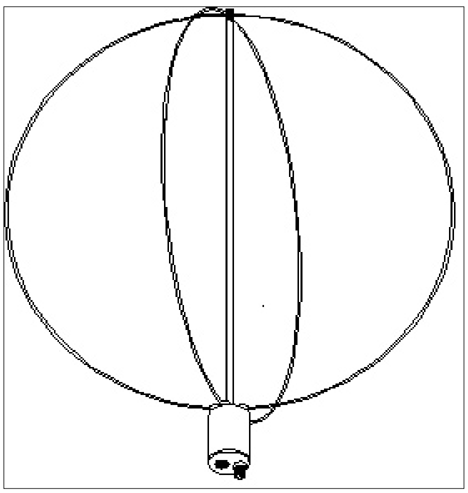
Getting Started on the Amateur Radio Satellites (Part III)

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

(The bulk of this article was previously published as "Working Your First Amateur Radio Satellite (Part III)" in the May 2010 issue of *Monitoring Times*, Brasstown, NC 28902)

I trust by now a number of you are up and running on our FM birds and are having fun collecting new grid squares or working DX with this (for you) new found part of our wonderful hobby. However, my hunch is that your arm is probably getting tired while working these satellites using just a small, portable, handheld radio and a handheld Yagi of some sort.

In anticipation of springtime's warmer weather (in the Northern Hemisphere at least!) my guess is that you'd like to now begin investigating a more permanent antenna array for your satellite station. For beginners on a budget, I suggest you consider some form of omnidirectional antenna.



The Eggbeater is a good omnidirectional base station antenna useful for working the LEO birds. (Courtesy: M2 Antennas)

That's because their use tremendously simplifies building your satellite station, as no rotors, cross booms, or rotor interfaces are needed. Use of omnidirectional antennas also greatly simplifies the satellite tracking part of this activity as it will allow you to fully concentrate on trying to hear, find (and/or track) your own downlink signals while working the bird as it rapidly moves across the sky.

But, unfortunately, and as we have discussed, not all omnidirectional antennas are suitable for satellite work. So, in this edition of our beginner's corner, I'll once again offer some tips to help you optimize your base station antennas for the satellites.

More Satellite Antenna Considerations

Contrary to what you might have heard (from well meaning veteran satellite ops) that only a cross-polarized set of multi-element Yagi antennas mounted on a non-metallic cross boom will do, I know from my own personal experiences that such talk is largely bunkum. That is, just as with most other pursuits in Amateur Radio, while the "ultimate" satellite base station antenna array may sport one or more circularly polarized Yagi antennas all mounted on a fiberglass cross boom and turned by an (expensive!) commercial alt-azimuth rotator, you can usually still get excellent results on the LEO birds for a whole lot less time, money and effort.

If you already have a VHF and UHF base station set up for scanning or for use on the amateur bands, you probably also have an external VHF or UHF antenna of some sort connected to it. Unfortunately, the gain of most of these terrestrial antennas occurs at the point in a satellite's orbit where it is farthest away from you (at the horizon) and its downlink signal is at its weakest.

What's more, as the satellite rises above your horizon, it will gradually move outside the beam width of most terrestrially optimized antennas to the point that, when it is at its closest approach to you (directly overhead) you may not hear the satellite … and it may not hear you … *at all!*

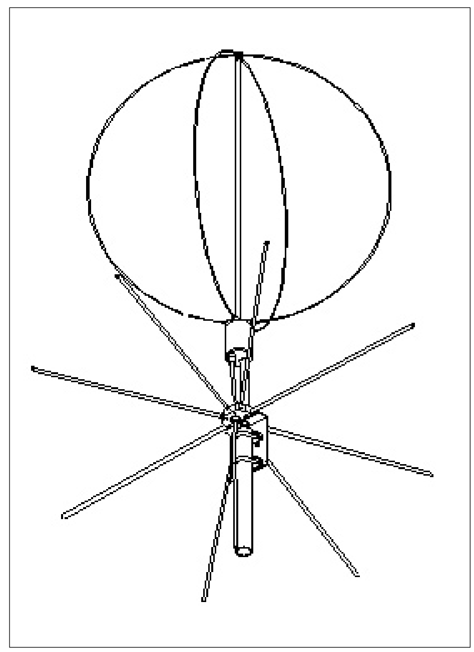
Remember, too, that Amateur Radio satellites are both tumbling and spinning in space. As we discussed in previous columns, cross-polarizing linear antennas results in a *huge* loss of gain. This means that if the antenna on the satellite is horizontally polarized and your antenna on the Earth is vertically polarized (or vice versa), you may not receive much of anything on the ground, no matter how much power is being transmitted to or from the satellite.

To help minimize these problems, satellite builders usually incorporate what are called circularly polarized antennas into their satellites. Building circularly polarized antennas into a satellite helps minimize the effects of antenna cross-polarization losses on the ground as the satellite moves through space. That's because the difference between right-hand circular polarization and left-hand circular polarization is only about 3 dB.

Thankfully, there are a couple of relatively simple, omnidirectional antennas that are also specifically designed to achieve this high angle, circular signal polarization pattern without *also* costing you a fortune … or making your home look like a NASA tracking station!

Scrambled Eggs, Anyone?

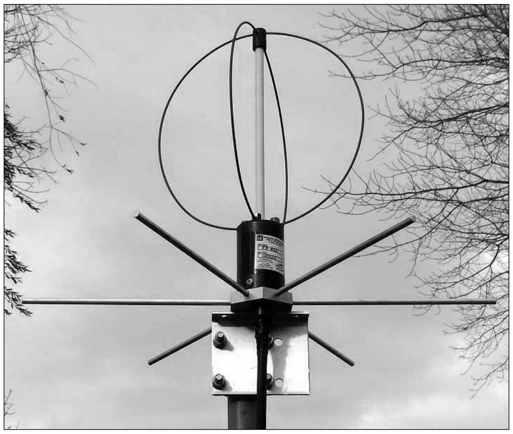
One relatively inexpensive omnidirectional base station antenna that is useful for LEO satellite work is called an Eggbeater. The Eggbeater antenna looks a lot like its namesake … an ordinary kitchen eggbeater. It's composed of two full-wave loops of wire (or some other rigid metal material) fed 90 degrees out of phase with each other. Some designs even sport parasitic reflector elements underneath the array to give the antenna more elevated gain. At the horizon, the eggbeater exhibits a horizontally polarized linear pattern, which



Adding ground plane elements under the Eggbeater increases the overall upward gain of the antenna. (Courtesy: M2 Antennas)

also makes it useful for weak signal VHF or UHF terrestrial work. However, at higher elevations, the antenna exhibits an ever more right-hand circular radiation pattern, which makes it *ideal* for satellite work.

Gerald Brown, K5OE, has published an excellent Web article on how to home brew satellite-optimized eggbeater antennas



This photo shows a view of the author's 70cm, M2 Eggbeater antenna. Note the ground radials mounted underneath the phasing coil. (Courtesy: KB1SF)

at: **http://victrolla.homeip.net/wo5s/junkpile/432/eggbeater2.pdf.** Eggbeaters are also available from commercial antenna manufacturers such as M2 Antennas of Fresno, California (**http://www.m2inc.com).**

I'm currently using a pair of commercially made M2 eggbeater antennas at my home QTH and find they work reasonably well for the LEO birds, particularly if the antenna's reflector elements are installed.

Now, granted, eggbeaters *won't* give you horizon-to-horizon, S9 signals either into (or out of) the birds like a long-boom Yagi will. But, remember, satellite work is by default, weak signal work. Using a reasonable amount of uplink power (usually 25 watts or less) and a pre-amplifier for the downlink mounted either on the antenna mast (or if your high quality feedline is short enough, in the shack) I've found I can get good results with these antennas on most overhead (or near overhead) passes. As a general rule, I don't bother trying to work a satellite pass with my eggbeaters unless the satellite will be at least 45 to 50 degrees above my horizon at its highest point.

A Quadrifilar WHAT?

Another omnidirectional antenna design suitable for satellite work is a Quadrifilar Helix (or Quadrafilar Helicoidal) antenna. A Quadrafilar Helix antenna consists of four quarter-wavelength or half-wavelength elements fed with a 90-degree phase difference. The polarization is circular, and the beam widths are often greater than 90 degrees, which means this antenna will cover a HUGE chunk of the sky.

These antennas are also relatively small and fairly easy to build out of common materials such as copper tubing and PVC pipe. However, element lengths and spacing have to be *very* precise to achieve a truly circularly polarized pattern.

A number of ham operators (and others who are also interested in weather satellite reception) offer design tips and construction details for these antennas via various Web sites including **http://www.n8imo.com/qha_4.html** and **http://perso.wanadoo.es/dimoni/ant_qha.htm.** Yet another Web site on the subject, (**http://www.jcoppens.com/ant/qfh/calc.en.php)** sports a helpful online calculator where element lengths and spacing for these antennas can be calculated simply by entering the desired resonant frequency.

The Lindenblad

Yet another omnidirectional antenna design that can be useful for satellite work is the Lindenblad. The antenna is named for Nils Lindenblad of the Radio Corporation of America (RCA) who, back in the early 1940s, began experimenting with antenna designs that might be useful for the (then emerging) television broadcast industry. The antenna uses four dipoles spaced equally around a 1/3-wavelength circle with each element canted at a 30-degree angle from horizontal.

Like the Quadrafilar Helix, construction articles on how to roll your own Lindenblad abound on the Internet. Howard Sodja, W6SHP, optimized the Lindenblad design for satellite work in a series of articles for *The AMSAT Journal* in the early 1990s. The articles can still be found in the AMSAT Web archives at: **http://www.amsat.org/amsat/articles/w6shp/lindy.html.** In addition, AMSAT's current Vice President of Engineering and BoD Member, Tony Monteiro, AA2TX, has written extensively on the Lindenblad design. Construction details of his 70 cm version of the Lindenblad appeared in the Proceedings for the 2006 AMSAT Annual Meeting and Space Symposium at: **http://www.qsl.net/nwlarn/sat/70ParaLindy.pdf.**

Directional Antennas

As the name implies, directional antennas focus RF energy in one direction. Not only do these antennas allow you to transmit your signal to satellites that are farther away from you, they also help your ground station pick up weaker signals, provided that the antennas are pointed in the right direction. As all satellite work is weak signal work, *anything* that boosts an already weak satellite downlink signal is a good thing.

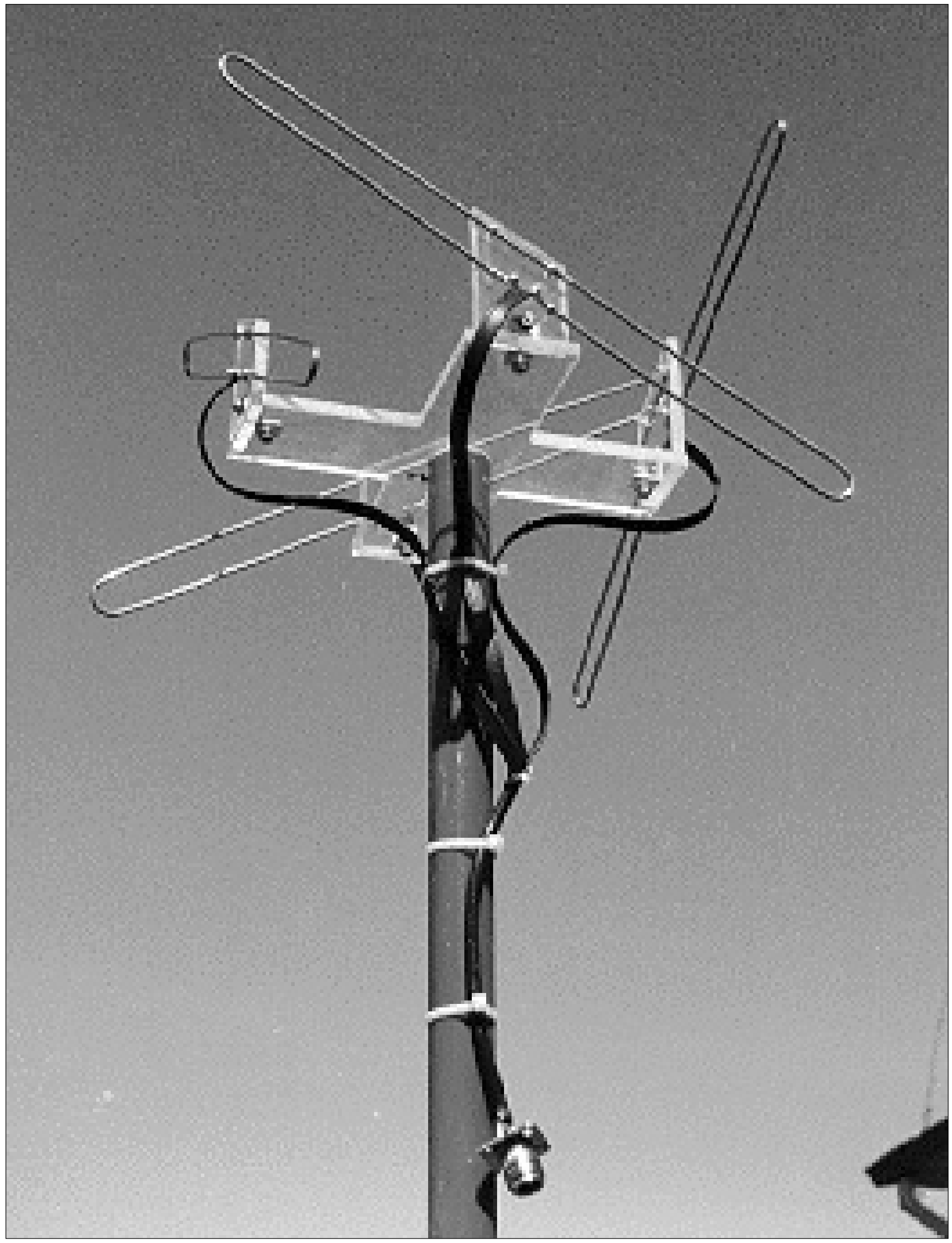
Here's a partial view of the phasing coil and ground plane of the author's 2 m, M2 Eggbeater antenna. Note that the ground plane radials are offset by about 1/2 wavelength (10.5 inches) from the top of the phasing coil and driven elements. (Courtesy: KB1SF)

Many satellite operators use some form of Yagi antenna in their Earth stations. The design is named for its Japanese inventor, Yagi-Uda, and consists of one or more dipoles that are fed with RF and act as driven elements. Parasitic (that is, non-fed) elements (called reflectors) are then mounted in back of the driven element and one or more parasitic elements (called directors) are mounted in front. The whole array is then mounted on a cross boom of some sort.

Yagi antennas can be either linear or circularly polarized. Yagis with only one row of elements are linearly polarized (either horizontal or vertical depending on which way you mount them). However, Yagis with two rows offset by a 90-degree phase difference are circularly polarized (either right-hand or left-hand, looking down the antenna from the rear).

As I've discussed, for satellite communication, circular polarization is desirable because the difference in loss between right-hand (RHCP) and left-hand (LHCP) circular polarization is only about 3 dB. And while this loss represents about half of your uplink or downlink signal, remember that the difference between horizontal and vertical polarization is theoretically infinite. In the real world, however, the difference between

The Quadrafilar Helix antenna is a relatively easy to build, omnidirectional antenna that can be optimized for both Amateur Radio and weather satellite work. (Courtesy: Bob Cash, N8IMO)



The Lindenblad antenna is yet another, relatively easy to build omnidirectional antenna suitable for satellite work. (Courtesy: AMSAT)

horizontal and vertical polarization is around 30 to 40 dB. But that's *still* over a thousand times more loss than the difference between RHCP and LHCP!

Also, the number of elements on a Yagi is directly proportional to its gain. More elements means more gain. However, as in most other things in life, there's a tradeoff between gain and beam width. That is, the higher the gain, the narrower the beam width. So, while a 40-element Yagi may provide excellent gain, it becomes quite another matter to keep it continually pointed directly at a satellite that's rapidly moving across the sky.

The bottom line here is that, while circularly polarized Yagi beam antennas are absolutely wonderful for full coverage satellite work (and I've used my share of them over the years) they are absolutely *not* essential. I've still achieved consistently good results, particularly on the LEO birds, using any number of simple, linearly polarized (hand-held or mounted) Yagi beams and/or eggbeater designs.

My success with linear polarized Yagi antennas is probably because most of our satellites use circularly polarized antennas for their downlinks and they also rotate and tumble through space. So, the practical effects of cross polarization are at least partially minimized by these two factors. This also means that the amount of time when your and the satellite's antennas will be *truly* cross polarized will usually be so brief that the momentary drop in signal strength will most often be imperceptible to your ear.

You can find any number of cheap and easy Yagi antenna designs and construction details on the Internet. A collection of three such articles by Richard Crow, N2SPI, ran in *The AMSAT Journal* in 2006 and have since been re-published on the AMSAT Web site at: **http://www.amsat.org/amsat-new/information/faqs/crow/index.php.**

Dish Antennas

Dish antennas are the next step up from Yagi antennas. However, the benefits of a dish are often not worth the cost at the VHF and UHF frequencies used by our current amateur satellite fleet. A dish starts to become feasible in the 1.2 GHz range. However, here again, the high gains achieved by a dish antenna are usually offset by the fact that the satellite is rapidly moving across the sky. What's more, complexity (and costs) increase dramatically when using dishes because there are not that many Amateur Radio dish suppliers around.

Usually, you'll have to adapt dish feeds and reflectors manufactured for other purposes.

Feed Lines for Satellite Work

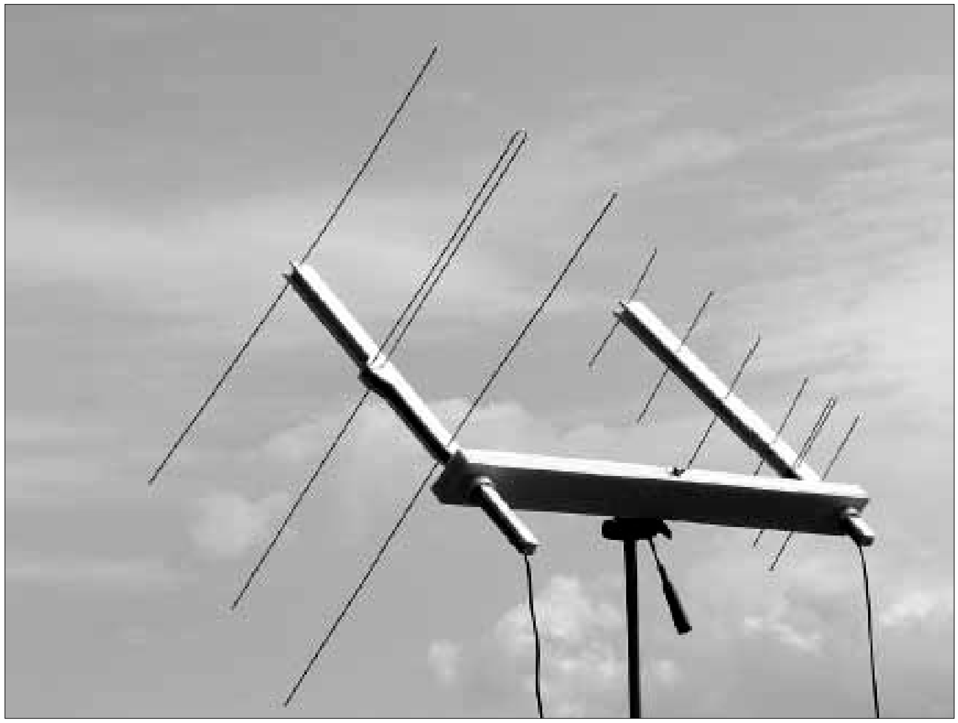
Most veteran satellite operators know that otherwise excellent antennas can be rendered quite useless if they are linked to your station equipment with poor quality feed line. The feed line is what connects your antenna to your radio. And, while the proverbial wet noodle feed line might work well for local VHF/ UHF repeater or scanner activity, again, because satellite work is weak signal work, many types of feed lines used in the former activity are *not at all* suited for the latter.

The principal concern with feed lines is *loss*, and every feed line has it to some degree. That is, if you insert 50 Watts into a feed line at your station, you'll have *less* than 50 Watts once your signal gets to your antenna. The rest of the power is lost somewhere in the feed line, usually in the form of heat. Unfortunately, these characteristics are also at work when you receive signals as well. And because the signal from one of our satellites is *already* weak when it strikes your antenna, it follows that you can ill afford to waste *any* of that RF heating up your feed line! What's more, those losses usually increase as the line length and operating frequencies being transmitted or received increase.

So, most of us working the birds these days are using some form of coaxial cable (or simply coax) for feed line. There are about as many varieties of coax as there are companies manufacturing them. However, most of us use some form of low loss coaxial cable such as Belden 9913 or Times LMR 400 as opposed to lengths of RG-58, RG-8X. RG-213 or RG-8 used in most other Amateur Radio work.

Veteran satellite operators use low loss coax cable in their Earth stations because, as the name implies, this coax exhibits much lower losses (particularly at VHF and UHF frequencies) than those used for other (primarily HF) amateur activities. For many years, I've used a variety of Belden 9913 coax for my various satellite stations. It exhibits a relatively low loss (on the order of about 2.6 dB at 400 MHz) per 100 feet), which is roughly half that of a similar length of RG-8 coax (about 4.1 dB).

The magic number to always keep in mind when comparing feed lines is 3 dB. That's because, for every 3 dB of loss, roughly *half* of your signal is being wasted in the feed line. So, in the example above, at frequencies close to our uplink and downlink frequencies (400 MHz), using a 100-foot length of RG-8 means that *well* more than half of your uplink power (or downlink signal) will be lost in the coax.



Satellite antennas don't need to be fancy to be effective. Here, a pair of vertically polarized, home brew Yagi antennas made from bits of wire and wood are mounted on a wooden cross boom. (Courtesy: AMSAT)

Unfortunately, for all of its low loss attributes, Belden 9913 also has a dark side. Because the dielectric in this coax is largely made up of air, it tends to attract moisture. And even though you can try your best to completely seal connection points from the elements, over time, the normal heating and cooling of the atmosphere *will* result in moisture getting into the cable. For this reason, veteran satellite operators sometimes (derisively) refer to 9913 and its variants as garden hose.

Fortunately, a newer brand of cable on the market, called Times LMR 400, offers about the same loss characteristics as Belden 9913 at about the same price, but without the garden hose issue. An excellent discussion on various types of transmission lines (including their loss characteristics) can be found at: **http://www.hamuniverse.com/coaxdata.html.**

Looking Ahead

In future articles, I'll continue our discussion of innovative ways to optimize your satellite base station, including how to select the proper connectors for your antenna feed lines and what to look for when selecting a base station radio. I'll also pass along some more tips on how to find and track our Amateur Radio satellites. See you then!