For Beginners – An Amateur Radio Satellite Primer

Keith Baker, KB1SF/VA3KSF, Treasurer and Past President

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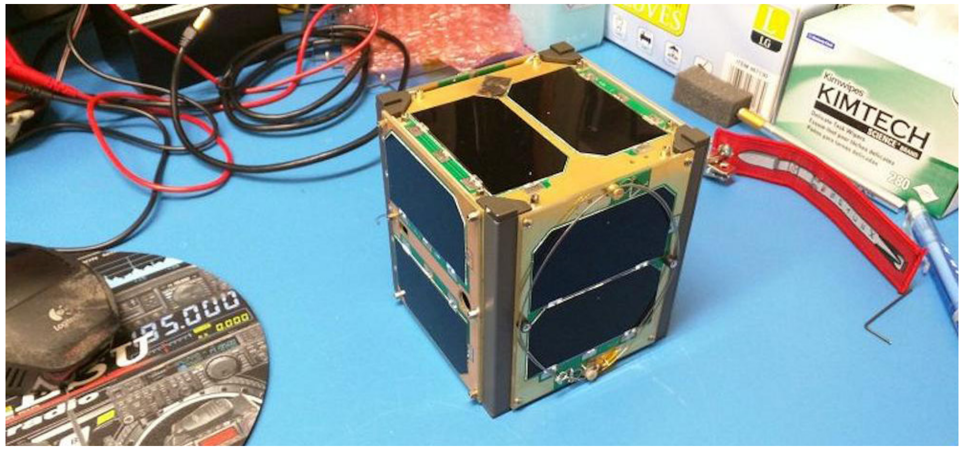


The flight model of AMSAT's RADFXsat-1 (Fox-1B, later AMSAT-OSCAR-91 on orbit) awaits final testing at the Fox Labs in Texas. (Courtesy: AMSAT)

One of the great features of amateur radio is that it is several hobbies rolled into one. If you become bored with one aspect of the hobby, there is always something new or different to try. For over the last 60 years or so, using our fleet of amateur radio satellites to communicate has always been one of the more interesting aspects of amateur radio.

My goal in my satellite-related writings for several publications (starting with my first "getting started" book called *How To Use the Amateur Radio Satellites,* which was used as an AMSAT member benefit back in the mid-1990s) and then for recurring columns in *Monitoring Times*, *The Spectrum Monitor* and *The Canadian Amateur* magazines) has always been to provide those interested in this aspect of the hobby with a general introduction to the basic concepts of tracking and operation as well as the customs currently in use on the amateur radio satellites. My other goal has been to give our more experienced satellite operators some practical, "hands-on" tips on how to use our current fleet of amateur radio satellites as well as to offer the very latest information on those satellites already in orbit, plus those currently "on the drawing boards" for eventual launch.

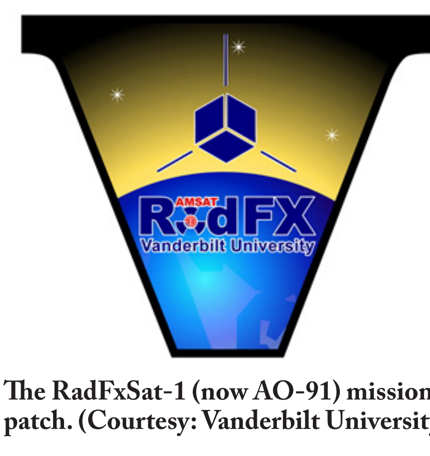
The author holds one of the early engineering models of our AMSAT Fox series of satellites at a recent AMSAT Symposium. (Courtesy: AMSAT)

However, if you are new to amateur satellites (or the "birds" as we satellite operators often call them) and have recently joined AMSAT, it's essential to establish a general understanding about how to find and track these modern-day wonders before you make your first attempts at using them.

As it's been a while since I've shared a basic introduction to satellite operating in our *AMSAT Journal* (and based on the scores of new AMSAT members I've since spoken to on the satellites and at our various AMSAT booths during recent hamfests) it's probably time to once again go back to the basics and share some "how-to" information for those who are just becoming interested in this fascinating aspect of our wonderful hobby. So, let's get started.

Overcoming the "Fear Factor"

Indeed, for most of us, the thought of using our own radio equipment to hear or talk through a satellite conjures up a sense of mystery and awe. At the same time, it creates a certain amount of fear...fear of doing something wrong, or of not ever being successful no matter how hard we try. In years past, when only one or two amateur satellites were in orbit, hams had to really work hard to even hear one of the OSCARs (Orbiting Satellites Carrying Amateur Radio) as they whizzed overhead.



The RadFxSat-1 (now AO-91) mission patch. (Courtesy: Vanderbilt University)

As of this writing, some 20 or so active satellites are up there (with scores more on the way!), and that's not even counting the crew of the International Space Station (ISS) who use the amateur radio equipment installed aboard that permanent orbiting laboratory. So, it's safe to say your chances of at least hearing one of them (or, if you have a U.S. Technician ticket, actually communicating through one or more of them with your current equipment) is far better now than at any time in the recent past. All it takes is a little knowledge and some basic equipment and antennas, some of which you may already have or that you can build for just a few dollars.

Tracking the Birds

To listen for, or communicate through, an amateur radio satellite you first have to find out when it will be within range of your station. Fortunately, most of us now have a computer in our ham shacks with access to the Internet, so tracking satellites has become much easier than it used to be.

Today, several satellite-tracking programs are available in shareware form or for purchase, as well as in a variety of different computer formats. What's more, numerous web sites related to amateur satellite operation now have online tracking programs that make rough tracking a snap. But, if you're serious about satellite tracking, you should also become familiar with how to use sets of orbital data called Keplerian elements.

Known to veteran satellite operators simply as "Keps," these data are derived from observations of each satellite's orbital motion. (Kepler, you may recall, discovered some interesting things about planetary motion back in the 17th century!)

Today, NORAD, the North American Aerospace Defense Command, keeps track of almost everything in Earth orbit. Periodically, they issue orbital information on non-classified satellites to the National Aeronautics and Space Administration (NASA) for release to the general public. The information is listed by each satellite's catalog number and contains numeric data that describes, in a mathematical way, how the satellite is moving around the Earth.

Without getting into the complex details of orbital mechanics (or Kepler's laws!), suffice it to say this data is what your computer software uses to plot the predicted paths of satellites. That is, once you've loaded your location (latitude and longitude), the current time (along with your local offset from Coordinated Universal Time (UTC)) along with the Keplerian element files into your satellite tracking software, the computer then solves the complicated orbital math to make a prediction of where a selected satellite should be at the current (or a future) time.

Keplerian Element Sources

However, because they are such a vital ingredient to this part of our hobby (and because they age over time) finding a reliable source for the latest Keplerian elements for amateur radio satellites should be high on your list of things to do as you get started in satellite work. Many amateur radio-related websites often list Keps.

Our AMSAT website lists the latest Keps in a variety of downloadable formats at **www.amsat.org/keplerian-elements-resources**. For the so-called "easy FM birds" (like our recently launched AO-91 and the ISS), the AMSAT website even sports an embedded online tracking feature which allows you to simply plug in your latitude and longitude (or your Maidenhead Grid Square) to find out when those satellites of interest will next be in range of your location. That online tracking program can be found at **www.amsat.org/track/index.php**.

Beacons

Probably one of the first things you will learn to do after you find out when a particular satellite will be within range of your station is to listen for the satellite's beacon. Most satellite beacons consist of one or more transmissions coming from the satellite that will assist you in your search as well as tell you other things about the satellite's health and the nature of its transponders.

Satellite beacons operate in many modes, from Morse code to a variety of digital formats, and can usually be found on frequencies immediately above or below the satellite's other downlink frequencies. In addition, as most satellite beacons transmit with a fixed amount of output power, they can also serve as a superb reference point for setting up and calibrating your station antennas and other equipment.

Most satellite telemetry signals, which consist primarily of transmissions about the health of the satellite, are also sent to ground controllers by way of the beacon. What's more, some satellites even provide information regarding their transponder schedules, along with other items of interest to satellite operators, using their beacons. However, in the case of AO-91 and most of our other popular FM satellites, the single-channel downlink itself is the beacon.

Transponders

So, once you have a reliable way to know when the satellite is within range of your station, and you've become familiar with its beacon, you next have to learn how to use its transponder. A transponder is a circuit that receives your uplink signal and then retransmits what it hears via its downlink transmitter, much like a terrestrial FM repeater does. However, unlike a terrestrial FM repeater, which has a specific input and output frequency in the same band, most amateur satellite transponders receive and then retransmit what they hear on another frequency (or frequencies) on another amateur band entirely. In short, most amateur satellites act much like cross-band "repeaters in the sky."

Moreover, as a satellite is a moving target, signals passing through it will exhibit a pronounced Doppler shift, just like the changing pitch of a train whistle as it approaches and then passes. During a satellite contact, as the satellite approaches you, both uplink and downlink frequencies will appear higher than those published. As the satellite passes overhead, both the uplink and downlink frequencies will then appear to drop slowly in frequency from those published. And, as if that weren't confusing enough, this apparent frequency shift will seem to be more pronounced on the higher frequency (shorter wavelength) amateur bands than on the lower ones.

Our example satellite (AO-91) uses what's called a "bent pipe," FM transponder. That is, whatever FM signals are sent up to the satellite on its single-channel uplink are then "sent through the pipe" back down on its single-channel FM downlink.

Operating Modes

One of the terms you will also come across in satellite work will be a reference to the

A worker bolts one of the three "PeaPod" carrying structures, one of which successfully carried AMSAT's Fox-1B satellite (now AO-91) to orbit to the upper stage of its Delta II rocket. (Courtesy: NASA)

The Delta II launch vehicle carrying AMSAT's Fox-1B satellite (which later became AO-91 on orbit) successfully lifted off from Vandenberg AFB at 1:47 Pacific Standard Time on November 18, 2017. (Courtesy: NASA)

mode of a satellite's transponder. A satellite's operating mode is nothing more than a shorthand way veteran satellite operators identify the various combinations of uplink and downlink frequencies available for use.

Back in the early days of satellite operating, one or more letters of the alphabet were used to designate satellite transponder modes. For example, if a satellite's uplink frequency was on 2 m and its downlink frequency was on 70 cm, the satellite was said to be operating in "Mode J." An uplink on 70 cm with a downlink on 2 m was called "Mode B," and so on.

Today, because so many satellites with different uplink and downlink transponder combinations are now in orbit, a more simplified system that includes the first letter of the band in use (VHF, UHF, SHF, etc.) has emerged. As a result, the old "Mode B" has now been renamed "Mode U/V" because the satellite's uplink transponder is tuned to UHF and its downlink transmitter is set for the VHF bands. Likewise, the old "Mode J" has now been dubbed "Mode V/U" and so on. The AO-91 transponder I'm talking about is the one for Mode U/V — or the old Mode B — with uplinks in the 70 cm band and downlinks in the 2 m band.

That's enough of the "getting started" information for this time. But please stay tuned. In subsequent *Journal* articles, I'll continue to show you how easy it is for you to become active on the "birds." We'll be exploring how to select your satellite antennas, feed lines, and radios as well as some helpful hints to make your first forays into satellite operating far more enjoyable. See you then!

SATELLITE	*MODE*	*UPLINK (MHz)*	*DOWNLINK (MHz)*	*BEACONS (MHz)*
AO-91 (Fox-1B)	U/V (Mode B)	435.250	145.960	FM Voice (67.0 Hz Tone to Access) FSK 9600 bps data

For Beginners – Amateur Radio Satellite Primer II

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

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

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 still on the drawing boards or presently being prepared for launch.

I trust my first article in *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 many people have labored long and hard to put into orbit (and then command) for our use.

However, before you progress further, I need to share a few more considerations and tricks of the trade with you so that your attempts at hearing or working through one or more of our so-called "EZ Sats" will be more successful.

One Arrow version 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.

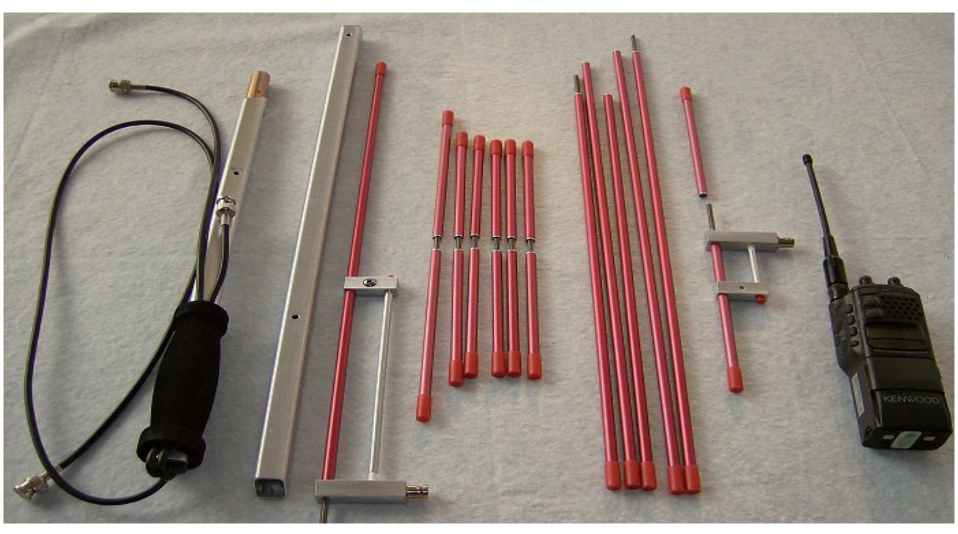
Some Additional Handheld Antenna Considerations

First, let me say right up front that, in satellite work, your antennas are, without a doubt, the most essential 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-91 and AO-92 — typically 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 (in the case of SO-50) what's called a "turnstile" antenna array that usually consists of a set of four; quarter-wavelength 2 m or 70 cm 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 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 hear them reliably. 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.

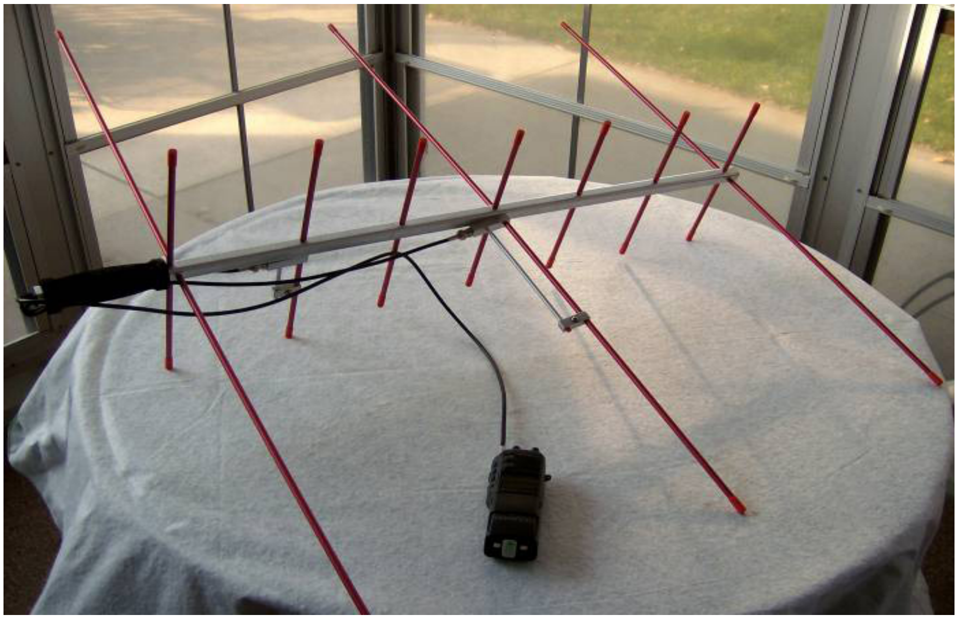


The author's satellite "hand shack" consists of an Arrow Model 146/437 Antenna and a Kenwood TH-78A dual-band handie-talkie (HT). The antenna easily breaks down into several pieces for easy transport. [All photos courtesy of Keith Baker, KB1SF unless otherwise noted.]

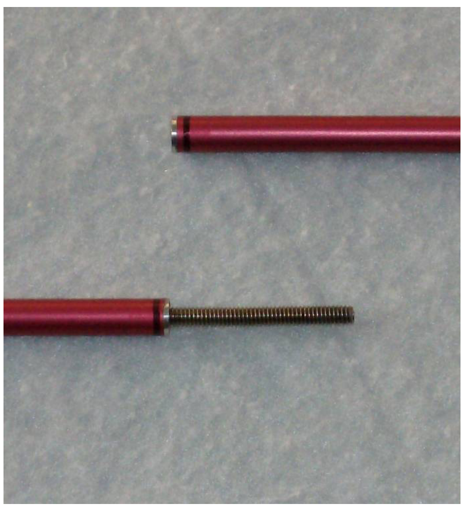
The Harsh Environment of Space

Another consideration you must take into account concerns 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! 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 quickly 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

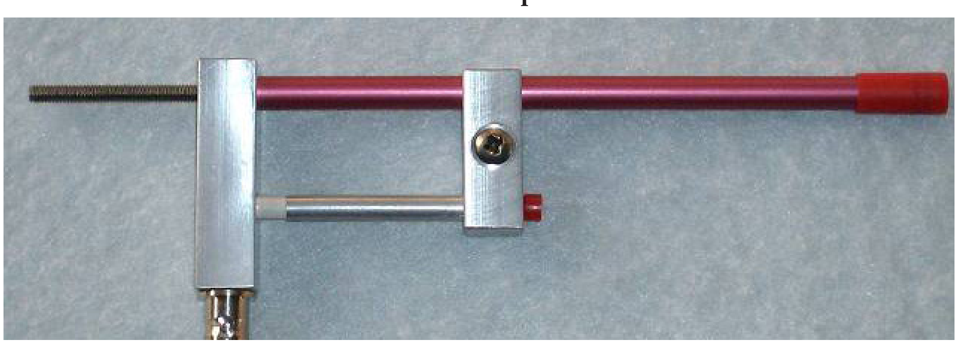


The author's assembled Arrow Antenna with Kenwood TH-78A HT attached.



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 their opposite element on the other side.

Removing the duplexer and foam grip reveals screw holes for mounting the Arrow Antenna on a lightweight photo tripod.



The Arrow features beautifully machined gamma-matching stubs for both the 2m and 70 cm feeds. Note the 70 cm feed stub.

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, 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 battery-powered, modern digital camera outside in sub-zero temperatures knows that you have to keep several sets of batteries in a warm pocket or two if you ever hope to capture more than one or two photos under such conditions.

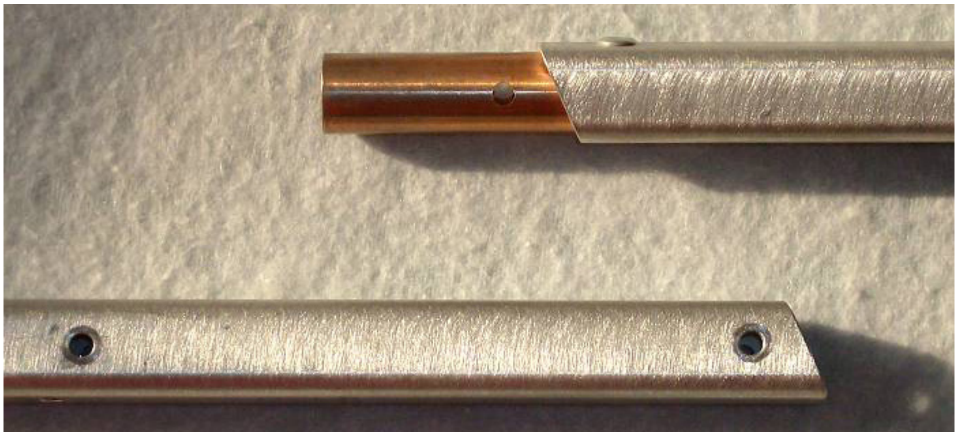
So, with our satellite batteries baking inside a metal box at 250 degrees Celsius in full sun (and then freezing at minus 250 degrees during eclipse), just imagine what they and other electronic components go through on every orbit! That's why our AMSAT satellites (and, indeed, most others) are all designed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

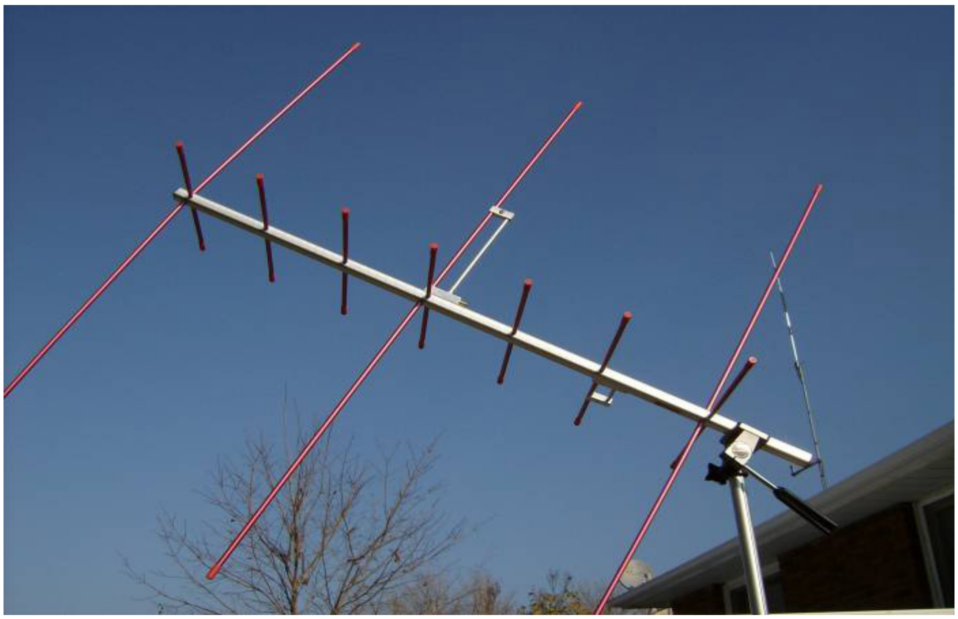
Doing the Tumble

Furthermore, to keep their downlink antennas properly oriented toward the Earth, some of these birds (like SO-50) 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, in the case of SO-50, this tumbling motion also helps keep what meager gain its transmit antennas are radiating pointed back down toward the Earth and us.

Unfortunately, this constant (and sometimes random for the CubeSats) tumbling motion means that the polarity of the satellite's receiving and transmitting antennas will be



An optional version of the Arrow sports a tight-fitting, split boom feature.



The Arrow mounted on a photo tripod.

An optional carry bag keeps all the disassembled Arrow elements together for easy transport.

continually changing as it moves overhead. And, as satellite work is line of sight, 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 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 don't provide the required ground plane for such antennas to be fully capable.

And, finally, because the downlink signal strength of most of these satellites is so weak to start with, most scanners (or other, so-called "broadband" 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 typically 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 whip and "rubber duckie" antennas are adequate 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.

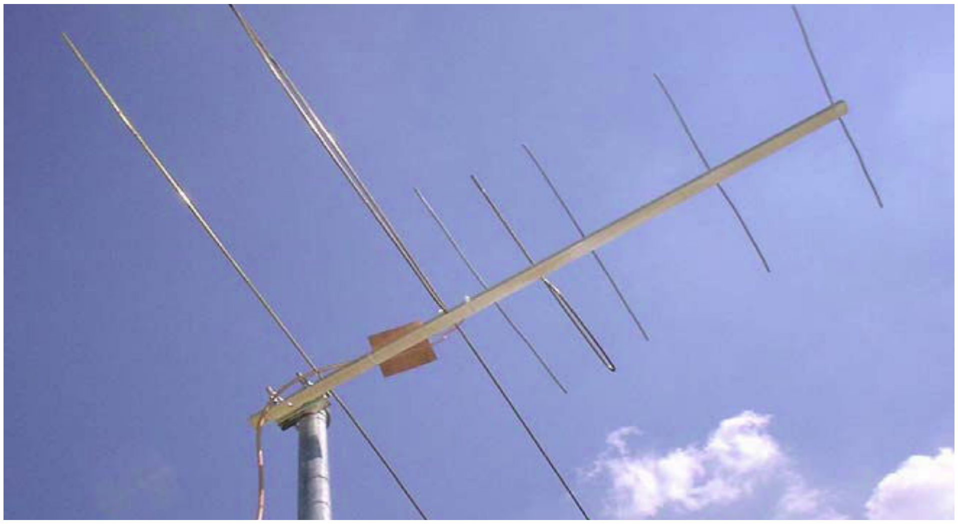
However, before you say, "I'll never be able to get on the birds" and give up in disgust, let me also say that with the creative addition of a set of small (and relatively inexpensive) Yagi antennas to produce a bit more uplink and downlink gain, your HT can become a very effective Earth station for use with these satellites.

Handheld Yagis to the Rescue!

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/UHF enthusiast Kent Britain (WA5VJB) have been freely sharing their learning by publishing numerous plans on the Internet for a series of homebrewed handheld yagis for 2 m and 70 cm 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).

In an excellent online article entitled "Cheap Antennas For The AMSAT LEOs" at **www.wa5vjb.com/references/Cheap%20 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 homebrew antennas can be found in an excellent series



Kent Britain's "Cheap LEO" antenna uses aluminum ground wire and bronze welding rods for elements, with a boom made of wood. [Courtesy: WA5VJB.]

AMSAT Board of Director's member Drew Glasbrenner, KO4MA, works the birds using one of Kent Britain's "Cheap LEO" antennas. [Courtesy: WA5VJB.]

of beginner articles on or own AMSAT website at **www.amsat.org/cheap-and-easy-yagi-satellite-antennas/.**

If building your own antenna from scratch isn't your thing, fortunately, several commercial antenna manufacturers cater to LEO enthusiasts. Antennas such as the Arrow model 146/437-10 dual-band handheld beam antenna (sidebar) or the Elk Antenna model 2m/440 from 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

A key point to remember is that when you attempt to communicate through them, these satellites will be spinning and tumbling in orbit, so their uplink and downlink antenna polarizations will continuously be changing. If you are using a whip antenna on an HT 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 polarization 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.

The same thing goes if you are using a hand-held Yagi antenna of some sort. Simply flicking your wrist to change the polarization of either the uplink or downlink portion of that antenna may make an otherwise unworkable downlink signal into one that's full quieting.

As I also noted in my first beginner's feature article of the *Journal*, if you are using an HT, you'll also want to 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. 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.

Another excellent 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, 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. Such activity will NOT make you a popular "camper" on the bird!

What's more, because they are so weak, the downlink signals from AO-91, AO-92 and SO-50 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, 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.

The author works through the AO-91 Satellite using an Arrow Antenna from the beach at Fripp Island, South Carolina. [KB1OGF photo.]

Also, if you're fortunate enough to be operating from a location within a few hundred miles of 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/status/ to be sure that the satellite is active and that 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 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 proves that even former AMSAT presidents (like me) are well capable of falling victim to such simple errors.

For best results, update your software's uploaded Keplerian Element files (I also briefly discussed Keplerian Elements in my previous article) at least once a month. If you don't already have a computer tracking program, check out the software tracking offerings at the AMSAT store at **www.amsat.org/shop/** and obtain a copy of AMSAT's SAT-PC32 software. For a small monetary donation to AMSAT, you can download the software from AMSAT's website or order a CD-ROM directly from AMSAT headquarters.

What's more, the AMSAT website sports an online tracking display at **www.amsat.org/track/index.php** for many AMSAT satellites (including AO-91, AO-92 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 my next installment appears, 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 shack, 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!

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 2 m and a seven-element Yagi for 70 cm. A removable foam handgrip and threaded horizontal and vertical photo tripod mounting holes underneath the handgrip make this 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 $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 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 handie-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 through AO-91 and AO-92 down to about 10 degrees elevation.

Several amateur radio dealers offer various versions of the Arrow satellite antenna in their catalogs, or they can be ordered directly from the AMSAT store at **www.amsat.org/product-category/hardware/**

For Beginners – Amateur Radio Satellite Primer III

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

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I trust by now a number of you are up and running on our FM birds and having fun collecting new grid squares or working DX with this (for you) newfound part of our enjoyable 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 antenna of some sort.

Now that warmer weather (in the Northern Hemisphere at least!) is upon us, my guess is that you'd like to 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. That's because their use tremendously simplifies building your satellite station, as no rotators, cross booms, or rotator interfaces are needed. The use of omnidirectional antennas also greatly simplifies the satellite tracking part of this activity as it will allow you to concentrate fully on trying to hear, find and track your 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 satellite primer, 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 experiences that such talk is mostly bunkum. 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 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 beamwidth of most terrestrially optimized antennas to the point that, when it is at its closest approach to you (i.e., 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 I've discussed in previous columns, cross-polarizing linear antennas results in a considerable 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.

In the past, and to help minimize these problems, satellite builders routinely incorporated 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.

Unfortunately, today's small CubeSat satellites simply don't have enough surface area to mount circularly polarized antennas. Most incorporate just single whip antennas for transmitting and receiving. As a result, you'll often notice deep fades in their signals as the satellite tumbles in orbit over your station. However, using circular polarized antennas at your station will still help (but not completely eliminate) most of these effects.

Thankfully, a couple of relatively simple, omnidirectional antennas are also specially 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.

This antenna is 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 higher gain. At the horizon, the eggbeater displays a horizontally polarized linear pattern, which also makes it useful for weak signal VHF or UHF terrestrial work. However, at higher elevations, the antenna exhibits an increasingly right-hand circular radiation pattern, which makes it ideal for satellite work.
Gerald Brown, K5OE, has published an excellent online article on how to homebrew satellite-optimized eggbeater antennas at wb5rmg.somenet.net/k5oe/Eggbeater_2.html. Eggbeaters are also available from commercial antenna manufacturers such as M2 Antennas of Fresno, California (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, especially if the antenna's reflector elements are installed.

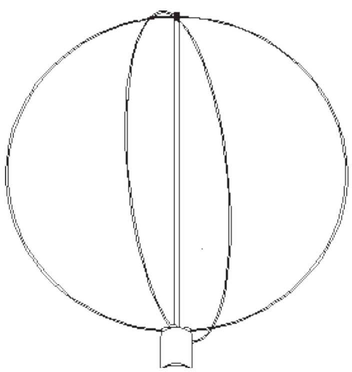
Now, granted, eggbeaters won't give you horizon-to-horizon, S9 signals either into or out of the birds like a long-boom Yagi will. But, as I've noted previously, satellite work is, by default, weak signal work. Using a reasonable amount of uplink power (usually 25 watts or less) and a pre-amplifier for the downlink mounted either on the antenna mast or, if your high-quality feedline is short enough, in the shack produces 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 and closest approach.

A Quadrifilar WHAT?

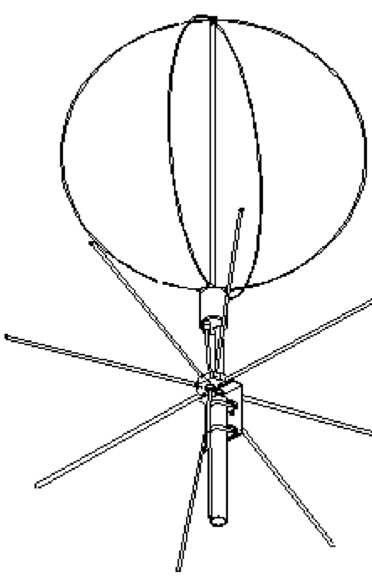
Another omnidirectional antenna design suitable for satellite work is a Quadrifilar Helix (or Quadrafilar Helicoidal) antenna. This antenna consists of four quarter-wavelength or half-wavelength elements fed with a 90-degree phase difference. The polarization is circular, and the beam widths are often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

These antennas are also relatively small and relatively 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.

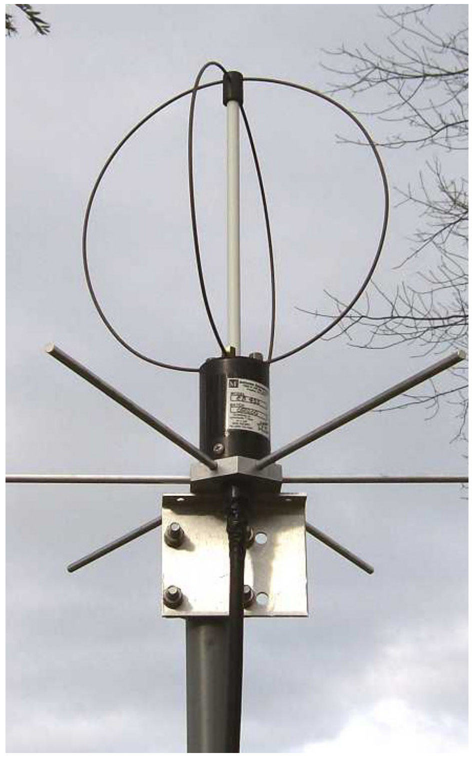
Some ham operators (and others who are also interested in other such pursuits as weather satellite reception) offer design tips and construction details for these antennas via various web sites. One appears at **web.archive.org/web/20190629211229/perso.wanadoo.es/dimoni/ant_qha.htm**. Another web site on the subject (**www.jcoppens.com/ant/qfh/calc.en.php**), actually sports a helpful online calculator where element lengths and spacing for these antennas can be calculated simply by entering the desired resonant frequency.



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



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



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

The Lindenblad

Yet another omnidirectional antenna design that can be useful for satellite work is the Lindenblad. This 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 back in the early 1990s. His articles can still be found in the AMSAT web archives at **www.amsat.org/amsat/articles/w6shp/lindy.html**.

In addition, AMSAT's past Vice President of Engineering and board member, Tony Monteiro, AA2TX (now, sadly, a Silent Key), wrote extensively on the Lindenblad design. Construction details of his 70 cm version of the Lindenblad appeared in the

Here's a partial view of the phasing coil and ground plane of the author's 2m, 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)

Proceedings for the 2006 AMSAT Annual Meeting and Space Symposium at **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, but they also help your ground station pick up weaker signals, provided that the antennas point 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.

Many satellite operators use some form of Yagi antenna in their Earth stations. The design, Yagi-Uda, is named for its Japanese inventors, 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 behind the driven element with one or more parasitic elements (called directors) 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. Yagi antennas with only one row of elements are linearly polarized (either horizontal or vertical, depending on which way you mount them). For example, the Arrow Antenna I've highlighted in a previous column is simply two linearly polarized Yagi antennas (one for 2m and one for 70 cm) mounted at 90 degrees to each other on the same handheld boom. However, Yagis with two rows of the same sized elements 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 also 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 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 mean more gain. However, as in most other things in life, there's a tradeoff between gain and beamwidth. That is, the higher the gain, the narrower the beamwidth. 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 wonderful for full coverage satellite work (and I've used my share of them over the years), they are not essential. I've still achieved consistently good results — particularly on the LEO birds —using any number of simple, linearly polarized (handheld or mounted) Yagi beams or eggbeater designs.

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 **www.amsat.org/cheap-and-easy-yagi-satellite-antennas**.

Dish Antennas

Dish antennas are the next step up from Yagi antennas for satellite work. 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

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)

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

(and narrow beamwidth) achieved by a dish antenna are usually offset by the fact that an LEO satellite is often (and 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.

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 feed line and connectors for your antenna as well as what to look for when choosing a base station radio. I'll also pass along some more tips on how to find and track our amateur radio satellites. In the meantime, you can always get the very latest information about current satellites in orbit (or those still on the drawing boards or awaiting launch) at our AMSAT web site, **www.amsat.org**.

For Beginners - Amateur Radio Satellite Primer (Part IV)

Keith Baker, KB1SF/VA3KSF
kb1sf@amsat.org

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Wow! It's been a busy year on the satellite bands here in North America! Many new satellite operators are putting new Maidenhead Grid Square roving contacts into our logs, with lots more "Satellite DXpeditions" planned for the summer months ahead.

However, now that spring has arrived for those of us in the Northern Hemisphere, it's probably time to begin thinking about how you can maximize your satellite ground station once the warmer weather arrives. In this installment of my satellite primer, I'll discuss some of the various types of feed lines and connectors that are particularly suited for satellite operation.

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 feedlines is loss, and every feedline has it to some degree. That is, if you insert 50 W into a feedline at your station, you'll have less than 50 W once your signal gets to your antenna. The rest of the power is lost somewhere in the feedline, 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 precious downlink RF heating up your feedline! 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 feedline. There are about as many varieties of coax cables as 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 that are 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 one of our popular satellite uplink or downlink frequencies (400 MHz), using a 100-foot length of RG-8 means that well over half of your uplink power (or downlink signal) will be lost in the coax. Ouch!

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 moist air working its way inside the cable and eventually condensing there. The fancy name for this effect is called diurnal pumping. 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 source for information about the various types of transmission lines (including their loss characteristics) can be found at **www.rfcafe.com/references/electrical/coax-chart.htm**.

Preamps

As I've noted, the downlink signal from these satellites is already weak when it strikes your antenna. So, another "nice to have" (but not necessary) addition to your base station setup is a receive preamplifier to boost the satellite's downlink signal. These preamplifiers (or "preamps" as we call them) come in many shapes and forms. Some are integrated into the radio itself (or into external, so-called "brick" amplifiers") while others are designed to be mast-mounted nearer to your antenna.

Over the years, I've found the mast-mounted variety work best because they boost the satellite's weak downlink signal where it is strongest, that is, before any of that weak satellite downlink signal is lost in the feed line to your station. However, unless the preamp is specifically equipped with internal switching relays, it is VERY important to remember that transmitting a signal back through one of them will often prove fatal to the device. I've "smoked" more than one of these in my time this way!

A Word About Connectors

While I have already discussed the importance of using a high quality, low-loss feed line to and from your satellite antenna (and keeping that feed line length as short as practicable) it is also important to use the very best connectors you can afford. Just as with choosing your feed line, if you try to skimp on the connectors for the feed line connecting your antenna to your radio, you could lose a significant portion of your signal through those connectors as well.

Remember, every dB of attenuation that weak satellite signals encounter while traveling from your antenna to your radio is a bit of the downlink you won't hear. A 3-6 dB loss from using cheap, HF-only rated coax and poor quality connectors can turn a marginal VHF or UHF downlink signal into one that simply isn't there.

Connectors add to line losses by creating impedance "bumps" that act like little resistors in the line. At HF (and to some extent at 6 m and 2 m) you can usually get by with using the common SO-239/ PL-259 connector combination. However, at higher frequencies (such as at 70 cm and above where many of our amateur radio satellites operate) most satellite-capable equipment now comes equipped with a Type-N connector. The type-N connector, when properly installed, will help minimize these small mismatches in the feed line which, in turn, will allow a greater portion of that (already weak) satellite downlink signal to make its way to your operating position from your satellite antenna.

As I've also noted, it is also critically important to make sure that these connectors are well seated — and well sealed! — when installed at your antenna. Otherwise, your coax will very quickly become waterlogged and then you'll really have line losses to contend with! One popular method I've successfully used over the years is to wrap electrical tape tightly around the connectors and/or feed line where they join, or use one of the many available hand-moldable compounds sold just for this purpose.

Finally, A Type-N Connector For The Masses!

PL-259 connectors are usually easy to assemble and solder. However, if you are like me, working with so-called "regular" N connectors has always been a problem. The typical Type-N connector consists of up to 6 components, all of which must be carefully seated and soldered to seal out moisture properly. However, no matter how carefully I assembled and installed feed lines using these traditional Type-N connectors, I often found that (particularly in outdoor applications) the slightest pull on the coax usually resulted in a detached (or shorted!) N connector.

Thankfully, innovation has now come to the rescue! The two-piece N connector shown in the accompanying photo is a silver-plated, gold-tipped connector of excellent quality that solders and assembles much like a PL-259. Yet, this version maintains most of the "bumpless" impedance and weatherized qualities of the classic Type-N. Even the same UG175 and UG176 reducers for PL-259s can also be used for smaller cable types. Those of us who are "all thumbs" (like me!) when it comes to working with coax connectors need never again struggle with a Type-N!

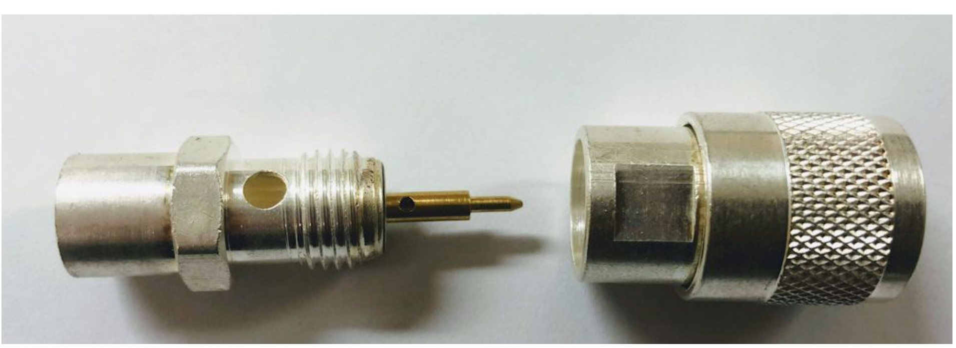
A good source for this modern, PL-259-like version of the classic Type-N connector is Part Number "#1273" from Universal Radio in Reynoldsburg, Ohio or Part Number "OPEK AT7302STG" from R&L Electronics in Hamilton, Ohio.

Looking Ahead

Back in the "Dark Ages" (when I was the President of AMSAT in the late 1990s) I often remarked that the majority of our supporting members back then (and perhaps still today) have never actually communicated through one of our satellites! So, if you are one of those folks who have, as they say, "Always wanted to do that but never got around to it", this series of satellite primers are all designed to help you (finally?) get up and running on one (or more) of the amateur radio satellites we now have in orbit.

So, with that thought in mind, in future columns, I'll be exploring some of the features of our current fleet of satellites in orbit plus some currently on the drawing boards or now being prepared for launch. I'll also be sharing some information on how our amateur radio satellites (along with the AMSAT organization and its predecessors) came to be. See you then.

Mast-mounted preamps, such as this one from SSB electronics, boost weak satellite downlink signals at the antenna feed point



This two-piece Type- N connector assembles like a PL-259 but still exhibits all the RF characteristics of the original N connector design. (Courtesy: Author)

For Beginners - Amateur Radio Satellite Primer (Part IX)

Keith Baker, KB1SF/VA3KSF
kb1sf@amsat.org

In previous columns, I focused on the many ways you can operate through the amateur radio satellites. But, without one or more satellites to operate through, even the very best ground station is little more than a money sink! So, in this installment, I'll again shine the spotlight on a whole series of linear satellites that our AMSAT friends in China have launched in the last few years that currently make up the vast majority of our amateur satellite fleet.

As I noted in previous columns, if you are new to AMSAT membership and are just now reading your very first copies of *The AMSAT Journal* — or perhaps you are ready to (finally?) try your hand at satellite operation — this column is part of a continuing series of "getting started" primers in the Journal that I've written on how you, too, can get in on the fun of amateur radio satellite operation.

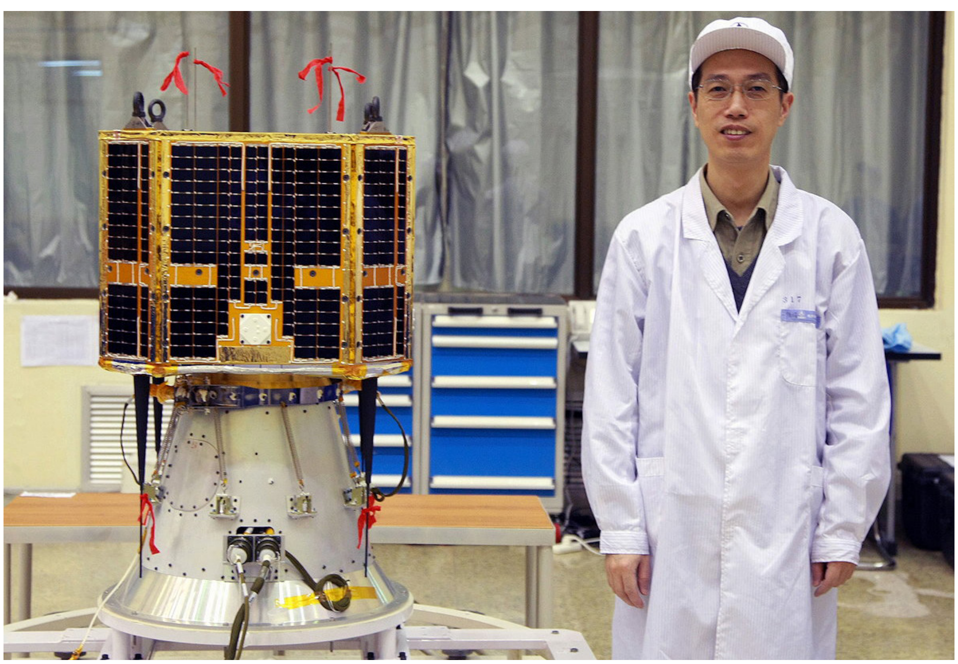
And now that most back issues of this magazine are online in AMSAT's Member Portal, you can start at the very beginning of this discussion. I suggest you start by downloading the September/October 2019 issue of the *Journal* that contains my first (updated) installment of these "getting started" columns. Hopefully, this column (and those that have already been published in the *Journal*) will help you to get up and running quickly on the satellites.

Beginnings

The Chinese AMSAT (CAMSAT) organization's group was largely responsible for the construction and launch of China's first-ever amateur radio satellite (CAS-1, the "CAS" most likely an acronym for "Chinese Amateur Satellite"). The satellite was also known as XW-1 (Xi Wang-1, Xiwang being the Chinese word for "hope") before launch, and, once activated on orbit, was also given the anglicized AMSAT designation "Hope OSCAR 68" (or just HO-68).

The 60 kg satellite was launched into a 1200 km by 1200 km orbit on 15 December 2009 from the Taiyuan Satellite Launch Center of China on a CZ-4C (LM-4C) rocket. Soon after launch, its linear transponder proved very popular and provided hundreds of SSB and CW contacts for satellite-equipped hams worldwide over the Christmas-New Year 2009-2010 holiday period.

However, since that time, HO-68's linear transponder has gone largely silent with only its 435.790 MHz (CW) beacon (sometimes!) being heard. While the cause of the transponder anomaly was not widely reported, it's believed an on-orbit software crash was the ultimate culprit.



Called XW-1 before launch, Hope OSCAR-68's project leader, Alan Kung, BA1DU, proudly stands beside his team's collective handiwork during the satellite's final ground tests. (Courtesy: CAMSAT)

CAS-2?

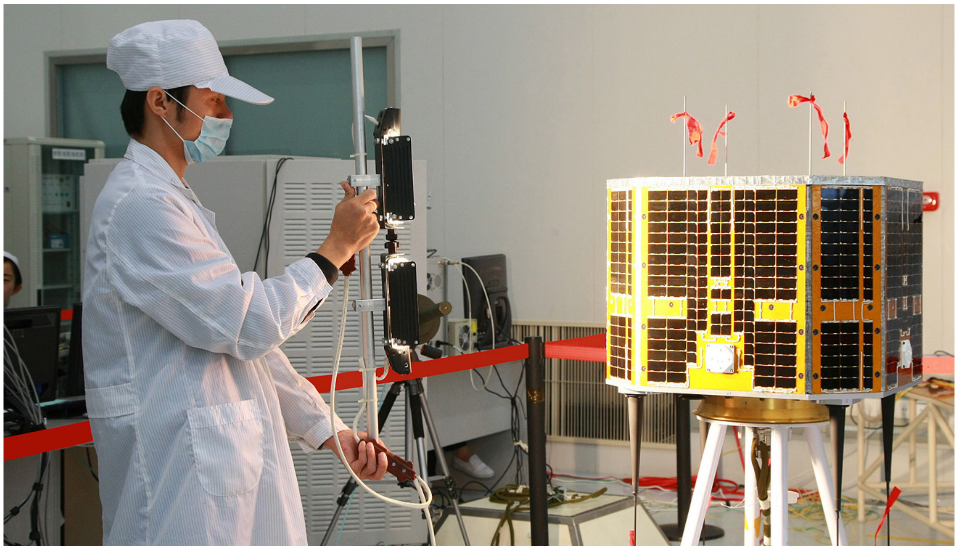
In the 2011-to-2013-time frame, CAMSAT and students at the Qian Youth Space Academy in China Academy began work on the next set of satellites in the series (CAS-2) as the successors of the first CAMSAT amateur radio satellite CAS-1 (XW-1, HO-68).

The launch of the first CAS-2 was initially planned for sometime in 2014 into a 1000 km orbit with an inclination of 12 degrees via a new Chinese missile from a new Chinese launch site into a sun-synchronous orbit to start. This orbit meant that the satellite's signals might not be receivable in those countries at high latitudes. It was also understood that most of the room in the CAS-2 satellite(s) would be taken up by the primary (non-amateur) payload. It was only possible to fit a single channel FM amateur transponder into the satellite. A later announcement indicated that two separate CAS-2 satellite structures were being built, A1 and A2.

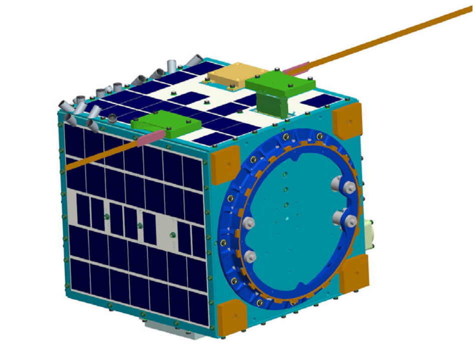
Unfortunately, no further information about this particular CAS-2 imitative was ever published. Whether the satellites were ever launched (or even made it to orbit) is anyone's guess. As these satellites were all to be riding on Chinese government launch vehicles (and apparently new vehicles at that!), it's not unusual that the rest of the world would not ever hear about it if launch failures or other anomalies prevented such efforts from ever coming to fruition.

Enter CAS-3, and Success!

Back in the mid-summer of 2016, Alan Kung, BA1DU (China AMSAT's CEO) stunned the amateur radio satellite community with news of the impending launch of not one but six new Chinese amateur satellites into low Earth orbit (LEO). The new satellite "family" included different weight category satellites, consisting of one 20 kg satellite, three 10 kg and two 1 kg satellites. All six satellites were equipped with substantially the same amateur radio payloads including a U/V mode linear transponder, a CW telemetry beacon and an AX.25 19.2 k/9.6 k baud GMSK telemetry downlink. Additionally, the amateur radio payloads all shared essentially the same technical characteristics, but operated on different frequencies of the 70 cm band (uplink) and 2 m-band (downlink).



The XW-1 (HO-68) satellite undergoes illumination testing prior to launch. (Courtesy: CAMSAT)



An artist's concept of the CAS-3B, CAS-3C and CAS-3D (XW-2B, 2C and 2D) satellites. For size comparison, the longer whip is the ¼ wave 2 m downlink antenna. (Courtesy: CAMSAT)

Alan went on to report that, over the years, his organization (CAMSAT) had been working closely with DFH Satellite Co., Ltd., to complete the project. DFH is a Chinese government aerospace contractor that provided most of the support for this project.

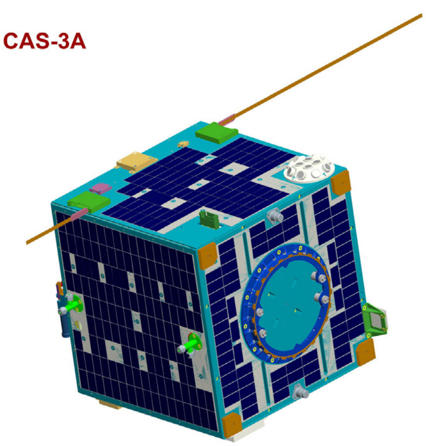
The satellites shared a similar micro-satellite structure (400 mm x 400 mm x 400 mm, or about 15 inches on a side). As opposed to much smaller CubeSats, this sizing puts these satellites firmly in the "Microsat" category (similar in size to AO-27 and AO-51).

Once again, dubbed "China Amateur Satellites" (or CAS for short) CAS 3A, 3B, 3C and 3D — all sported three-axis stabilization with antennas consisting of ¼ wave monopoles. The inverting downlink transmitters were in the 100 mW category. CAS 3E and 3F were designed to be spin-stabilized and to carry U/V Mode inverting linear transponders (again in the 100 mW power category) with a 20 kHz bandwidth.

All six satellites were successfully launched on September 19, 2015 on a brand new Chinese launch vehicle named Long March 6 (LM-6 or CZ-6) from Taiyuan Satellite Launch Center in China. CAS-3A is in a 450 km height sun-synchronous orbit, while the other satellites are in a slightly higher, 530 km sun-synchronous orbit. The launch carried a total of 20 satellites, including three other satellites using amateur radio frequencies (named CAS-3G, CAS-3H and CAS-3I) built by other satellite-related agencies in China. CAMSAT assisted the Chinese government administration to coordinate and allocate their frequencies as well.

As of late January 2021, five of the six CAS-3 satellites (now renamed XW-2A thru XW-2F) have been heard at one time or another over North America with several radio amateurs either copying the telemetry downlinks or actually making contacts through them. XW-2D was not ever heard from, and unfortunately, the batteries on the rest of the family are now starting to age, so one (or more) of them may not be operational all the time. A complete listing of their uplink and downlink frequencies (along with other technical information for each) is available (in PDF format) from the AMSAT web site at: **www.amsat.org/wordpress/wp-content/uploads/2015/09/XW-2CAS-3-Sats.pdf**.

CAS-4A and CAS-4B

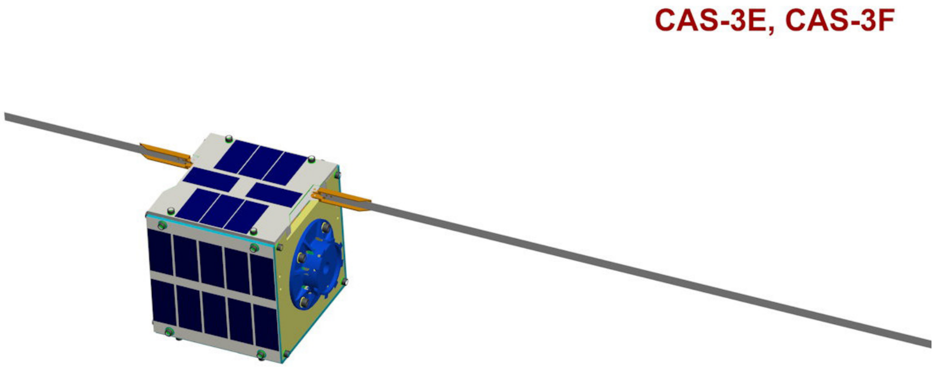


An artist's concept of the CAS-3A (XW-2A) satellite. For size comparison, the longer whip is the ¼ wave 2 m downlink antenna. (Courtesy: CAMSAT)

In mid-June 2017, CAMSAT announced the launch of its CAS-4A and CAS-4B linear transponder payloads. These payloads were to ride "piggyback" on the Chinese OVS-1A and OVS-1B optical remote sensing satellites. Both were launched (along with the hard X-ray modulation telescope (HXMT)) satellite aboard a CZ-4B rocket from Jiuquan (China) Satellite Launch Center at 03:00 UTC on June 15, 2017. Both satellites are now in a 43-degree inclination orbit with an apogee of 524 km.

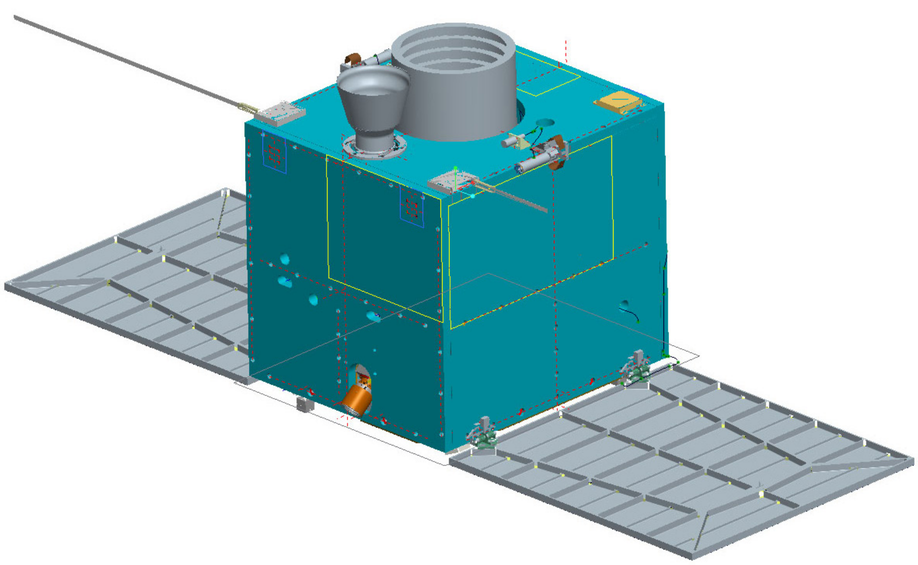
Once again, CAMSAT worked closely with a Beijing government aerospace contractor to build the two satellites and equip them with amateur radio linear transponder payloads. Both payloads carry a 435/145 (U/V) 20 dBm (100 mW) SSB/CW linear transponder, a 2m CW 17 dBm (50 mW) telemetry beacon and an AX.25 4.8 kbps GMSK 20 dBm (100 mW) telemetry downlink. Each set of amateur radio equipment packages have the same technical characteristics, but each have different frequencies for the 70 cm band uplinks and 2 m band downlinks. With identical 494 x 499 x 630 mm dimensions, a regular square shape and approximately 55 kg mass, each satellite also contains a three-axis stabilization system.

A 43-degree inclination orbit, while not unique to amateur radio satellites, presents somewhat of a challenge to those of us located in the northern part of North America who may also wish to use them. That's because the satellite(s) will only appear to be (briefly) overhead in our part of the world, and never farther North than 43 degrees north latitude once or twice a day. And that apogee point will also tend to



An artist's concept of the CAS-3F (XW-2F) satellite. For size comparison, the longer whip is the ¼ wave 2M downlink antenna. (Courtesy: CAMSAT)

CAS-4A and CAS-4B were launched aboard a CZ-4B Rocket from the Jiuquan (China) Satellite Launch Center on June 15, 2017. (Courtesy: CAMSAT)



An artist's concept of the Spaceframes carrying the CAS-4A and CAS-4B transponders. (Courtesy: CAMSAT)

shift steadily westward as the day progresses and the Earth turns underneath their orbit.

When last heard, the linear transponders of these two satellites were very popular with North American hams, with many stations occupying their transponders as they whizzed above the North American continent. Much like the XW series satellites, these two satellites also tend to follow one another. So, it's not unusual to hear a conversation started on one CAS satellite and then completed soon after on the other CAS satellite immediately following.

However, as these transponders are riding "piggy back" on a three-axis stabilized satellite designed to always point Earthward, I've also noted deep fades on both my uplink and downlink signals as these satellites pass from west to east over my QTH in Ontario. As the amateur transponder's antennas are just simple monopoles, I suspect some of my uplink (and/or downlink) signals are being blocked by the satellite's structure and/or solar panels.

More information about these two satellites can be found at: **ukamsat.files.wordpress.com/2017/03/camsat-cas-4a-and-cas-4b-news-release.pdf.**

CAS-7A?

In the spring of 2020, CAMSAT announced the proposed launch of CAS-7A for the September 2020 time frame. The project was announced several years ago but has been postponed again and again. However, the special thing about CAS-7A is that HF will be used with its transponders — a configuration similar to that of the very popular Russian RS satellites (RS-10 and RS-12) back in the 1990s! A sun-synchronous orbit with an inclination of 98 degrees is planned with an orbital height of some 500 km. The transponders are also slated to have a bandwidth of 30 kHz.

Besides the 21 MHz uplink and 28 MHz downlink linear transponder, the satellite is also being built to contain an HF to UHF linear transponder with an uplink on 21 MHz and a downlink on 435 MHz.

Clearly, if this satellite eventually makes it to orbit and becomes operational, it will open up a brand new world of satellite operating for those not (yet) equipped to operate on our VHF and UHF analog satellites. Stay tuned to our AMSAT website (www.amsat.org) for all the latest news about the status of CAS-7A.

A large team of CAMSAT Members attended the Dayton Hamvention® in 2011. Here, then AMSAT President Barry Baines, WD4ASW (L) accepts a plaque of friendship from CAMSAT President Alan Kung, BA1DU. (Courtesy: Author)

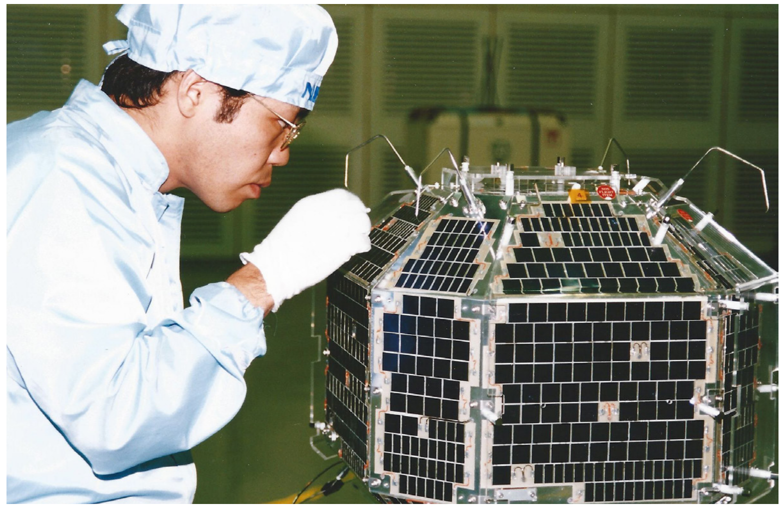
Wrap Up

I hope you have enjoyed reading this brief series of "getting started" articles in our Journal. And I also hope they have whetted your appetite to actually get up and active on our satellites if you aren't already there. It's also important to remember that keeping your membership in AMSAT active will help ensure new satellites continue to be developed, built and launched in the future so that you and I may meet one day on one of our "birds." Until then, take care, stay safe and 73!

For Beginners - Amateur Radio Satellite Primer (Part V)

Keith Baker, KB1SF/VA3KSF
kb1sf@amsat.org

[Portions of this column previously appeared as "How To Use The Linear Amateur Satellites" in the November 2010 edition of Monitoring Times Magazine. *Thank you* MT*!]*



A cooperative effort between the JARL and the JAMSAT, JAS-2 (which later became Fuji OSCAR 29 (FO-29) on-orbit) is a linear transponder satellite shown here just before its launch in 1996. The satellite remains semi-operational to this day. (Courtesy: JARL.)

In previous columns, I've discussed ways to find, track, listen for, and then communicate through our expanding fleet of amateur radio satellites. In this installment, I'll introduce you to another (non-FM) type of satellite transponder called a linear transponder that is carried aboard many of our current amateur satellites.

Transponder "Flavors"

You'll remember from previous columns that a transponder is a circuit in a satellite that receives an uplink signal and then retransmits what it hears via its downlink transmitter, much like your local FM repeater does. However, unlike your local FM repeater (and most of our FM satellites), which has a specific input and output frequency, most so-called "linear" satellite transponders (sometimes also called "analog" transponders…the terms are often used interchangeably) receive and then retransmit a whole band of frequencies commonly called a passband.

What's more, linear amateur satellite transponders come in one of two flavors. These transponders are usually classed as inverting or non-inverting. If the satellite has a non-inverting transponder, when an operator's uplink signal frequency is on the high end of the uplink passband, their downlink signal will also be in the high end of the downlink passband.

Conversely, in an inverting transponder, when an operator's uplink frequency is on the high end of the uplink passband, it will become inverted (hence the name) and come out on the lower end of the downlink passband. Put another way, inverting transponders make mirror images of the signals they pass.

This holds true for the sideband sense as well. In a non-inverting transponder, the signals an operator sends up to the satellite (USB or LSB) will come out the same way on the downlink. However, in an inverting transponder, a USB uplink will be inverted and come out as LSB on the downlink. Conversely, a LSB uplink will be inverted and come out as USB on the downlink. The latter approach (USB signals on the downlink) is also what's most preferred by operators using our linear satellite transponders today. Fortunately, CW will be CW regardless of the transponder's variety!

Note that most linear-transponder-equipped satellites currently in orbit, (including FO-29, AO-73, RS-44 as well as the CAS and XW series of satellites) contain inverting linear transponders. The one exception is our old AO-7 satellite launched back in 1974 and which is still "sort of" operational. It uses a non-inverting, linear transponder while in Mode V/H (the old Mode A).

As with the FM birds, common operating practice on amateur satellites with linear transponders is to first listen for your own signal on the downlink. You'll remember from my previous columns that working through a satellite transponder is usually a full-duplex operation, much like talking on a telephone. This means that others can usually hear you while you are hearing yourself.

Finding your own signal in the downlink passband of a satellite with a linear transponder the first few times can be tricky. However, I've found that placing your transmit frequency somewhere in the middle of transponder's passband and then sending a few (widely-spaced) "dits" of CW while tuning your receiver to find your downlink signal works best. This approach causes minimal interference to others who are then working through the transponder. Once you've located your signal, you're ready to try making a contact.

Unlike the FM birds, calling CQ on these satellites is acceptable, and you'll usually find the convention of CW operations in the low end of the passband with phone operation in the upper part of the passband (an arrangement common to High Frequency (HF) amateur radio operation) generally holds true for satellite work as well.

As I have also noted in previous columns, since a satellite is a moving target, its downlink signals will exhibit a pronounced Doppler shift, just like the changing pitch of a train whistle as it approaches and then passes. During a satellite QSO, the "old" (that is, before computer frequency control) so-called "one true rule" of thumb for linear satellite operation is that if the uplink band is higher in frequency than the downlink, you should slowly shift your transmit frequency on the uplink as the Doppler effect changes the frequency of your downlink signal.

Conversely, you should shift your receive frequency if the uplink band is lower in frequency than the downlink. Or, to put it another way, the highest frequency band in use (uplink or downlink) is what you should shift as Doppler affects your signals. This approach will usually help prevent an inadvertent shift of your conversation into someone else's on the transponder. However, in the heat of the moment with everyone frantically searching through the passband for their own downlink signals, these conventions are often ignored.

Technicians make a final adjustment to JAS-2's (FO-29's) upper stage attachment mechanism just prior to the final integration and eventual launch of the satellite. (Courtesy: JARL)

Keep The Power Down!

Also, because it is generated from the Sun, satellite power is a finite (and, therefore, scarce) resource. That's why it is very important to use only enough power on your uplink transmissions to produce a readable signal on the downlink.

As I've said, you need to get used to the idea that satellite work is weak signal work. It's not like operating on HF (or terrestrial VHF or UHF) where the use of more power is usually better. Besides being potentially harmful to a satellite's battery life by using more uplink power than is necessary, overpowering your uplink signal beyond the point of creating a discernable signal through the satellite's transponder on the downlink will not appreciably improve the overall strength of your downlink signal.

On the contrary, such activity will do little more than "pump" the satellite's automatic gain control as it tries to compensate for the onslaught you are creating with your overpowered uplink signal. Such activity will only gobble up yet more of the satellite's precious available power, not to mention limiting the overall downlink power available for others using the transponder.

Unfortunately, all it takes is one overpowered uplink signal in the passband to drastically cut the strength of everyone else's downlink signal. As you might expect, such activity will not make you a popular camper on the satellites as crocodiles — those who operate with "all mouth and no ears" — are about as welcome on the birds as lids are elsewhere in amateur radio.

FM Is Particularly Unwelcome

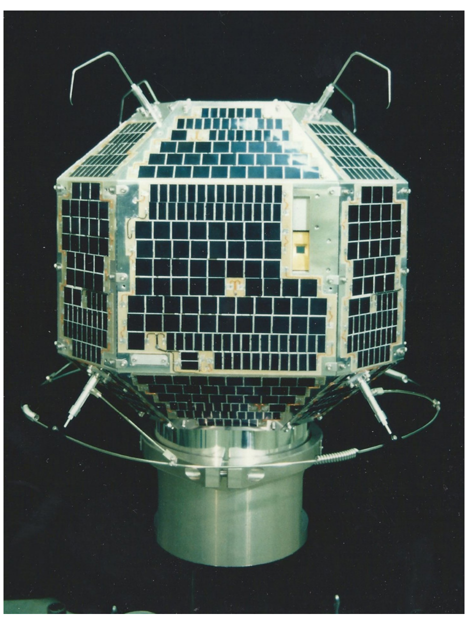
In addition, because satellite power is such a scarce commodity, most linear satellite transponders are built to use the most efficient operating modes possible. Normally, this equates to single sideband (SSB) voice and/or Morse (CW).

Therefore, it should also come as no surprise that another big "no-no" is running FM through linear satellite voice transponders. FM signals occupy a much larger bandwidth and take a significantly greater portion of a transponder's precious output power to re-broadcast than do CW and SSB signals.

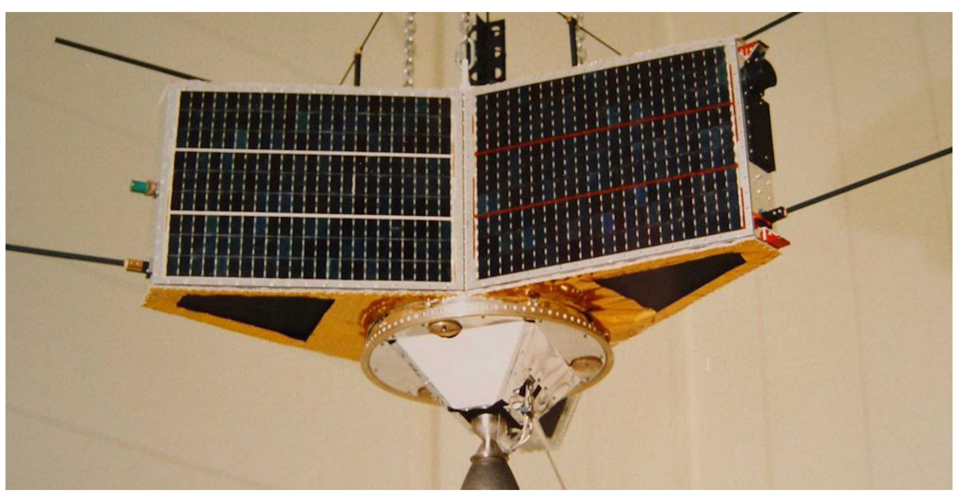
Your FM signals will gobble up lots of downlink power, not to mention causing your transmissions to stick out like a sore thumb. Just imagine how obnoxious you'd sound running SSB signals through your local FM repeater, and I think you'll agree that all use of FM should be avoided when operating through one of our linear satellite transponders.

Wrap Up

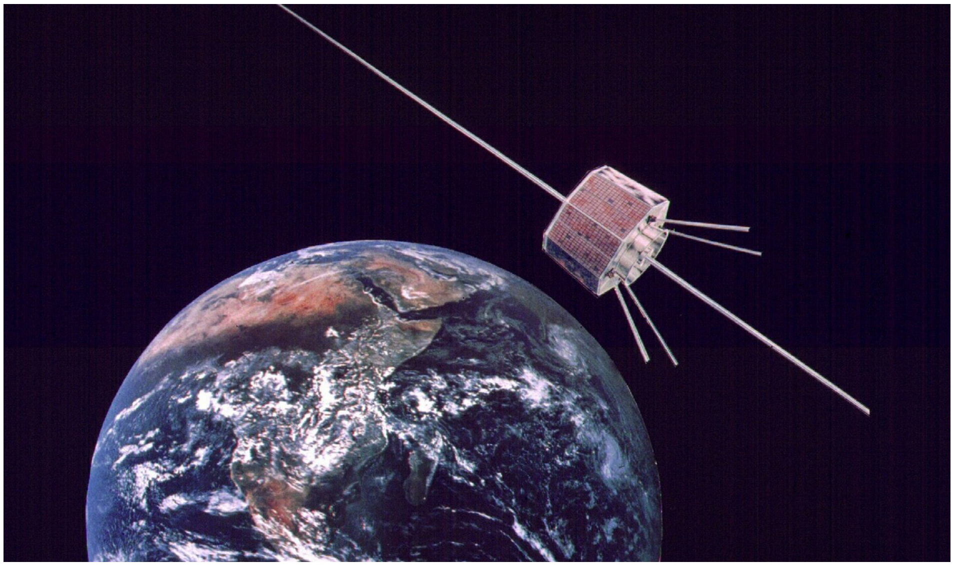
That's all for this time. In future installments, I'll be discussing some more detailed aspects of this unique part of our amateur radio satellite hobby by shining the spotlight on several of our satellites now in orbit. See you then!



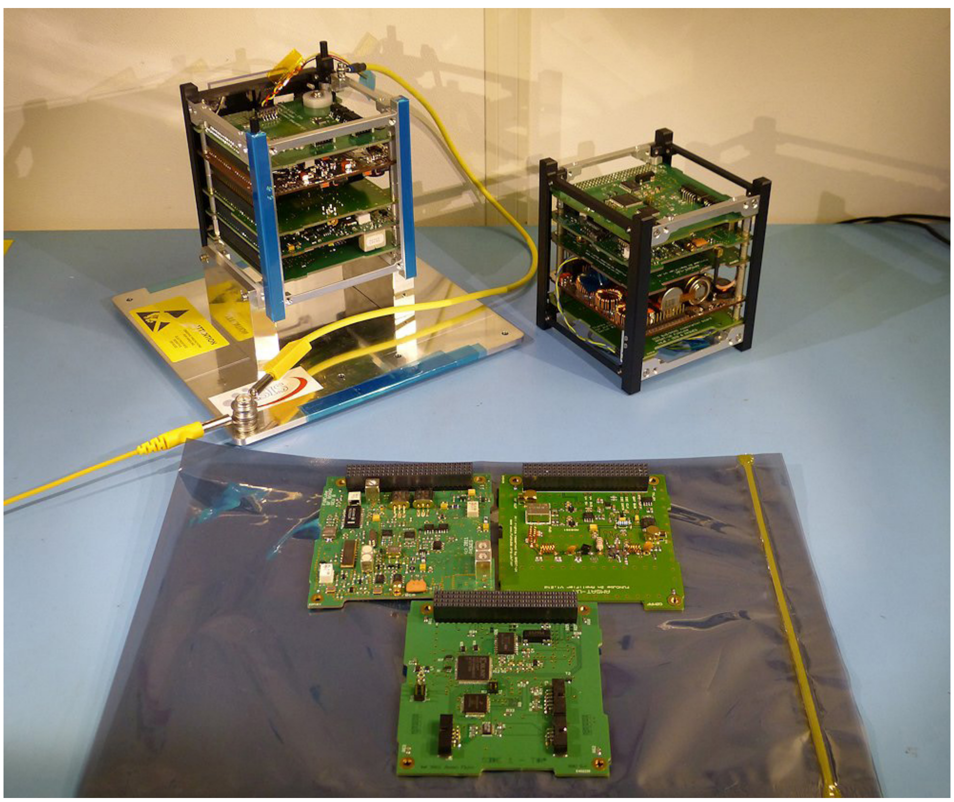
JAS-2 (FO-29) is shown here just after final assembly and integration of the satellite were completed. (Courtesy: JARL)



AMSAT-Germany's Phase 3-C satellite (which later became AMSAT OSCAR 13 (AO-13) on-orbit) was a very popular linear transponder satellite that provided amateurs with near worldwide coverage before its (unplanned!) de-orbit in late 1996. (Courtesy: AMSAT-DL)



AMSAT OSCAR 7 (AO-7) another satellite carrying linear transponders was launched in 1974 and went silent in 1981 due to battery failure. Then, after 21 years of apparent silence, the satellite was heard again on June 21, 2002, and remains semi-operational to this day when sunlight illuminates its solar panels. (Courtesy: AMSAT)



A working engineering model of AMSAT-UK's FUNCube-1 is shown here on the left along with the actual flight model (minus its solar panels) on the right. FUNCube1 (which later became AMSAT OSCAR 73 (AO-73) on-orbit) was successfully launched in 2013. The satellite carries both a linear and an FM transponder. (Courtesy: AMSAT-UK)

OSCAR Who?

Since 1961, some 100 plus "OSCARS" (short for Orbital (or Orbiting) Satellite Carrying Amateur Radio) have been built and launched by a number of amateur radio-related organizations worldwide. And just like their Hollywood counterpart of the same name, there are some very strict rules as to how our amateur satellites get to be so honored.

First, they have to be capable of transmitting and/or receiving in the amateur radio bands. They also have to successfully achieve orbit and be activated in space. And, lastly, the builders of the satellite have to formally request that an OSCAR number be assigned to their orbiting handiwork.

Today, by mutual agreement between AMSAT and the original Project OSCAR team (who built and launched the very first OSCAR satellites), those formal requests all go to our AMSAT Board of Directors and Vice President of Operations member Drew Glasbrenner, KO4MA, who then determines the "amateurness" of the payload before he assigns an OSCAR number.

Most amateur satellites have other names before launch. For example, AMSAT-North America has chosen to use sequential alphabetic characters for their satellites. One of AMSAT's current (and very popular!) FM birds, AO-91, was dubbed "Fox-1B" before its successful launch and activation on orbit. The fleet of Japanese amateur satellites uses "JAS" (Japan Amateur Satellite) followed by a sequential number for their amateur satellites. Their current, semi-active amateur satellite, FO-29, was called "JAS-2" before its successful launch in 1996.

Usually, the "O" stands for "OSCAR", while the number following it is sequentially assigned, depending on when the satellite's transponder is activated on-orbit or when its builders request that an OSCAR number be assigned. What's more, the first letter of the OSCAR designator usually is suggested by the satellite's builders or sponsors and often gives a hint about its heritage.

For example, the "F" in FO-29 stands for "Fuji" (for "Fuji OSCAR") while the "A" in AO-91 stands for "AMSAT" (as in "AMSAT- OSCAR 91"). The "S" in SO-50 stands for "SaudiSat" as a university team in Saudi Arabia sponsored the building and launch. Just remember that the letter "O" in a satellite's official, on-orbit name followed by a dash, and then one or two numbers, usually indicates that the satellite is one of our fleet of amateur radio (OSCAR) satellites.

For Beginners - Amateur Radio Satellite Primer (Part VI)

Keith Baker, KB1SF/VA3KSF
kb1sf@amsat.org

[Portions of this column previously appeared as "Amateur Radio Satellite Update" in the August 2013 edition of Monitoring Times Magazine. *Thank you MT!]*

I trust you are all continuing to have fun listening for (or, if properly licensed, working through) our ever-expanding fleet of amateur radio satellites. In this installment, I'll once again shine the spotlight on one of AMSAT's remaining satellites from our MICROSAT series that is both still in orbit and operational. I'll also share some more helpful tips on where to look for some online data resources that may prove useful to you as you progress in your "satellite education."

SAUDISAT 1C (SO-50)

With the demise (several years ago) of AMSAT's AO-51 satellite along with the on-again, off-again nature of AMRAD's venerable AO-27 satellite from that era, fortunately, there are several more FM "Easy Sats" now in orbit and consistently operational. One of the oldest of that original genre is SAUDISAT 1C.

SAUDISAT 1C (or Saudi-OSCAR 50) successfully launched on December 20, 2002, into a 625 X 692 Km, 64-degree inclination orbit from the Baikonur Cosmodrome in Kazakhstan. It was a project of the Space Research Institute of the King Abdulaziz City for Science and Technology in Saudi Arabia.

The SAUDISAT 1-C (SO-50) mission patch. (Courtesy: SARS)

SO-50 carried several experiments aboard, including a Mode V/U (Mode J) FM amateur repeater experiment operating on a 145.795 MHz uplink and 436.795 MHz downlink. Miraculously, the repeater remains available to amateurs worldwide as power permits, using a 67.0 Hz CTCSS (PL) tone on the uplink for on-demand activation. SO-50 also has an on-board 10-minute timer that must be armed before use.

That is, to "turn on" the bird (if it isn't already turned on), you must first transmit an initial carrier with a PL tone of 74.4 to arm the timer, and then a 67.0 Hz tone for access. The repeater consists of a miniature VHF receiver with a sensitivity of about −124 dBm and an IF bandwidth of approximately 15 kHz. The receive antenna is a 1/4 wave vertical whip mounted in the top corner of the spacecraft. The receive audio is filtered, conditioned and then gated in the control electronics before feeding it to the 250 Milliwatt UHF transmitter. The downlink antenna is a 1/4 wave whip mounted in the bottom corner of the spacecraft and canted inward at 45 degrees.

Unfortunately, the comparatively low power transmitter carried aboard SO-50 means that some form of gain antenna (such as an Arrow hand-held cross-polarized Yagi or the Elk 2m/440 hand-held Log Periodic antenna discussed in previous columns) is all but required to successfully hear the downlink while attempting to work through the satellite.

And, for those who are unfamiliar with the satellite, Howard Long, G3LVB, has posted an excellent how-to beginner's article about working through SO-50 on the AMSAT-

SAUDISAT 1-C (mounted in the foreground at the right) sits atop its launching structure just before launch (Courtesy:

SELECTED FREQUENCY AND MODE DATA:

SATELLITE	*Uplink (MHz)*	*Downlink (MHz)*	*Mode*
SAUDISAT 1C (SO-50)	145.850	435.795	FM Voice (67.0 Hz CTCSS Tone For Access)

UK web site at www.g6lvb.com/Articles/operatingSO50.htm.

Satellite Data Resources

With the advent of the internet, obtaining amateur radio satellite operating mode and status information is now easier than ever. Unfortunately, because it has become so easy, obtaining the most current information from a reliable source is NOT an easy task because of what I have come to call "information overload."

So, that said, what follows are several of my recommendations on where to look that will (hopefully) make your search for the most current satellite information just a bit easier.

The AMSAT Web Site

My go-to source for the most current satellite information continues to be our own AMSAT web page at www.amsat.org. A quick scroll down from the main page header will bring you to our "Apogee View" column where our current AMSAT president shares his views on the very latest doings of the organization. A further scroll down on that same page will bring you to the "Updates" area that contains current items of satellite status and information. Many of these items are re-posts from AMSAT News Service (ANS) bulletins.

SAUDISAT 1-C was launched on a Dnepr rocket from the Baikonur Cosmodrome in Kazakhstan in December of 2002. The satellite remains operational to this day. (Courtesy: ROSCOSMOS)

The upper stage shroud that covered SAUDISAT 1-C during launch is shown here. (Courtesy: ROSCOSMOS) (Courtesy: ROSCOSMOS)

Speaking of the AMSAT News Service, this bulletin service dates from the very earliest days of Packet Radio (that is, WELL before the rise in popularity of the Internet!) when AMSAT began to send out a weekly bulletin of satellite news and information via the (then) worldwide Packet Radio network. Those bulletins are still being sent worldwide via Internet subscription and, as the headers of the bulletins still contain Packet Radio routing information, some are actually still finding their way into what remains of the Packet Radio network!

However, you, too, can now sign up to receive these bulletins in your e-mail directly from AMSAT by clicking on "Services" and then "Mailing List Services." Scroll down to the "ANS" link and follow the directions about how to subscribe. However, if you don't want yet more e-mail filling up your (most likely) overloaded e-mail inbox, you can also browse through the ANS Archive by clicking on the "AMSAT News Service" link under the "Services" tab off the main AMSAT web page and then selecting the timing and/or threads you'd like to read.

AMSAT also offers some other mailing lists that you can subscribe to. And, what's nice is that subscribing to one or more of them is still very much free to members and non-members alike. These lists include, among others, the AMSAT-BB, an online forum for satellite discursions, as well as our weekly Keplerian Element Bulletin.

AMSAT UK

Another excellent source of amateur satellite information from "across the pond" is contained on the AMSAT United Kingdom (AMSAT UK) web site at amsat-uk.org. Of particular note is their very extensive list of resources under the "BEGINNER" tab off the main page. Also, the AMSAT-UK folks routinely post full-motion videos of their various meetings (such as their annual colloquium) and other such gatherings.

Gunter's Space Page

I don't know how he does it, but Gunter Krebs, via his "Gunter's Space Page" (space.skyrocket.de), has his finger on the pulse of the entire worldwide "space biz," including a wealth of amateur radio satellite information. He routinely gathers, correlates and catalogs a whole host of rocket launch and satellite information from various sources and puts it all in one place on his page. Indeed, if I'm looking for more background, construction and/or historical information regarding a particular satellite, Gunter's page is my first stop.

The N2YO Page

Another very useful web page is Ciprian Sufitchi's N2YO Web Page (**n2yo.com**). Ciprian's site focuses mainly on satellite tracking and offers real-time pass predictions for various popular satellites by using your internet IP address to set your location. The main thrust of his page is tracking the International Space Station (ISS) showing via a map on his home page where the Station is at the moment, and when it might be visible from your location.

Wrap Up

These are but a few of the many satellite information pages that I have found most useful out of the tens (if not hundreds) of similar pages now springing up on the web. Usually, searching for "amateur radio satellite information" will bring up related links.

In future columns, I'll again be shining the spotlight on other interesting amateur radio satellite launches of late as well as keeping you apprised of what AMSAT (and its worldwide sister organizations) are up to in space. See you then!

For Beginners - Amateur Radio Satellite Primer (Part VII)

Keith Baker, KB1SF/VA3KSF
kb1sf@amsat.org

[Portions of this column previously appeared as "Spotlight on UOSAT-2 (UO-11)" in the May, 2012 edition of Monitoring Times Magazine *Thank you MT!]*

In this installment, I'll shine the spotlight on some amateur radio satellites our brethren in the United Kingdom have built, including one of AMSAT-UK's remaining satellites from their UOsat series (UO-11) that is both still in orbit and semi-operational. I'll also share some information on their (very popular) FunCube (AO-73) analog satellite.

By the way, if you are new to AMSAT membership and are just now reading your very first copies of *The AMSAT Journal* — or perhaps you are ready to (finally?) try your hand at satellite operation, this column is part of a continuing series of "getting started" primers in the *Journal* that I've written on how you, too, can get in on the fun of amateur radio satellite operation.

And now that most back issues of this magazine are online in AMSAT's Member Portal, you can start at the very beginning of this discussion. I suggest you start by downloading the September/October 2019 edition of the *Journal* that contains my first (updated) installment of these "getting started" columns. Hopefully, it (plus subsequent columns that have already been published in the Journal and those that will follow in the future) will help you to get up and running on the satellites —quickly!

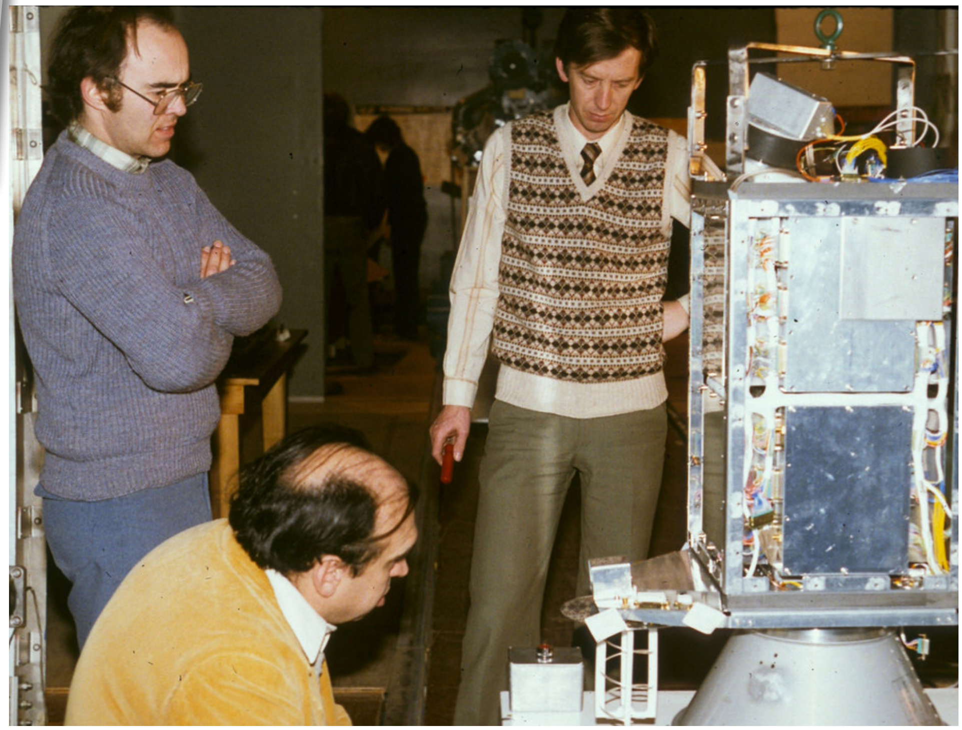


Figure 1 — Professor Sir Martin Sweeting , G3YJO, Director of the University of Surrey's Space Centre in England (left) oversees the final assembly of UoSAT-2 which later became UO-11 on orbit. (Courtesy: AMSAT-UK/SSTL).

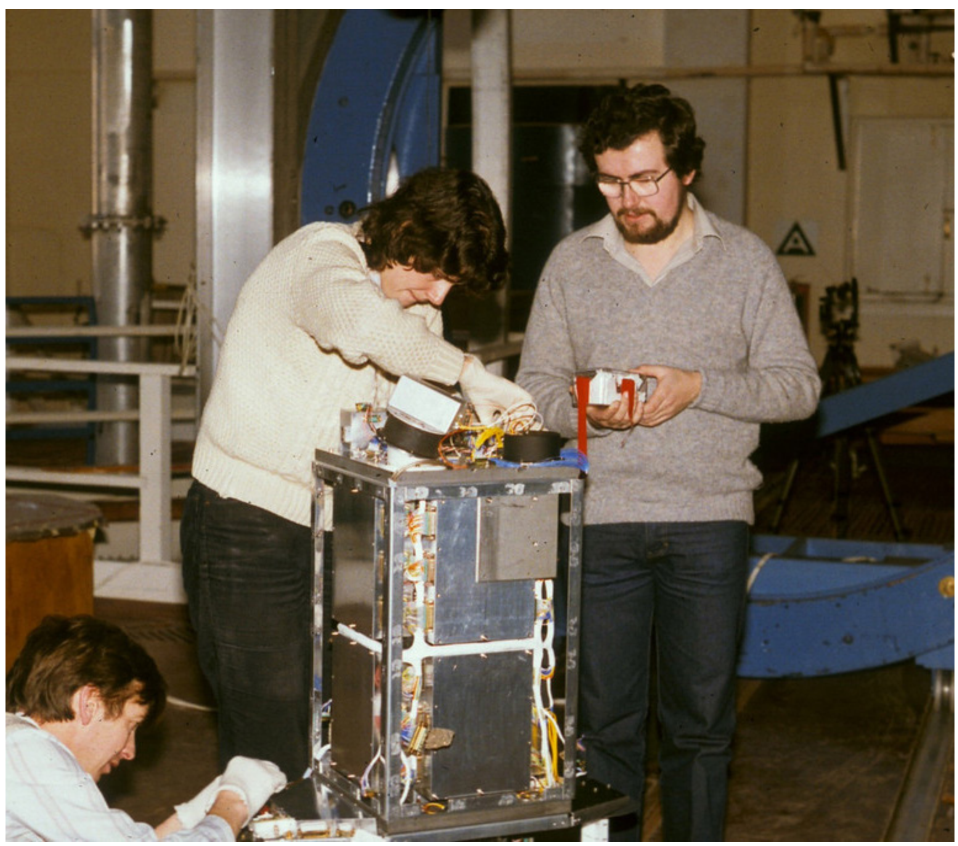


Figure 2 — Technicians put the final touches on UoSAT-2 (UO-11) just prior to environmental testing. Note the absence of the spacecraft's solar panels. (Courtesy: AMSAT-UK/SSTL).

UoSAT-2 (UO-11)

UO-11, also known as UoSAT-OSCAR 11, UoSAT-2 or UoSAT-B, was the second in a series of amateur satellites built at the University of Surrey in England. Its beacon remains active, although it is very unstable with irregular periods of transmission. Miraculously, the satellite has still been heard occasionally transmitting telemetry more than 36 years after launch! As I said, it transmits a beacon on 2 m, with inactive beacons on 70 cm and 2.4 GHz.

The satellite carried a so-called "Digitalker" (speech synthesizer), magnetometers, a CCD camera, a Geiger-Müller tube and a microphone to detect satellite vibrations caused by micrometeoroid impacts. Like its predecessor, UoSAT-2 transmits telemetry data on the VHF beacon at 1200 baud, using asynchronous AFSK, although all of its analog telemetry channels have long since failed.

A Brief History

UO-11 was launched on March 1, 1984 from Vandenberg AFB, California, with the aim of providing telemetry and other digital services for amateur radio and educational users. During its many years of operation, it has amazingly survived both long periods of eclipse and continuous full sunlight.

In 2002, its batteries began failing and, much like AO-7, it began operating principally with power generated from its solar panels — panels which were bought at a premium compared to those of UoSAT-1, the design having been space-tested by its predecessor. The satellite's so-called "watchdog timer" — a device to reset the satellite's main computer if all contact with the ground is lost — started suspending activity for up to three weeks at a time following numerous power anomalies.

Then, in 2005, all the satellite's analog telemetry channels failed. Long solar eclipses also caused UO-11's watchdog timer to completely reset the satellite from time to time, switching it off for approximately 15 days. In 2008, solar eclipses became a permanent feature of every orbit, sometimes causing the satellite to switch off after only one orbit. At that time, the satellite was not expected to be heard from again for any continuous period until 2019, when there would be some eclipse-free periods.

However, miraculously, the satellite started transmitting once again in November of 2008, followed by yet more long periods of silence. Then, after another long gap in observations, UO-11 resumed sending telemetry in December 2009, and has apparently continued its watchdog timer-controlled transmission regime ever since, although now on a very intermittent basis.

Sadly, the satellite's orbital condition has not otherwise improved apart from a small recovery of its battery power, allowing some broadcasts to continue into partial eclipse. As of late, the satellite has been heard from occasionally, sometimes with excellent signals reported from stations located around the world.

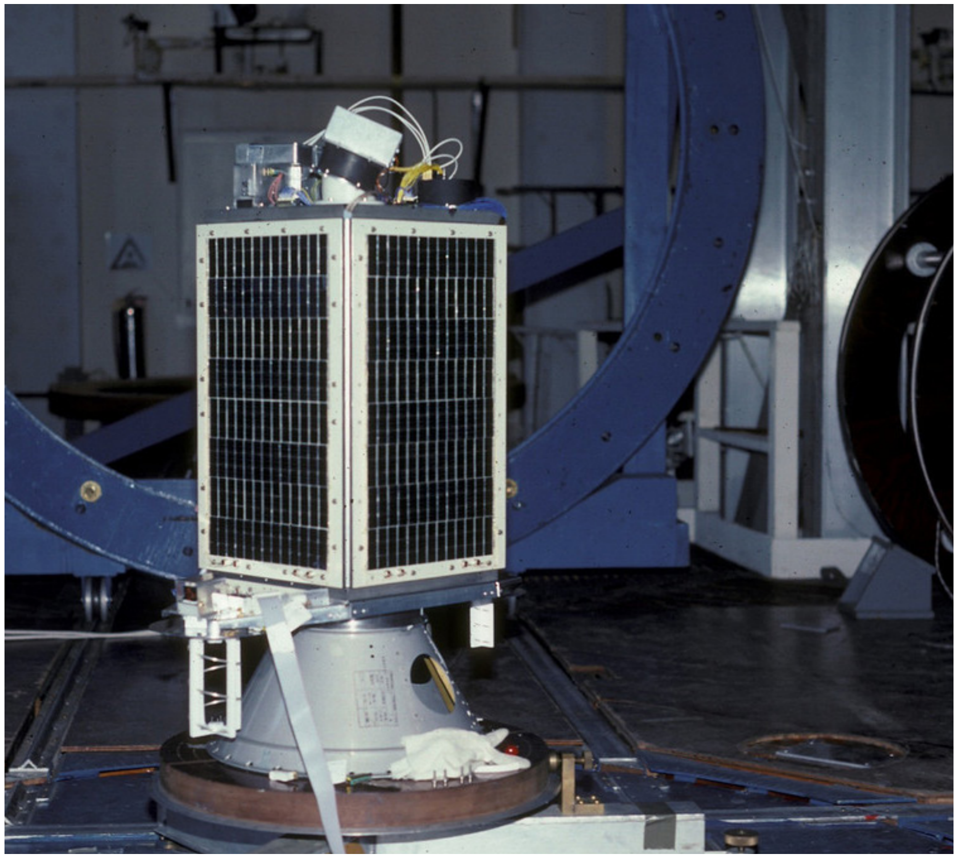


Figure 3 — UoSAT-2 (UO-11) is shown here mounted on its "shake table" with its solar panels attached. (Courtesy: AMSAT-UK/SSTL)

Figure 4 — UoSAT-2 (UO-11) was successfully launched aboard a NASA Delta II rocket from Vandenberg AFB, California on March 1,1984. (Courtesy: AMSAT-NA)

When and Where to Listen

UO-11's VHF downlink frequency is on 145.826 MHz. There are no uplinks. OSCAR-11's VHF downlink has a unique sound, rather like a raspy slow Morse code signal. If you are receiving a very weak signal, I suggest you switch your receiver to CW or SSB. You should hear several sidebands around the carrier frequency, and you should be able to hear the characteristic Morse code-like sound on at least one sideband. You'll also need a clean (that is, " noise-free") signal to decode UO-11's downlink, and your receiver must be set to NBFM mode for such a decoder to work.

More information about UO-11 can be found on the AMSAT-UK website at amsat-uk.org/satellites/tlm/uosat-2-oscar-11/.

FUNcube-1 (AO-73)

AMSAT-United Kingdom, in collaboration with AMSAT-New Zealand, has built and successfully launched a satellite they call "FUNcube" that features a 435 to 145 MHz linear transponder for SSB/CW operation. The project received major funding from the Radio Communications Foundation (RCF) in Great Britain and was developed in collaboration with ISIS-Innovative

Solutions in Space BV.

The first FUNcube, built around a standard, 1-U CubeSat space frame, was conceived as an educational CubeSat with the goal of both interesting and then educating young people about radio, space, physics and electronics. It directly supports the United Kingdom's educational Science, Technology, Engineering and Math (STEM) initiatives as well as provides an additional resource for the GB4FUN Mobile Communications Center in England. The target audience for FUNcube consists of primary and secondary school pupils. To further this aim, FUNcube's 145 MHz telemetry beacon provides a strong signal for school pupils to receive using just simple antennas and ground station equipment.

A wide-band, relatively low-cost receiver board called a "FUNcube Dongle" has also been developed to aid in achieving FUNcube's educational goal. The dongle can be connected to the USB port of a laptop (along with a simple receiving antenna) so as to display telemetry and messages from the satellite in an interesting way. The satellite also contains a materials science experiment from which the school students can receive telemetry data that they can compare to the results they obtained from similar reference experiments in the classroom.

FUNcube-1 was successfully launched on November 21st 2013 on a Dnepr rocket from the Dombarovsky launch complex near Yasny in Russia and was placed in a 682 x 595 km orbit. FUNcube carries a 1200 bps BPSK telemetry beacon on 145.935 MHz, a linear transponder with a downlink pass band of 145.950-145.970 MHz for SSB/CW

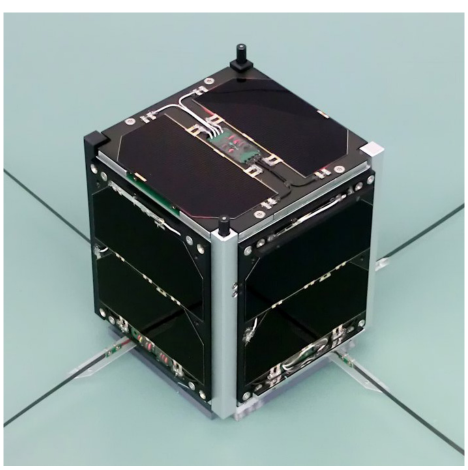


Figure 5 — The flight model of FUNcube-1 (AO-73) is shown here with its VHF and UHF antennas deployed. (Courtesy: AMSAT-UK)

Figure 6 — Members of the UKube-1 team are all smiles as they pose with the fruits of their labor — the flight model Ukube-1. (Courtesy: Clyde Space)

Figure 7 —An artist's depiction of how the UKube-1 satellite might appear on orbit. (Courtesy: Clyde Space)

communications, with an uplink receiver that will tune from 435.150-435.130 MHz. More information about the FUNcube project is available at AMSAT-UK's website at amsat-uk.org/funcube/funcube-cubesat. There is also a website dedicated exclusively to the FUNcube at funcube.org.uk/. Information about the FUNcube Dongle is at amsat-uk.org/funcube/funcube-dongle-sdr. Indeed, for those not otherwise equipped to receive the "birds," obtaining a low-cost FUNcube Dongle may be just your ticket to getting in on some of the action.

Funcube-2 (UKube-1)

The UKube-1 satellite was successfully launched on Tuesday, July 8, 2014, at 1558 UT from Pad 31/6 at the Baikonur Cosmodrome in Kazakhstan and is Scotland's very first satellite. It was designed, along with several onboard experiments, to carry a set of AMSAT-UK FUNcube circuit boards which provide a 1200 bps BPSK telemetry beacon on 145.915 MHz and (when it is finally activated) a linear transponder downlink on 145.930-145.950 MHz for SSB/CW communications with a linear transponder uplink on 435.080-435.060 MHz.

In addition, UKube-1 also carries a 1200 bps BPSK telemetry beacon on 145.840 MHz and a myPocketQub 442 on 437.425-437.525 MHz with 11 mW output using spread spectrum emission techniques along with a 1 W transmitter on 2401.0 MHz built by students and staff at the Cape Peninsula University of Technology (CPUT), Cape Town, South Africa. This transmitter downlinks high data rate mission data using up to one Mbps QPSK or OQPSK modulation.

At present, the other mission(s) of the satellite are continuing and there may be times when the 145.915 MHz FUNcube telemetry transmitter is activated. However, the amateur radio transponder is not expected to be available until later in the mission. Stay tuned to the AMSAT UK website (amsat-uk.org) for all the very latest information on this and future FUNcube projects.

Wrap Up

In future columns, I'll again be shining the spotlight on many other interesting past and future amateur radio satellite projects, as well as keeping you apprised of what AMSAT (and its world-wide sister organizations) are up to in space. See you then!

SELECTED FREQUENCY AND MODE DATA:

SATELLITE	***Uplink (MHz)***	***Downlink (MHz)***	***Mode***
UOSAT-2 (UO-11)		145.826	AFSK FM
UKube-1 (Transponder Not Yet Operational)	435.080 - 435.060	145.930 - 145.950 145.915, 145.840, & 437.475 2401.0	SSB/CW 1200 bps BPSK 1 Mbps QPSK
FUNcube-1 (AO-73)	435.150 - 435.130	145.950 - 145.970 145.935	SSB/CW 1200 bps BPSK

For Beginners - Amateur Radio Satellite Primer (Part VIII)

Keith Baker, KB1SF/VA3KSF
kb1sf@amsat.org

Over the summer and fall of 2020, I've heard many brand new call signs on our satellites as the COVID-19 pandemic has kept most of us close to home. However, I'm also noticing several of our new folks having various difficulties, including finding themselves in the passbands and then compensating for the inevitable Doppler shifts of their uplink and downlink signals while also trying to get their very first contacts on our analog birds.

So, in this installment, I'll once again share some more (hopefully helpful!) advice on both the proper etiquette and operating techniques now in use on our ever-growing fleet of analog satellites.

As I noted in my previous column, if you are new to AMSAT membership and are just now reading your very first copies of The AMSAT Journal – or perhaps you are ready to (finally?) try your hand at satellite operation, this column is part of a continuing series of "getting started" primers in the Journal that I've written on how you, too, can get in on the fun of amateur radio satellite operation.

And now that most back issues of this magazine are online in AMSAT's Member Portal, you can start at the beginning of this discussion. I suggest you start by downloading the September-October 2019 edition of the Journal that contains my first (updated) installment of these "getting started" columns. Hopefully, it (plus subsequent columns that have already been published in the Journal and those that will follow in the future) will help you get up and running on the satellites quickly.

Finding Yourself

As with all FM satellites, our satellite fleet operates as cross-band repeaters in what's called "full-duplex" mode. That's because, if you hear yourself on the downlink, others should be able to hear you as well. Over the years, I've perfected a simple manual operating technique that seems to work beautifully for me while also minimizing QRM to others in the passband.

The author's Kenwood TS-2000S is a 1990s-era, HF/VHF/UHF satellite-capable radio that, while allowing for computer input to compensate for Doppler shifts, still works very well with manual tuning. [All photos courtesy Keith Baker, KB1SF/VA3KSF.]

Shifting one's uplink frequency is easily accomplished manually on the TS-2000 by a quick flick of the RIT/SUB knob when a satellite's uplink frequency is programmed into the radio's sub-band VFO.

That is, once the satellite pops over the horizon, I first do a quick check to see if the satellite's beacon is operating. Once I confirm that it is, and I'm listening on the correct downlink frequency band, I'll then set my uplink frequency to the middle of the transponder's passband, and then send just a few, very widely spaced "dits" (in CW) while tuning my downlink VFO until I hear my own "dits" coming back at me. This response confirms that I'm "in the ballpark" with the right combination of uplink and downlink frequencies at that moment.

This simple technique effectively prevents an annoying "swishing" one's uplink and downlink signals (often in broad SSB) across the satellite's passband in a desperate search to find one's downlink. Unfortunately, that "swishing" also causes copious amounts of QRM to others in the passband already in QSO. CW "dits" are not nearly as offensive to others as broad SSB signals are, and they are just as effective in finding yourself while manually hunting for your downlink.

Which Sideband?

One of the other issues I've noted with newcomers to our analog birds is confusion about which combination of sidebands should be used on voice contacts. Often, newcomers have difficulty finding their own voice downlink signals because they are attempting to communicate through the satellite using the wrong (that is, opposite) sideband.

In short, the convention on all of our analog satellites is to use whatever combination of lower or upper sideband emission results in your downlink being on the upper sideband. This means that on an inverting satellite transponder, your signals going up to the satellite should be on the lower sideband. Conversely, on a non-inverting satellite transponder, your uplink signals can also be on the upper sideband. Fortunately, a CW uplink signal will always result in a CW downlink, regardless of the transponder's "flavor."

Compensating for Doppler

Back in the amateur radio satellite "dark ages," when veteran satellite operators (yours truly among them!) first became active on the analog satellites, we didn't have tracking software connected to computer-controlled radios to do our antenna tracking or Doppler tuning for us. Indeed, many of us (like me) used two manually tuned radios — one for the uplink and one for the downlink — to make our contacts. This meant that we were continually manipulating not one but two VFOs plus manually moving our antennas to keep up with the satellite as it moved across the sky.

Most of us soon developed our own set of (ambidextrous) tracking and tuning techniques that have served many of us well over the years, including what became known as the "One True Rule" for tracking the Doppler shift on our satellites.

Briefly, "The Rule" suggests that, when manually tuning for Doppler, you should try to keep one frequency steady while tuning the other. It also indicates that you should manipulate the higher frequency while keeping the lower frequency constant.

So, for example, on a Mode U/V satellite (the old Mode B), you should try to hold your VHF downlink steady while manipulating your UHF uplink to keep up with the Doppler shift. On a Mode V/U satellite (such as RS-44 and FO-29), the reverse is true.

Now, practically speaking, I've found that simply moving your uplink frequency while trying your very best to hold your downlink frequency steady on both "flavors" of satellites seems to work reasonably well. Granted, while the other person is talking, both their (and your) uplink frequencies will be shifting.

However, a quick flick of your uplink VFO (or your uplink RIT knob) will soon bring your downlink signal back into line with theirs once the other person hands the conversation over to you. Again, the goal here should be to minimize QRM on the bird and prevent your conversation from drifting into someone else's in the passband.

When connected between your computer and satellite antenna rotator box, a tracking interface, such as this AMSAT LVB Tracker, does a superb job of moving your satellite antennas to track the satellite as it moves across the sky. While no longer in production, LVB Tracker boxes can still be found on the used market.

Alan Biddle, WA4SCA, wrote a very detailed article about the "One True Rule" in an AMSAT Journal a while back. Those of you who might want to investigate a more detailed explanation of this whole subject can find his article at: www.amsat.org/wordpress/wp-content/uploads/2015/02/FDT-WA4SCA.pdf

Signal Reports

While I've sometimes heard signal reports and S-meter readings being exchanged on satellite contacts, they really are relatively meaningless. That's because downlink signal strengths have to be considered in relation to the satellite's orbital position, the orientation of its antennas with respect to yours, and the satellite's on-board power load.

The amount of power allotted to run a satellite's transponders (not to mention the rest of the satellite) will usually vary depending on how much solar power the satellite is producing at the time. That amount will often change considerably depending on a number of factors. For example, as the satellite moves from night to day (or as the angle of solar radiation striking its solar panels changes), so, too, will the amount of power available for its transponders change.

Another factor is the age of the satellite's on-board batteries. As batteries age, the amount of power they can store and deliver drops considerably. Combine these inherent power fluctuations with a continually changing transponder load — the number of QSOs in progress through the transponder simultaneously. It should be rather apparent that the strength of everybody's downlink signal will be continually changing.

If either operator has a receiver pre-amplifier in line, then downlink S-meter readings become even more suspect! Even "low-noise" pre-amplifiers tend to shift the S-meter reading upward. This means if you have a noise level from a receiver pre-amplifier generating an S-3 reading, then an S-6 signal ought to get an S-3 report, not an S-6!

Once again, the lesson here is that you need to forget most, if not all, of what you've learned about exchanging signal reports on VHF repeaters and the HF bands when you're working the birds. That's because satellite work is weak signal work! What's most important is for your downlink signal to simply be strong enough to be readable — period!

Software Control

Now, don't get me wrong; computer-based satellite tracking software has come a long way since the days when their only output was a set of printed Azimuth and Altitude vectors along with rise and set times for a particular satellite as it passed over your QTH. Indeed, AMSAT's SAT-PC32 now does far more than that, including a beautiful color display as well as providing wired outputs to control both your satellite antennas as well as to tune both uplinks and downlinks to compensate for "Dr. Doppler." Plus, the newer satellite-capable radios such as the Kenwood TS-2000 and the brand new ICOM IC-9700 also provide inputs for frequency tuning and, once set up and operating, mate quite well with SAT-PC32.

While the computer-controlled motion of antennas via software (using such equipment as AMSAT's LVB Tracker) does that job quite well, my own and others' experience, with the tuning aspect of those hardware and software features is a far more complicated endeavor to both set up and maintain.

For that reason, I strongly suggest a newcomer's first attempts at operating on our satellites be a manual affair to get started. Practice using the "One True Rule" I've outlined above before adding the complexity of computer control of both antennas and tuning to your operation. Hopefully, that approach will yield far more satisfying results for you and get you "up and running" on the birds without a lot of needless frustration. This is also called "Eating the elephant one bite at a time!"

Indeed, part of the fun (at least for me) of operating on our analog satellites over the years has been the inherent challenge of the tracking and tuning aspects of it. Or, to put it another way, if my computer, connected to my radio and antenna rotator control box, is doing all the work, why am I still in the loop?

That's why, even to this day, while I let my computer and LVB Tracker move my antennas, I'm still employing the "One True Rule" and doing the "finding myself" and Doppler compensation manually most of the time. But, as they say, "To each his (or her) own!"

Wrap Up

In future columns, I'll again be shining the spotlight on other exciting past and future amateur radio satellite projects as well as keeping you apprised of what AMSAT (and its world-wide sister organizations) are up to in space. See you then!

ICOM's new IC-9700 is a superb VHF/UHF/SHF radio with lots of satellite features, including computer software input to control the radio's uplink and downlink frequencies to compensate for Doppler shift.