Getting Started on the Amateur Radio Satellites (Part II)

By Keith Baker, KB1SF/VA3KSF, kb1sf@amsat.org

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Greetings and welcome once again to the Beginner's Corner of *The AMSAT Journal*! My goal in this series of articles is to help beginning satellite operators (or would-be beginners!) demystify the world of Amateur Radio satellites by sharing a wealth of practical information about how to listen for (and work through) our ever-expanding fleet of OSCARs (Orbiting Satellites Carrying Amateur Radio). I'll be examining some of those satellites currently in orbit as well as those that are still on the drawing boards or are now being prepared for launch.

I trust my first article in the July/August issue of *The AMSAT Journal* served to "whet your appetite" about how to listen for and use these largely "home brewed", modern-day wonders constructed from aluminum, silicon, glass and other electronic components that a lot of people have labored long and hard to put into orbit (and then command) for our use. However, before you progress further, there are a few more considerations and "tricks of the trade" that I need to share with you so that your attempts at hearing or working through one or more of our so-called "EZ Sats" will be more successful.

Some Additional Handheld Antenna Considerations

First, let me say it right up front: In satellite work, your antennas are, without a doubt, *the* most important part of your station. That's because the power output of the majority of amateur satellites now in orbit seldom runs more than a watt or two. Indeed, two of the satellites I mentioned in my previous article … AO-51 and AO-27 … normally transmit with a power output of only about ½ watt or so. The power output of SO-50 is even lower.

What's more, *all* of these satellites transmit into either a single, quarter wave whip or what's called a "turnstile" antenna array that usually consists of a set of four; quarter-wavelength 2m or 70cm whips canted inward (or outward) at a 45-degree angle on the bottom of the spacecraft. But, unfortunately, even with their multiple elements, the nominal gain of these arrays is still pretty close to zero. The end result is that most of these satellites are transmitting with little more than "flea power" into a proverbial "wet noodle" for an antenna. And if transmitting with low power wasn't enough of a hurdle to overcome, it is important to remember that most of our satellites are in what we call a Low Earth Orbit (LEO). This means that the bulk of them will never be closer to you than about 500 miles (800 km) even when they are directly overhead. And they'll be over 2,000 miles (3,200 km) distant when they are near the horizon.

So, it should go without saying that you *will* need a good receiver and some sort of gain antenna in your setup to reliably hear them. And, as you might guess, the "rubber duck" antennas that usually come supplied with most handheld radios are simply *not* large enough to routinely hear or communicate through these satellites, except under absolutely ideal conditions. By "ideal" I mean with the satellite located almost directly overhead and with just a few other people using the transponder.

The Harsh Environment of Space

Another consideration that has to be taken into account has to do with the harsh environment of space where our satellites operate. For example, when their solar panels are in full sunlight, these satellites are being "baked" at about 250 degrees Celsius. When they go behind the Earth and out of direct sunlight, the external temperature of these satellites rapidly cools down to a temperature near *minus* 250 degrees Celsius! Needless to say, such rapid temperature swings would soon destroy the fragile electronics onboard if something weren't done to move heat around inside the spacecraft.

As we all know, high temperatures can very easily destroy the modern semi-conductor components in our equipment. That's why most modern ham transceivers come equipped with a fan or metal heat sink of some sort. However, it's important to remember heat sinks and fans are both designed to work with *air*. Unfortunately, there's *no* air in space to cool such components in the same way as we do on Earth. So, it goes without saying that our satellites need to dissipate all of that blistering excess heat they get from the Sun in some other way.

Likewise, such things as batteries do not operate *at all* well in the cold. Anyone who has tried to use a modern digital camera outside in sub-zero temperatures knows that you have to keep several sets of batteries in

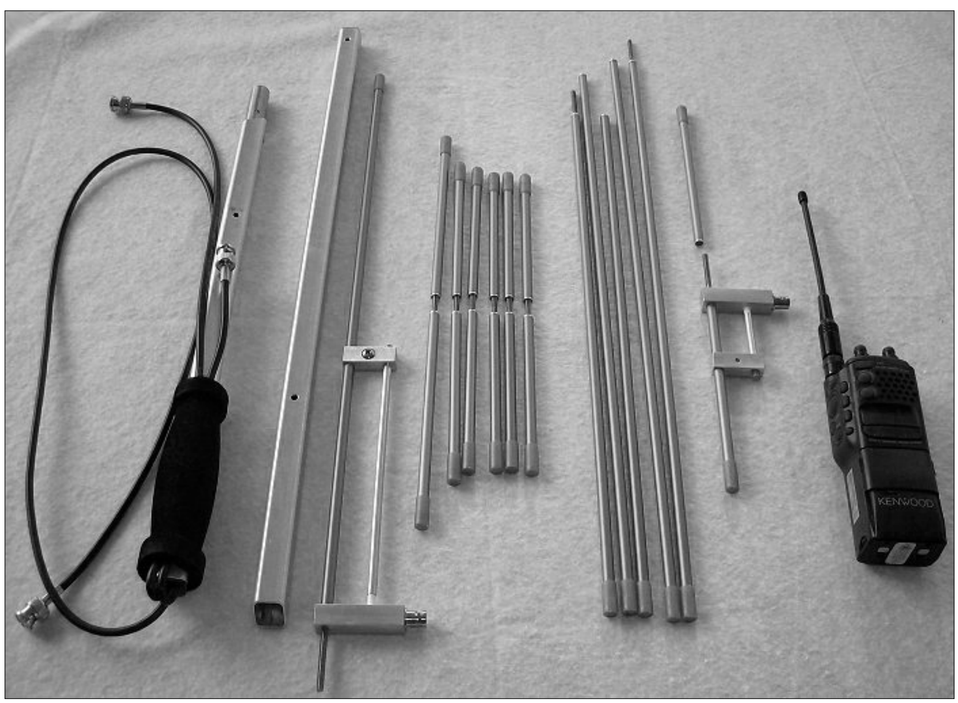

Photo 1: The author's satellite "hand shack" consists of an Arrow Model 146/437 antenna and a Kenwood TH-78A dual band handi-talkie (HT). The antenna easily breaks down into several pieces for easy transport. (KB1SF Photo)

Photo 2: The Arrow sports a 10W 2m/70cm duplexer tucked inside the handle under a removable foam grip. This allows for a single feed line to connect the antenna to a "rubber duckie" connection on a handheld radio. (KB1SF Photo)

a warm pocket or two if you ever hope to capture more than one or two photos under such conditions.

So, with them baking inside a metal box at 250 degrees Celsius in full sun (and then freezing at *minus* 250 degrees during eclipse) just imagine what our satellite batteries and other electronic components go through *on each and every orbit!* That's why our AMSAT satellites (and, indeed, most others) are all designed to spin about their vertical axis (much like a barbeque rotisserie does) as they orbit the Earth. This motion helps to move heat and cold around in the innards of the satellite evenly (usually by direct thermal contact of internal components to the space frame) so as to keep the batteries and other electronics inside the satellite heated and cooled within their proper operating parameters.

This is also one of the main reasons why simply sticking a couple of cheap, off-the-shelf, VHF/UHF ham transceivers into a metal box powered by some surplus store nickel-cadmium batteries, adding a bunch of solar panels and then mounting the whole thing on a rocket and launching it often results in a highly unreliable satellite. While such "cobbled together" satellites *may* work in orbit for a time, they usually don't work for very long!

Doing the Tumble

Furthermore, to keep their downlink antennas properly oriented toward the Earth, most of these birds are *also* designed to slowly tumble end over end as they move from South to North (or North to South) over the planet. While also contributing to balancing out those rapid heating and cooling cycles caused by the Sun's radiation, this tumbling motion also helps keep what meager gain their transmit antennas are radiating pointed back down toward the Earth and us.

Unfortunately, this constant tumbling motion means that the polarity of the satellite's receiving and transmitting antennas will be constantly changing as it moves overhead. And, as satellite work is "line of sight" work, unless you are able to change your antenna's polarity in sync with the satellite, its downlink signals will undergo some very deep fades in your receiver due to severe (sometimes as great as 5 or 6 dB) antenna cross-polarization effects during the course of the satellite's pass.

So, while they *will* work for "hit and miss" satellite contacts, my experience has shown that most fixed and mobile vertical antennas are simply not good enough to overcome these limitations. That's because they usually cannot be easily (or rapidly) tilted to match the ever-changing polarity of a satellite's transmit and receive antennas as it tumbles across the sky.

For this same reason, quarter-wavelength and 5/8-wavelength HT-mounted whips are *also* not recommended for such activities, either. Besides being frequently cross-polarized with the satellite's antennas, most handheld radios simply don't provide the required ground plane for such antennas to be fully effective.

And, finally, because the downlink signal strength of most of these satellites *is* so weak to start with, most scanners (or other, so-called "broad band" receivers that cover 145 or 436 MHz) will usually not be able to reliably receive the downlink with just a whip antenna (even an external one!) because their unamplified receiver gains usually aren't high enough to do so.

The bottom line here is that, no matter how you cut it, satellite work *is weak signal work*. And while little whips and "rubber duckie" antennas are fine for most terrestrial applications, they usually don't provide enough downlink gain to be useful for reliable weak signal satellite work beyond casual "hit and miss" contacts.

However, before you say, "I'll never be able to get on the birds" and give up in disgust, let me also say that with the creative addition of a set of small (and relatively inexpensive!) Yagi antennas to produce a bit more uplink and downlink gain, your HT *can* be turned

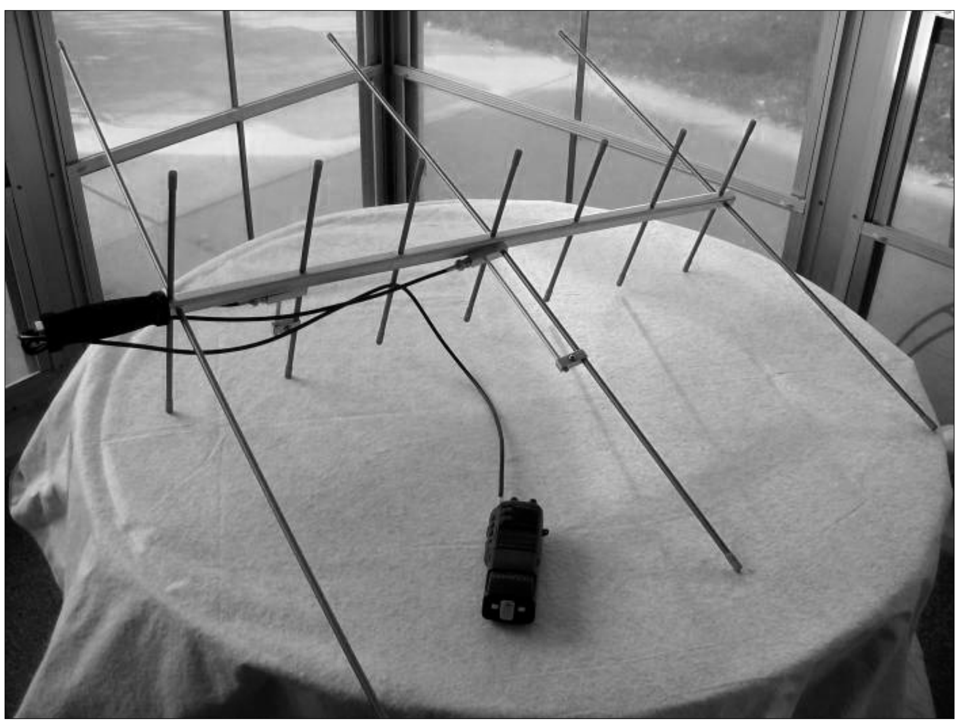

Photo 3: The author's assembled Arrow Antenna with Kenwood TH-78A HT attached. (KB1SF Photo)

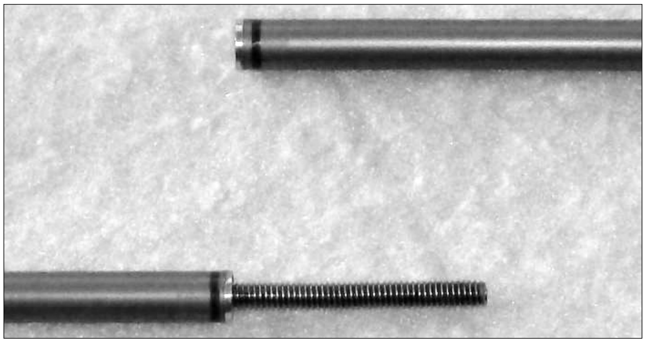

Photo 4: The Arrow's elements are nicely machined from aluminum arrow shafts … hence the name. Threaded elements easily slip through the boom to provide a secure connection to its opposite element on the other side. (KB1SF Photo)

into a very effective Earth station for use with these satellites.

Handheld Yagis to the Rescue!

As I have said, if you are truly serious about routinely hearing or working through our FM birds with an HT, a hand-held Yagi antenna of some sort will be needed to provide your transceiver with enough effective uplink power (and downlink receiver gain) to reliably do so.

Over the years, many amateur satellite enthusiasts have "rolled their own" hand-held Yagi antennas exclusively to work these LEO satellites. For example, radio hams like long time VHF enthusiast Kent Britain, WA5VJB, have been freely sharing their learning by publishing numerous plans on the Internet for a series of "home brewed" hand held Yagis for 2m and 70cm made out of easily obtainable materials. These materials include pieces of aluminum ground wire or brazing rod along with scraps of lumber from your basement, garage or shed (or, when all else fails, from your local hardware store.)

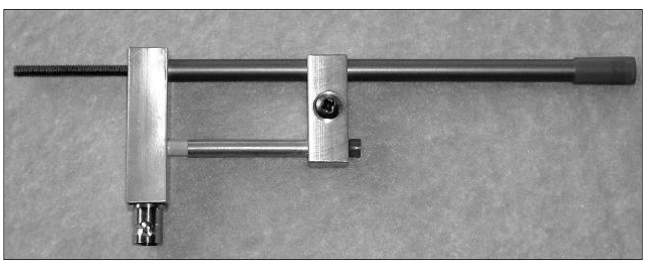

Photo 5: The Arrow features beautifully machined gamma-matching stubs for both the 2m and 70cm feeds. The 70cm feed stub is shown here. (KB1SF Photo)

In an excellent online article he's dubbed *Cheap Antennas for the AMSAT LEO Satellites* at **www.oh1sa.net/data/satellite/antenna-lna-etc/Cheap_Antennas-LEOs.pdf,** Kent shows how you can easily build a dual band hand-held Yagi to work the FM birds. Another reliable source of plans for these "home brew" antennas can be found in an excellent series of beginner articles on or own AMSAT-North America Web site at **www.amsat.org/amsat-new/information/faqs**.

However, if building your own antenna from scratch isn't your thing, fortunately there are at least a couple of commercial manufacturers who offer hand-held satellite antennas for LEO satellite enthusiasts. Antennas such as the commercially manufactured Arrow Model 146/437-10 dual-band handheld beam antenna (sidebar) or the Elk Antenna Model 2m/440L5 (available either from Martha at the AMSAT-NA office or via www.elkantennas.com) are highly recommended commercial substitutes. Both of these antennas will provide more than enough gain for you to work the FM satellites with a 3-5 watt output, dual-band HT or to hear them with a handheld VHF/UHF scanner.

Other Helpful Operating Hints

As I have said, it is important to remember that when you attempt to communicate through them, these satellites will be both spinning and tumbling in orbit, so their uplink and downlink antenna polarizations will be constantly changing. If you are using a whip antenna on an HT just to try and listen for one of them, moving your HT around a bit during the satellite pass may be helpful. That motion should result in your (and the satellite's) antenna polarizations (briefly!) meeting up at some point. I've also found that reflections from conductive surfaces (such as a car body) will sometimes help improve your received and transmitted signals as well.

As I also noted in my feature article in the July/August edition of the *Journal*, if you are using an HT, you'll also want to

Photo 6: Removing the duplexer and foam grip reveals screw holes for mounting the Arrow Antenna on a lightweight photo tripod. (KB1SF Photo)

use a speaker-mike (or better yet, a headset with a boom mike attached) while working through these satellites.

A boom headset will free you from the task of having to hold an antenna in one hand and your radio near your mouth and ears with the other. Believe me, even though they are made from lightweight materials, your arm *will* get tired after holding one of these antennas for a 15 minute satellite pass … so much so that you will probably want to switch hands a time or two during your contact. Another approach that works well is to enlist the aid of an assistant who can hold your radio (or a small external speaker connected to your HT) during the pass.

As I also noted in my previous article, another very good reason for using some form of speaker microphone or boom headset is that if you are communicating through the satellite using a full-duplex HT,

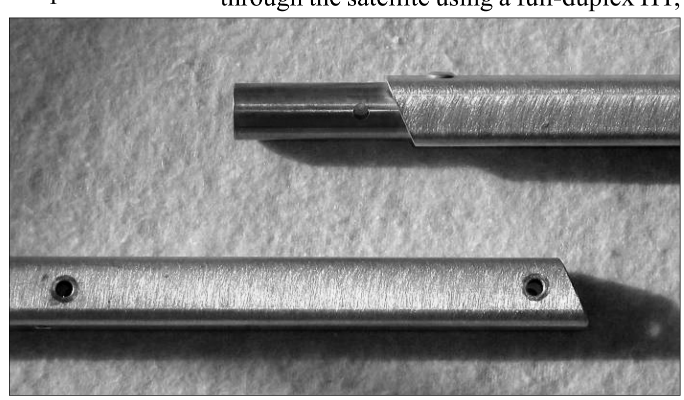

Photo 7: An optional version of the Arrow sports a tight fitting, split boom feature. (KB1SF Photo)

Craig Wolsey, AC8EJ/VA3ICW, uses his HT and Elk Model 2M/440L5 antenna to make a contact through AO-51 from the shores of Lake Huron in Canada. The antenna's unique log periodic design allows for dual band operation using just five elements connected to a single feedline and without the need for a duplexer.

having your microphone and speaker so close together in the same unit will usually create howls of audio feedback … *through the satellite* … when you transmit! Again, such activity will NOT make you a popular "camper" on the bird!

What's more, because they are so weak, AO-51, AO-27 and SO-50 downlink signals are unlikely to be strong enough to trip the squelch on most FM receivers. So, be sure to open your receiver's squelch all the way (until you hear the rushing sound) before you begin listening. When the satellite comes into range of your location, the rushing sound will "quiet", giving you a clear indication that you have, indeed, "captured" the bird's downlink.

Swimming with Alligators

Speaking of capturing signals, it is also important to remember that, because FM signals exhibit a very definite capture effect, there will be times when there are so many people trying to use the bird that you simply won't be able to get into the transponder no matter how hard you try. And you will also occasionally encounter high-powered, so-called "alligators" on the birds. These are people who routinely operate with "all mouth and no ears" and, in the process, end up hogging the bird's FM uplink.

If this happens, just keep trying to drop your call sign in between their transmissions. Or, failing that, simply try again on another pass when, hopefully the "alligators" will be out of the satellite's footprint … or out to lunch! I've had the best luck on these satellites with my HT and Arrow during less busy, mid-week passes where the maximum elevation angle to the satellite from my location was at least 30 degrees above the horizon.

Also, if you're fortunate enough to be operating from a location within a few hundred miles of an ocean coast, you may find it easier to get into these satellites with low power when the bird is out over the ocean than when it's passing over, say North America or Europe. That's because there will be fewer stations within the footprint to compete with you at that time, and most of those competitors will be farther from the satellite than you are.

What if I Don't Hear The Satellite?

This has happened to all of us at times, so *don*'t give up! Go back and re-check the satellite's operating schedule at **www.amsat.org/amsat-new/satellites/status.php** to be absolutely sure you are listening and transmitting on the correct frequencies. Another culprit may be that your tracking software is providing you with erroneous pass data. Double check your satellite tracking program to be sure that you have a fresh set of Keplerian elements loaded, that your location file (station latitude and longitude or Maidenhead Grid Square entry) is correct and that you *also* have the proper

More on Antennas

The Arrow II Satellite Antenna Model 146/437 provides an impressive forward gain of approximately 10.3 dBd at 70 cm and 4.6 dBd at 2 meters. Sturdily machined from aluminum arrow shafts (hence the name), this antenna actually consists of two antennas mounted at right angles to each other on the same boom … a three element Yagi for 2m and a seven element Yagi for 70cm. A removable foam handgrip and threaded horizontal and vertical photo tripod mounting holes underneath the handgrip make this totally collapsible antenna also useful for terrestrial radio direction finding or portable emergency work.

Options include a split boom and a removable 10-watt duplexer inside the boom along with an assortment of cloth carry bags. With prices starting at about US $75 (minus the split boom and duplexer options) the antenna has, quite literally, spawned a whole new way for thousands of hams worldwide to work the "birds".

I actually own two of these split-boom and duplexer-equipped Arrow antennas and I remain absolutely delighted with their performance. One of them, along with my Kenwood TH-78A handi-talkie (HT), goes with me in my vehicle or suitcase whenever I travel. Using my Arrow and my HT, I've been able to consistently work thorough AO-27 and SO-50 down to about 10 degrees elevation. I've also heard and worked AO-51's half-watt transmitter nearly all the way out to the horizon.

Several Amateur radio dealers offer various versions of both the Arrow and Elk Antennas in their catalogs or they can be ordered directly from their respective manufacturers (www.arrowantennas.com or www.elkantennas.com). Right now, the Elk antenna is also available in limited quantities via telephone order from Martha at the AMSAT office with the proceeds going to benefit AMSAT. You can call Martha toll free from the US or Canada at 888-322-6728 (or 301-589-6062 elsewhere) to order yours today!

Photo 9: An optional carry bag keeps all the disassembled Arrow elements together for easy transport. (KB1SF Photo)

GMT versus local time offset loaded into the software. And don't forget to take into consideration Daylight Savings Time at your location.

It is also important to remember that transponder schedules and pass times for these satellites are all expressed in GMT and will vary from day to day … that's why you need computer software to track them. I can't begin to tell you how many times I've gone outside to work one or more of these satellites only to find I was listening for them at the wrong time or on the wrong frequency! All of which simply proves that even former AMSAT Presidents (like me) are *well* capable of falling victim to such simple errors!

For best results, your software's uploaded Keplerian Element files (I also briefly discussed Keplerian Elements in my previous article) should be updated at least once a month. If you don't already have a computer tracking program, check out the software tracking page on the AMSAT web site at **www.amsat-na.com/store/category.php?c=Software** and obtain a copy of their SAT-PC32 software. For a small monetary donation to AMSAT, the software can be obtained either via download from our Web site or via CD-ROM directly from Martha at AMSAT Headquarters.

What's more, the AMSAT Web site sports an online tracking display at **www.amsat.org/amsat-new/tools/predict/satloc.php?lang=en&satellite=AO-51** for a number of AMSAT satellites (including AO-51, AO-27 and SO-50). Use the drop down box under the map display to select the satellite you wish to track. I routinely use it as a quick cross-reference to what my computer's tracking software is displaying to make sure I have everything in my computer set correctly. The orbital position of the satellite you are tracking with your computer software should roughly match what's being displayed online by AMSAT.

Looking Ahead

By the time we next meet, I hope to have contacted many of you on one of our EZ Sats. In future columns I'll be discussing some innovative ways to optimize your base station antennas and feed lines to work the birds from inside your "shacks", as well as to pass along some other "tricks of the trade" to make your beginning satellite contacts more frequent and enjoyable. See you then!

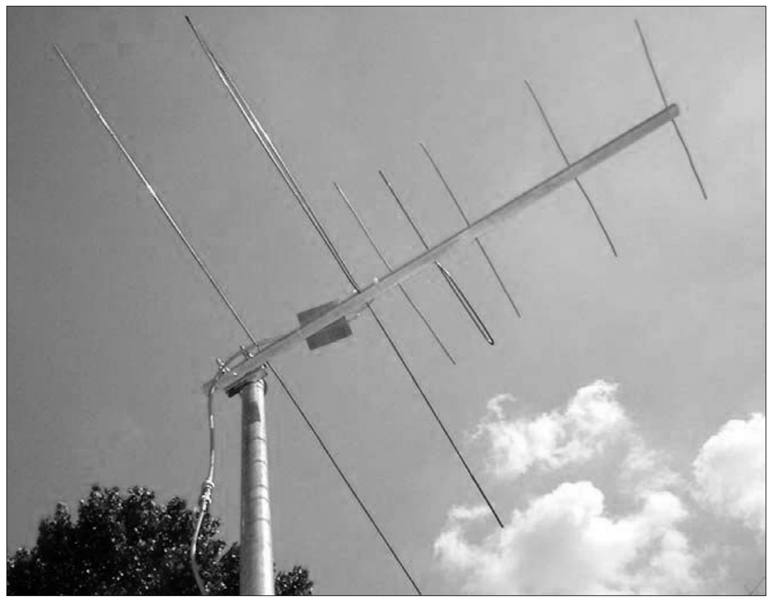

Photo 10: Kent Britian's "Cheap LEO" antenna uses aluminum ground wire and bronze welding rods for elements. The boom is made out of wood. (Courtesy: WA5VJB)

Photo 11: AMSAT board of directors member Drew Glasbrenner, KO4MA, works the birds using one of Kent Britain's "Cheap LEO" antennas. (Courtesy: WA5VJB)