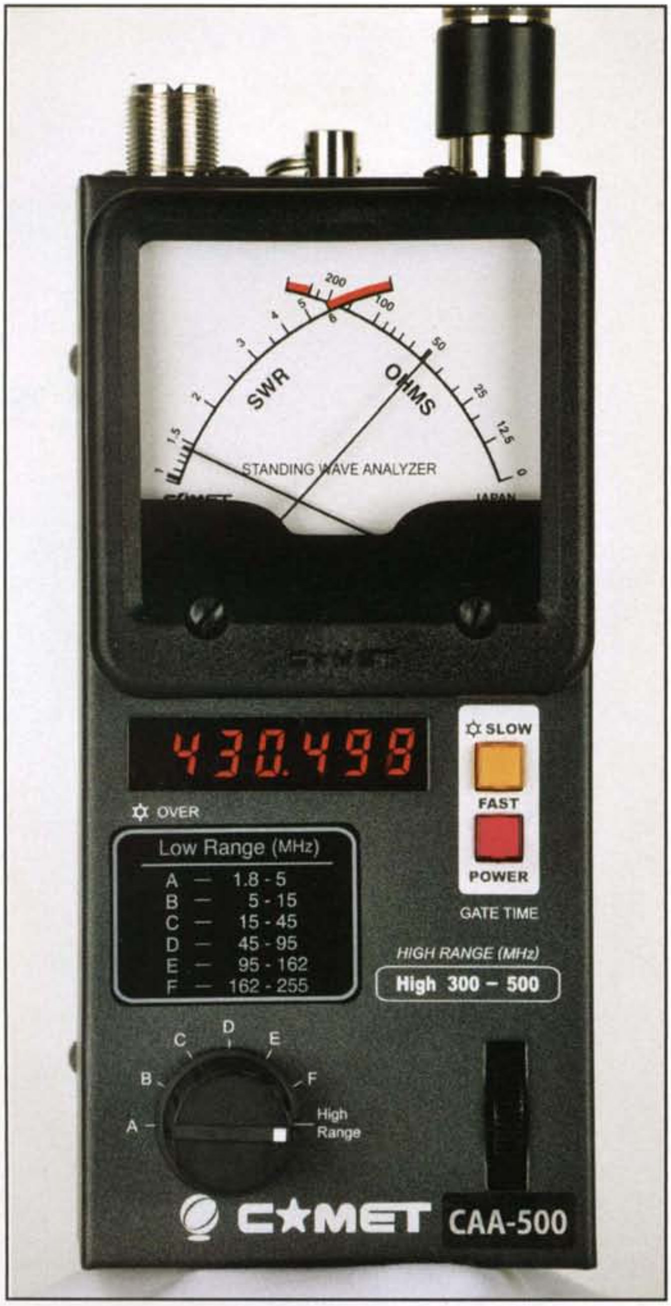
Rules and applications for the WAZ program may be obtained by sending a large SAE with two units of postage or an address label and $1.00 to the WAZ Award Manager: Floyd Gerald, N5FG, P.O. Box 449, Wiggins, MS 39577-0449. The processing fee for all CQ awards is $6.00 for subscribers (please include your 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>.

**P.O. Box 449, Wiggins, MS 39577-0449; e-mail: <n5fg@cq-amateur-radio.com>*

*First Look!*

# The Comet CAA-500 HF/VHF/UHF Antenna Analyzer

**By CQ VHF Staff**




*The NCG Company made a big splash at this year's Dayton Hamvention® with the new CAA-500 HF/VHF/UHF Antenna Analyzer.*

At this year's Dayton Hamvention®, the NCG Company booth drew quite a crowd as representatives displayed a prototype of the new Comet CAA-500 HF/VHF/UHF Antenna Analyzer. The staff of *CQ VHF* has now had the opportunity to have some "hands-on" time with this handy station accessory, and we're bringing you the highlights in this edition of *CQ VHF*.

## Feature Highlights

The CAA-500 has several unique features that it provides to the owner. The first is the frequency coverage, which includes the 50 MHz, 70 MHz (in Europe), 144 MHz, 222 MHz, and 430 MHz amateur bands. The frequency coverage is divided into seven bands, and coverage is continuous except for a small gap between about 259.8 MHz and 282.5 MHz, of no consequence for amateur radio use.

Another new feature in this analyzer is the provision of dual analog meters, with precision needles for accurate measurements. One meter displays the SWR, while the other displays impedance (in ohms); this pairing of meters thus allows the user to determine the resonant frequency of an antenna system more easily than if only one parameter was displayed.

The third major feature is the provision of two antenna connection jacks: one jack, used below 300 MHz, is a "UHF" (a.k.a. "SO-239") receptacle, while the other, used above 300 MHz, is a "Type N" jack that provides better maintenance of a 50-ohm impedance at the higher frequencies. The unused jack is automatically switched out when the frequency selection is performed by the user.

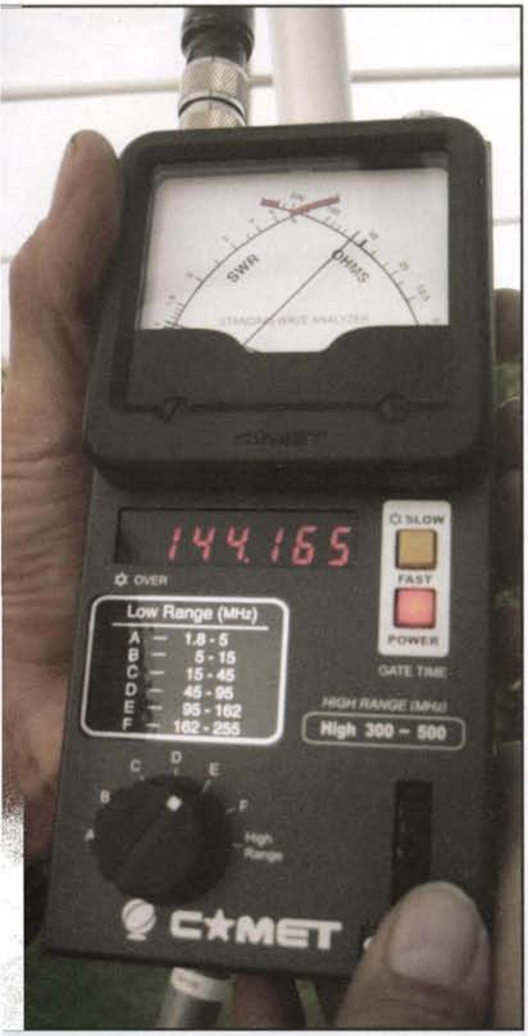
The CAA-500 is powered by six 1.5V "AA" cells, and it also has an "External DC" jack on the side of the case; DC voltages between 8V and 16V (250 mA minimum) will power the CAA-500 (a DC cable is supplied). Most users will just run it off of batteries, of course.

## First Impressions

The first thing that comes to mind when picking up the CAA-500 is "quality." It has a solid, somewhat heavy feel to it, and the actions of the switches and controls remind one of high-grade laboratory test equipment. This unit feels built to last!

The digital frequency display is bright, and the cross-needle metering is very easy to read with excellent clarity.

The documentation supplied with the CAA-500 covers many aspects of field operation of the analyzer, including advice on coaxial-cable lengths, common-mode current problems, and




*The Comet CAA-500's bright frequency display and precision metering make SWR analysis in the field simple and quick.*

*CAA500_top: The CAA-500 utilizes a high-quality "Type N" connector above 300 MHz, to ensure accuracy of SWR measurements relative to 50 Ohms in the UHF range.*

other helpful tips that display an appreciation of questions that hams might have while using this product. Nice job, Comet!

## Using the CAA-500

Operation of the CAA-500 couldn't be simpler. Just install the batteries, connect your antenna to the appropriate coaxial jack, set the frequency range using the seven-position rotary switch, and then use your thumb to set the CAA-500 onto the frequency of interest. The two meter needles move smoothly as the frequency is adjusted, and if all goes well you'll see a 1:1 SWR and a 50-ohm impedance on the frequency on which you *want* resonance to occur. If not, a simple sweep of the frequency range via the thumb-wheel control will give you a quick indication of where your antenna system *is* resonant, allowing you to make corrective adjustments. While the CAA-500 does not have separate display of the resistive and reactive components of impedance, it does tell you the essentials:

(A) What is the SWR?

(B) If the SWR isn't 1:1, is the impedance higher or lower than 50 ohms?

This information is all the data most users require, and the ease of operation of the CAA-500 is a real plus in the field.

We tried the CAA-500 on several antennas on Field Day, including HF dipoles and beams, VHF Yagis, and a 435-MHz Moxon Rectangle that turned out to have a broken connection on the driven element. The CAA-500 performed flawlessly in all cases, and it was a simple and intuitive device that clearly was well designed.

## Summary

The Comet CAA-500 is a high-quality, well-conceived standing-wave analyzer that has wider frequency coverage than other such devices in the marketplace. The inclusion of the 222-MHz band is a real benefit to U.S. VHF operators, who have not had access to a handheld antenna analyzer for that band up to now. The CAA-500 may well be the ideal tool for your future antenna projects!

The manufacturer's suggested retail price for the Comet CAA-500 is $449.00, and more information may be obtained from NCG Company, 15036 Sierra Bonita Lane, Chino, CA 91710 (http://www.cometantenna.com).

*The Comet CAA-500 may get a workout on your next Field Day adventure, or some of the forthcoming VHF/UHF contests!*

# HOMING IN

## Radio Direction Finding for Fun and Public Service

# New Products, New Hunt Opportunities, and Foxhunting "Down Under"

"I want to start transmitter hunts in my area, but I need a fox transmitter. What shall I use?"

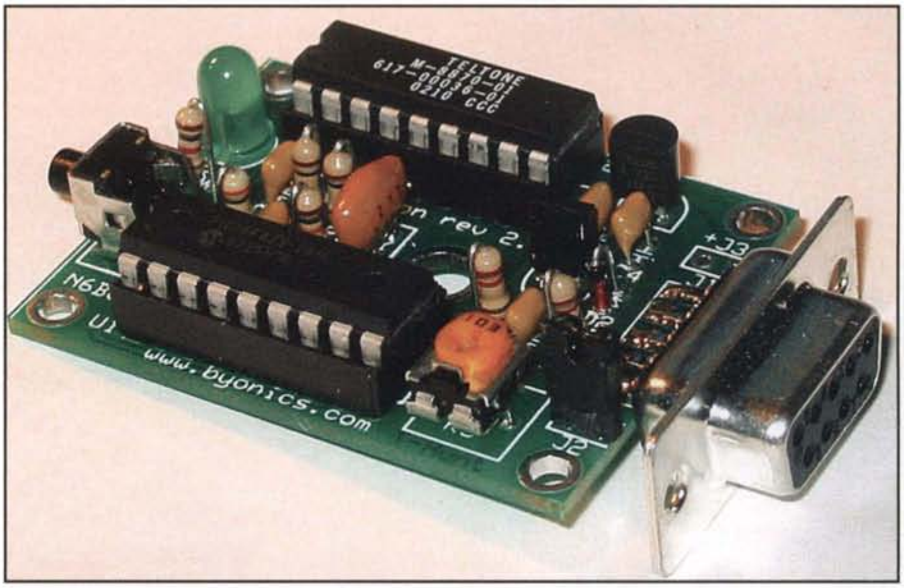
That's near the top of the list of frequently asked questions in my e-mail inbox. It also shows up regularly on internet mailing lists for radio direction finding (RDF) enthusiasts. Often the requester has just won his (or her) first hidden transmitter hunt, which might be called a T-hunt or foxhunt, depending on where he lives. He is looking for a transmitting device because it's his turn to hide for the next hunt.

For a club of beginners who will be doing RDF in their cars, the first hunt can be very easy for the hider. Just drive to an unlikely location and yak into the microphone at intervals called for by the hunt rules. Give them verbal taunts or read articles in *CQ VHF*. If they are having lots of trouble, you may need to give a clue or two.

For a few ham clubs, this continues to be the usual format for mobile hunts, especially when they occur only a few times a year. The hiders wait and transmit in the parking lot of a restaurant where everyone will eat afterwards, or they set up a picnic or barbecue in a park that everyone has to find.

Most groups eventually graduate to more difficult hunts (or they run out of new restaurants and parks!). An unattended foxbox adds to the fun and saves the hider's voice. The familiar vehicle is no longer a giveaway. An unattended fox (or "T") frees you to move around, drawing attention away from the transmitter's location. You can enjoy the spectacle of the hunters scurrying to locate it. It saves your voice, too. The easiest audio source for this purpose is an MP3 file of voice or random notes. To cycle the T on and off, put a blank file in the rotation and use a transmitter with VOX.

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




*PicCon from Byonics turns any VHF/UHF handie-talkie or mobile radio into a fox transmitter with distinctive tones and on/off timing. (Photo courtesy Byon Garrabrant, N6BG)*

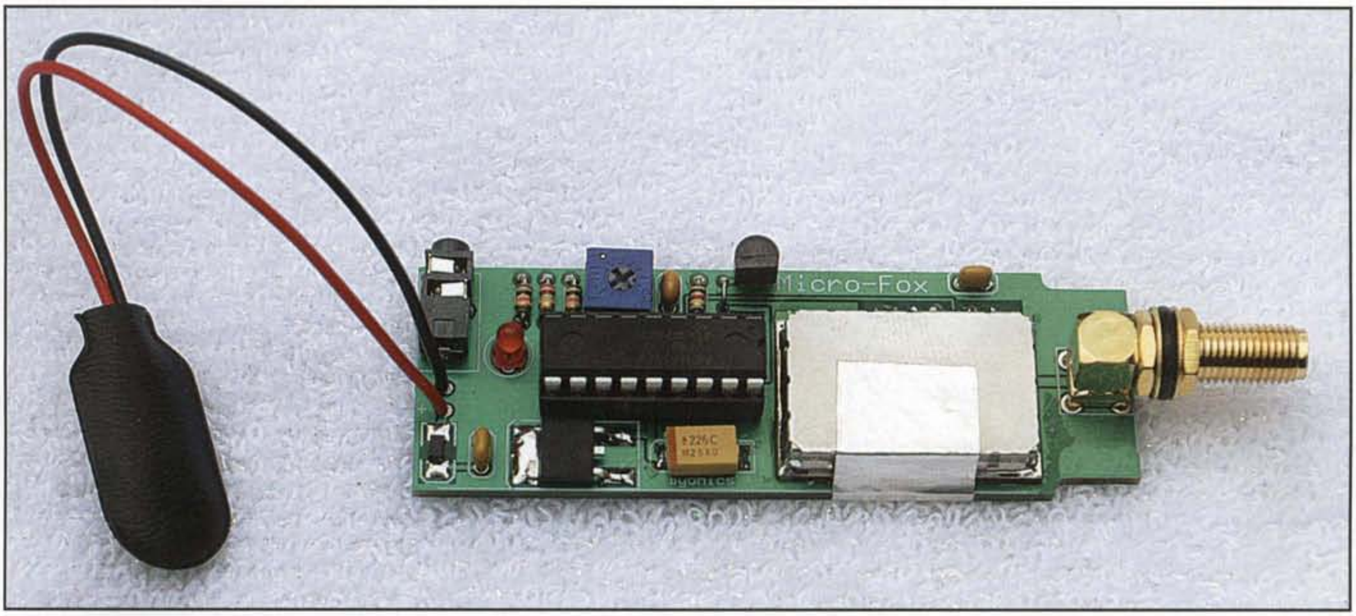
Mobile T-hunts around the country have an endless variety of rules, calling for transmissions ranging from a few seconds every few minutes to continuous. On the other hand, championship on-foot foxhunts under International Amateur Radio Union (IARU) rules[1] require five synchronized fox transmitters sending a prescribed CW message for 60 seconds each in numbered sequence.

The optimum solution for most hunts is a device with no moving parts that provides distinctive audio and versatile on-off cycling for ordinary mobile and handheld transceivers. Several designs for fox controllers have appeared in recent years, using CMOS logic, microprocessors, or PICs.

For a controller that's almost ready to plug and play with your rig, consider PicCon by Byon Garrabrant, N6BG. This was the first product of Byonics, his company, and it has become the most popular controller for both mobile T-hunting and on-foot amateur radio direction finding (ARDF). PicCon has fully programmable transmit on/off timing and a delay feature to start transmissions automatically at hunt time. With a connection to a receiver, you can change programming from a remote location before or during the hunt.

PicCon's parts are packed onto a 1 7/8" × 1 3/4" circuit board. You can build it from a kit in about 30 minutes if you have a fine-tip soldering iron. It is also available assembled and tested. Connectors and cables for the mic, speaker, and push-to-talk (PTT) lines of the radio are not included. Byon sells cables for many popular radios, or you can make them yourself.

When you first activate a new PicCon, it sends a pre-programmed 3-second tone sequence over and over for 30 seconds and then identifies in CW with the software version number. Your first task is to change the CW message to your callsign and set the transmission on and off times as appropriate for your local hunts. You do this by sending DTMF com-




*Micro-Fox 15 from Byonics is a synthesized 2-meter transmitter and foxhunt controller powered by a 9-volt battery. (Photo by Joe Moell, KØOV)*

mands to the fox transceiver connected to PicCon using another radio that transmits on the frequency where the fox rig is listening.

You can get fancy by designing your own tone sequence. There are 99 tone pitches to choose from, and the sequence can have up to 28 tones before repeating. The speed of the tone sequence is programmable, as is the speed of the CW ID. You can even program a repeating 8-event series of tone sequences, off times, and IDs.

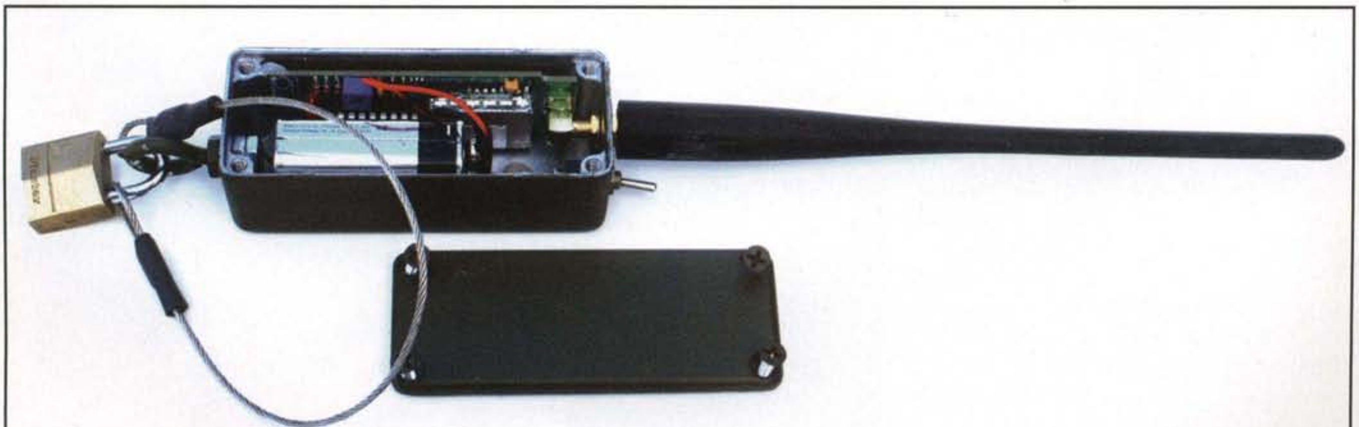
Want to hide your T on Thursday and have it come on at hunt time on Saturday? One DTMF command lets you specify a delay of up to 100 hours before the first transmission. If the hunt must end at a certain time, another command will terminate all transmissions after a pre-programmed duration.

## A New Micro-Fox

For Byonics' latest transmitter hunting product, Byon teamed with Allen Lord of VHS Special Services to create Micro-Fox 15, a complete QRP 2-meter transmitter and controller on a 1" × 3" circuit board. It is ideal for hamfest foxhunts in city parks and for short-range ARDF training sessions.

Instead of DTMF tone programming like PicCon, the Micro-Fox has a RS-232 data cable. Configuration software, available for free download from the Byonics website, sets the transmit frequency, on/off cycle times, delay for turn-on and shut-down, plus callsign or message for modulated CW ID. The software also lets the user enter a custom tone pattern, which could be MOE/MOI/MOS messages for ARDF.

Not many new computers have RS-232 ports. In my closet was a laptop that is 10 years old and runs a very early version of Windows® XP. After Byon made a minor modification to the software so that it would run on that XP build, it was easy to program the Micro-Fox with its serial port. I also used a USB-to-serial adapter to test the software on my Windows® 7 laptop. Once I figured out that the adapter was on COM7 and I set the software



*The Micro-Fox 15 in a LMB die-cast enclosure with lockdown wire, ready to deploy for a transmitter hunt. Not shown is the label with my cell phone and pager numbers, in case a passer-by reports it as a suspicious package to the authorities. (Photo by KØOV)*

*Marvin Johnston, KE6HTS (left), makes kits for tape-measure Yagis and offset attenuators. He also sells tape holders, handles, and radio mounts made by Julianne Walsh, KI6DYX (right). (Photo by KØOV)*

accordingly, it programmed Micro-Fox perfectly. Firmware upgrades of the Micro-Fox can also be performed through this serial connection.

The microprocessor clock in Micro-Finder isn't precise, but it is a simple matter to compensate for timing errors. Let it run for 10 minutes and measure the time error with a stopwatch. Enter this error into the configuration program, and thereafter it will be dead on, except for temperature drift.

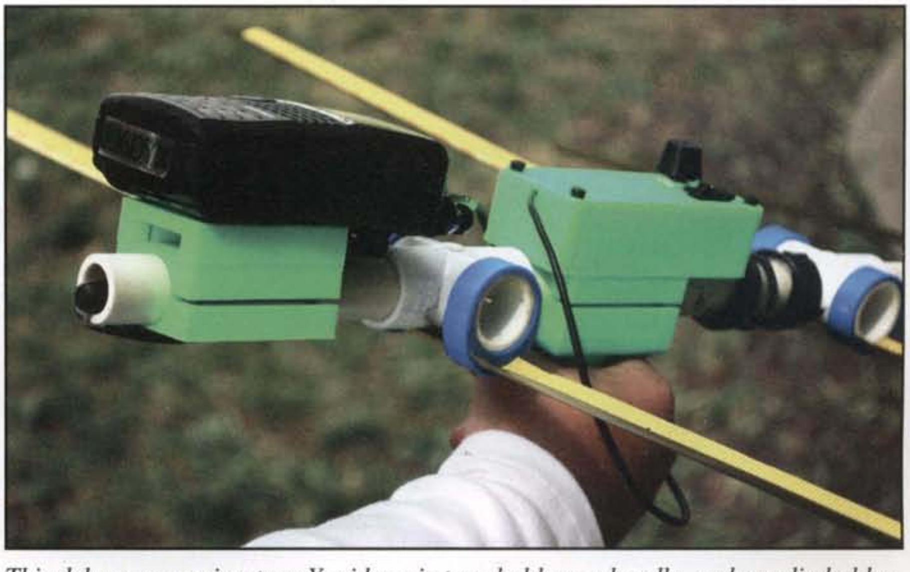
The new Micro-Fox is rated at 15 milliwatts output. I measured 17 milliwatts with a fresh 9-volt battery. That is not nearly enough power to cover a standard IARU ARDF course, but it is plenty for a suburban park. It will continue to work (at reduced power) until the voltage gets below about 4.5 volts, so one battery will give over 10 hours total transmit time. Byon says that he and Allen are looking into making a power amplifier board that would take the output to 600 milliwatts or more, enough for full-size ARDF courses with elevated antennas.

Micro-Fox 15 comes in a 6" × 1" × 5/8" clear plastic tube for protection. You could put a battery inside and mount the antenna on the cap to make a complete foxbox, ready to conceal in a hollow log or other clever hiding location. For the rigors of our regular ARDF training sessions, I wanted something more sturdy and secure. A miniature transmitter in a public park is at risk for theft, as I discovered the hard way.

I found an ideal die-cast metal box from LMB, model KAB-3321. There is room inside for the board, battery, and power switch. I added an eye bolt to fasten down the package with piano wire and a small padlock. Fortunately, most park visitors aren't carrying bolt cutters! The metal box and lockdown wire form a counterpoise for the whip antenna that seems to increase the transmit range.

## Get a Handle on It

For simple and effective on-foot RDF on 2 meters, the most popular antenna is the



*This deluxe measuring-tape Yagi has six tape holders, a handle, and a radio holder from the 3D printer of KI6DYX. Inside the top of the handle is the active attenuator board. (Photo by KØOV)*

3-element Yagi with PVC-pipe boom and measuring-tape elements. Its flexible elements are not suitable for mounting on a car and use at highway speeds, but they are just right for safely beating the bushes, because they spring back into place.

Joe Leggio, WB2HOL, was first to publish the design[2] for a measuring-tape antenna over a decade ago. Since then, many variations have followed for 2 meters and other bands. If you have a length of coax with a connector to match your hand-held radio[3], then a trip to the hardware store will get you all the rest of the parts. Complete kits are also available.[4]

You will also need an RF attenuation system to keep the receiver from overloading and to allow you to take bearings as you approach the hidden transmitter. Resistive attenuators are not effective for on-foot use with handie-talkies, because strong signals will penetrate the receiver case. On-foot hunters prefer active attenuators (also called *offset attenuators*) with an oscillator and mixer diode that puts a controlled amount of signal in another frequency where the receiver does not overload.[5]

The biggest problem with 2-meter RDF Yagis is how to hold onto them while beating the bushes for hidden transmitters. A hand around the boom is a bit awkward, and it introduces body capacitance that may affect antenna performance. An extension of the boom behind the reflector as a handle solves the hand-in-the-antenna problem, but it is even more awkward, because the entire antenna pulls the hand down at the wrist. Most pre-teens cannot hold an antenna this way.

My solution was a wooden handle at the balance point of the boom. It keeps body parts out of the field of the beam and avoids torque on the wrist. At one of our ARDF sessions, Julianne Walsh, KI6DYX, of Goleta, California saw my handle and decided that she needed one. She had just the right equipment to fabricate it at home.

Julianne and her husband Peter enjoy making small objects with their 3D printer.[6] The next time I saw Julianne at one of our hunts, there was a bright-orange handle clamped to her Yagi. Atop the handle was a compartment that was just the right size to hold the circuit board for her active attenuator.

A month later at our next on-foot hunt, Julianne showed off another improvement for the measuring-tape Yagi. She had made plastic rings to hold the elements to the boom securely in place. No more screws, sticky tape, or hose clamps! I told her that all she needed now was a way to mount the radio to the antenna for one-handed hunting. Sure enough, she was back at the next hunt with a nifty plastic platform behind the reflector that secured her handie-talkie via its belt clip.

KI6DYX's plastic parts in fluorescent colors attracted a lot of attention and interest. People wanted to know how to get them, so Julianne decided to make them available for sale through Marvin Johnston, KE6HTS. He makes the antenna and attenuator kits for first-timers to assemble before our hunting sessions. Several colors for the parts and styles for the radio holders are available. A page on Marvin's website is in the works, which will be linked from my "Homing In" website. You can also contact Marvin directly by e-mail.[7]

## Foxhunting Opportunities Abound

For many years in southern California the first Saturday of each month was the day for 6-meter transmitter hunting. Vehicles with unusual antennas would be in a row atop a hill

*A military-surplus loop antenna such as this one with a built-in attenuator makes a very simple RDF system for 6-meter hunts when used with a scanner or hand-held receiver for that band. (Photo by KØOV)*

in Fullerton at 10 AM as the hunt teams took bearings on a 50.3-MHz FM signal. A few of the cars and trucks had Yagis, full-size quads or shrunken quads on top, but most hunters relied on small loop antennas, either home-built or military surplus.

Loops aren't very sensitive, but the hidden transmitters often ran 50 watts or more. It wasn't uncommon for them to be 30 or more miles from the starting point. After a couple of hours, all teams had found their way to the hider's site, either by following the signal or getting some clues. Then it was time for lunch and storytelling.

Six-meter hunts are starting up again, led by Will Anderson, AA6DD, of Riverside. "We don't do it as much anymore," he told me, "but every few months when the stars are in alignment and enough hunters are available, we'll have a hunt."

If you live near the Inland Empire of California, join in and find out what 6-meter RDF is like. Newcomers are welcomed and encouraged. Announcements of upcoming hunts will be posted in the "Homing In" website.

More opportunities to hunt transmitters in southern California await you at the ARRL Southwestern Division Convention in Torrance on the second weekend of September.[8] On Friday evening, September 9, there will be a multiple-transmitter mobile hunt on 146.565 MHz, set by J. Scott Bovitz, N6MI.

Then on Sunday afternoon, I will be putting lots of hidden transmitters in a nearby park. How many can you find in 90 minutes? The convention organizers have promised nice prizes for both hunts.

After the Torrance hunts, ARDF fans will head for the "Land of Enchantment" for the USA's 11th national championships of on-foot RDF. Albuquerque Amateur Radio Club and New Mexico Orienteers are bringing together radio-orienteers from all over the USA for two days of intense competition on the third weekend of September. It is also the sixth championships of IARU Region II (North and South America), pitting stateside foxtailers against Canadians in friendly competition. Several experienced ARDFers from Germany have also registered to attend and participate.

The activities get under way on Wednesday, September 14 with a two-day optional "training camp" where beginners and experts can hone their radio-orienteering skills. Formal activities begin on Friday with a competitor meeting and an equipment testing session, called a "model event." The championship 2-meter competition will begin early on Saturday in a nearby forest, followed by an awards banquet that evening. On Sunday, the 80-meter competition and medal-awards ceremony will take place in a different location.

USA's ARDF Championships are open to anyone of any age who can safely navigate in the woods for several kilometers with hand-held radio gear. An amateur radio license is not a requirement. Medals will be awarded for the top three finishers on each band in ten age categories, six for males and four for females. To avoid parking problems in the forest and provide for rapid evacuation in case of wildfire, competitors will be bused between the event hotel in Albuquerque and the mountain venues.

If you are interested in being a part of these championships, contact the organizers right away to see if there is room left for you on the buses. More information is at the event website[9] and at my "Homing In" site.

## A Fox on the Barbie?

Speaking of national championships, the results of the annual foxhunting event at Mt. Gambier have been posted. Every year, the South East Radio Group puts on a ham radio convention at this volcanic site in South Australia. Included are the Australian Foxhunting Championships.

Although there are a few on-foot foxhunting champions there, most hunts "down under" involve mobiles and pedal-to-the-floor driving. Every month hunters in the Melbourne area gather and draw starting positions. The fox departs in his car and is given about a 10-minute start. After that, hunters are permitted to track and follow the mobile fox. Soon the fox goes to ground (stops moving), sometimes staying in the vehicle and sometimes putting the transmitter out in the bush.

To save time on hunts where the fox is not right out on the road, back-seat team members jump out and take off on foot when they think they are within rapid hiking distance of the fox. This practice is called *dropping runners*. The front-seat hunters continue, trying to drive the vehicle closer, as the runners beat the bushes. Usually they find an unattended foxbox, but on occasion the fox has been one of the hunters in disguise, waving a beam around and supplying strong signals to individual hunters.

*Yagis, loops, motors, chain drives, cathode-ray-tube displays, and computers are all part of the annual Australian Foxhunting Championships at Mt. Gambier in South Australia each June. Each hunt vehicle needs RDF equipment for six ham bands. (Photo by Mark Diggins, VK3MD)*

Radio foxes in Melbourne often are hidden on the banks of the Yarra River. At least one team carries an inflatable rubber dinghy and compressed-gas cylinder in the car in case they drive up on the wrong side of the river and want to cross quickly. That ploy is foiled, however, when hiders put the transmitter along the bank in heavy brush, with thorns.

The high point of the year for Australian foxhunters is the Mt. Gambier event. This year it was June 11–12, celebrated nationwide as the Queen's Birthday Weekend. There were nine events in two days with about twenty foxes to find on the 80-meter, 10-meter, 6-meter, 2-meter, 70-centimeter, and 23-centimeter bands.

The biggest challenge was the Wayne Kilpatrick Memorial Night Foxhunt on Saturday. FM foxes keyed down on 10 meters, 6 meters, 2 meters, and 70 centimeters, to be found in a prescribed order. Marshals kept close watch to ensure that the rules were obeyed. One rule stated: "Should it be necessary to leave the vehicle, only one set of RDF equipment is permitted amongst the group from that vehicle. This includes foil under T-shirts and hand-helds."

Each team was given distinctive tokens to be dropped into a well-secured tube at each fox when found. Afterwards, the marshals used the order of the tokens in the tube to determine the order in which the foxes were found by each team. Direction-finding was difficult, but the recent rains made the going even more treacherous, with some teams getting stuck in the mud and wet grass. A report and video are now on the web.[10]

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That's all for this time. I will be back in three months with the medal winners and photos of the championships in New Mexico. I also want to get stories and photos of your local hunts, so please keep sending them to me at the addresses listed on the first page of this column.

73, Joe, KØOV

## Notes

1. http://www.homingin.com/intlfox.html#rules
2. http://theleggios.net/wb2hol/projects/rdf/tape_bm.htm
3. Small and flexible RG-174 is ideal, but RG-58 can also be used. Wrap several turns around the boom as shown in the handle photo. This forms a choke balun which prevents feedline signal pickup from adversely affecting the directional pattern.
4. http://www.west.net/~marvin/wb2hol.htm
5. http://www.homingin.com/joek0ov/offatten.html
6. http://en.wikipedia.org/wiki/3D_printing
7. marvin@west.net
8. http://www.hamconinc.org
9. http://www.wb8wfk.com/2011_ARDF_WEB/ index.html
10. http://www.ardf.org.au/WordPress/2011/2011-fox-hunting-championships-at-mt-gambier/

By Kent Britain,* WA5VJB

# ANTENNAS

## Connecting the Radio to the Sky

# Roving Antenna Range and Much More

I am sure the Central States VHF Society Conference in Irving, Texas this July 29–30, 2011 will be covered in many venues, but I would like to point out our roving antenna range. Marc, WBØTEM, takes care of the 50-, 144-, 222-, and 432-MHz antenna measuring.

I take care of 902 MHz though 24 GHz, and sometimes even higher. On a typical Friday morning we will measure 100–125 antennas. Even if you can't actually attend the conference, you may know someone who will, and if they have a bit of space and you have an antenna you have wondered about, here is your chance to get it tested. This way we can skip the specs of the antenna companies and measure the antennas side by side at the same time under the same conditions.

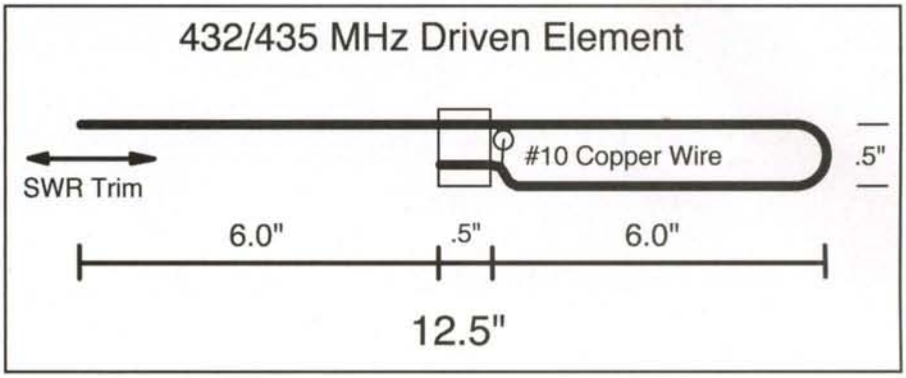

*Figure 1. The 432/435-MHz driven element.*

On the microwave range we take time to let you tweak your antenna designs. Quite often moving a dish feed in or out a bit can pick up several dB and help clean up the antenna pattern.

Do you think you have invented a new super-duper, gazillion-dB antenna? I have an HP415E and detector diode wait-

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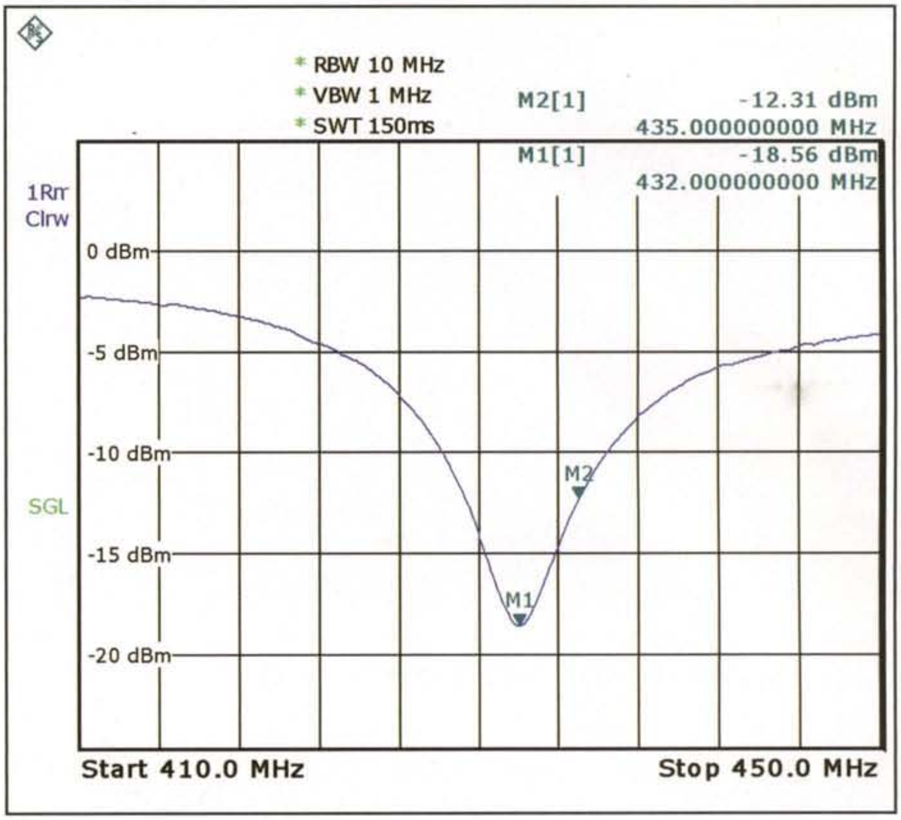
*Photo 1. CSVHF antenna range.*

| Element | Length | Distance from Reflector Element |
|---|---|---|
| Ref. Point | 13.5 | 0 |
| Driven | see fig. 1 | 5.25 |
| D1 | 12.3 | 9.5 |
| D2 | 11.9 | 14.0 |
| D3 | 11.8 | 19.5 |
| D4 | 11.8 | 27.3 |
| D5 | 11.6 | 36.4 |
| D6 | 11.4 | 47.3 |
| D7 | 11.4 | 57.5 |
| D8 | 11.4 | 68.8 |
| D9 | 11.4 | 79.0 |
| D10 | 11.4 | 89.0 |
| D11 | 11.4 | 99.5 |
| D12 | 11.4 | 109.5 |
| D13 | 11.4 | 117.25 |
| D14 | 11.4 | 124.5 |
| D15 | 11.4 | 135.0 |
| D16 | 11.4 | 146.5 |
| D17 | 11.4 | 156.0 |
| D18 | 11.3 | 166.0 |

*Table 1. Dimensions for the 432/435-MHz driven element (see figure 1). All dimensions in are in inches. All elements are 1/8-inch diameter.*




*Plot 1. Return-loss plot of the prototype Yagi.*

ing for you. Someday I'll have to mention the 123 dBi gain 1296-MHz antenna one chap submitted. It is a long story. Furthermore, the lad had some problems mixing linear and logarithmic math. Nevertheless, for a dish antenna to have 123 dBi gain at 1296 MHz, it would need to be about the size of the state of Texas. I'm afraid he came up about 111 dB short of his prediction.

## Boom Correction Factor

"But I built it exactly to your dimensions!" As shown in an accompanying photo, a fence post may make a good strong boom, and while wood is an insulator, it still affects the length of elements.

When designing and then building an all-metal Yagi, you have to compensate for the part of the element that is inside the boom. In general, the element is slightly smaller to allow for that fat area in the middle of the element. We have a similar issue with a wood boom. If you have ever built a couple of 40-meter dipoles, you noticed that a dipole made of bare wire, and one with the same gauge wire but insulated, is about a foot shorter. Light waves travel more slowly when passing through water or glass, and radio waves travel more slowly when passing through a dielectric.

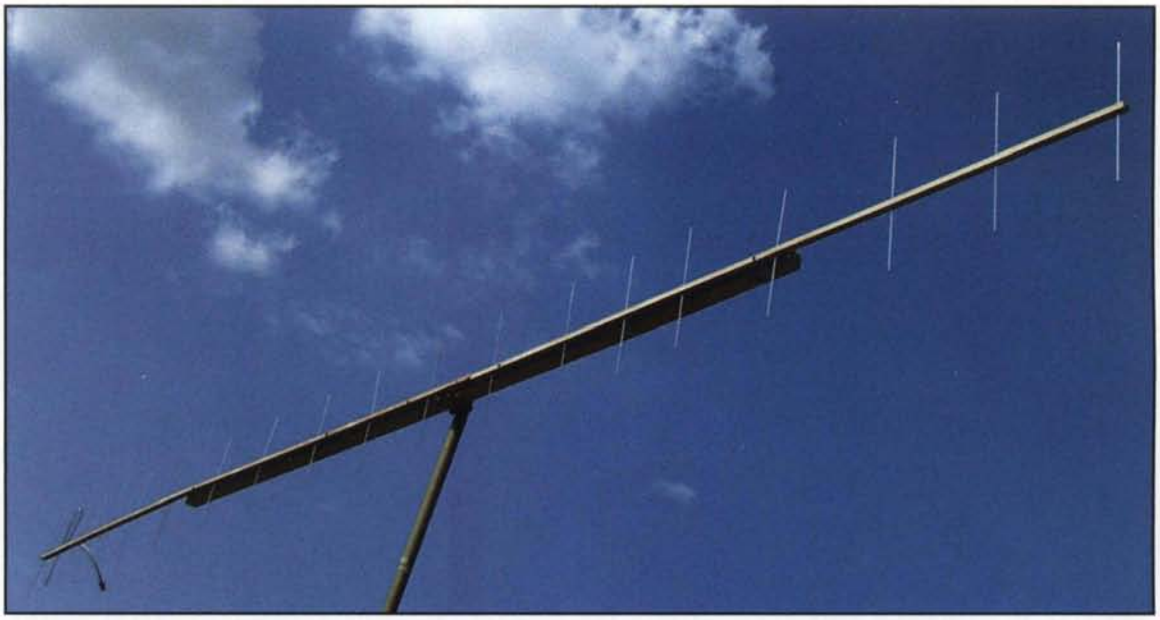
The plastic insulation on the wire is a dielectric and slightly slows down the radio wave. Therefore, the antenna has to be shorter to allow for the plastic. Wood does the same thing.

While many have worked out boom correction factors for metal booms, I don't know of anyone who has worked out similar correction factors for a wood boom. I can just see it now—tables of dimension corrections based on pine, ash, hickory, teak, etc. With additional correction factors for moisture content, I think that I'll just stick with my 1/2-inch wood on 1 1/4-inch wood for now.

Figure 1 shows the 432/435-MHz driven element (see Table 1 as well). You

*Photo 2. "But I built it 'exactly' to your dimensions."*

Photo 3. Twenty-element 432-MHz Yagi.



want to use something that is about 1/8-inch in diameter, and it is nice to have something to which you can solder. No. 10 bare copper wire works well. For this antenna I used 1/8-inch bronze welding rod. It is a bit stiff for bending the loop, and you need some pretty good wire cutters when trimming for best SWR. But hey, it was already on the work bench and time was short.

The coax is soldered directly to the driven element. Coax shield goes to the center of the element. The coax center conductor goes to the tip of the J. For those who are good at finding fly specs in pepper, yes, the connection points are not *exactly* the tip and the center, but close. Built to these dimensions, the SWR is usually better than 2 to 1.

If you can measure SWR at 432 MHz, then experiment to your heart's content. I have a supply of 1/8-inch hobby tubing. If, or when, I make that one-too-many-cuts mistake, then I just slip some tubing over the element tip and lengthen it back out a bit. The dimensions for the driven element are experimentally determined, the fancy way of saying these are the dimensions that worked best, not a computer prediction.

Plot 1 is the return-loss plot of the prototype 20-element Yagi. Minus 10 dB return loss is about a 2 to 1 SWR. -20 dB Return Loss is about a 1.2 to 1 SWR. SWR-wise, the antenna came out pretty successfully.

## Construction

The boom is 1/2" × 3/4" trim wood. You have a lot of options here, but as we just talked about, you want the element to be inside about 1/2-inch of wood.

The elements can be just about any 1/8-inch diameter rod material. Aluminum ground-rod wire works well after you have straightened it out. Copper/brass hobby tubing and bare #10 copper wire also work. Oh, do I have some stories about a welding supply house that no longer wants to talk me about gasses and welders when I come in.

Photo 4. Support boom and mounting.

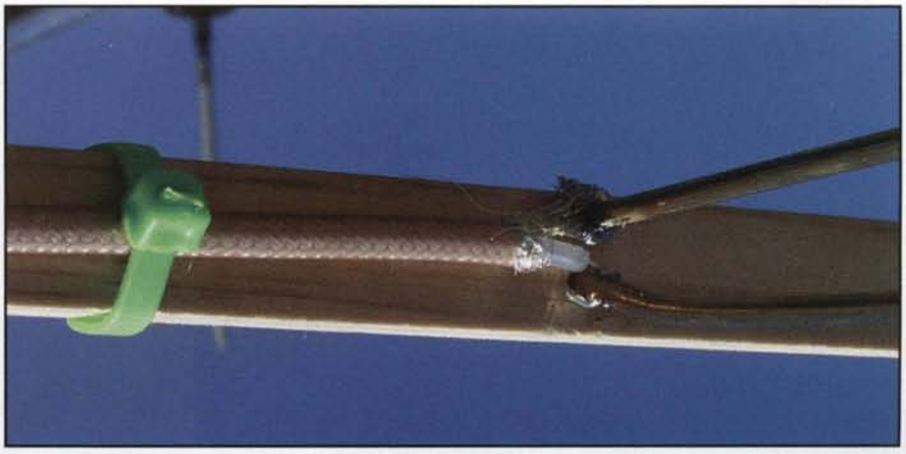


Photo 5. Driven element and coax attachment.

For this particular antenna the elements are 1/8-inch aluminum welding rod. The driven element can be either phosphor bronze or silicon bronze welding rod. The bronze welding rods are easier to solder to. There is nothing wrong with using the bronze welding rod for all the elements. It is just that the aluminum rods are a bit cheaper when they are selling the welding rods by the pound.

After drilling your boom with a 1/8-inch drill bit and putting in the elements, use a drop of glue to hold the elements in place. Almost any of the construction adhesives, or even "Super" glues, can be used. No big blobs of glue, however. We're back to that dielectric problem again.

I drilled a couple of holes in the antenna booms and fastened them to the larger wood with several drywall screws. Again, you can use your favorite fasteners, but I wanted to be able to take the antenna apart and store it when not in use.

When I get a second antenna built we will cover how to stack them for more gain or to run circular polarization. In another photo you can see how I drilled the boom for mounting the U-bolts. Don't do what I did; I drilled the wood for the U-bolts then attached the 1/2-inch wood with the elements.

You want any mast to split the elements—that is, it needs to be as far away from the director elements as possible. In the photo you can see the "oops" where the mast would hit a director element. Also note how I offset the elements to make room for the U-bolt.

## AMSAT

Do you want to have one heck of a signal on one of the Low Earth Orbit (LEO) Birds? Trim the driven element ever so slightly for best SWR at 435 MHz and the antenna's 17 dBi gain is virtually unchanged from 432 MHz. From Plot 1 you can see the SWR hardly changes between 432 MHz and 435 MHz.

## Arecibo and EME

From a short conservation with Joe Taylor, K1JT, at the Dayton Hamvention® this year, it seems there are plans to put the 1000-foot Aercbio dish on EME again. No exact dates have been set. However, another year or so is likely. Want to put 432-MHz KP4 in your logbook? Well, it's time to get prepared!

Oh, did I mention they want to have 1296 MHz off the Moon next time at Arecibo? How about some long Cheap Yagis for 1296 MHz? I have those in the pipeline.

## Future Projects

I have a second 20-element 432-MHz Cheap Yagi under construction. I kind of ran out of time to write about it in this column. With the second antenna I can show combinations of phasing harness and mounting points such that the antennas can be mounted for vertical, horizontal, and right-hand circular or left-hand circular polarizations.

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As always I welcome antenna questions and column suggestions from readers. Send an e-mail to <wa5vjb@cq-vhf.com>, or <wa5vjb@amsat.org> will work. Also, for several dozen other antenna projects, visit <http://www.wa5vjb.com>, the Reference section.

73, Kent, WA5VJB

By Rich Arland,* K7SZ

# BEGINNER'S GUIDE

## All you need to know but were afraid to ask . . .

# Computers and Amateur Radio

The following is a record of a recent conversation between my wife, Patricia, KB3MCT, and me:

KB3MCT: "You just spent $800 for a *what*?"

K7SZ: "A computer—a laptop, actually—a really, *really* nice high-end Toshiba laptop."

KB3MCT: "Are you totally out of your mind?"

K7SZ: "No, I needed a new one, since the six-year old HP had a hard-disk failure. I have columns to do, a book to publish. I mean it's not that I won't make the money back in a few months."

KB3MCT: "You had better hope that your royalty check comes in or we're going to be eating a lot of beans and rice!"

And that, faithful readers, is the way things transpired between us few months ago. This got me started thinking about *why* I needed a new high-end computer in the first place. My good friend and world-class CW operator Mike Weathers, ND4V, told me once that "there is no such word as *need* in the ham radio vocabulary; *want,* on the other hand, is a completely different matter."

Welcome back for another installment of "Beginner's Guide." This time we will diverge a bit from the radio portion of the hobby to talk a bit about computers and their relationship to our hobby.

Over the last 35 years the growth of the personal computer industry has been phenomenal, if not downright frightening! Having been involved with amateur radio for almost half a century, I would never have believed how much we've come to depend on computers in the ham shack. Starting with a phone call from Lee Horton, W5IAV, in 1976, I became involved with some of the very first personal computers. In those days virtually all PCs were built by hams or electronics geeks, since Apple and Microsoft didn't exist and IBM was still heavily into the massive main-frame computers that ruled the financial and logistical worlds.

Lee's little Digital Group computer was extremely primitive by today's standards. You programmed it using DIP switches

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*My new (used) HP computer alongside my Elecraft K3.*

or front-panel toggle switches! Slow and tedious was an understatement. There were no snappy GUIs or graphics at all, for that matter. Those early days were pretty stark. Comparing Lee's Digital Group computer to today's offerings is like comparing the original Wright Flyer to an F-22 Raptor!

It wasn't long before computer kits were being sold, which, of course, led to the first commercial offerings which included the Radio Shack TRS-80 and the Color Computers (CoCo), along with a host of other manufacturers flooding the newly generated home-computer market with their gear.

While stationed in England in the USAF, I procured a Sinclair ZX-81 (Timex-Sinclair 1000 in the states), a 16-kb RAM pack, and a small cassette recorder for my shack. This thing was such a pain in the tail to program with its undersized membrane keyboard and/or cassette recorder/player that I finally relegated it to keeping time as the shack digital clock! Of course, it was not all that accurate, getting its timing from the AC line! However, it was a computer and I programmed it in Sinclair Basic and it did work . . . sort of.

Then, in rapid succession, came a Commodore VIC-20, a Commodore 64, a Tandy TRS-102 "laptop," an IBM-XT, IBM-AT, etc., etc. Each was an improvement over the previous computer. I even had a couple of CoCo-IIs for use as RTTY terminals, CW keyboards, and, of course, packet radio.

Today, some 30+ years later, I have a number of computers in the house that are linked by my own wireless LAN. Where, oh where, did I go wrong? Man, computers are so integrated into our lives that just thinking about not having access to the internet makes me depressed! Although I don't have access to the actual data, I would be willing to bet that at least 85% (possibly more) of the *active* radio amateurs in the U.S. have some form of computer(s) in their home/shack. That is a *lot* of computing power!

All this being said, what do you really need (want?) for your shack? That is a question that we'll try to answer. After all, that's what we're here for: to get you answers to your questions and hopefully guide you in the right direction to further enjoyment of the radio hobby.

## New or Used?

There is something magical about bringing home a brand-new computer (laptop or desktop), opening the box, and unpacking the new computer, pulling it out of the plastic wrap, setting it up, plugging all the things into their respective jacks. Ah, yes . . . it is almost a religious experience! However, just like a new car, obsolescence is built in, and once out the door of the "dealership," its value plummets like a stone!

I am not one to get the "latest and best" when it comes to computers, or ham gear for that matter. However, I have managed to violate my own buying code and purchase computers and radio gear new on rare occasions. I usually don't make a habit of doing that. It's just not prudent economically. I'd much rather buy a good-quality, brand-name, reconditioned, used computer from a reputable reseller.

Recently, after my $800 purchase of a new Toshiba tri-core ultimate-whizz-bang computer, I got "schooled" in the fine art of finding a good used computer for about 75% less money!

First of all, I had convinced myself that I "needed" a high-end laptop with all the latest technology to do my writing, internet research, and to integrate with my radio gear in the shack. With the upsurge in software defined radios (SDRs), a fast computer with a high-end sound card is an absolute "must have." Ergo, let's go spend $800! Well, I got the bloody thing home and then found that I couldn't get it to talk to my radios! It seems that no computer manufacturers currently produce a consumer-grade laptop with an RS-232 port anymore. Everything has gone USB! This presented a problem in that now I had to procure a USB-to-DB9 serial cable and software in order to make the new whizz-bang laptop talk to the radios! What's another $35–$40? Then there is the unfortunate truth that not all serial cables are created equal. I ended up trying three different cables before I found one that worked to my satisfaction.

The other problem I encountered was the physical size of the new computer. It would not fit comfortably on the shack operating table. Sometimes size really does matter! In this instance, the 17-inch screen, while great for watching videos and general computing, was not able to integrate into the shack! I had spent $800 for what?

## Arland Goes Back to School

Finding a reputable computer shop that handles used gear (and that offers a warranty) is similar to finding a good mechanic! There are a lot of computer "gurus" out there, and very, very few of them actually know what they are doing, let alone offer their services at a reasonable cost. After several abortive attempts to find a reputable computer repair shop that also recycled older computers coming off commercial lease, I stumbled upon Pro Computer in Buford, Georgia (http://www.procmog.com/). Sheldon, the owner, had helped me previously with several computer problems concerning our desktop machine at the house and my six-year old HP laptop.

I was lamenting the loss of DB9 RS-232 ports on the newer laptops when he suddenly produced a commercial HP laptop from behind the counter. This was a reconditioned off-lease machine featuring a titanium case, high-resolution screen (1020 × 1240), 60-GB hard disk, four USB ports, a Firewire port, an honest-to-goodness RS-232 port terminated in a DB9 connector, CD/DVD drive, 1 GB RAM, IEEE port, Wi-Fi internal card, and loaded with XP Pro for the unbelievable price of $225! I was literally blown away! Having just sold one of my HF transceivers that was surplus to requirements at K7SZ, I quickly bought this HP laptop and, for $30 extra, purchased a one-year extended warranty from Sheldon. The 15-inch screen and smaller overall footprint of the new HP laptop fits right into the shack motif. Talk about a win-win!

The morale of this story is this: Big money doesn't necessarily produce the desired results when it comes to computer equipment. Ditto with ham gear. Had I consulted Sheldon at Pro Computer prior to my mindless buying spree, I would have saved close to $600 that could have been used on other much "needed" ham gear. Therefore, it pays to do your homework before you strike out with the plastic or checkbook.

How does this commercial HP laptop work? In a word, *great*! My burning desire had been to interface my computer with my Elecraft K3. I had done this several years previously when I owned a K2, with outstanding success. I used Ham Radio Deluxe as a starter package with the K2 and the newest version of HRD works very well on the new laptop hooked to the K3.

The Elecraft K3 is such an awesome radio that it deserves my best efforts from the driver's seat! Ergo, the new HP laptop. In addition, I am planning on using the HP laptop for some upcoming experiments with some of Tony Park, WB9IYG's very inexpensive SDRs that I am building (check <http://www.kb9igy.com> for availability and price). Actually, Phil Graitcer, W3HZZ, did the SMD work for me (I have problems seeing, handling, and soldering the very small surface-mount [SMD] parts.), and I am doing the through-hole components and final packaging. I am hoping that the soundcard in the new laptop will be up to the task; otherwise I will be going on a quest for a new soundcard post haste.

In addition to interfacing with the K3, my newly acquired HP laptop is loaded with several satellite tracking programs, WinLink software, packet software, a couple of propagation programs, Digi-Pan software, along with a few other ham-radio-related programs. In short, my new addition is really earning its keep in the shack. My only regret is not exploring reconditioned off-lease laptops prior to spending a significant amount of money for a computer that did not fill my requirements.

Another way to allow hams to interface their USB-only serial port computers to a true RS-232 serial port is to use an Inside Out Networks Edgeport/2 USB Converter, readily available on eBay for around $25–$30 with software. This little box converts one of your USB ports into a true RS-232 serial port with the proper levels to control an external device such as a radio, rotator controller, or older communications equipment. The main reason I did not go this route is the lack of space on my ops bench. Adding another box is not the solution for me, although it might well be a workable solution for you and your station gear.

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That's a wrap for this installment, gang. Six meters has been open and I now have a roof tower, rotator, and 5-element Yagi for 6 meters. Therefore, with any amount of perverse luck I will have a decent signal on the "Magic Band" in the not too distant future.

73, Rich, K7SZ

By Bill Brown,* WB8ELK

# UP IN THE AIR

## New Heights for Amateur Radio

## Field Day Balloon

For several years in a row I've launched a balloon for Field Day. This year I put together a payload with a 25-milliwatt multi-mode transmitter on 2 meters FM sending down the balloon's position in DominoEX, RTTY, and CW formats. Since the payload was a very lightweight 8 ounces, I decided to hitch a ride attached to the weekly ozone sounding bal-

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e-mail: <wb8elk@aol.com>

Photo 1. Brian Huang (left) and Shane Wilson, N4XWC (right), launch the Field Day balloon.

Photo 2. Tammy Cockrell listens to the balloon's signals at the Huntsville ARC Field Day site.

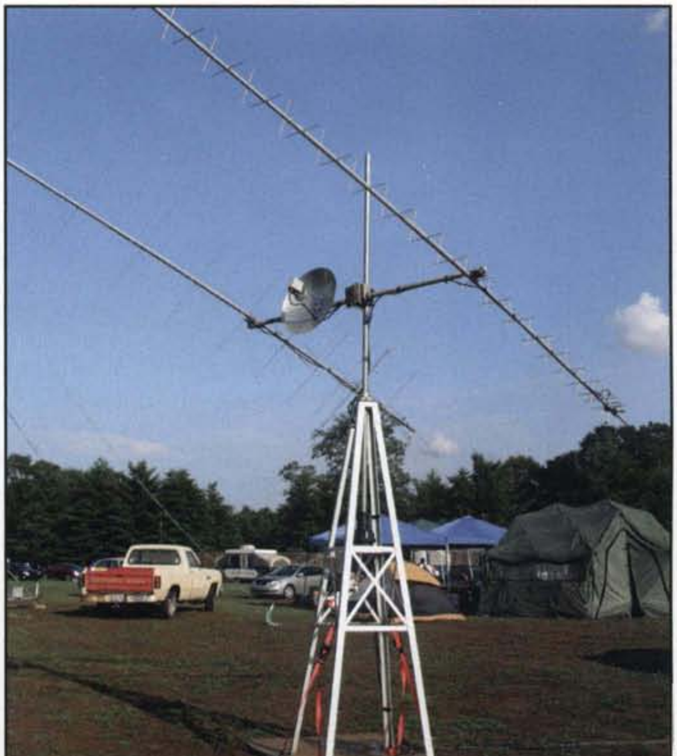

Photo 3. The high-gain satellite array at the HARC site did a great job receiving the balloon.

*Photo 4. Shane Wilson, N4XWC, climbs the tree to recover the payloads.*

*Photo 5. The payloads being lowered out of the tree.*

loon. Every Saturday an ozonesonde is launched from the NSSTC (National Space Science and Technology Center) building in Huntsville, Alabama at 1:00 PM Central Time, which conveniently was the start of Field Day this year. The launchsite is less than a mile from the Huntsville Amateur Radio Club's Field Day site in a grassy area next to Space Camp.

We used my netbook and a Verizon cellular modem to stream live video of the launch via the British Amateur Television Club's streaming video website (http://www.batc.tv) and had a number of viewers from around the world.

## Great Day to Fly

It was a great day for a flight, with clear skies and no surface winds. The balloon took off and headed straight south to fly directly over the HARC Field Day location. We took the short drive to hang out with the HARC folks and to demonstrate how to track the balloon's digital modes. We dropped by the satellite station, and Tim Cunningham, N8DEU, turned the full force of his large AZ/EL satellite array towards the balloon. In between satellite passes we had great reception of the balloon's low-power signals using this setup. Since the upper-level winds were very low, the balloon stayed within 15 miles of Huntsville, so we were actually able to receive the signals using nothing more than an HT with a rubber duck.

## The Chase

Shane Wilson, N4XWC, and I took off in his well-equipped chase vehicle to track down and recover the payloads. The fast CW telemetry really helped, since I could copy the altitude without having to look at the computer while we drove. We used the <http://spacenear.us/tracker> website to track the balloon's position and sent the position reports to that website via the modified dl-FLDIGI program on Shane's laptop hooked up to the internet via a Verizon modem.

Shane managed to catch up with the payload as it was parachuting back from the edge of space after the balloon burst at 92,000 feet just south of Huntsville. We were just a few hundred yards away when it landed. After a few minutes perusing a satellite map, we figured out that it was in a tree line just north of a large pond.

## Treetop Adventure

Sure enough, we saw an orange parachute way up in a large pine tree behind a house on the shore of the pond. The owner


*Photo 6. Sabrina Cline, KJ4YAJ, operating the GOTA station at the Huntsville Field Day site.*

warned us to watch out for a beaver dam at the base of the tree and also to be careful of snapping turtles. We braved the beavers and the turtles and hiked back to the tree to discover that the main payloads (the ozonesonde and my transmitter) were actually in a second tree and only about 30 feet high. Shane loves to climb trees and without hesitation jumped right into the tree and scurried up to grab the payloads. The last several flights have ended up in tall trees, and Shane wouldn't know what to do if we ever land in a pasture or field. Apparently I must have a tree-tracking sensor in my payloads. Even if there is a single tree in the middle of a thousand-acre pasture, my payload usually will land in the tree.

Shane lowered down the payloads from the treetops and we headed back to the Huntsville Field Day site with our catch of the day. We arrived back just in time for a fantastic cookout and showed everyone the transmitters that they had been hearing earlier.

During the show-andn-tell, Sabrina Cline, KJ4YAJ, saw us holding the unusual payloads while she was operating the GOTA (Get On The Air) station. Since she is fascinated by atmospheric research and meteorology, we presented her with the ozonesonde payload.

As usual we had a great flight with the balloon transmitter being heard by other Field Day sites in a several-state area. I look forward to doing this again next year!

73, Bill, WB8ELK

*Photo 7. Shane, N4XWC, presents the ozonesonde payload to Sabrina, KJ4YAJ.*

By Bob Witte,* KØNR

# FM

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

# FM VHF Distance from Pikes Peak

One of my favorite ham radio activities is getting on top of a big mountain and seeing whom I can contact on VHF. One of the prime spots in the country for doing this is from the top of Pikes Peak, Colorado, which is a short drive from my home. Not only does Pikes Peak exceed 14,000 feet in elevation, there is a road to the top so you can drive to the summit.

## The Question

I recently received this question via e-mail from Dave Joseph, NØMUA:

Bob, I ran across your pictures of mountaintopping on Colorado peaks and thought if anyone could answer this it would be you and your group. We run on 146.52 here in Coffeyville, Kansas, and a group of us have brought up the question how far east can a mobile atop Pikes Peak be heard on 146.52 FM? The mobile would be mine running an ICOM V8000 into a Tokyo Hy-Power amp at 375 watts, LMR 400 coax to a Cushcraft 13B2 beam pointing to the east.

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e-mail: <bob@k0nr.com>

This is one of those "How far will my signal go?" questions that always gets my attention. Other folks may find this interesting, so I decided to spend some time researching the topic. For the purposes of this discussion, I will assume we are talking about tropospheric propagation and not some of the more exotic propagation modes such as meteor scatter, aurora, or sporadic-*E* skip.

## Radio Horizon

The (incorrect) conventional wisdom is that VHF propagation is "line of sight," extending a bit beyond the optical horizon. From Wikipedia, we find that the distance to the optical horizon can be approximated by:

$$d = \sqrt{1.5h}$$

where $d$ is the distance to horizon in miles and $h$ is the height of the observer above ground in feet.

Pikes Peak reaches to 14,110 feet above sea level. The eastern portion of Colorado is relatively flat, with the elevation typically ranging between 4000 and 5500 feet above sea level. The Front Range of the Rocky Mountains (which includes Pikes Peak) towers over the eastern flatlands, creating an ideal situation for radio propagation. With that in mind, we'll use a simple model that assumes Pikes sticks up 9610 feet above a pancake-flat eastern Colorado at 4500 feet.

*Pikes Peak at 14,110 feet above sea level towers over the eastern plains of Colorado.*

We can calculate the optical horizon of Pikes Peak as equal to:

$$\sqrt{1.5 \times 9610} = 120 \text{ miles}$$

Yes, this is an approximation, so feel free to knock yourself out with a more precise calculation. As you will see, it doesn't really matter.

It is interesting to note that there is a community 30 miles west of the Kansas border called Firstview, Colorado which is supposed to provide the first opportunity to see Pikes Peak when traveling from the east on Highway 40. First view is about 135 miles east of Pikes Peak, so the 120-mile calculation is in the right ballpark.The radio horizon is generally 15% beyond the optical horizon, so that means our line-of-sight radio horizon is about 1.15 × 120 = 138 miles away. I've operated from the summit of Pikes, and working stations on 2 meters at this distance is not difficult.

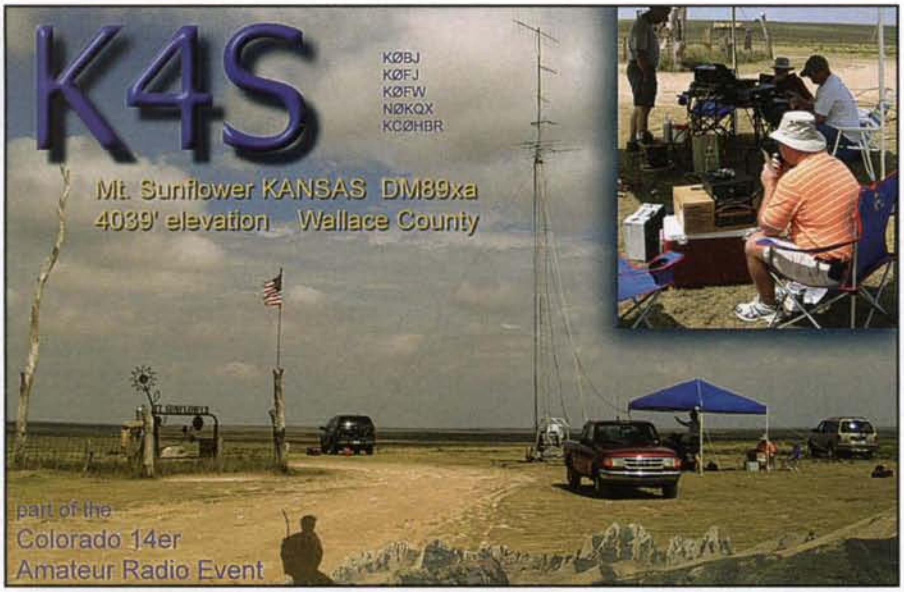
## Colorado 14er Event Records

The Colorado 14er Event involves mountaintopping from the summits of the fifty-four 14,000-foot mountains of Colorado (and sometimes California!). We've held the Colorado 14er Event every year for well over a decade, so we have some experience with operating FM transceivers from these peaks. FM is the dominant mode for this event, since most of the radio operators climb the peaks on foot, making a handheld radio the preferred rig. A few years ago during the 14er Event I recall working the Mt. Sunflower crew (highest point in Kansas at 4039 feet, 160 miles from Pikes) from Pikes Peak on 2 meters FM using a 25-watt mobile and a not-very-well-positioned 1/4-wave antenna on the SUV fender.

I pulled up the distance records for the Colorado 14er Event and found that the best DX using 2 meters FM was when Phil Krichbaum, NØKE, on Mount Bross worked Larry Lambert, NØLL, in Smith Center, Kansas at a distance of 375 miles! Clearly, we are well beyond line-of-sight for this radio contact. NØLL has a *very* capable big-gun VHF station on his end, and NØKE was using a 13-element KLM Yagi antenna and running 160 watts of power. Mount Bross sits at 14,172 feet and is about 60 miles west of Pikes Peak.

Despite the popularity of FM, we know


*This map of eastern Colorado and Kansas shows the various locations discussed in the article.*




*The K4S QSL card shows the radio setup at Mount Sunflower in Kansas.*

that it is not that great for weak-signal work. When signals are weak, the FM *threshold effect* kicks in and the receiver's ability to demodulate the signal drops off quickly with decreasing signal level. Using SSB is much more effective than FM. For example, during VHF contests I have worked NØLL from Pikes using 50 watts and a single 2M9 Yagi on 2 meters SSB with no difficulty.

Also during the Colorado 14er Event, Phil, NØKE (and Jeff Gerst, NØXDW) on Mount Bross worked W7XU in Parker, South Dakota on 2 meters CW at a distance of 551 miles. Keep in mind that as the signal strength fades, SSB has a serious advantage over FM, and CW is even better! Therefore, for squeaking out the marginal contacts, CW is the way to go.

We generally do not get much tropospheric ducting as far west as the Colorado mountains, so I don't believe there was any ducting going on during these 14er Event contacts. If tropospheric ducting is in play, then even longer distance contacts are possible. Here's a report I received from NØKE:

During a CSVHF [Central States VHF] Conference in Colorado Springs one summer there was a very stable mass of hot air going east from Colorado and some exceptional tropo. I was running 100 watts to a 4-ele 2-meter Yagi mounted on my vehicle's spare-tire bike rack. My first QSO was near South Bend, Indiana, and I was just barely above most of the homes in Colorado Springs. I worked stations in Missouri, Kansas, Nebraska, Iowa, Illinois, Indiana, Michigan, and Wisconsin, and the opening lasted until about 11 AM on Saturday and Sunday. Two VHF stations in the Colorado Springs area worked 432 tropo as far as Columbus, Ohio. Tropo like this rarely gets as far west as the populated areas of the front range of Colorado.

The original question concerned working Pikes Peak from Coffeyville, Kansas using 2 meters FM. I had to look up where Coffeyville is and discovered that it is way the heck over on the east side of Kansas, maybe 50 miles from Missouri and about 525 miles from Pikes Peak. To get back to Dave's question, making a contact from Pikes to Coffeyville on 146.52-MHz FM on any given day is not very likely. Maybe if we got some exceptional tropospheric propagation . . . but I think even then it would be unlikely to complete the contact using FM. Using SSB or CW would raise the odds a bit, but it would still be a stretch. However, you never know what might happen on VHF. That's what makes it fun.

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So what have we shown? VHF doesn't just stop at line-of-sight and typically propagates well beyond the optical horizon. Under the right operating conditions, we can make contacts hundreds of miles away.

If you happen to be in Colorado, try a little mountaintop operation from Pikes Peak. You might get hooked on it!

Also, thanks for taking the time to read another one of my columns on the Utility Mode. I always enjoy hearing from readers, so stop by my blog at <http://www.k0nr.com/blog> or drop me an e-mail at <bob@k0nr.com>. 73, Bob, KØNR

## References

Colorado 14er Event: <http://www. 14er.org>
Mount Sunflower, Kansas: <http://www. kansastravel.org/mountsunflower.htm>
Line-of-Sight Propagation: <http://en. wikipedia.org/wiki/Line-of-sight_propagation>

By Keith Pugh,* W5IU

# SATELLITES

## Artificially Propagating Signals Through Space

# ARISSat-1 "Ready to Go," AMSAT at Dayton, Project Fox, and Field Day

ARISSat-1 is still on board the International Space Station (ISS) waiting on a Russian space walk (EVA) in late July or early August for deployment. Also, Dayton Hamvention® 2011 is now history, but let's review what went on at Dayton in the world of amateur radio satellites, including Project Fox, our next satellite. Finally, let's explore a different approach to working satellites on Field Day 2011.

## ARISSat-1 Ready to Launch

As this column is being written (4 July 2011), ARISSat-1 is still on board the ISS awaiting deployment; however, it is currently scheduled for deployment in late July or August 2011. Once launched, due to a very-low-altitude orbit and battery uncertainties, it will only be usable for two or three months. Optimistically, this might go as long as six months. We need to be ready to go and use it to the greatest extent possible. Deployment will happen right at the start of the school year in the Northern Hemisphere, so let's get it into the schools immediately.

ARISSat-1 was launched from Baikinor on a Progress Supply Ship to the ISS on January 28, 2011. ARISSat-1 was hooked to an external antenna shortly after arrival and successfully tested. Many stations throughout the world heard and recorded data during that brief test. The scheduled deployment on February 16 did not occur due to insufficient time available during the EVA. Roscosmos (the Russian Space Agency) now indicates that ARISSat-1 will be deployed during the next planned Russian EVA in July or August 2011. A planned turn on as part of a celebration of the 50th Anniversary of Yuri Gagarin's First Manned Space Flight on April 12 was unsuccessful. Indications from our Russian counterparts are that, due to earlier testing, the charge state of the spacecraft battery was too low to support the activity and a concern for the limited number of re-charges available precluded charging it at that time. A full charge will be placed on the battery before deployment; meanwhile, ARISSat-1 (also known as RADIOSKAF-V and KEDR) is in storage on board the ISS. Hopefully, by the time you read this the launch will have been successful and ARISSat-1 will be in operation. *Don't forget the limited time to use it!*

Get ready to participate and to help introduce this valuable teaching asset into the classrooms of the world. A listing of capabilities and "get ready instructions" follows courtesy of the ARISSat – 1 Team and the AMSAT News Service (ANS). This information is more intensive than usual for this column, but I want to help get the word out to as many folks as possible.

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*e-mail: <w5iu@swbell.net>*

**145.950 MHz FM Downlink:** FM transmissions will cycle between a voice ID as RS01S, select telemetry values, 24 international greeting messages in 15 languages, and SSTV images. One of the messages will be a conversation between Yuri Gagarin and ground control. See the SSTV item below for pointers to get your station ready to receive the SSTV images.

**435 MHz/145 MHz Linear Transponder:** The linear transponder will operate in Mode U/V (70 cm Up, 2m Down). It has a 16-kHz wide inverting passband and the convention will be to TX LSB on the 435-MHz uplink and RX USB on the 145-MHz downlink. This mode is designed to work with low-power transmitters and omni antennas.

**145.919 MHz/145.939 MHz CW Beacon:** The CW transmissions will be callsign ID RS01S, select telemetry, and callsigns of people actively involved with the ARISS program.

**145.920 MHz SSB BPSK-1000 Telemetry:** The BPSK transmissions will feature a new 1kBPSK protocol developed by Phil Karn, KA9Q, to be readable in low-signal-level conditions. The BPSK data will transmit satellite telemetry and data from the Kursk Experiment.

The ARISSat-1 BPSK-1000 downlink is transmitted in SSB mode on 145.920 MHz. When the CW2 beacon on 145.919 MHz is active, this indicates that the BPSK-1000 format is being transmitted. If the CW1 beacon on 145.939 MHz is active, this indicates the backup of BPSK-400 format is being transmitted.

Transmitting at 100 mW, both BPSK rates include Forward Error Correction (FEC), and it is expected that modest quarter-wave antennas with low-loss coaxial cable will provide sufficient signal strength for decoding and display by the ARISSatTLM software.

An audio feed from a SSB receiver to the computer's soundcard input is needed. An initial "Receive Only" configuration is easily done consisting of an audio patch cable between your radio and the soundcard. Take the speaker or headphone output from the radio and run it into the line (or mic) input on your PC soundcard.

BPSK-1000 sounds like a "shusssch" with a higher pitch than the 400-bps growl. It is difficult to tune by ear. The CW2 beacon is used as a tuning signal for BPSK-1000. The PC and Mac ARISSatTLM software display contains a dotted line that you use to tune your receiver until the CW signal bumps line up with the dotted line on your PC screen. This will allow you to decode the BPSK-1000 signal and you will also be able to copy the CW2 beacon.

Download the free Windows® ARISSatTLM ground-station soundcard demodulator and display software: <http://www.arissattlm.org/download/ARISSatTLM_050_Setup.exe>.

Download the Mac ARISSatTLM software: <http://www.arissattlm.org/download/ARISSATTLM.zip>.

*Antenna Control Roger Ley, WA9PZL, controls demo antennas.*

*Col. Doug Wheelock, KF5BOC, interviews a "future astronaut."*

The ARISSatTLM software user guide is available: <http://tinyurl.com/42uhtyf> (amsat.org)

Get your color ARISSat-1 Frequency Guide: <http://tinyurl.com/4t497t2> (amsat.org)

ARISSat-1 Presentation Slides (~1MB): <http://tinyurl.com/4n4pzkm> (amsat.org)

**SSTV Downlink Details:** The ARISSat-1 FM downlink on 145.950 MHz includes live SSTV images as part of the cycling voice ID, select spoken telemetry values, and the international greeting messages. Here are some pointers to help you get your station ready to receive and display the SSTV pictures transmitted by ARISSat-1.

One fun feature is that there are four SSTV cameras mounted on the spacecraft. On photos of ARISSat-1 you may have noticed black brackets on the outside of the spacecraft. These hold the mirrors that reflect the light onto the lens of the cameras. The software-defined-transponder will use the image data from the cameras to generate the SSTV downlink.

ARISSat's software will sequentially select a new or stored image from one of the four cameras. There are two pre-recorded images as part of the sequence. The camera that took the picture can be identified by the color of the callsign in the upper left of the SSTV image. The SSTV image will be sent down as FM audio SSTV in Robot 36 format on 145.950 MHz about every 140 seconds.

The RF downlink power on the 145.950-MHz FM downlink will be 250 mW, which is predicted to provide a link margin around 6 dB on an HT with a "big whip" when the satellite is at 15 degrees elevation. This should be sufficient to receive SSTV pictures, although you may need to orient the whip to line up the antenna polarization.

ARISSat-1 is not stabilized, so the antenna orientation is unpredictable and a certain amount of fading will happen. The receiving link margin may be improved with a handheld beam such as an Arrow, Elk, or Cheap Yagi antenna (http://www.wa5vjb.com/references/Cheap%20Antennas-LEOs.pdf).

**General Overview Radio-to-Soundcard Interface:** To view the SSTV downlink from ARISSat-1 you'll need a computer running SSTV software for your soundcard and an audio connection between your radio and the computer.

If you are already on the air with other amateur radio soundcard applications, chances are you are ready to receive ARISSat's SSTV downlink with little or no modification to your setup.

The audio from the radio to the computer is the key link. An initial "Receive Only" configuration is easily done, consisting of an audio patch cable between your radio and the soundcard. Take the speaker or headphone output from the radio and run it into the line (or mic) input on your PC soundcard.

Setting the level is simple, as the MMSSTV software has a bar indicator. Just adjust the soundcard gain slider and/or radio volume control so that the SSTV signal is within the center part of the bar. MMSSTV will give you an "overflow" indication if the volume is too high.

If your rig has a "Line Out" connection, this can be run to the soundcard "Line In." Using the radio "Line Out" you won't have to deal with the interaction of the radio's volume control with the soundcard levels, but you will still need to use the soundcard "Volume Control"' to set the "Line In" levels.

**SSTV Software Download Sites:** There are many amateur radio SSTV software decoding applications available. One of the easiest to use on Windows®

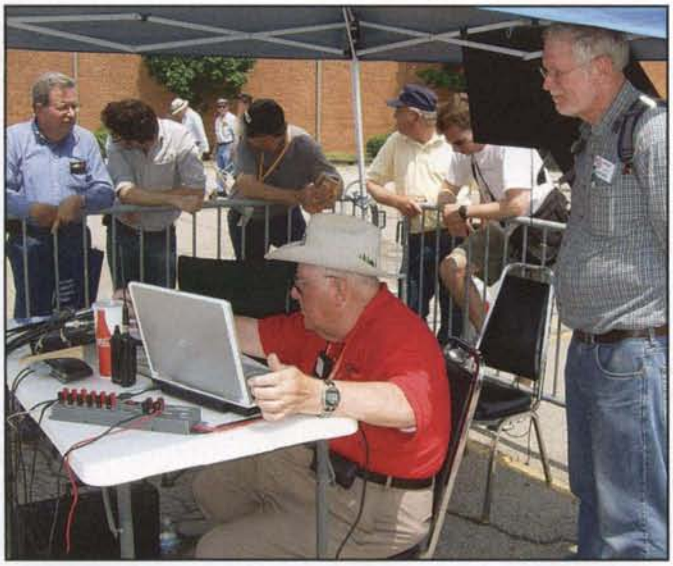
computers is the MMSSTV program. This can be downloaded from: <http://mmhamsoft.amateurradio.ca/pages/mmsstv.php>. The Ham Radio Deluxe software package also includes SSTV operation.

SSTV software for the Mac is available at: <http://web.me.com/kd6cji/MacSSTV/MultiScan.html>.

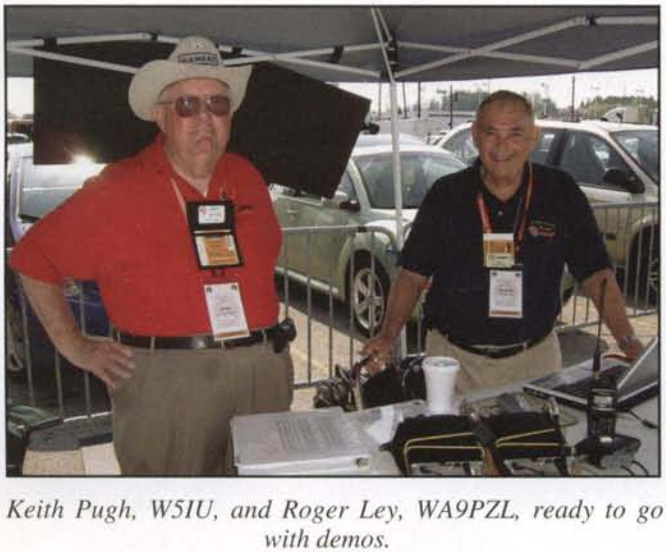
**ARISSat-1 Conclusion:** What better way to introduce science, technology, engineering, and mathematics (STEM) into the classroom. Visit <http://www.arissat1.org> and <http://www.amsat.org> regularly. Stay tuned for additional updates!!

## AMSAT at Dayton 2011

Once again, AMSAT had a great presence at the Dayton Hamvention® with a large booth, engineering displays of new satellite gear, a great forum, an AMSAT/ TAPR banquet, a Thursday evening "Get Together," and a satellite demonstration area. This year we shared booth and forum space/time with AMSAT-China for the first time. We also co-hosted, along with the ARRL, a visit by Col. Doug Wheelock, KF5BOC, NASA astronaut. Doug was a very open and gracious guest. He was certainly a real "crowd pleaser."



*Keith Pugh, W5IU, operating as Andy Squires, VK3AS, looks on. (All photos courtesy of Keith Baker, KB1SF/VA3KSF, AMSAT Treasurer)*



*Keith Pugh, W5IU, and Roger Ley, WA9PZL, ready to go with demos.*

The AMSAT Forum, moderated by Alan Biddle, WA4SCA, AMSAT Secretary, featured the following speakers and topics:

Barry Baines, WD4ASW, AMSAT President,"AMSAT Status Report"

Alan Kung, BA1DU, CEO of AMSAT-China, "Say Hi to the world – from AMSAT-China"

Gould Smith, WA4SXM, AMSAT VP User Services, "ARISSat-1 in Space"

Tony Monteiro, AA2TX, AMSAT VP Engineering, "Project Fox—AMSAT's First Cubesat"

Alex Harvilchuck, N3NP, NextGen Program Manager, "NextGen CubeSat Program Update"

Slides and audio from these presentations will be available in future AMSAT publications. Project Fox will be featured later in this column.

As usual (for the last several years), I spent most of my time in the outdoor AMSAT satellite demonstration area. First, I want to recognize Roger Ley, WA9PZL, and Mark Hammond, N8MH, for their outstanding help again this year. I also want to recognize some great help from "down under," VK3AS, Andy Squires, for unsolicited help with tear down and other support.

We still don't know what happened, but on Friday we were "snake bit" for the whole day. We blamed equipment, setup,


*AMSAT-China at AMSAT booth at Dayton.*

operator error, and anything else that came to mind. At the end of the day, we were very discouraged. On Saturday and Sunday we used the same basic setup, with some modifications for equipment we thought was bad, and "went on with the show." Everything worked great and we had a good finish. Subsequent tests of equipment we thought had failed indicate that it was all good. I guess Murphy is still "alive and well."

Col. Doug Wheelock, KF5BOC, and Kenneth Ransom, N5VHO, visited with us for a while and drew quite a crowd.

On Saturday, we were able to let the AMSAT-China Team listen to HO-68's beacon (their satellite) and let them talk to some U.S. stations via VO-52, an Indian Satellite.

With the help of Mark Hammond, N8MH, in Dayton and Drew Glasbrenner, KO4MA, in Florida (both AO-51 command stations) we were able to make a reluctant satellite, AO-51, behave and produce some great demonstrations.

## Project Fox—AMSAT's First CubeSat

Now that ARISSat-1 is (or soon will be) "on its way," AMSAT has returned to work on Project Fox. This effort was approved by the BOD a couple of years ago but had been overtaken by the ARISSat-1 effort. Tony Monteiro, AA2TX, AMSAT VP Engineering, gave an excellent presentation on this effort during the AMSAT forum at Dayton. Further details are available at: <http://www.amsat.org/amsat-new/fox/>. Tony described the goals of the project and how AMSAT intends to reach them with an affordable but very small satellite (CubeSat).

With today's technology, it appears to be possible to build a CubeSat replacement for AO-51, which is the principal goal. Developments of some of the key designs have been done by partnering with the State University of New York (SUNY), Binghamton. This is another implementation of a long-standing goal of AMSAT—to enhance education through the development and use of satellites.

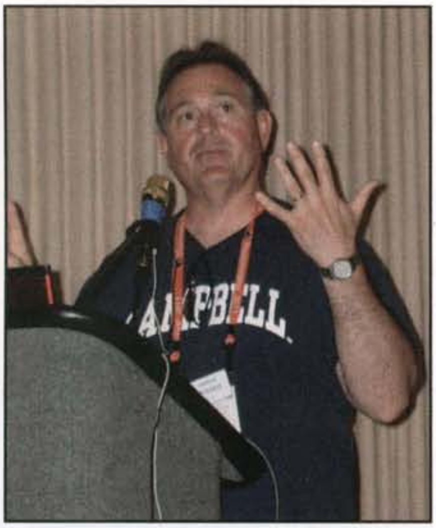
Alex Harvilchuck, N3NP, NextGen Program Manager, gave a presentation on the SUNY effort during the AMSAT forum at Dayton. We will be hearing much more about Project Fox in the near future. A picture of our *CQ VHF* Editor, Joe Lynch, N6CL, his wife Carol, W6CL, Douglas Quagliana, KA2UPW, and Tony Monteiro, AA2TX, along with a full scale model of the Project Fox CubeSat is included in this column. Also included is a picture of AMSAT Office Manager Martha Saragovitz with AMSAT member John Shew, N4QQ.

## Field Day 2011

Every year I get questions regarding how to work satellites on Field Day. Usually, I answer these questions "one on one" and then report on how Field Day went after the fact. This year, Field Day operations were discussed "up front" in my last column. A short operations report follows:

Being basically lazy, I decided to take the lazy approach" and not carry so much baggage to the Field Day site this year. Instead of my Hy-Gain, auto-tracked antenna array, I went with the same "Cheap Yagi" and "Cheap AZ/EL positioner that I have used at Dayton and other hamfests for several years. Tracking was to be done manually. I took only one radio, my FT-847, and left any external amplifiers at home. This approach greatly reduced the ERP available and limited the success of the entry, especially on the FM Birds. I was still able to make one

*AMSAT-China gets "suited up."*




*Mark Hammond, N8MH, AO-51 Controller and "satellite demonstrator extraordinaire."*

AO-51 (directly overhead) contact and several contacts via AO-07 and VO-52. The linear Birds came through as usual; however, even the linear Birds suffer from crowding and excess power on the uplink by some stations.

Lesson learned: *Field Day is a really rough environment, much worse than Dayton demos!* If you want to make a lot of contacts, be sure to take along the bigger antennas and auto-tracking. We tried several methods of manual tracking and finally settled on giving the "antenna controller" (another ham) my iPhone with the PocketSat3 tracking program running and letting him just keep the antennas updated with an occasional call for polarization changes.

## Summary

Let's welcome ARISSat-1 to the classroom and the ham shack once it's "in orbit." It represents a golden opportunity to showcase amateur radio and amateur radio satellites to kids in the classroom and promote STEM while having "hands on" and "heads on" fun. Stay alert for its launch and be ready to participate.

Continue the Amateur Radio Satellites in Education theme with Project Fox. It is a natural carry-on to ARISSat-1, and will be AMSAT-NA's next satellite. Support FUNCube, a similar AMSAT-UK satellite that may launch before Project Fox.

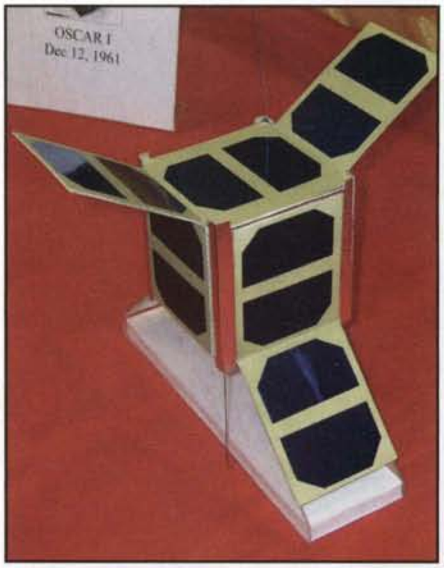
Take the lessons learned from Field Day 2011 and apply them to next year's effort. Don't forget to make the Field Day satellite station the "showplace" of the event.

Come to Dayton next year and participate in this great event. If you can't make it to Dayton, support AMSAT at your local hamfest. We never have enough volunteers representing AMSAT, so don't be bashful.

It's time to plan to attend the AMSAT Space Symposium and General Meeting in San Jose, California on 4–6 November 2011. Attend the BOD meeting on 3 November to gain additional insight into how AMSAT operates.

Please continue to support AMSAT's plans for the future of amateur radio satellites. AMSAT is now updating its web page at <http://www.amsat.org> on a much more regular basis. Satellite details are updated regularly at <http://www.amsat.org/amsat-new/satellites/status.php>. Follow the projects and progress of AMSAT-UK at <http://www.uk.amsat.org/>.

'Til next time! 73, Keith, W5IU




*Project Fox full-scale model.*


*Carol, W6CL, and Joe, N6CL, of CQ VHF with Project Fox model, Douglas Quagliana, KA2JUPW, ARISSat-1 software, and Tony Monteiro, AA2TX, AMSAT VP of Engineering.*

*John Shew, N4QQ, and Martha Saragovitz, AMSAT Office Manager.*

By Mitch Gill, NA7US

# EMERGENCY COMMUNICATIONS

## The Role of VHF in EmComm

# How Prepared Are We?

I am always looking for more ways I can be prepared for an emergency. As amateur radio operators our ability to send and receive information has saved lives and property, but is that all we need to do? I don't think so. I believe that we need to be even more prepared.

### Form a Neighborhood Emergency Response Group

I share a well with 15 other families. We all live on one to five acres, and until a change was made we only saw each other once a year to discuss what was needed for the well or to wave at each other as we went to work. It is a sad state of affairs, but it is the way most of us live. I decided after the 2000 Nisqually earthquake here in Washington State that I needed to do something. We lost all telephone and cell phones for about two hours and it was intermittent for several hours after.

Two meters and 70 centimeters became my eyes and ears to what was happening in my local area. I was able to find out that the river near me had changed course and was potentially going to overflow onto a major roadway into our area. With that information I was also able to advise other hams to let people know that the road was closed indefinitely .

I was also aware of major damage in the downtown Seattle area, the hospitals on emergency power, and people that were stranded for various reasons. My ability to help out a few people made me realize how vulnerable my neighbors were. If the earthquake had been stronger (and we are anticipating that the "Big One" will occur sooner rather than later), I could have been dealing with trapped or injured neighbors.

This event was a life-changing experience that helped me to start our neighborhood emergency group. It was, at first, my offer to assist in any communication needs that could arise in the event of an emergency, but it has since grown into much more. One neighbor happens to be a nurse and he and his wife became our medical support. All of the neighbors pitched in and bought first-aid supplies and medical books that they maintain.

Another neighbor became the keeper of the emergency food. Each of us was required to purchase a one-month supply of food and water, and this neighbor collected them all and stored them in his shed set off from the house. Another neighbor was a mechanic and another was an electrician. I could go on, but you get the idea.

I, of course, was in charge of communications, and since I had all the spare equipment I needed, there was no need for the group to purchase any radio equipment. My emergency setup is in my trailer and I have the ability to quickly set up HF, VHF, and UHF communications. I can operate FM, SSB, CW, packet, and PSK. With five gallons of gas I can operate two hours a day for weeks, and with my solar cell and batteries I can run low power indefinitely.

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The main goal of the group was to meet the needs of the neighborhood in the event of an emergency, but we also agreed to assist anyone who needed help even if it meant reducing our food supply or first aid supplies. With those goals in mind, many of us have donated more food so that we can help others who have not prepared.

### What About Your Neighborhood?

You may be thinking that it's all well and good if you live like I do, but that's just not true. It does not matter whether you live in a suburb or a condo or wherever. If you have neighbors, you can be of service and you can get the ball rolling to start your own group. Believe me when I tell you the satisfaction of knowing I can help others and that I will have everything my family needs even if it is a large disaster. It lets me sleep comfortably at night. Expect the worst, prepare for it, and pray that it never happens. That's my motto. At the very least we all should prepare. It is what our families expect of us.

### What is Your State Doing?

We all are aware of how hams like us have assisted during emergencies, but what are the states and counties doing to ensure that communications are maintained? Has amateur radio been incorporated into their interoperability plans? I decided to review a few plans.

The first one I chose is New York, for obvious reasons. Here is what I found: In the State of New York's State Communications Interoperability Plan it states in paragraph 5.11.3 what communications equipment *must* be, at a minimum, included in order to interoperate with their vehicles and to restore and sustain communications during a disaster. One of those pieces of equipment is a dual-band VHF/UHF "amateur radio." It is one thing to state VHF/UHF radios, but to define it as amateur radio shows that amateur radio is a major player in that state's mind.

Now that I had looked at New York, I decided to look at states that may not have incorporated amateur radio into their plans. I hope that I am wrong, but let's see what I can come up with in your state. The states I chose are South Dakota, Minnesota, and Rhode Island.

In South Dakota, I found no references to amateur radio or ham radio in its interoperability plans. Maybe I am missing something? I tried to look at Minnesota's plan but found that the state government was shut down and none of its websites were operational. No mention of amateur radio in Rhode Island's plans either. I am disappointed but not totally surprised. In order to be fair, I have decided to also look at some states where I know that amateur radio plays a key role. Those states are Florida and Washington. Washington definitely uses amateur radio for interoperability and backup emergency communications. Florida should, as hams are very actively assisting during and in the aftermath of hurricanes, but are they in the plan for the state? Not that I could find.

Does this mean that these states do not use amateur radio in an emergency? No, I am sure that they all do, but it does show me that they may not be specifically addressed in the state plans. I believe that the many ARES groups in your states should check to see if they are addressed, and if not, maybe you can change it.

## Last Thoughts

A great program to get your neighbors involved is the Community Emergency Response Team (CERT), which is located at <http://www.citizencorps.gov>. It does not address amateur radio emergency communications, but it does address all forms of disasters. Even if you cannot find a course locally, the entire course and materials are located at that site and are worth downloading and reading.

Until next time, remember the better prepared you are, the more you can help your family, friends, and neighbors.

73, Mitch, NA7US

By Tomas Hood,* NW7US

# VHF PROPAGATION

## The Science of Predicting VHF-and-Above Radio Conditions

# Calling All North American VHF Amateur Radio Operators!

What is the most exotic VHF propagation mode you personally have experienced while operating on VHF? Pinging your signal off of a meteor trail? Catching aurora-mode DX? Making contacts by way of back-scatter propagation? Or, have you worked stations in nearby states by way of sporadic-*E* propagation?

Have you worked *low-power moonbounce*, yet? Do you think that you have to have 1500 watts of RF concentrated with a highly directional, high-gain radio telescope to bounce your VHF signal off the Moon? Gone are the days when receivers were deaf and moon-bounce required such Herculean efforts. Now, armed with the right software, a good soundcard-equipped personal computer, a modest beam antenna, and some patience along with a modern VHF transceiver and you can easily work DX via the visible Moon!

In the 1990s, an enterprising scientist who loves amateur radio pioneered a protocol that changed the way moonbounce enthusiasts approached making two-way contacts off the reflective visible lunar surface. This mode became known as JT65, and specifically the flavor of JT65 that is used in moonbounce communications is JT65B.

The JT65A communications protocol was conceived and first implemented by Joe Taylor, K1JT. Joe (Joseph H. Taylor, Jr.), who has a B.A. in physics (Haverford College, 1963) and a Ph.D. in astronomy (Harvard University, 1968), participated in the discovery of the first pulsar in a binary system as well as the first confirmation of the existence of gravitational radiation in the amount and with the properties first predicted by Albert Einstein. Joe shares a Nobel Prize with Russell Alan Hulse for the discovery of this binary pulsar. Joe has many more honors and awards recognizing his achievements. Joe has contributed to the amateur radio community in a very significant way, changing the playing field for weak-signal operation.

Joe was first licensed as an amateur radio operator while he was still a teenager. His ham radio interest led him to astronomy. When he applied his mind to the idea of developing a communications protocol that would work well under very low signal-to-noise ratio conditions on a communications signal path between the Moon and Earth-bound amateur radio stations, he formulated a number of protocols that have revolutionized the amateur radio world of weak-signal DXing.

In 2001, Joe wrote the WSJT (for "Weak Signal/Joe Taylor") software (http://physics.princeton.edu/pulsar/K1JT/wsjt.html) which implemented these new weak-signal communications protocols. WSJT offers several modes (including FSK441, the JT65 family, and JT6M) intended to support meteor scatter, troposcatter, and Earth-Moon-Earth (EME, or "moonbounce") communications. JT65 is a specific protocol family designed for weak-signal conditions. JT65B is designed to optimize EME contacts on the VHF bands. JT65B includes error-correcting features that make it very robust, even with signals much too weak to be heard.

Before we can talk about the benefits of a mode such as JT65B we need to delve into a bit of background on communications and information theory. In the earliest days of wireless the conversion

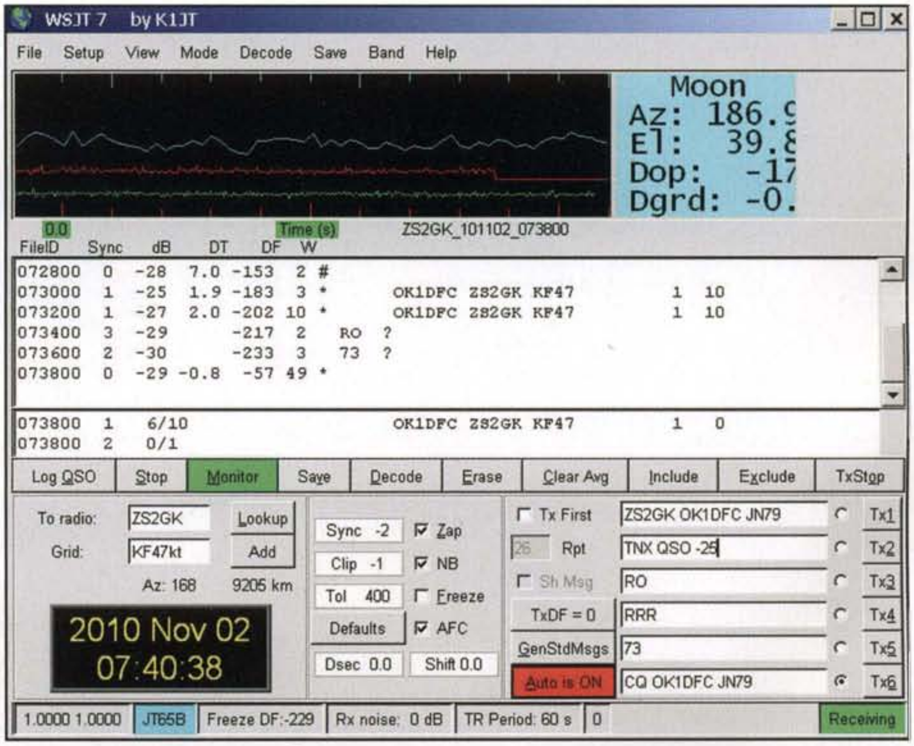


*Figure 1. Screen capture of the JT65B Earth-Moon-Earth QSO between OK1DFC and ZS2GK, who is running 35 watts with two stacked Yagi beams. Many stations work EME now with a single beam and 100 watts, because JT65B has made such contacts possible. (Source: OK1DFC: <http://www.ok1dfc.com/eme/emeJT_MAP.htm>)*

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mechanism between received signals and language was via the human ear, the difference between background static and the static of a spark-gap transmitter interpreted as Morse code and written down by an operator at the receiving end. Technology advancements would later give rise to continuous wave (CW) and voice (phone) transmitters; the difference between the two being a trade-off between better detection of weak signals for CW and faster throughput for phone. Using the same antenna and power level, the useful range of a CW signal is much greater than that of a SSB signal. This is why CW has been noted as a great mode for weaker-signal operation, and why low-power (QRP) operation is typically a CW-mode endeavor.

Speaking strictly in terms of detectable signal-to-noise ratio (SNR), a CW signal that is "encoded" at 12 words per minute (12 wpm) is generally held to be copyable at an SNR of –15 dB, whereas a phone transmission that sends information at 250 wpm requires an SNR of +6 dB. (These ratios typically are calculated based on a 2.5-kHz channel bandwidth.) If we normalize these to a one-character-per-second (cps) rate—e.g., 12 wpm CW versus speaking one letter per second phonetically on phone—the detectable SNR for phone becomes –8 dB. Thus, on a truly level playing field CW yields an improvement of 7 dB over phone.

The adoption of machine-to-machine communication (for instance, RTTY, Hellschreiber, and so on) in the early 20th century provided faster throughput and a marginal increase in SNR performance, but at the expense of channel bandwidth. The normalized SNR of these early machine-to-machine modes works out to be only about 2 dB—hardly an improvement worth getting excited about. (Although to be fair, the value of RTTY was not so much from SNR improvements, but rather that it printed directly to paper, freeing the radio operator to do other tasks.) Even the development of PSK31 in the late 1990s by Peter Martinez, G3PLX, did not yield an improvement in normalized SNR, although it did reduce the bandwidth requirements through the use of Varicode, a form of data compression.

If the application of data compression can reduce bandwidth requirements, are there other techniques that can be applied to improving SNR performance? And how much room for additional improvement might there be?

As it turns out, for real-time data streams we can't get to the theoretical limit. Each modulation technique (for example, RTTY uses "frequency-shift keying," CW and Hellschreiber use "on-off keying," and PSK31 uses "phase-shift keying") has an inherent limitation in the ability of the receiver system, whether machine-human or pure machine, to discriminate between states. Improving SNR beyond a certain point becomes impossible.

However, all is not lost. An alternate technique for improving SNR is to implement redundancy in the data. We use redundancy all the time in amateur radio—repeating callsigns, signal reports, locator grids, etc. Of course, this effectively reduces the channel capacity (the "throughput"), which appears in Shannon-Hartley as bits/second—i.e., a function of time. If PSK31 has a throughput of 30 wpm, and we repeat our callsign six times to overcome a weak path, then clearly our throughput is less than 30 wpm. What we've effectively done by using redundancy is we've reduced the SNR required for detection of our callsign. Of course, in this example we still rely on the operator to look at the decoded text, and using the human mind's awesome ability to do pattern recognition, extract the callsign from the garbled text.

Thus, if we're willing to accept lower throughput and use redundancy, we can improve SNR for a given modulation method. Further improvement can be achieved by using an error-correcting code, leveraging the power of a computer to encode the data in a process known as Forward Error Correction (FEC). We can then use a computer on the receiver to invert the FEC encoding and correlate the redundant data blocks into a single error-free block of data. Combining redundant sending and error-correcting codes allows us to reach the theoretical throughput limit. JT65B's performance tracks well with theory and has been shown to yield an additional 7 dB of detectable SNR (nearly approaching the theoretical limit), which equates to a 5× improvement in system performance. This means that reliable decoding of a signal at –24 dB SNR is now possible!

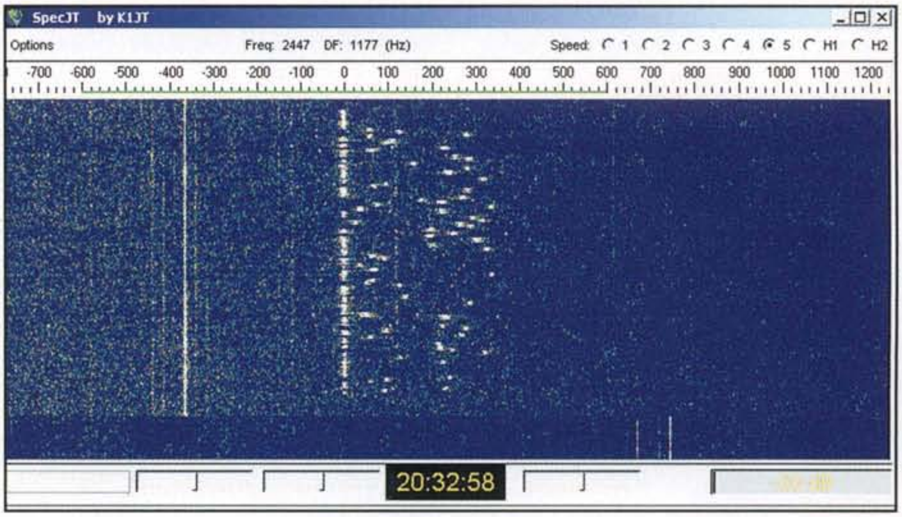


*Figure 2. An example of the waterfall display in the WSJT software by K1JT showing the JT65B protocol transmission during an Earth-Moon-Earth QSO (in this example, the signal of station K2UYH). JT65B allows anyone with a modest beam and low power to work moonbounce, unlike the "old days" when a station had to have maximum power and very high-gain antenna arrays (see text). (Source: OK1DFC: <http://www.ok1dfc.com/eme/emeJT_MAP.htm>)*

## Moonbounce on a Budget

Do you have a directional 2-meter antenna, a 2-meter transceiver with the ability to transmit 50 watts output, and a modern PC? All that is required for a beam antenna for moonbounce is a four-element VHF Yagi! The rest of the equation is the JT65 software and a good PC, plus some operating skill.

The great news is that unlike the early days of moonbounce activity, the need to know Morse code is no longer a requirement. Now you just need to know how to use the software and how to orientate the antenna for a successful EME QSO.

In order to make an EME QSO, the most important requirement is (obviously) that both stations can see the Moon simultaneously (both stations must have "a common window"). If you have a typical tropo/meteor-scatter antenna, you likely will not be capable of elevating it (aiming it higher or lower on the horizon), but you still can make EME contacts when the Moon is near the horizon.

A single Yagi antenna pointing to the horizon normally allows you to use your station to work EME until the Moon is up to 15 to 18 degrees above the horizon. If you have a clear take-off toward your Moonrise/Moonset, this means about three hours of possible operation every day!

If you can install a low-noise VHF preamplifier mounted as close to the antenna as possible, it can improve your ability to hear the weaker EME signals, but it is not always necessary in order to make your first contacts. The larger EME stations are using a lot of power and will compensate for your station's lack of receive gain. You can always get a preamplifier later, when you decide it's time to improve your reception.

## Steps to Moonbounce Success

**Step 1.** Get the free WSJT program, the digital communications program written by K1JT and specially intended for weak-signal communications. For 2-meter EME you will use the JT65B mode. You can download it from K1JT's site at <http://physics.princeton.edu/pulsar/K1JT/>. Install it according to the latest setup instructions on K1JT's site.

**Step 2.** Connect your PC to your VHF radio. If you have already worked some kind of digital communications (for instance, RTTY, PSK31) you may be able to use the same interface for the WSJT program, and you could skip this step.

If you have never connected your PC to the transceiver, then you will need some kind of interface to connect them. If you can afford it, the best is to buy a commercial interface.

If you want to build your own interface, you will need to make the serial port cable from your computer able to key the PTT line of your transmitter. You also must isolate and attenuate the audio from the computer soundcard so it can be connected to the transmitter MIC input. Information on how to do this can be found in many places.

Finally, you will have to split the audio output from your receiver and run an audio line over to your computer soundcard. This will permit your computer to also hear your receiver and process the signals coming in.

**Step 3.** Automatically synchronize the PC Time. WSJT modes (especially JT65B) require a very accurate PC clock time in order to achieve good results. The PC clock must be highly accurate; in fact, that it is not enough to manually update the PC time. It is necessary to update it automatically according to some reliable source. The most common way to do it is by way of a Time Synchronization program, such as *Dimension 4* or *Automachron*, and configuring either one to synchronize the time every 5 minutes or so via the internet.

It is important that you select one of the time servers that will provide accurate and reliable time corrections to your computer from your particular location and internet connection. You can verify that the time has been properly set within a half second by listening to WWV and watching the seconds display on the *Dimension 4* program screen.

**Step 4.** Run WSJT for the first time and configure it. Configuring the WSJT options properly is important in order to make successful QSOs, so please read the configuration options carefully, being sure to enter your station information and other parameters.

**Step 5.** As to transceiver setup, make sure that your transceiver is configured for upper sideband (USB) operation and that the receiver is set to the widest filter width. If you have bandpass adjustment on your receiver, make sure it is set to pass tones from 1200 Hz to 1800 Hz (usually by turning the bandpass off). In general, you could leave the noise blanker active, but make sure you turn the AGC off. If your transceiver has a microphone compressor or speech-processor button, you should also deactivate it, but be sure to adjust your sound-level output on the soundcard and the microphone level on the transceiver for a good ALC level for full power output when transmitting the tones. Some operators do turn on the compression/speech processor function to ensure full-power output of all tones, but doing so may cause distortion and introduce problems with decoding at the distant receiver.

Always make your first attempts at arranging a "sked" with some of the bigger stations (stations that are equipped with eight stacked Yagi antennas or more!). Scanning the band looking for signals is not a very good idea. Only stations with large arrays can detect the weak EME signals by ear. You had better look for the frequency of the stations calling CQ on the DX Cluster or in a JT65 EME chat. Then you can try to detect their signal and answer their CQ.

Don't expect to hear the signals via the speaker or headphones. While you could eventually listen to the signals of the most powerful stations, that won't be the rule for JT65B EME operation.

Don't give up if you don't succeed in you first EME attempts. There are many factors affecting the Earth-Moon-Earth path and some of them are unpredictable. Often you will have to try several times until succeeding in a QSO.

## Meteor Showers

VHF radio enthusiasts can also count on working meteor showers during the summer season. One of this summer's good radio meteor showers should be the *δ-Aquarids* (SDA), active from July 12 through August 23 with a peak expected on July 30 with a zenith hourly rate (ZHR) of 16. Indeed, the shower has sometimes given a surprisingly strong radio signature. Be sure to use modes such as CW or FSK441 (using the WSJT software by K1JT).

Also look for the *Draconids*, primarily a periodic shower that produced spectacular, brief, meteor storms twice in the last century, in 1933 and 1946. Most recently, in 2005, we saw the return of the stream's parent comet, 21P/Giacobini-Zinner, returning to perihelion. This year's peak is expected to occur on October 8, possibly at storm level. The shower should be active from October 6 through October 10. The *Draconid* meteors are exceptionally slow moving, a characteristic that helps separate genuine shower meteors from sporadics accidentally lining up with the radiant. This is a good shower to work meteor-scatter mode, since we might see storm-level activity this year. For more information, take a look at <http://www.imo.net/>.

## The Solar Cycle Pulse

The observed sunspot numbers from April through June 2011 are 54.4, 41.6, and 37.0. The smoothed sunspot counts for September through December 2010 are 19.6, 23.2, 26.5, and 28.8.

The monthly 10.7cm (preliminary) numbers for April through June 2011 are 112.6, 95.9, and 95.8. The smoothed 10.7-cm radio flux for September through December 2010 are 82.4, 85.3, 87.7, and 89.6.

The smoothed planetary *A*-index (*Ap*) for September through December 2010 are 6.3, 6.4, 6.4, and 6.5, showing a slow increase in overall geomagnetic activity. This is consistent with the increase in solar energy. The monthly readings for April through June 2011 are 9, 9, and 8.

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

The monthly sunspot numbers forecast for August through October 2011 are 61, 64, and 66. The monthly 10.7 cm is predicted to be 116, 118, and 120 for the same period. That's really great news, as we'll likely see days with significantly higher 10.7-cm readings (as the monthly figures are averages from a month of daily readings); there may well be days when the solar energy will rise high enough to support VHF propagation. If this happens, please report to me!

## 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. I'll create summaries and share them with the readership. Up-to-date propagation information is found at my propagation center at <http://sunspotwatch.com/>. If you are using Twitter, follow @hfradiospacewx for space weather and propagation alerts, and follow @NW7US to hear from me about various space weather and amateur radio news. Facebook members should check out the CQ VHF Magazine Fan Page at <http://www.facebook.com/CQVHF>, and the Space Weather and Radio Propagation Group at <http://www.facebook.com/spacewx.hfradio>. Until the next issue, happy weak-signal DXing.

73 de Tomas, NW7US



mid-latitude 'sondes. It is clear from the foregoing that the MUF can potentially reach 350 MHz when *foEs* reaches 30 MHz, but we already know that such occasions are rare.

## Two Case Studies of *Petit Chordal Hop* *Es* Propagation

**50 MHz:** To demonstrate the validity of the *petit chordal hop* model, I examined VK Logger 6-meter spots for the VK7RAE–VK4CZ path (figure 8) and looked for instances where the ionogram closest in time to a spot had an *foEs* value well below that required for classical (or plane) *Es* propagation. It was not difficult to find one. Indeed, there were many over the past few years. VK4CZ spotted the VK7RAE beacon at 0255 UT on 29 Dec 2010, giving a 569 report. Figure 15 is the Canberra ionogram for 0253 UT on that day. With *h'Es* of 101 km, the raypath elevation angle (e) is 3.2°, (*i*) is 79.38°, and (b) 10.62°. The classical M factor would be 5.42 (eq. 2.6) and, with an *foEs* of 4.7 MHz, the MUF (eq. 2.5) would be about 25.4 MHz. With spread *Es*, the VK7RAE raypath would need to find an *Es* tilt angle (t) of half 10.62° = 5.31°. Now, the MR factor is 10.81 (eq. 2.7) and thus the MUF (eq. 2.8) is 50.8 MHz!

**144 MHz:** As before, I trawled VK Logger 2-meter spots for the VK4–VK7 path, seeking instances where the ionogram closest in time to a spot had an *foEs* value well below that required for classical *Es* propagation. Doug, VK4OE, in Brisbane, Queensland, spotted a contact with Karl, VK7HDX, in Launceston, Tasmania, on 10 Jan 2008 at 0533 UT, on 144.13 MHz SSB, giving a 52 report. Figure 16 shows the path, which reveals the mid-point (PoR) within the Sydney ionosonde's view.

Figure 17 is the Sydney ionogram for 0535 UT on the day. With *h'Es* of 98 km, the raypath elevation angle (e) is 3.4°, (*i*) is 79.46° ,and (b) is 10.54°. In this case, the classical M factor would be 5.47 and the related MUF almost 75 MHz. With spread *Es*, the raypath would need to find an *Es* tilt angle (t) of half 10.54° = 5.27°. Now, the $M_R$ factor is 10.89 and thus the MUF is 149.16 MHz!

## Discussion

In relating reported contacts to ionograms at or near paths' mid-points, I have found that spread *Es* is more the norm than the exception. I can conclude that, for a given path, the sporadic-*E* MUF depends on three things:

(a) the height of the *Es* layer (*h'Es*),

(b) the peak electron density (*foEs*), and

(c) the presence or absence of spread *Es* at the path mid-point.

However, as spread *Es* can arise from a variety of structural morphologies in an *Es* layer, for *petit chordal hop* VHF propagation, spread *Es* is a necessary but not sufficient condition of itself. The spread *Es* needs to arise from ripples or other favourable structures that present a series of small tilts in the vicinity of the propagation path mid-point.

A 2003 paper by Grassman and Langenohl[24] on long-distance *Es* propagation paths at 144 MHz provides ionograms relating to the paths of many reported single-hop and two-hop *Es* contacts involving the Canary Isles, the Iberian Peninsula, and Central Europe. The ionograms are from 'sondes at Roquetes (northeast Spain) and Huelva (southwest Spain). Both ionograms show intense, spread *Es* with *ftEs* at 13.6 MHz in each case. This implies an *foEs* of 12.9 MHz, which the auto-scaling correctly scales in one case (Roquetes), but the other incorrectly scales *foEs* at 9.9 MHz. The authors reject the simple (classical) ionospheric model and other suggested models, such as cloud-to-cloud skip or Pederson ray propagation, but don't advance a model for the ionospheric refraction geometry. It seems to me that *petit chordal hop* available via the spread *Es* at each general area of ionospheric reflection would adequately explain the propagation model for the great European 144-MHz DX opening of 20 May 2003.

To support 200–222 MHz Es propagation[25, 26, 27], the classical propagation model would require *foEs* of at least 37 MHz for a layer at 90 km, or greater than 40 MHz for *Es* at 110 km; see Table 2. Given that, from my own experience and from the literature, instances of *foEs* values of 30 MHz are notably rare, and considering the accumulated instances

| h'Es | (e) | (t) | D (km) approx. | $M_R$ factor | $MUF_R$ for foEs of | | foEs for MUF ≥ (MHz) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 5 MHz | 20 MHz | 50.5 | 70.5 | 144.5 |
| 90 km | 1 | 4.815 | 1920 | 11.91 | 59.55 | 238.2 | 4.3 | 6.0 | 12.2 |
| | 2 | 4.89 | 1731 | 11.73 | 58.65 | 234.6 | 4.4 | 6.1 | 12.3 |
| | 4 | 5.185 | 1417 | 11.07 | 55.35 | 221.4 | 4.6 | 6.4 | 13.1 |
| | 6 | 5.64 | 1175 | 10.18 | 50.9 | 203.6 | 5.0 | 6.9 | 14.2 |
| | 8 | 6.225 | 991 | 9.22 | 46.1 | 184.4 | 5.5 | 7.7 | 15.7 |
| 100 km | 1 | 5.065 | 2031 | 11.33 | 56.65 | 226.6 | 4.5 | 6.3 | 12.8 |
| | 2 | 5.14 | 1842 | 11.16 | 55.8 | 223.2 | 4.6 | 6.4 | 13.0 |
| | 4 | 5.42 | 1522 | 10.59 | 52.95 | 211.8 | 4.8 | 6.7 | 13.7 |
| | 6 | 5.86 | 1273 | 9.8 | 49 | 196.0 | 5.2 | 7.2 | 14.8 |
| | 8 | 6.425 | 1080 | 8.94 | 44.7 | 178.8 | 5.7 | 7.9 | 16.2 |
| 110 km | 1 | 5.31 | 2140 | 10.8 | 54 | 216 | 4.7 | 6.6 | 13.4 |
| | 2 | 5.38 | 1949 | 10.67 | 53.35 | 213.4 | 4.8 | 6.7 | 13.6 |
| | 4 | 5.645 | 1622 | 10.17 | 50.85 | 203.4 | 5.0 | 7.0 | 14.3 |
| | 6 | 6.07 | 1366 | 9.46 | 47.3 | 189.2 | 5.4 | 7.5 | 15.3 |
| | 8 | 6.615 | 1164 | 8.68 | 43.4 | 173.6 | 5.9 | 8.2 | 16.7 |

*Table 3. MUFs achievable for petit chordal hop Es for common path geometry parameters and two indicative values of foEs, plus foEs values required for propagation on 6, 4, and 2 meters. Note the values of foEs required to support 2-meter Es propagation compared with those in Table 2.*

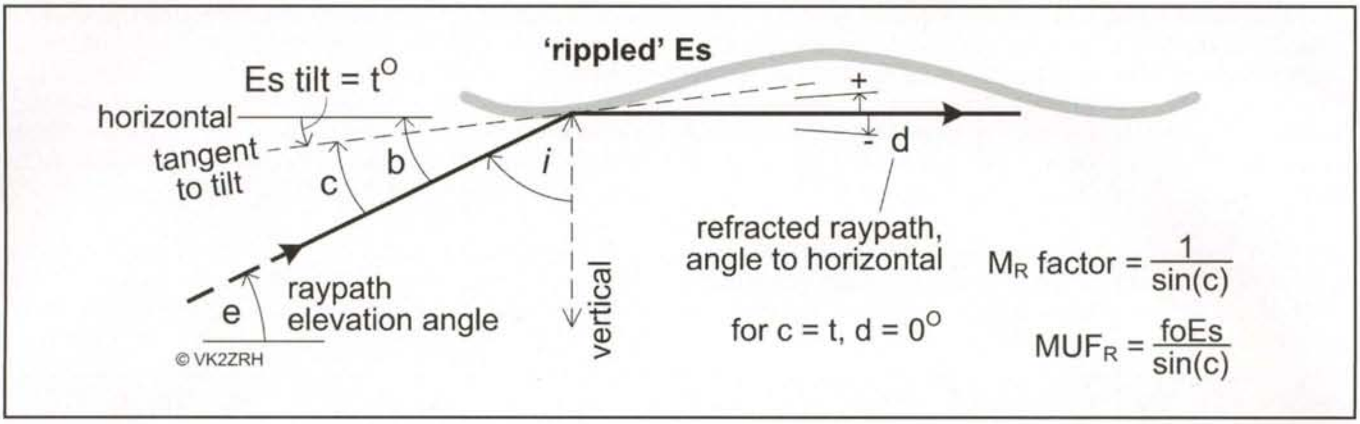


*Figure 12. Close-up of the geometry for propagation via rippled Es. The refracted raypath will be horizontal when angle (c) equals the tilt angle (t), yielding angle (d) of zero degrees. The ripples do not need to be orthogonal to the propagation path. On an ionogram, h'Es will be the lower height of the crests and the Es trace will be spread, as in figure 4. The impact is to almost double the MUF.*

recorded of *Es* above 200 MHz, including TV DX reception, suggests a more prevalent propagation model is called for.

Table 3 highlights the opportunities for 222-MHz propagation where *Es* conditions like that in figure 4 prevail (spreading, *ftEs* >20 MHz), which appears to happen rather more often than previously suspected, at least in the Southern Hemisphere, judging by the instances with which it can be observed on IPS station ionograms. It's a pity that the 222-MHz band is not an amateur allocation in Australia! The *Es* layer height needs to be in the lower range, 90 to 100 km, and raypath elevation angles below 4°, to provide high enough $M_R$ factors when *foEs* reaches or exceeds 20 MHz. Geometrically, the limit would be *Es* at 105 km, requiring a path elevation angle (e) of 0.4° to yield an $M_R$ of 11.1. The path length would be about 2210 km.

The literature and online contact loggings note many instances of extended *Es* propagation beyond the maximum classical single-hop skip range of about 2100–2300 km (for *h'Es* of 110 km, see Tables 1 and 2), in circumstances where double-hop skip can be ruled out. This particularly applies to 2-meter *Es* contacts. Some notable occasions have been reported in the amateur radio literature over the years where propagation has extended to about 3200 km without an intervening ground hop. Mel Wilson, W2BOC[1] and Emil Pocock, W3EP[3] both proposed cloud-to-cloud chordal hop via tilted clouds spaced fortuitously 600–1000 km apart as a model for extended path VHF *Es* propagation up to 3200 km, without intermediate ground reflection, or *grande chordal hop,* to continue my French nomenclature.

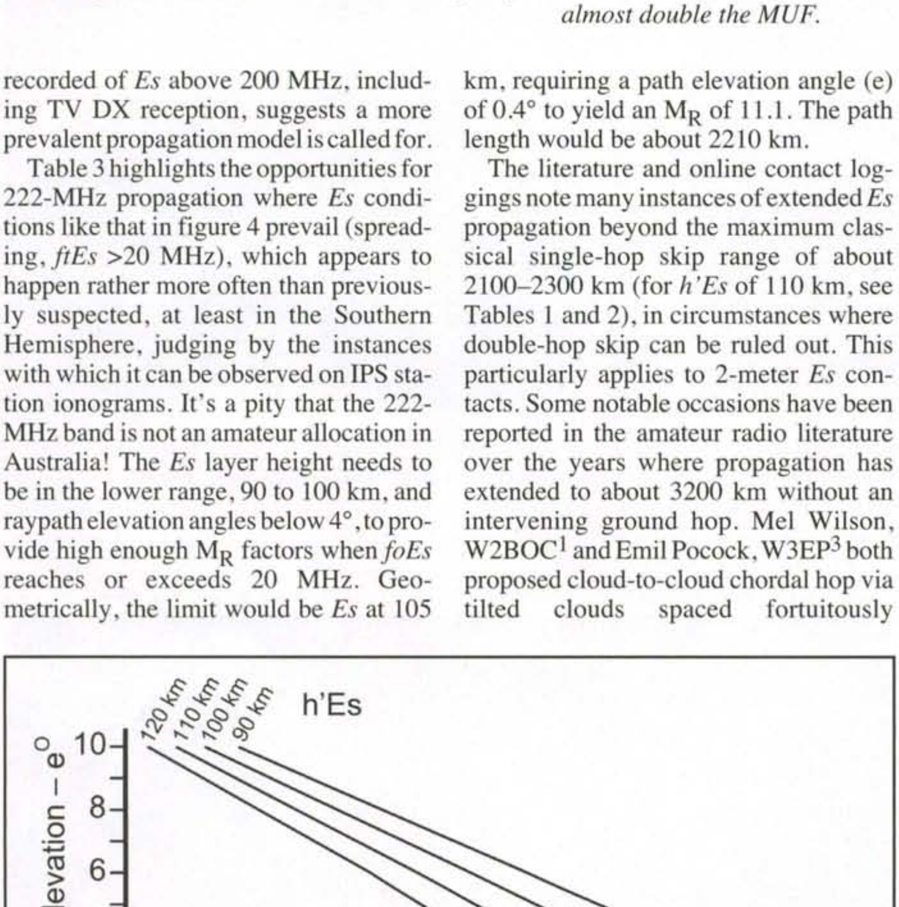


*Figure 13. Under the right spread Es conditions, leading to petit chordal hop propagation, the M factor ($M_R$ factor here) increases dramatically, almost doubling. Compare this to figure 6.*

To support the *grande chordal hop* hypothesis, Pocock[3] cited a 1986 research paper on ionospheric propagation models by A .K. Paul[28] in which the author used digital phase comparison measurements between three spaced receiving antennas of an ionosonde to determine angle-of-arrival from sporadic *E* layer echoes. Paul concluded that the ". . . layers are frequently tilted in different directions with deviations from the horizontal ranging up to 30°." Clouds were assumed to be "relatively small, on the order of 50 km," pancake-shaped and tilted as a whole, yielding echoes tens of kilometres away from overhead. Ionosonde observations of *Es* showed rapid variation, but Paul could not discern "whether those changes mean formation and decay of patches or rapid motion of patches (in different directions?) through the observation area, or changes of tilts and orientation of *Es* patches." If tilted *Es* clouds are short-lived, whether in time or geographically, the chances of two fortuitously placed tilted clouds supporting *grande chordal hop* propagation for anything more than seconds at a time seem remote indeed.

In a study of *Es* structure and motion, From and Whitehead[19] used a steerable beam (4° wide) HF radar near Brisbane, Australia, to observe plane and spread *Es*. In regard to plane blanketing *Es* (*F*-layer reflections not seen), they concluded that the clouds are sizeable—varying ". . . from a few (km) to 25 (km) measured in the direction of travel"—larger in the transverse direction and tilted less than 1°. Additionally, they observed that spread *Es* echoes appeared short-lived in the radar records, concluding that the "... echoes presumably come from small clouds of ionization, but only last two or three seconds,, noting that each cloud moved with the same velocity. However, later research by R. I. Barnes[29], supervised by Dr. Whitehead and using a later version of the steerable beam (2.5° wide) HF radar, demonstrated through observation and modelling that the short-lived appearance of the echoes is an artifact of From and Whitehead's original analysis procedure. Barnes concluded that a "better model for spread-*Es* (is) one where a larger cloud, produced by the wind-shear mechanism, subsequently has many small irregularities of the order 1 km in extent produced within it by some other disturbance (that) move with the same velocity as the larger cloud." Barnes' work also throws doubt on the conclusions drawn by Paul, reducing the likelihood of *grande chordal hop* as an explanation for 2300–3200 km extended range VHF *Es* propagation.

Under some circumstances, *petit chordal hop* propagation via spread *Es* may extend path distances farther than the maximum classical single-hop skip range of about 2300 km (for

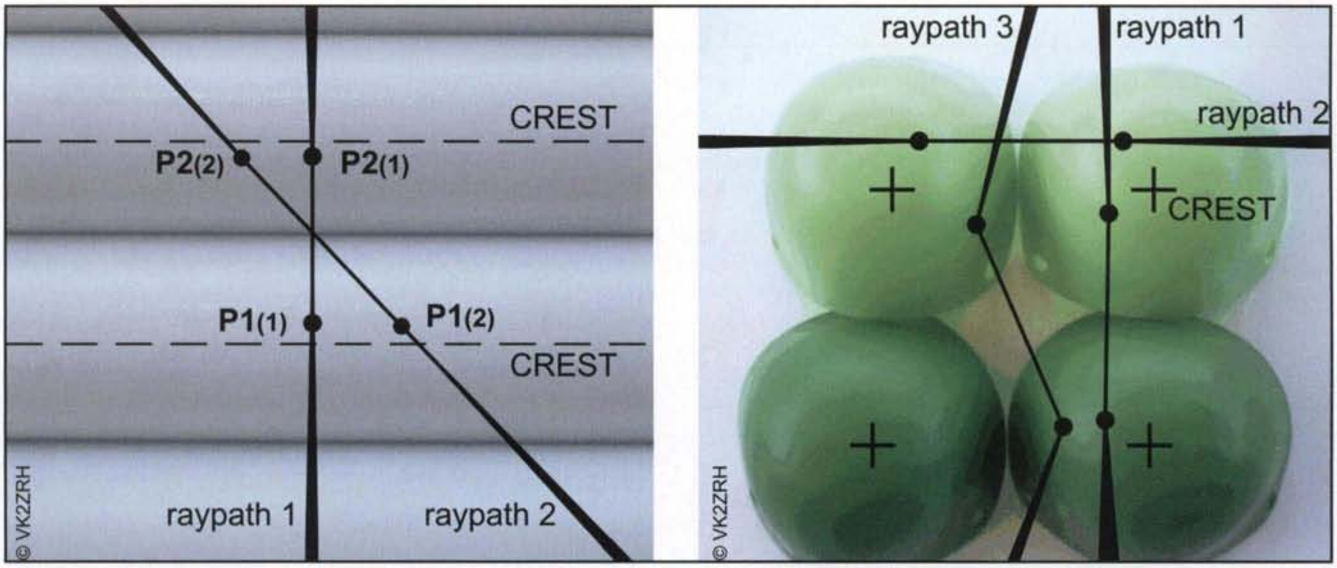


*Figure 14. I've used shaped plastic to model these plan views of petit chordal hop propagation raypaths as if seen from the ground. At left is the rippled Es case, as in figure 10(1). At right, lobe ("mammatus") structures as in figure 10(3). With rippled Es, as raypaths approach paralleling the crests, the less certain it becomes that petit chordal hop will be supported. Lobe structures in the Es layer will support raypaths in any direction.*

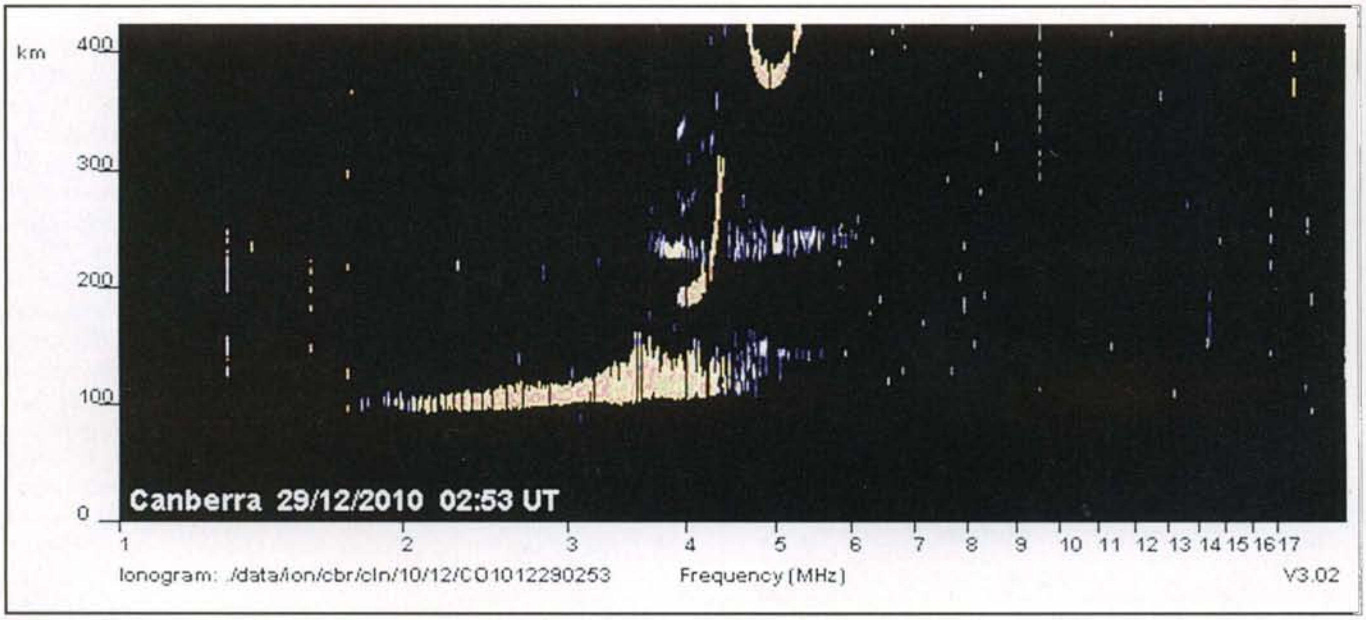


*Figure 15. Ionogram relating to VK7RAE-VK4CZ spot of 29 Dec 2010 at 0255 UT. Note the distinct Es spreading; ftEs = 5.5 MHz (foEs = 4.7 MHz) and h'Es = 101 km. Path length is 1648.7 km. The path MUF was calculated to be 50.8 MHz!*

*h'Es* of 110 km). Small-scale ripples on a long wave of, say, 300+ km extent, as illustrated in fiigure10 (2), would create suitable conditions for a "whispering gallery" that would extend single ground-*Es*-ground paths to 2600–2700 km. Path lengths of this order are common for contacts between New Zealand (ZL) and eastern states Australian (VK) stations and for VHF TV reception (see VK Logger History page).

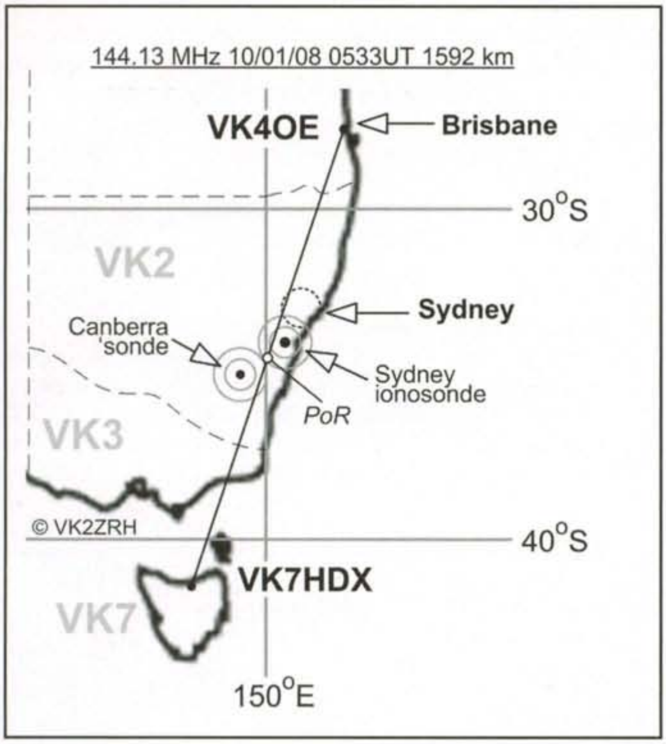


*Figure 16. Path for the VK4OE-VK7HDX 2-meter SSB contact of 10 Jan 2008, showing the relationship to the Canberra and Sydney ionosonde views. Path length is 1592 km. The PoR is within the Sydney 'sonde's view.*

An incident signal meeting the crest of a ripple at the base of a long wave will be deflected with some raypaths emerging above the horizontal (see figure 12), which are then able to reach the next crest of a ripple at a slightly higher altitude, and so on, following the curve of the long wave, and eventually returning a suitable raypath towards ground when the long wave curves downward. Those raypaths deflected below the horizontal may not be sufficiently deflected to intersect the ground. Raypaths deflected horizontally may meet the downward-curved section of the long wave a considerable distance away and advantageously find a plasma frequency (or refraction coefficient) that deflects the raypath towards the ground. If not, the raypaths will be "lost" to ground-*Es*-ground propagation. Propagation paths following the curve of a long wave's whispering gallery will support higher MUFs because the incident angles are favourably reduced. For example, if angle (c) is reduced to 3.3° (see figure12 and Table 3), and provided it is no worse than that across the whispering gallery, the $M_R$ factor increases to 17.37. Hence, for an *foEs* of 20 MHz, the MUF would be 347 MHz. How often this might happen depends on the possible incidence of long waves modulating *Es* layers, a subject that requires further investigation.

A more likely geometric propagation model able to support 2300–3200 km extended-range VHF *Es* propagation, without intermediate ground reflection, involves spread *Es* structures like that illustrated in figure 10 (3) and B, and figure 14. In the latter, the zig-zag shaped raypath 3 would be able to pass across a large-spread *Es* cloud (a bit like shooting river rapids in a canoe), eventually finding a raypath to ground. Mammatus (literally, breast-like) structures in the ionization would tend to collimate raypaths, providing signal reinforcement at the other end of a path. The question is: Do large clouds of spread *Es* occur?

The Canberra and Sydney ionosondes are 208 km apart, with


*Figure 17. Ionogram relating to the VK4OE-VK7HDX contact at 0533 UT on 10 Jan 2008. h'Es is 98 km. ftEs is 14.5 MHz, so foEs is 14.5 – 0.8 = 13.7 MHz. The E, F1, and F2 layers are fully blanketed and the Es shows spreading. This ionogram could be interpreted in several different ways, but the fact that it shows spread Es is sufficient for the purpose in this case.*

combined views at *Es* heights extending some 400 km edge-to-edge (for *h'Es* of 100 km; at 110 km, the 'sonde views overlap). Spread *Es* seen at simultaneous times on the ionograms of both is notably frequent during the major summer and minor winter *Es* seasons, at least for the seasons I have examined since 2008 (e.g., 2118 UT, 21 Jan 2011. Hence, if mammatus structures are present, a shooting-the-rapids model would be a reasonable proposition, supporting VHF *Es* propagation paths out to at least 2600–2700 km where classical double-hop VHF propagation could not be supported because *Es* electron densities (and thus MUFs) are too low for two successive paths of 1200–1350 km. As noted above, apparently single-hop path lengths of 2400–2700 km are common for 6- and 2-meter contacts and VHF TV reception across the Tasman Sea between eastern Australia and New Zealand. On fewer occasions, spread *Es* is seen at simultaneous times on the Canberra, Sydney, and Brisbane ionosondes (e.g., 0518 UT, 13 Jan 2011). The edge-to-edge views of the Canberra and Brisbane ionosonds are some 1100 km, although it is not known if the *Es* layer "fills in" the distance from Sydney to Brisbane. These circumstances offer tantalizing potential.

## The Heide Model of *Es* Reflection Geometry

In the German DUBUS VHF-uwave magazine No. 4 of 2010 **[30],** Klaus von der Heide, DJ5HG, proposed an intriguing and novel explanation for 144-MHz *Es* propagation in which the wave is "captured" within the *Es* layer if it is bent (or curved) such that the quotient of bending divided by the layer thickness (b/d) lies between 1.5 and 4.0, and that the value of *foEs* is between 12 MHz and 16 MHz.

This model improves the raypath's obliquity to the *Es* layer and thus the path MUF. However, I think that the conditions Dr. Heide proposes for capturing a wave at 144 MHz are difficult to achieve in nature, if not impossible. Firstly, the electron density gradient in a plane *Es* layer does not appear to vary linearly, with a constant gradient from base to top. The electron density reaches a sharp peak, sometimes at half the layer thickness, and sometimes closer to the base.[31, 32] In ionospheric science, the profile of electron density in an *Es* layer, from base to peak, is taken to be quasi-parabolic[33], for which modelling and real-world results agree.

Secondly, Dr. Heide calculates that a value for *foEs* of only 2.5 MHz is necessary for 144-MHz waves to be captured inside the "bent" layer. For the VK4–VK7 paths, which pass through the circles of view of the Sydney and Canberra

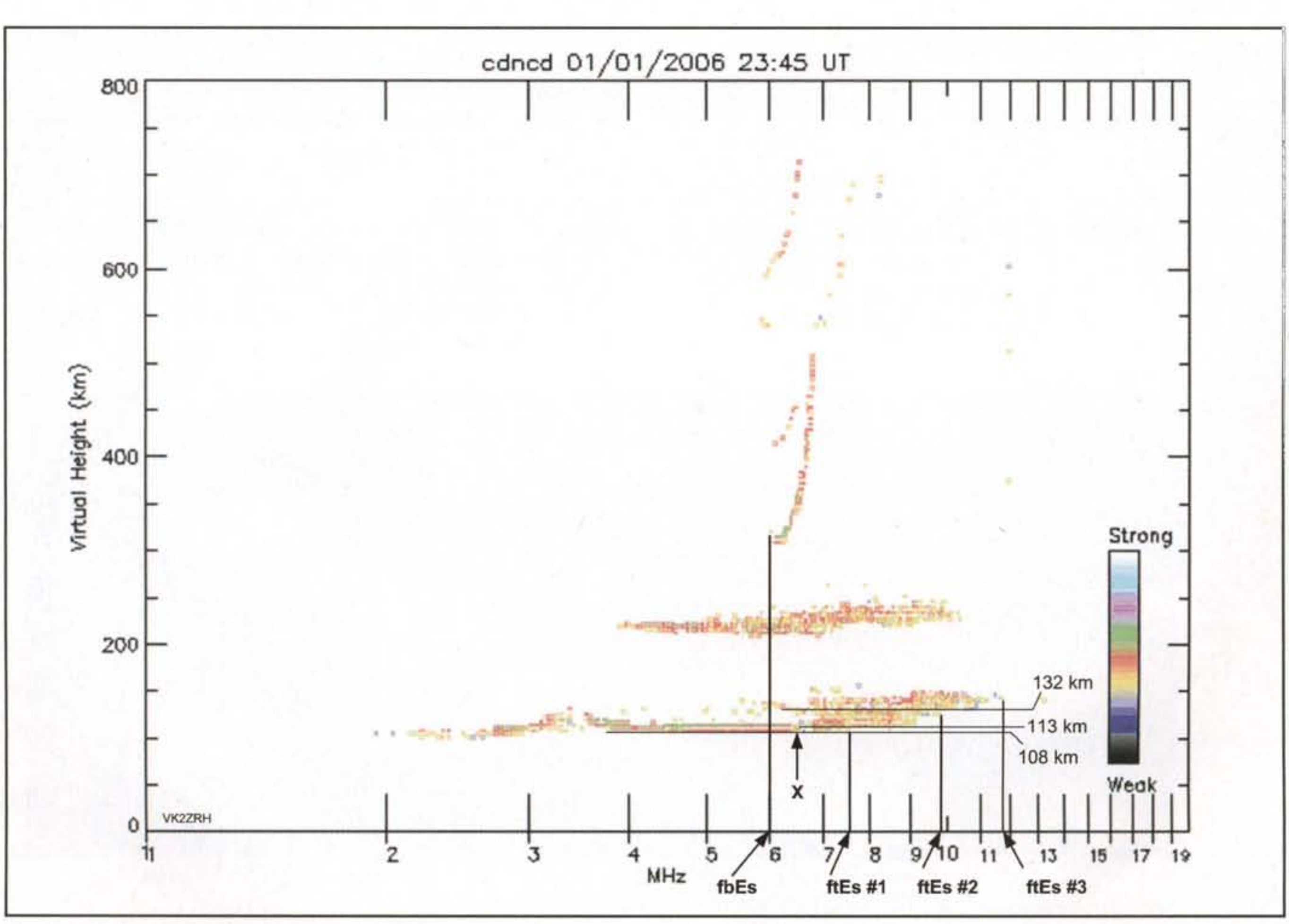


*Figure 18. Sydney ionogram for 2345 UT on 1 Jan 2006, showing multi-layer Es that may have "trapped" 2-meter signals between them, supporting contacts over 1750–1950 km at the time. Short-skip propagation at 6 meters was not evident at the time, but it was for 10 meters. An foEs of 6.7 MHz for the lowest layer (108 km) meant that the classical MUF only reached about 40 MHz.*

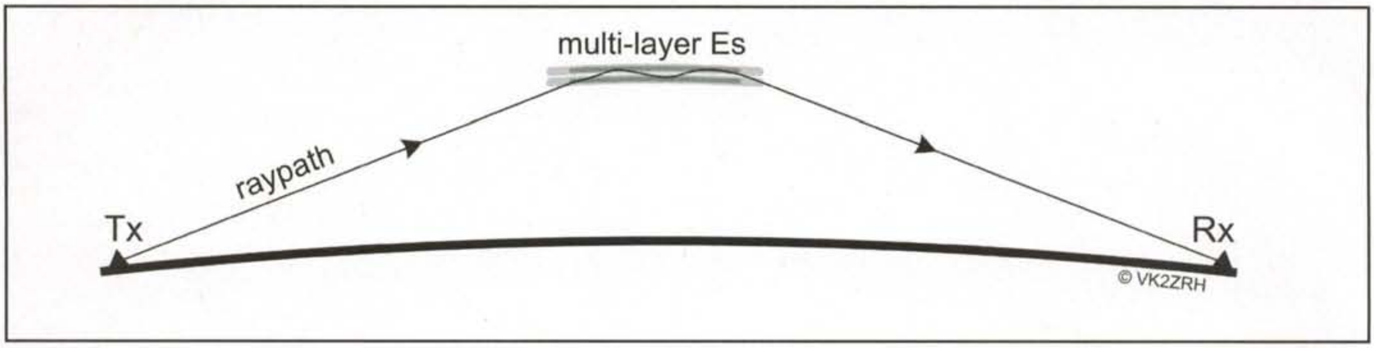


*Figure 19. The principle of "layer trapping" VHF propagation. The grazing angles of the raypath trapped between the layers provides a higher MUF than the lower layer could support.*

ionosondes, I have trawled many, many VK Logger 144-MHz spots since January 2008, but cannot find a single instance of such a low *foEs* coincident with 2-meter propagation.

## Layer-Trapping VHF *Es* Propagation

In January 2006 a 2-meter opening between VK3 and southern VK4 showed some peculiar characteristics. Path lengths ranged from 1750 to 1950 km. No short-skip 6-meter propagation was reported at the time. Short-skip 6-meter signals are often a tell-tale indicator for 2-meter openings.[3] However, reception of the 28-MHz VK2RSY beacon located NW of Sydney was reported in Melbourne (VK3) at the time (a path of about 880 km).

With tropospheric refraction ruled out on the basis of signal characteristics and a negative Hepburn indication, I examined the sequence of IPS ionograms for the period spanning the signal reports, from 2330 to 2350 UT. The terminals of the N-S paths indicated that the mid-points were close to the latitude of the Sydney ionosonde. The ionograms showed that a multi-layer structure had developed, with two closely spaced layers at 108 km and 113 km (see figure 18).

Analysis of the ionogram for 2345 UT shows the *F*-layer is blanketed at 6 MHz, while the *Es* layer at 108 km blankets the 113-km layer up to about 6.5 MHz (point X), after which some spreading of the 113-km layer is evident. Another *Es* return is seen at 132 km. From the sequence of ionograms, this latter return turns out to be an echo from another *Es* patch at an oblique angle, moving horizontally. Three values for *ftEs* are identified—7.5, 9.9, and 11.8 MHz. For the 108- and 113-km layers, *foEs* values are 6.7 MHz and 9.1 MHz, respectively, which means the electron density of the layer at 113 km was greater than the one below.

The path lengths of 1950 km and 1750 km mean raypath elevation angles to the 108-km layer ranged between 1.9° and 3°. The plane *Es* MUF for a 1950-km path would be 40.6 MHz, while for a 1750-km path it would be 39.7 MHz.

My proposition is this: An incident signal at 144 MHz would be partly refracted by the lowest (108 km) *Es* layer and then continue to the *Es* layer above (113 km), meeting it at a grazing angle, to be refracted back towards the 108-km layer, in turn reaching it at a grazing angle, to then be refracted back toward the upper layer and so on, the signal being "trapped" or "guided" between the layers for a distance before exiting the pair of *Es* layers some distance later or upon meeting some discontinuity that directs a raypath towards the ground.

Figure 19 illustrates the principle. Once the incident signal penetrates the lower layer, and with a grazing angle of just less than 3° between the raypath and each *Es* layer, the calculated MUF in this instance would have been above 148 MHz. Multi-layer *Es* is not uncommon, being reported many times over decades from rocket observations of *Es*.[31, 32, 34] Figure 20 shows a relatively recent rocket sounding (2005), where two thin layers 2 km apart were observed over Japan.[34]

As layer trapping propagation can exclude short-skip 6-meter propagation while at the same time supporting 2-meter propagation, this may act as a tell-tale for observant operators (provided 6-meter stations are on the air). In addition,if multi-layer

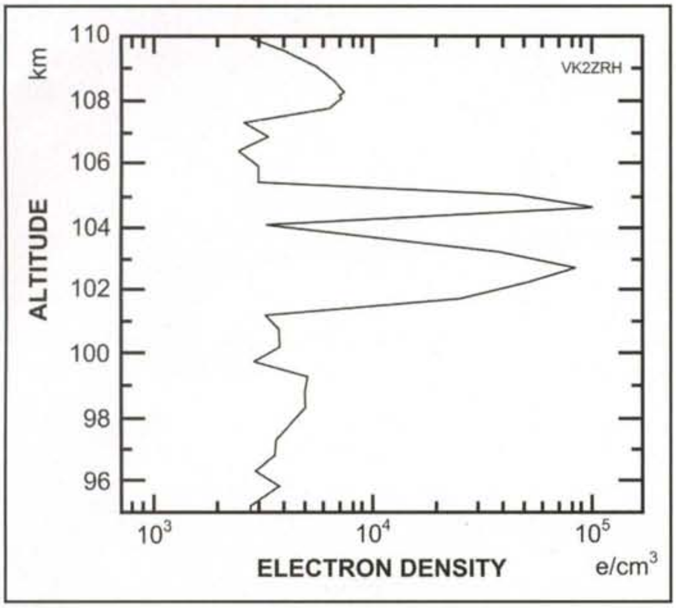


*Figure 20. Multi-layer Es from a rocket sounding [34]. The layer peaks here are separated by 2 km, the lower layer being 2.5 km thick, the upper one being 1.5 km thick with slightly higher electron density.*

*Es* extends over a large geographical extent, path lengths would be extended well beyond the classical maximum single-hop skip range.

Reading the accounts of 200–222 MHz *Es* propagation by Cooper[25] and Pocock[26], the characteristics of the layer trapping model can readily be discerned in some of the quoted instances.

Layer trapping has the potential to extend MUFs beyond 350 MHz. It may have been involved in the few reports of 220-MHz *Es* propagation in North America. Anecdotal evidence from VK operators suggests one-way signals have been observed on 432 MHz during an intense 144-MHz opening.

I am indebted to Terry Bullet[35] for help with the ionogram analysis (figure 18) and beneficial comments on the propagation models.

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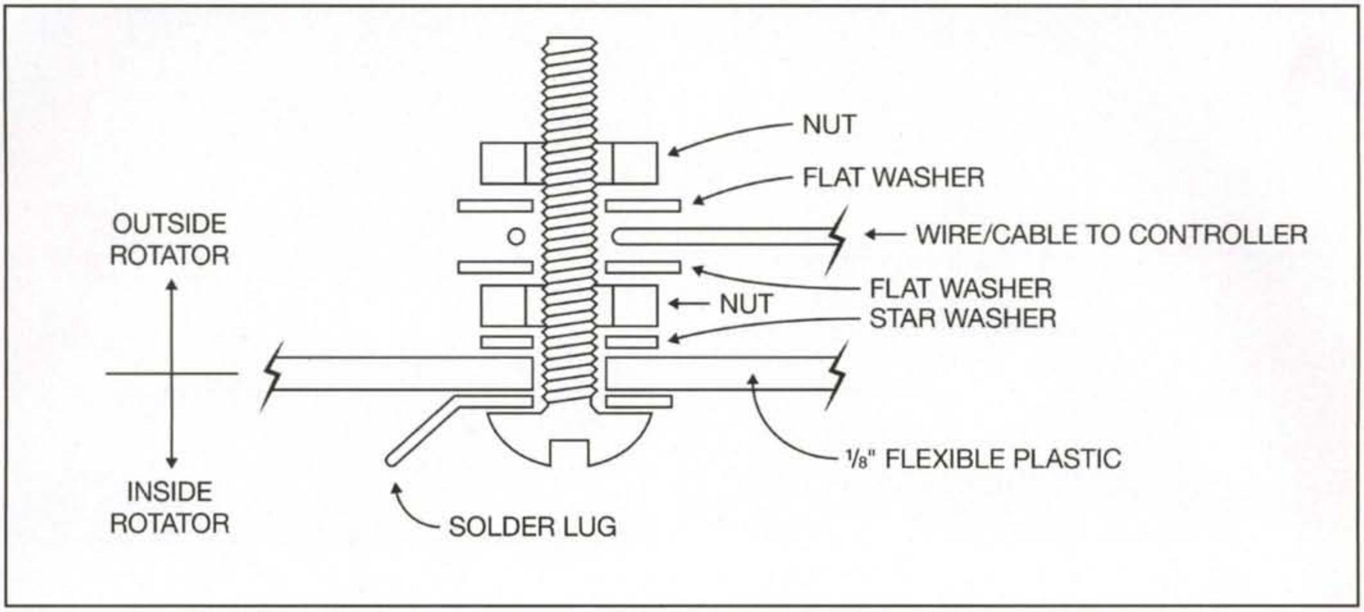



*Figure 5 . The order of parts for one terminal on the EL rotator terminal strip.*

The original circuit on the website shows feedback signals as 0 to 2.5 V. The signal from the rotator in my setup is not in this range, so some additional circuitry is needed to amplify and offset it. U5a–d perform the needed offset and amplification. A stable reference voltage (provided by U7) is needed so that readings and thus positions don't change with internal temperature changes in the cabinet. R49 and R50 remove any offset voltage at 0 degrees. This offset voltage and the feedback voltage are buffered by U5b–c and then added in U5d. The gain (amplification) is set to unity by R52 through R55. This same voltage is reduced by R58 and R59 to bring it into the range of the panel meter that displays the angle in degrees. R56–57 scale the feedback voltage into the range matching the request—0V to 2.5V. The values of the fixed resistors may need to be adjusted slightly if the potentiometers don't bring the voltages into the ranges needed.

*Photo 7. The large plastic gear that goes in the EL rotator. It shows how to begin forming the slot so that it can be mounted on the rotator collar. Be sure to stay completely inside the scribe marks.*

## II. Modifications to the Rotators

A gear and potentiometer was added to the AZ rotator. It engages with the teeth on the existing ring gear. The gear I used is made of steel and came from a junk box but a new plastic gear is available from MSC Industrial Supply Company; <www.mscdirect.com>. The EL rotator uses a large modified gear added to the collar and a smaller gear and potentiometer mounted to the body. The large gear for the EL rotator and its small mate are also available from MSC.

Since the EL rotator is mounted on its side (a position not originally intended) rain water can easily leak inside. A plastic container that formerly held cat litter was cut to fit over the rotator. Cut off the top third of the container then cut notches on both sides to fit the crossboom (see photo 4). Secure it with nylon rope and you have a (mostly) water tight enclosure.

Before wasting any time and effort cleaning or modifying the rotators make sure the motors work. First perform a resistance check on the motor windings. The EL rotator should measure approximately 2 ohms for each half of the motor winding and 4 ohms across both. The AZ rotator should measure approximately 6.5 ohms for each half of the motor winding and 13 ohms across both. Next connect just the three motor leads and the

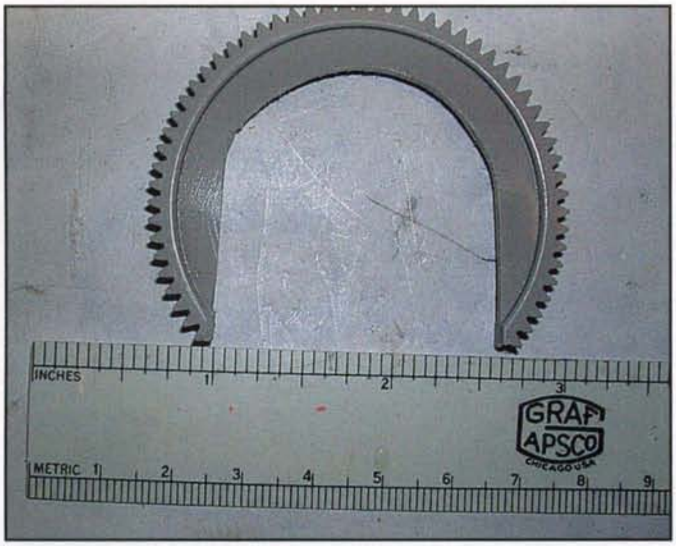



*Photo 8. The large gear completed and ready to be installed on the EL rotator collar.*

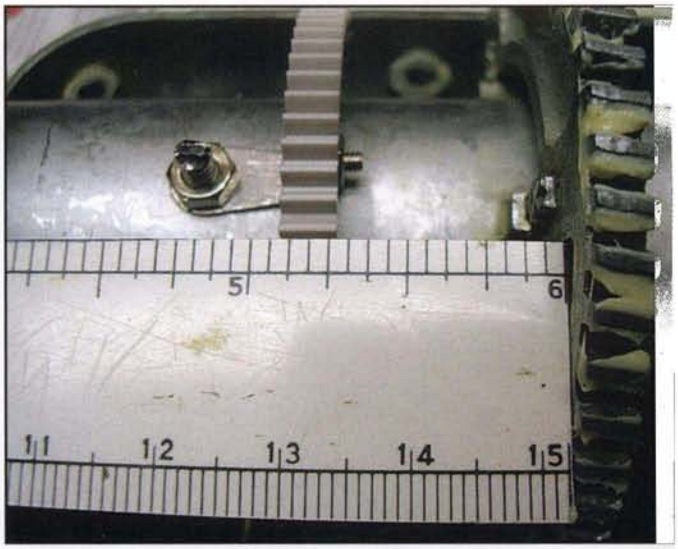


*Photo 9. Close-up showing where the new plastic gear is located on the EL rotator collar.*

capacitor to the transformer as shown in figure 4 to see if it will move. If the resistance readings are proper, the transformer measures 28 VAC, and the rotator still doesn't move, then the capacitor may be bad. Measure the capacitor to make sure its value is near that shown on it or try the capacitor from the other rotator. If it still fails to turn, the grease may be so hardened that it is keeping the motor from moving.

Take it apart and see if this is the case. Take pictures with a digital camera and make drawings as you take it apart so that you can put it back together with all the gears and other parts in the proper locations and order. You will need someone to take the pictures for you, since your hands will be dirty and greasy as you disassemble the units.

When disassembling the AZ rotator, put a bulky rag or blanket underneath to catch the ball bearings that may fall out when you remove the top. When disassembling the EL rotator, use a secure grip on the small wire clips that secure the gears in place or they will go flying across the room. A good way to prevent the "launch" of these clips is to use a side cutter and a light grip to pull them off the post. Better yet, wrap a short length of bare wire around the curved end a few times and pull on the wire to remove the clip. Not that I ever launched one.

**Cleanup and New Lubrication**

Once you have determined both motors function, they will need to be cleaned up and new grease applied. Mount each rotator in a vise so you can easily work on the unit and don't have to chase it across the floor. Completely remove all the gears, clips, etc. Remove the potentiometers and the associated wiring from both units, as you will be installing new potentiometers. (I have found the existing wipers bounce. This will drive the controller electronics crazy. A good stable feedback signal is needed.) Clean all gears, shafts, and seats completely. Use a degreaser that leaves no residue, or use alcohol for the final rinse. You may have to lightly scrape off some of the grease that has hardened on the gear teeth, surfaces, etc. Use a brass brush, not steel, so that you don't remove any metal from the gears. Replace any hardware that is rusted or damaged.

**For the Bell (AZ) Rotator**

1. Fabricate a small plate to hold the potentiometer in place (see photo 5). (I am unable to supply a diagram of the plate showing dimensions, since I forgot to make measurements and now it's on the roof. Regardless, there is plenty of room to accommodate the potentiometer.)

2. Attach color-coded wires to the three terminals of the potentiometer. Cut them so that they can easily reach three of the terminals, but don't connect them to the terminals at this time.

3. Mount the potentiometer in the plate, making sure the terminals and wires are positioned such that they won't touch any moving parts.

4. Drill two .107" ($^{7}/_{64}$") diameter holes approximately 90 degrees apart in the hub of the 1" gear. Tap the holes to accept $^{1}/_{4}$" × 6-32 setscrews. Mount the gear on the potentiometer shaft.

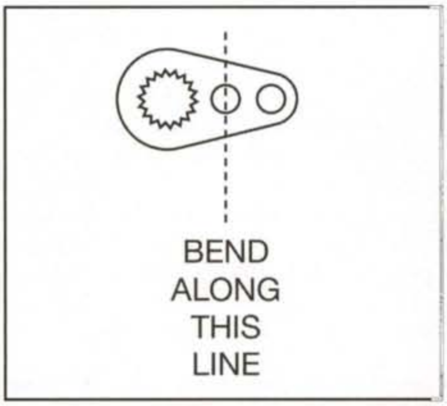



*Figure 6. Where to bend the ground lug to form the bracket that holds the large gear to the EL rotator collar.*

5. Preset the potentiometer to the middle of travel.

6. Connect the three potentiometer wires to three terminals on the terminal strip.

7. Mount the assembly using the original large bolt and a star washer top and bottom to make sure the assembly doesn't move.

8. Apply power to the rotator and make sure that the new gear engages the ring gear properly and nothing touches any moving parts during one full rotation (photo 6). This process may take several iterations to get it "just right" since (1) the gear may be too high or too low on the shaft, (2) the gear may not be fully

engaged into the ring gear resulting in the teeth skipping over each other, or (3) the gear may be pushing too hard against the ring gear causing it to put side pressure on the potentiometer.

9. If needed, replace the terminal strip screws with brass screws. The terminals in my rotator were clean, but the screws were badly rusted. Place stainless-steel washers under the screws so the cable wires don't move as you tighten the screws during finally assembly.

**For the "Sideways" (EL) Rotator**

Major modifications are needed for this unit and are the most difficult part of the entire project. The changes are: (1) fabricate a new terminal strip, as the old one has only four terminals and six are needed; (2) add a partial gear (about 330 degrees of a $2^1/4$" diameter gear) to the "collar" (the hollow part of the rotator where the antenna mast passes through); and (3) mount a potentiometer/gear combination to a bracket. Here is a detailed description of the required modifications:

1. Completely remove the phenolic terminal strip plate. Make a new one from $^1/8$" plastic after tracing the shape of the old one onto the plastic. I found some drawer separators that were made of a hard but somewhat flexible plastic; a brittle material won't work, since it will crack when you drill holes or file it to shape. Six terminals are needed, so you will have to space them closer than on the original plate. Use stainless-steel screws, nuts, and washers so that they don't rust. The hole pattern for the terminals should be such that you can tell which is which when you attach the rotator-control cable wiring. I recommend two rows of three terminals with the motor connected to one row and the potentiometer to the other row. Connect the center tap of the motor and the wiper of the potentiometer to the center-screw terminals. You can use an ohmmeter to determine which wire is which at the controller end. The order of parts for each terminal is shown in figure 5. The screw and nearest nut should be tightened with a wrench much tighter than you will tighten the outermost nut so that the entire assembly doesn't come apart when you loosen the outermost nut.

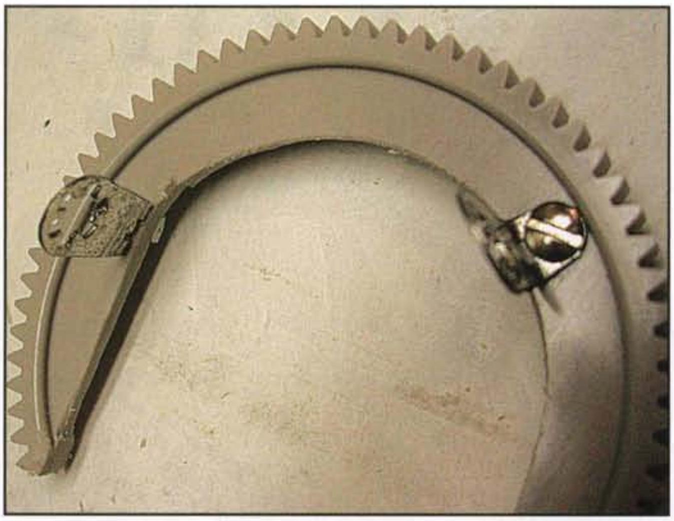


*Photo 10. The homemade "brackets" that secure the gear to the collar.*

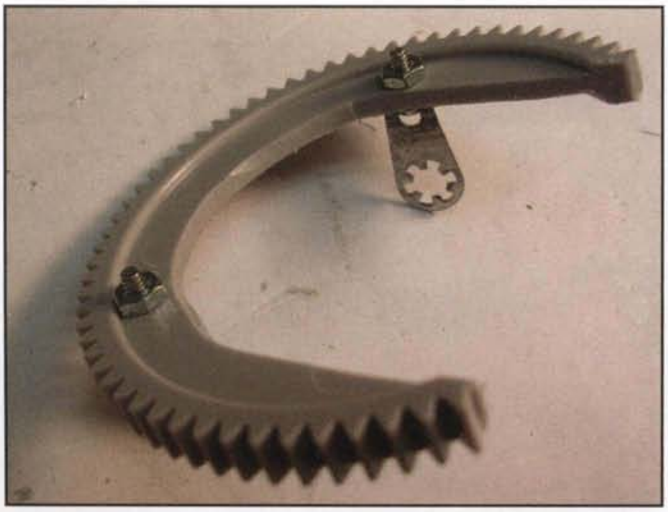


*Photo 11. Another view of the EL gear with the homemade "brackets."*

2. The $2^1/4$"-diameter gear must have a large slot cut in it so it can be attached to the "collar." Photos 7 and 8 show the slot cut in the gear. This needs to be done carefully, since the gear is plastic. Use a small-scale (ruler) to measure out $^3/8$" out from the hub and place a small dimple every 20 degrees or so using a pointy object; I used a scribe. Then connect the dots by scratching a line with the scribe. This will form a circle approximately $1^9/16$" diameter to match that of the collar. Use a straight edge to draw two lines parallel to each other from the circle you just created to the outer edge of the gear. Now drill $^1/8$" holes in the gear about $^1/8$" apart in the shape of a "U"; stay completely inside the scribe lines. Then use a hand saber saw to cut from hole to hole until the center pops out. Use a half-round file to form the rounded part of the slot and a flat file to form the straight edges. Go slowly with this step, as you don't want to remove too much material. You can't add it back! Support the gear with your fingers only and use light pressure on the file. Hold the gear up to the collar and make sure the edge of the teeth are all equidistant from the collar so that the gear is centered on the collar. Put the collar into one half of the rotator body and

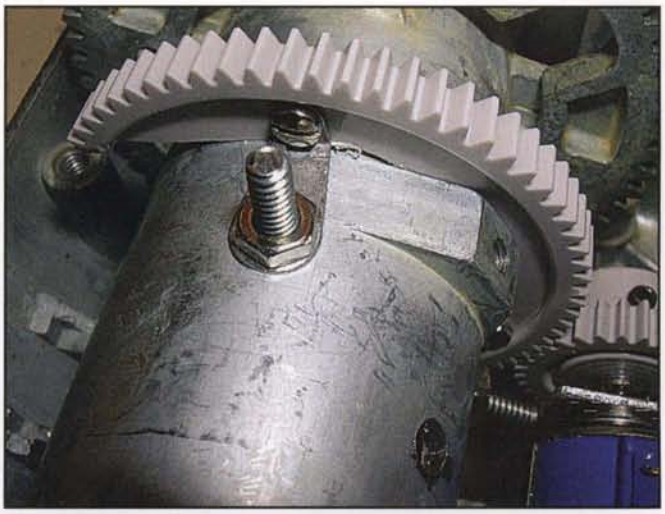


*Photo 12. A close-up showing how the gear is secured to the collar and its location between the existing metal gear and the "bump" on the collar. Note the 6-32 flathead screw securing all to the collar. Your unit won't have the threaded hole in the "bump." I tried unsucessfully to mount the new gear using a bracket there. The method shown works fine!*

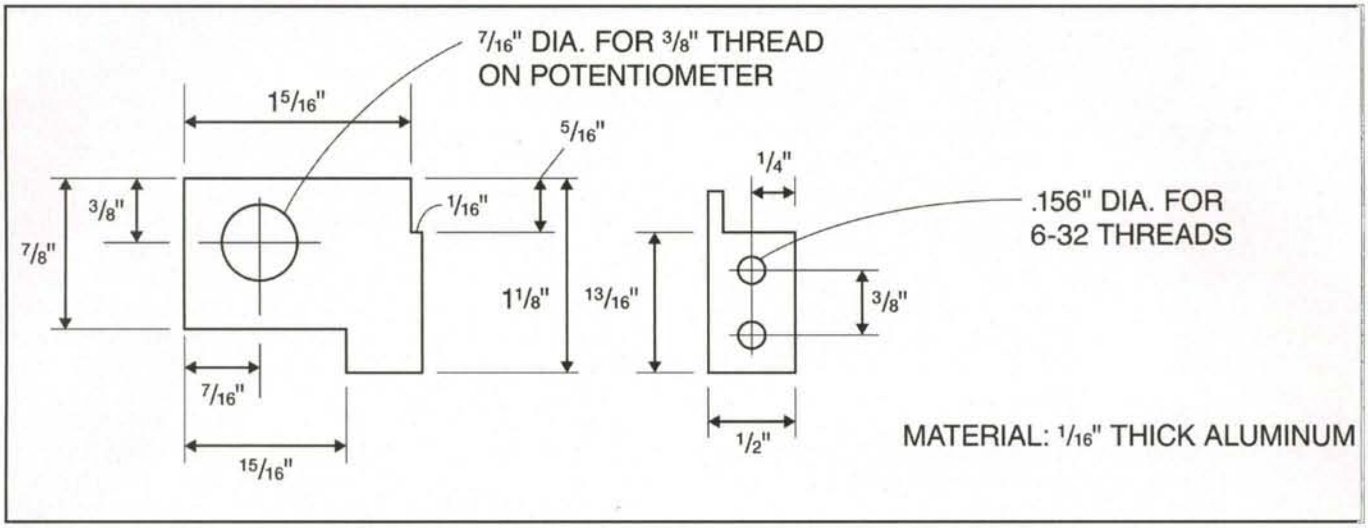



*Figure 7. EL rotator potentiometer bracket dimensions.*

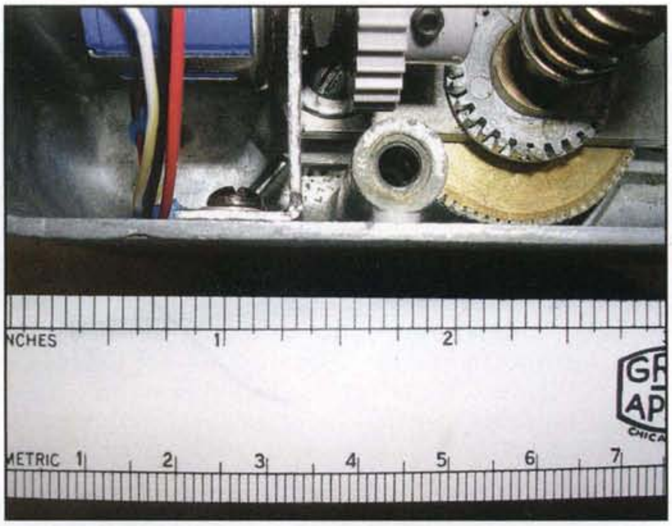


*Photo 13. This picture shows the location of the potentiometer bracket in the EL rotator. Note the distance between the bracket and the hole in the bottom part of the rotator body.*

rotate it and the gear to see if the gear is centered on the collar. Keep filing until the gear is centered. The correct position on the collar is next to the protrusion on the collar. The distance between the existing and new gear facing surfaces is approximately 11/16" to 3/4". See photo 9.

3. Next you will need to fabricate two tiny rightangle brackets to attach the gear to the collar. Modify two ground lugs to accept a 6-32 thread through the star washer portion. A small round file will work fine for this. Bend the two ground lugs as indicated in figure 6. Hold the gear in place against the large protrusion on the collar using a small clamp. Slide up the two small brackets approximately 90 degrees apart and make a mark on the plastic gear where the outermost solder hole is located. Drill .077" (5/64") diameter holes at each location to accept a 2-56 screw. Attach the gear to the brackets using 1/4" × 2-56 screws, lock-washers, and nuts. Replace the gear and brackets on the collar and reclamp it in place. Drill a hole for a 6-32 screw at each location in the collar where the star washer part of the bracket meets the collar. Install flat head 6-32 screws from inside the collar to secure the brackets in place. (You must use a flat-head screw so it doesn't prevent passing the cross

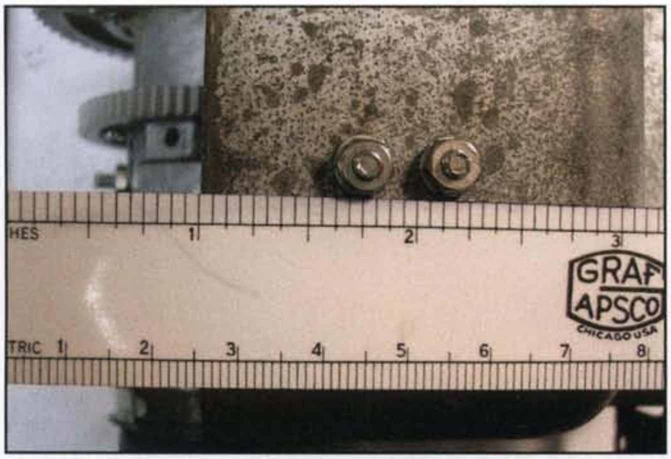


*Photo 14. The location of the two screws that secure the potentiometer bracket to the rotator body. The "1" mark is lined up with the top edge of the body.*

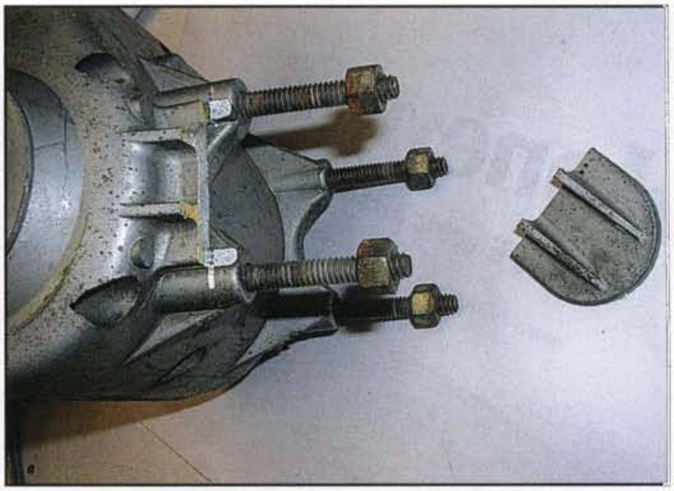


*Photo 15. The tab that must be removed from the EL rotator body so that it can be mounted on top the flange.*

*Photo 16. These are the parts that must be removed from the EL rotator. They are: the tabbed gear, two inserts (I believe they're shear pins), the tab removed from the body, and the overtravel switch.*

*Photo 17. The stock worm gear before the gear shaft has been removed.*

*Photo 18. The worm gear after removal of the gear shaft.*

boom through the EL rotator). See photos 10, 11, and 12. Rotate the collar in place to verify the new gear is centered and doesn't wobble as it is turned. Adjust the 6-32 and 2-56 screws until it is perfectly aligned.

4. Fabricate a bracket from $^{1}/_{16}$" thick aluminum as shown in figure 7.

5. Drill two $^{5}/_{32}$" diameter holes $^{3}/_{8}$" apart for mounting the potentiometer bracket to the bottom half of the rotator body. See photos 13 and 14 for the exact location.

6. Mount the potentiometer in the bracket and then attach the 1" gear on the shaft of the potentiometer by drilling and tapping two holes .107" ($^{7}/_{64}$") diameter 90 degrees apart to accept 6-32 × $^{1}/_{4}$" setscrews. With the gear ratio used (2.25:1), the potentiometer will rotate approximately a half turn. Make sure the potentiometer wiper is 25% up from ground and the center of the $2^{1}/_{4}$" gear teeth is touching the 1" gear. This is required so you don't run off the end of the partial gear as the rotator reaches either the 0 or 90 degree position. The 1" gear, the potentiometer mounting nut, set screws, and two 6-32 screws will need to be adjusted so the two gears align properly.

7. The support for each end of the collar in the body has a thin metal "C-shaped" strap curved to fit the body and collar. These two strips wrap around the collar and must be installed in the body perfectly or the rotator will bind up and not turn. The strap is properly installed when the top half of the rotator body seats all the way down (no space between halves of the body) when using a very light force. Lubricate these points with lithium grease.

8. Use a hacksaw to remove the large tab (photo 15) where the support mast would normally bottom out. This is required so that the rotator body sits flat on top of the pipe flange.

9. Remove the overtravel switch, gear with small tab, and small inserts. Also remove the post that formerly held the gear with the small tab. See photos 16, 17, and 18.

10. Connect three wires to the potentiometer terminals. Also connect the three motor wires as follows: brown = motor center tap, red = one end of motor winding, yellow = other end of motor winding. (Note that there are two yellow wires connected to the motor. The correct one to use can be verified by measuring the resistance between a yellow and the one black lead. The yellow wire that measures zero ohms to the black is *not* a motor lead. That yellow wire and the black wire are connected to a thermal cutout switch. I chose to cut off the wires to the thermal cutout switch to get them out of the way.)

Lubricate all moving parts with lithium grease and re-install in the proper order. I found lithium grease maintains a constant viscosity at very low temperatures, since it turned the same speed at 0 degrees F as it did at room temperature. I tested the grease by putting a completed rotator in a freezer set to 0 degrees F. I applied power and it turned easily.

## III. Checkout and Adjustment as a System

The first step of checkout is to learn how to setup, use, and become totally familiar with SATPC32 before testing the controller. Spend time reading over all the help file sections. I use version 12.4 of SatPC32, Windows® XP, and a 450-MHz Dell desktop PC. Here is how to set up the program for checkout of the controller and allow you to play with it to learn its operation:

1. Left click "Setup," "Rotor Setup"—Rotor Interface/Controller = "FODTrack"

2. Port = "1"

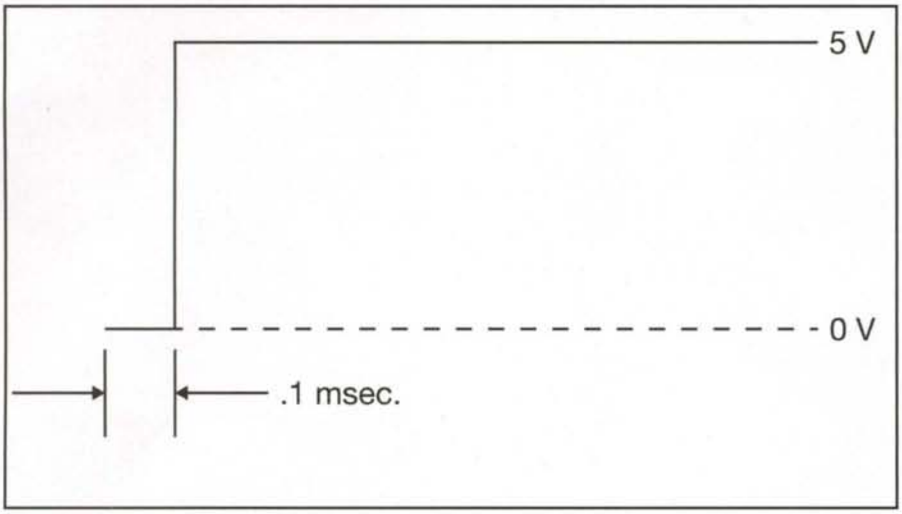



*Figure 8. The waveform of the write and D/A channel select pulses coming from the printer port of the PC.*

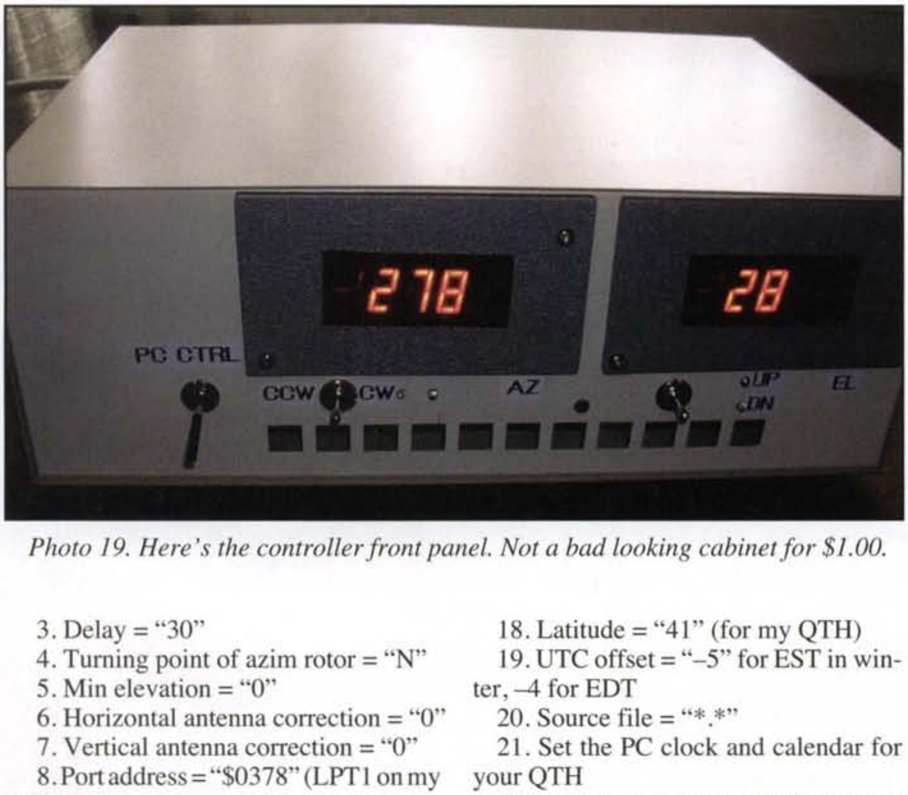



*Photo 19. Here's the controller front panel. Not a bad looking cabinet for $1.00.*

3. Delay = "30"
4. Turning point of azim rotor = "N"
5. Min elevation = "0"
6. Horizontal antenna correction = "0"
7. Vertical antenna correction = "0"
8. Port address = "$0378" (LPT1 on my PC)
9. Optional settings/Update antenna positions = "in time intervals"
10. Max elevation = "90"
11. Update antenna position in time intervals
12. Time Interval = "1"
13. Left click "Store"
14. Left click "Setup," "Observer"
15. Station altitude = "150" meters (for my QTH)
16. Grid locator = your grid locator (mine is EN61VR for northern Indiana)
17. Longitude = "–86" (for my QTH)
18. Latitude = "41" (for my QTH)
19. UTC offset = "–5" for EST in winter, –4 for EDT
20. Source file = "*.*"
21. Set the PC clock and calendar for your QTH
22. Close and re-open SatPC32 to have these changes take effect

That's all that is required in the program setup for checkout of the controller! Next is operation of the program.

Left click the letters A–L at the lower right to see what satellites are preloaded into SATPC32. Select one that is a LEO (Low Earth Orbit) so it will move across the screen at a fairly rapid rate and frequently change the values loaded into the D/A. The one remaining HEO (High Earth Orbit) satellite (AO-10) doesn't move very quickly across the sky, so the controller won't change position very often. Depending on the local time and the position of the satellites in your list, you may or may not have any visible to you. Left click on "Tracking," "Preview," "OK," and then use the left and right pointers (upper right screen) to quickly advance to where the satellite will be at the time/date shown on the screen (upper right screen). You want to find a LEO that is high in the sky at some time during the pass and the starting time of the "pass" for your QTH. Click "Tracking," "Real Time," "OK" to return to the current position. Then set the PC clock/calendar to the starting time/date of the upcoming "pass." (What you're doing is fooling the PC into thinking that it's time for a "pass" and to point the antenna at the satellite going by your QTH.) To begin sending commands to the parallel port and controller, left click the "R" (in the upper left part of the screen); it should change to "R+" to indicate activity.

At this point you should see voltages at U6 pin 7 for AZ and U6 pin 1 for EL. The readings should be as follows: 0 to 5 volts spread over 0 to 360 degrees AZ; 0 to 2.5 volts spread over 0 to 90 degrees EL. If they aren't close, check the wiring at U1 and U6. The voltages should change as the screen shows the satellite passing by. Check various passes, either to the east or west of you to see the D/A outputs change over the full range. If you don't see any changes, look at U1 pins 18 and 20 with an oscilloscope. There should be pulses at both pins. The pulses are very, very short—approximately .1 millisecond at 0V, and then rest of the time at 5V. To see the pulses, set up an oscilloscope as follows: trigger level approximately 2 VDC, 2 volts/div, triggered mode, DC coupling, sweep time .2 millisecond/div. The pulse at pin 18 selects which D/A (A or B) is loaded with the 8 bits and the pulse at pin 20 loads (or writes—"WR") the data into the selected D/A. If either is missing check for wiring error s in this area. Figure 8 shows the waveform. New pulses should appear at both pins at 1 second intervals as set in SatPC32 in the rotor setup menu.

Next is the adjustment of the potentiometers (R38, 46, 47 for AZ and R49, 57, 59 for EL) to bring the feedback voltages into the same range as the request voltages and make the digital panel meters display actual position.

Connect the rotator motor and potentiometers to the circuit board.

**For the AZ Rotator**

1. Use switch S1 to set 5V on the rotator potentiometer wiper.

2. Use switch S1 to move the AZ rotator 180 degrees CCW when looking down on the rotator (do not use the meter display for this step). The voltage should decrease; if not, reverse the potentiometer outer leads and go back to step 1.

3. Adjust the AZ zero potentiometer, R38, for 0 volts at U4 pin 14.

4. Use S1 to move the AZ rotator to point South (180 degrees AZ).

5. Adjust the AZ f/b pot, R47, for 2.5 V at its wiper.

6. Adjust the AZ DPM gain potentiometer, R46, for .180 V on the DPM "+" input.

**For the EL Rotator**

1. Use S2 to set 1.25V (this is 45 degrees EL) on the rotator potentiometer wiper.

2. Use the manual switch S2 to move the EL rotator to point at the horizon (zero degrees EL; do not use the meter display for this step). The voltage should decrease. If not, reverse the potentiometer outer leads and go back to step 1.

3. Adjust the EL zero potentiometer, R50, for 0 volts at U5 pin 14.

4. Use S2 to move the EL rotator to a straight-up position (90 degrees EL).

5. Adjust the EL f/b pot, R57, for 2.5V at its wiper.

6. Adjust the EL DPM gain potentiometer, R59, for .9 volts on the DPM "+" input.

Manually run the rotators through their ranges to see that the DPMs display 0–360 and 0–90 degrees over the full ranges. As luck would have it, both of my potentiometers were wired the wrong direction, causing the rotators to turn one way and the potentiometers to indicate they were turning the other way! Consider yourself lucky if even just one is wired backwards and very lucky if both are wired correctly.

Connect two 10-turn potentiometers (1K to 5K ohm) mounted on a board to simulate feedback signals from the AZ and EL rotators. Set S3 to PC Enable. This will allow you to see if the LEDs switch CCW/CW and UP/DOWN when you go through the requested position, where $V_{req}=V_{fb}$ (request = feedback). To check either AZ or EL, put a DMM on the feedback and a second meter on the request. ( I used a DMM and an analog meter, as that's all I have and it was good enough for this part of the checkout). As you adjust the feedback potentiometers through the point where $V_{req}=V_{fb}$ the LEDs should go out until you move the potentiometer again. If they don't, check the wiring in the respective areas.

Mount the rotators together with a short piece of pipe threaded on one end to fit a flange. The flange will need four holes drilled to match up with the four bolts on the EL rotator. Attach all the wiring to the rotator terminals.

Set up SatPC32 to track a real satellite pass with lots of movement of both rotators. A near-overhead pass is ideal. When it gets well above the horizon for your QTH (approximately 30 degrees EL), use the manual switches S1 and S2 to position both rotators to the positions displayed and then flip S3 to "PC Enable." If all goes well, it will track the satellite across the sky! If it takes off in the wrong direction – moves away from the satellite – either the motor or potentiometer leads are wired backwards.

Mount the antennas on the cross boom and slightly tighten everything. You may need to decrease the 1-megohm resistor values at R19 and R23 significantly so the rotators don't cycle off and on too often. The final values will vary depending upon rotator gear "slop" and the size of your antennas (system dynamics). Note that I arrived at 330K and 470K ohms—very different from the 1-megohm values specified in the original circuit. A bigger deadband was needed in mine. The large moment arm caused the rotator to keep moving after power was removed, and by then the position was outside the deadband, causing it to hunt/ swing back and forth in an oscillation around the requested position.

Once everything is working properly, drill a 1/8" diameter hole through each end of the collar of the EL rotator and through the crossboom. Pass a 6-32 screw through everything to eliminate any slippage (see photo 1). Tighten the U-bolts a bit more, but not so tight that you crack the PVC tubing.

Transmit at both 144 and 436 MHz to see if RF is getting into the circuitry. It will show up as a change on either DPM reading. With shielded cable, LC filters, and the 47K resistors at the rotator potentiometer wipers I see only 1-degree change in the AZ display.

## Conclusion: So How Does It Work?

It works great! Now I can concentrate on communicating with other stations while my computer and SatPC32 software are directing my antennas to follow the satellite across the sky. Previously, I moved the antennas manually while the satellite moved by. I was only using SatPC32 to for Doppler-shift correction (using the RS-232 port). When working SSB through a LEO (Low Earth Orbit) satellite, you can get very busy correcting for Doppler shift and manually pointing the antennas!

As you can see, the controller has a high "neat factor," since the displays show where the antennas are positioned and the LEDs indicate when the motors are running and what direction they're moving —and it's all being done automatically. If you can set your radios' transmit and receive frequencies via a PC, you will also get to see the frequency changes sent out by SatPC32!

After the system is working correctly, update the Keplerian data in SatPC32 from <www.amsat.org/amsat/ftp/keps/current/nasa.all>, set the PC clock (use WWV), wait for a real satellite pass, and then just sit back and enjoy a relaxing contact!

By Dr. H. Paul Shuch,* N6TX

# DR. SETI'S STARSHIP

## Searching For The Ultimate DX

## Allen Telescope Disarray

The Allen Telescope Array was to have been the world's greatest radio telescope, a field of 6-meter parabolic dishes stretching across the California countryside, eventually growing to 350 in number, tasked with full-time SETI observations. Thus, the dismay of the scientific community was palpable, when it was announced in April of 2011 that the whole facility was being temporarily put into cold storage.

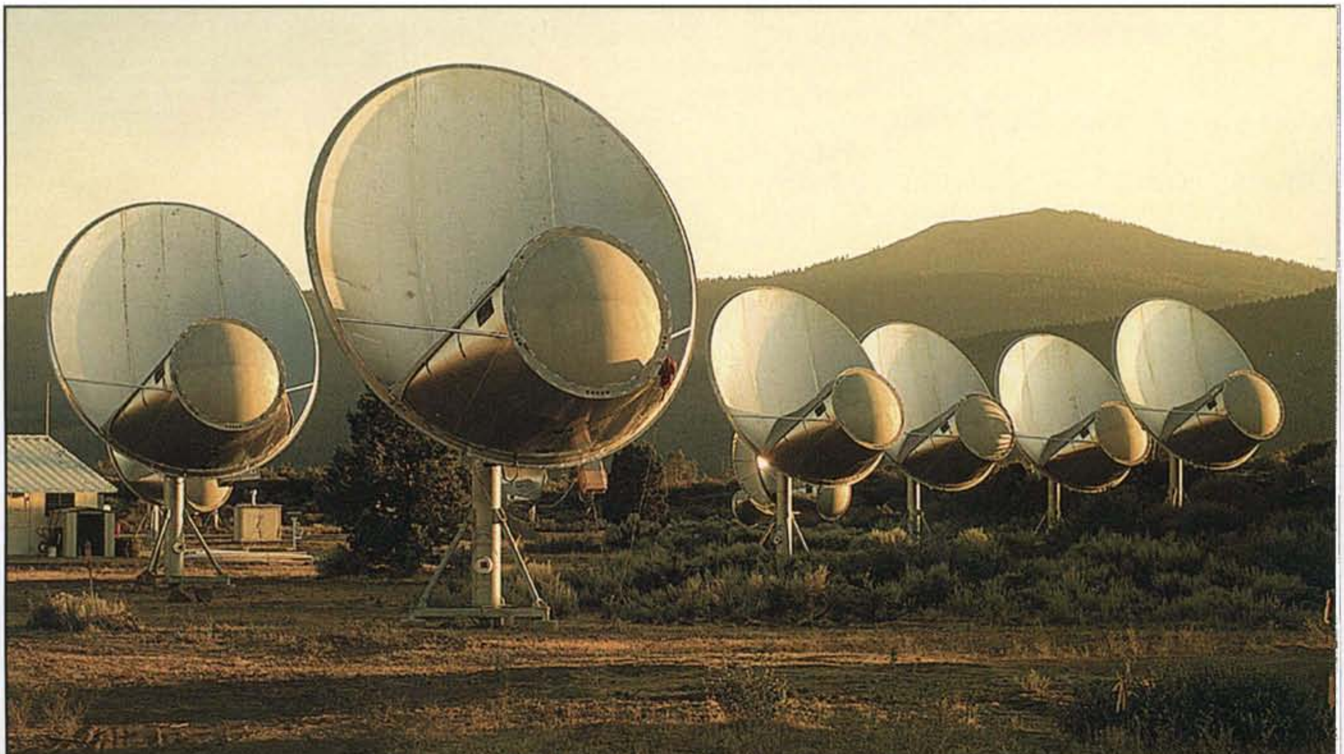
Not that I was particularly surprised at this turn of events. The ATA was a joint initiative of two fine organizations. One player is the nonprofit SETI Institute (a California alliance of professional astronomers, engineers, physicists, and astrobiologists, not to be confused with The SETI League, our own global alliance of radio amateurs and experimenters). They partnered with the Radio Astronomy Laboratory at the University of California, Berkeley (my own alma mater, and arguably the world's premiere institution of higher learning).

The project had received significant and generous funding from industry icons such as Paul Allen, co-founder of Microsoft, and Nathan Myhrvold, the Princeton astrophysicist turned intellectual-property entrepreneur. It had received somewhat more modest funding from a host of enthusiastic donors, including The SETI League's own president, Richard Factor, WA2IKL. With 42 antennas up and running, the facility was already doing credible science . . . when the money ran out.

The array had set back its donors on the order of $50 million, which works out to in excess of a megabuck per antenna (just a bit pricey for an oversized satellite dish). Still, one must consider that most of that sum was spent not on concrete and steel, but rather on research and development—plus, the not inconsiderable cost of operations. Also, eventual expansion of the array to its planned 350 elements notwithstanding, it was those operating costs (or rather, the lack thereof) that ultimately pushed the project into its present hiatus.

The SETI League can sympathize. A decade ago, we launched our own very modest effort at combining satellite dishes into a research-grade telescope. The Very Small Array (VSA) was never completed, although we did get eight small dishes up and running, and proof-of-concept hardware and software tested, before we, too, ran out of money. Our budget was less than stellar; the project consumed about 10 thousand of your generously

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



*The Allen Telescope Array in Hat Creek, California sits idle, while the SETI Institute and University of California seek financial support to resume its scientific mission. (SETI Institute photo)* donated dollars. It wasn't nearly enough. Thus, we also had to put our array on hiatus, but not before I managed to score a patent on the underlying technology. I assigned that patent to The SETI League, in hopes that commercializing it might generate revenues sufficient to support our humble scientific efforts. Unfortunately, the "dot-com" bubble burst before anyone beat a path to our door.

To turn their own array back on, our California colleagues need to raise some 5-million dollars. I just checked my wallet, and I don't have quite that much cash to spare. As for the VSA, the SETI League would need another $20k to finish the project. That sum, too, exceeds the contents of my wallet—by several orders of magnitude.

Thus, I, the author of this column, am asking you to check your own wallet. Have you an extra 5 megabucks to fund a couple of years of ATA operation? If so, I encourage you to step forward and help restart SETI's finest observational instrument. Or do you maybe have a couple of kilobucks to throw into the Very Small Array? If so, please send it along to The SETI League, and I'll be happy to resume work on that suspended project.

You say neither project is within your financial reach? I understand completely, as I am in the same situation. If possible, I am asking you to dig not quite so deeply. A $50 membership in The SETI League (and an equivalent contribution to the SETI Institute's Team SETI) will be a worthy show of support. Besides, if a few thousand others will follow your lead, both organizations (and their respective technology projects) will find themselves back on the road toward SETI success.

73, Paul, N6TX

*The SETI League's VSA (Very Small Array) sits behind the author's home in rural central Pennsylvania, awaiting the funds to complete it. (N6TX photo)*

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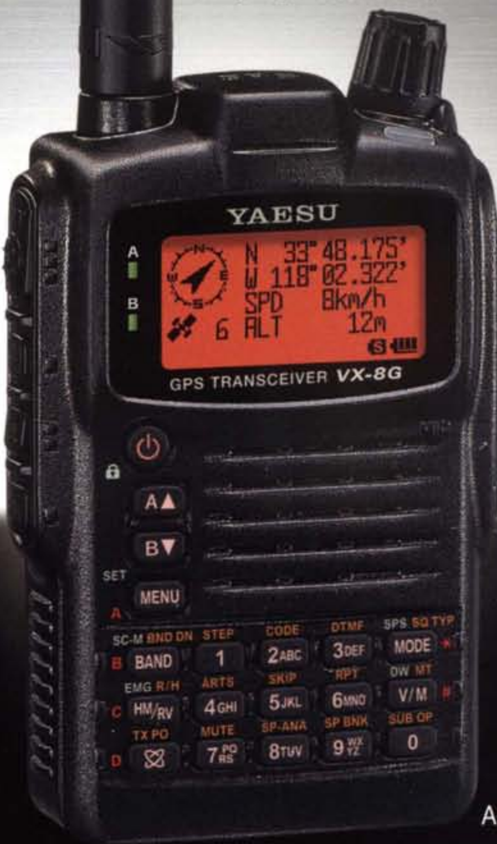


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**Built-in GPS Antenna - Waterproof**
**Wide Band Receive for 108-999 MHz** (Cellular blocked – US Version)

## Supports APRS® communication by the Built-in Worldwide Standard AX.25 Data TNC

**The VX-8 series radios are compatible with the world wide standard APRS® (Automatic Packet reporting System) using the GPS system to locate and exchange position information.**

- SmartBeaconing™ Function
- Memories to list 50 stations
- Memories to store 30 APRS® messages
- DIGI-PATH routing indication function
- 8 DIGI-PATH routing settings
- GPS Compass Display - "Heading Up" or "North Up"
- APRS® Symbol Icon pre-set function
- Clearly displayed APRS® Beacon Messages
- Selective Message Received indicated by Flashing LED

APRS® is a registered trademark of Bob Bruninga WB4APR. SmartBeaconing™ from HamHUD Nichetronix

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**http://www.yaesu.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.

YAESU
*Choice of the World's top DX'ers℠*

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

# Advanced Dual Band Mobile Radio
# 5.2" x 1.6" Large dot matrix (264 x 64 dots) LCD displa
# GPS / APRS® / Bluetooth® Features
# FTM-350AR

**New Vacuum Cup-Mounting Bracket permits Angle Adjustment**
**New APRS® Operation Capability, and newly Expanded User Friendly Functions**


144/(220)*/430 MHz 50 W FM Dual Band Transceiver

## FTM-350AR NEW

220 MHz 1 W (USA version only)

## New Features of The FTM-350AR

### 1. New Vacuum Cup-Mounting Bracket with Angle Adjustment

The new MMB-98 Mounting bracket allows easy installation of the radio control display to your Dashboard by placing the vacuum mount in the desired location and pressing a lever. You may then adjust the display to the optimum viewing angle.

### 2. Expanded APRS® functions

- Uses the worldwide-accepted GPS NMEA data format
- Navigation to another APRS® BEACON station is pos- sible, even if the beacon station is moving.
- Waypoint data (Data in/out) is available from the AC connector on the rear of the main unit.
- Sub-Band APRS® operation may be active in the back- ground, even when operating in Mono-Band Display mode.
- Newly added Voice Alert function
- Re-allocated often used keys to more convenient posi- tions for easier operation
- Programmable keys on the DTMF Microphone provid direct access to APRS® functions

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