

Getting Started on the Amateur Radio Satellites

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One of the great features of Amateur Radio is that it is really several hobbies rolled into one. If you become bored with one aspect of the hobby, there is always something new and different to try. For the last 40 years or so using the fleet of Amateur Radio satellites to communicate has always been one of the more interesting aspects of Amateur Radio.

However, if you are new to amateur satellites, or the "birds" as we satellite operators often call them, it's important to establish a general understanding about how to find and track these modern day wonders *before* you make your first attempts at using them. My goal in this short series of articles for *The AMSAT Journal* will be to provide you with a general introduction to the basic concepts of tracking, operation and customs currently in use on the satellites and to give you some practical, hands on tips on how, you too, can get started in this wonderful aspect of ham radio. For starters, I'm going to be using one of AMSAT's relatively easier-to-operate (one of or so-called "EZ sats") - AO-51 - as an example for you to try out your newfound knowledge.

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.

As of this writing, there are some 20 or so active ones up there, 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. What's even more exciting is that there are several other Amateur Radio satellites currently on the drawing boards or awaiting launch. So, it's safe to say your chances of at least hearing one of them (or, if you have at least a Technician Class ticket, actually communicating through one with your current equipment) is far better now than at any time in the recent past.

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 and 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 or for purchase, as well as in a variety of different computer formats. What's more, a number of Web sites related to amateur satellite operation now have online tracking programs that make rough tracking a snap. But, if you're really 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 individual catalog number of the satellite 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 the Keplerian element files into your satellite tracking software, the computer then solves the complex orbital math to make a prediction of where a selected satellite should be at the current (or a future) time.

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. Keps are often listed on many Amateur Radio Internet Web sites. The AMSAT-North America Web site lists the latest Keps in a variety of downloadable formats at: www.amsat.org.



The author uses a Kenwood TH-78A dual-band HT and a lightweight Arrow Antenna to make a contact through AO-51 from the shores of Lake Huron in Michigan. When used with a 5 watt, full-duplex handheld in an open location free of foliage, such as a beach or a field, the antenna provides enough uplink and downlink gain to successfully work the FM birds, even on passes close to the horizon. (KB1OGF Photo)



amsat.org/amsat-new/tools. And, as I said, for the so-called “easy FM birds” like AO-51 and the ISS, the AMSAT Web site 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 to you will next be in range of your location.

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 and/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-51 and most of our other FM satellites, the single channel downlink is itself, the beacon.

Transponders

Now that you have a reliable way to know when the satellite is within range of your station and you’re familiar with its beacon, you next have to learn how to use its transponder. A transponder is the circuit that receives your uplink signal and then retransmits what it hears via its downlink transmitter, much like an 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.

What’s more, as a satellite is a moving target, signals being passed 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 slowly drop in frequency than 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-51, uses what’s called a “bent pipe” transponder. That is, whatever form of radio communication is sent up to the satellite on the uplink is simply “sent through the pipe” back down on the downlink. AO-51 sports a variety of transponders, but the one I will be helping you attempt to use is its FM voice transponder.

Operating Modes

One of the terms you will soon come across in satellite work will be a reference to the 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 old 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 meters and its downlink frequency



The author’s wife, Kate Baker, KB1OGF/VA3OGF, makes a contact through the AO-51 satellite on the shores of Lake Huron in Michigan with her Kenwood TH-78A dual band HT. The extended “rubber duck” (MFJ Model 1717 from MFJ Enterprises) antenna and about 5 watts of uplink power provides just enough gain on the uplink and downlink to briefly work the satellite on near overhead passes.

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 somewhat more complex 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 receiver 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. For this article, the AO-51 transponder we’re interested in is the one for Mode V/U ... or the old Mode J ... with uplinks in the 2 M band and downlinks in the 70 cm band.

Schedules

Most amateur satellites operate on a published schedule that lists when its various transponders will be switched on and off and at what times. As AO-51 has multiple transponders, it’s very important to always check the published schedule for the satellite before you attempt to use it. AO-51’s current operating schedule is always available via the AO-51 Control Team page



Dubbed “Echo” before launch, the AO-51 satellite sits in the “Space Head Module,” the upper stage of its launch vehicle at the Baikonour Launch Complex in Kazakhstan. (AMSAT Photo)



Some Popular Amateur Radio FM "Easy Sat" Frequencies

Satellite Name	Uplink	Downlink	Remarks
AO-51 (Echo)	145.920 MHz 145.880 MHz	435.300 MHz 435.150 MHz	Default FM Voice
AO-27 (Eyesat)	145.850 MHz	436.795 MHz	Daytime Passes
SO-50 (SaudiSat 1-C)	145.850 MHz	436.795 MHz	67.0 Hz CTCSS Tone Required for Access

of the AMSAT Web site at: www.amsat.org/amsat-new/echo/index.php. Click on the "check the schedule" link and look for the "FM Repeater" frequencies. During a typical month, traffic on the transponders might be FM voice, Slow Scan TV (SSTV), low power (QRP) FM operating and/or the digital modes. By looking at the schedule you'll know when to expect the various modes and at what frequencies they'll be operating. Also, look for other activities on the schedule such as College Satellite Night or when AO-51's control operators reverse the spacecraft attitude to favor the southern hemisphere.

Equipment

Contrary to what you might believe, you *don't* need a super powerful FM transceiver and a huge antenna to work the birds. In fact, I (and many other amateur satellite operators) have sometimes met with success using just a simple dual-band hand-held radio and an antenna with just a bit more gain than the ordinary "rubber duck." However, because the UHF downlink output power on these "EZ sats" is usually pretty weak

(often less than 1 watt) you'll have far better success if you can create some signal gain on the downlink.

Several people have "rolled their own" Yagi satellite antennas for AO-51 using nothing more sophisticated than a series of trimmed coat hangers mounted on a block of wood. However, for many years and for most of my own AO-51 contacts, I've been using a commercially made, hand-held antenna from Arrow Antenna of Cheyenne Wyoming, www.arrowantennas.com. Their "Arrow II" Satellite antenna (with models starting at about \$75) is specifically manufactured for hand-held radio satellite work, is very well constructed (from aluminum arrow shafts, hence the name) and is collapsible for easy portable use.

It is also important to remember that AO-51, like most amateur satellites, operates in what's called *true duplex* or *full duplex* mode, meaning that the uplink receivers and downlink transmitters are both operating at the same time. It is helpful (but not absolutely necessary!) for your ground-based equipment to do so as well. By operating your station (or your hand-held) in full duplex mode, you will get immediate feedback that the satellite hears you because you will actually hear your own uplink signal coming back down to you on the downlink.

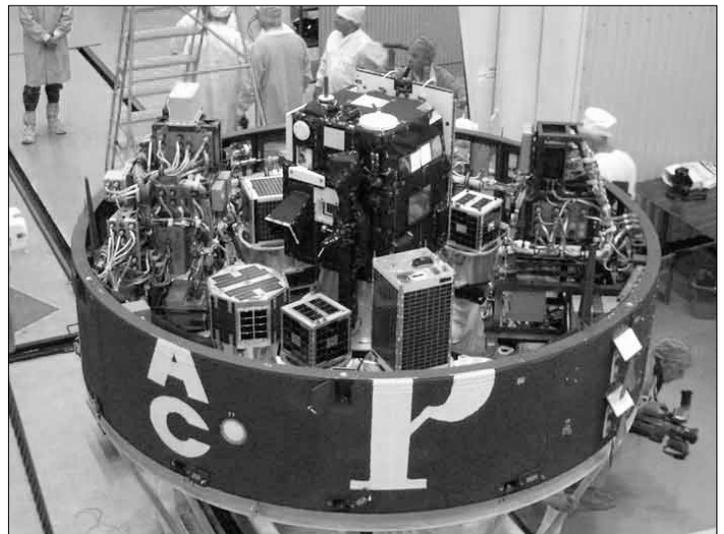
Unfortunately, fewer and fewer commercially manufactured radios these days have the capability to operate in full duplex mode. As of this writing, a short list of those (mostly older) radios compiled by Andrew,

KE5GDB, which do so can be (temporarily) found at <http://bit.ly/bUGJR3>.

However, even if you don't have a full duplex radio, you can still get in on the fun of working these satellites by using two separate radios, or a radio that can transmit on the satellite's uplink and another radio that can receive the downlink. If there is enough gain in your antenna, the latter radio can even be a hand-held or other programmable VHF/UHF scanner of some sort. Many novice satellite ops have also met with some success on AO-51 by simply waiting for a break in the action to transmit "in the blind" on the uplink and then listening for someone answering them on the downlink.

Setting Up Your Radio

Now that you have found out what time of day AO-51 will be in range of your location and you have assembled the equipment and antennas to do so, you are *almost* ready to make your first contact. But, first, you'll need to program your radios so as to take into account the Doppler shift that we discussed



Numerous other satellite passengers dwarf AO-51, shown here sitting in its upper stage carrying structure just prior to launch from the Baikonour Launch Complex in Kazakhstan. AO-51 is the small cube-shaped satellite shown in the lower left of the photo between the octagonal-shaped Italian UniSat-3 and the taller SaudiSat 2. (AMSAT Photo)



Chuck Green, N0ADI, prepares AO-51 for launch at the Baikonour Launch Complex in Kazakhstan. (N0ADI Photo)

earlier. If your radio has programmable memories, it's a good idea to program one or two additional frequencies into the memory bank above and below the published uplink and downlink frequencies. These can be used as the satellite first moves toward you and then away from you as it passes overhead.

For example, if the operating downlink frequency for AO-51 is listed in the satellite's operating schedule on the AMSAT Web site as 435.300 MHz, you should program



memories into your radio for 435.320 and 435.310 on the high side and 435.290 and 435.280 MHz on the low side of the published downlink frequency. Likewise, if the uplink frequency is listed as 145.920 MHz, you should program memories for 145.925 and 145.930 MHz on the high side and 145.915 and 145.910 on the low side of the published uplink frequency.

Also, like many of today's terrestrial repeaters, a number of our FM satellites require a CTCSS tone for access be sent on the uplink, so be sure and determine if the satellite you want to use requires one and set your radio accordingly. As of this writing, AO-51 required a 67 Hz CTCSS tone for access.

For a whole lot of reasons that are well beyond the scope of this article, the Doppler shift is more pronounced as the operating frequency increases. This means the Doppler shift will appear more pronounced on AO-51's downlink frequency than on its 2 M uplink. I've most often found that simply switching between my programmed 435 MHz downlink frequencies as the satellite passes overhead is usually enough to keep the satellite's downlink on frequency in my radio during the time that it is in range.

Power: How Much is Enough?

The issue of power is a relative one. It depends on the number of other people using the transponder; how much uplink gain you have in your antenna system, and how close or far away (overhead *vs.* at the horizon) the satellite is compared to your location. Usually, a 5-watt HT and the antennas shown in some of the pictures in this article are sufficient to work AO-51 on non-contentious days.

I say "non-contentious" because it is important to remember that the satellite is much like a terrestrial repeater mounted on a 500-mile high tower. With only one channel, it can get very busy, particularly on weekends. On some days, my 5-watt, dual band HT and an extended rubber duck antenna are sufficient for a quick contact on a near-overhead pass. On the other hand, during some busy weekend satellite passes, even my external Yagi and 50 watts of power isn't enough to overcome the high-powered uplinks of some inconsiderate operators.

Working in the Footprint

While it is technically possible to work these satellites at the horizon, you'll need something more than 5 watts from an HT and

a hand-held antenna to do so. It is important to remember that the footprint of the satellite, which is the area on the Earth where two people can see these Low Earth Orbiting (LEO) satellites and work each other through them, is about the size of North America.

Some hams on the U.S. East coast have, for example, used AO-51 to make contacts into Western Europe (and from the U.S. West coast to Hawaii). But that happens *only* when one person is on the extreme edge of the footprint and their counterpart is on the other edge. [And those contacts don't last long because the mutual footprint coverage moves away very quickly! – Ed.]

Polar orbit satellites such as AO-51 will typically give you three chances to work them, twice a day. Pass duration ... the time during which you'll be in the footprint ... can range from 7-15 minutes depending on whether you are in the full footprint or just part of it during the pass.

It's interesting to note that on many passes the footprint will cover the entire Atlantic Ocean. I know of several hams who have taken their Arrow, Elk or home-brew hand-held Yagi antennas and HTs along on cruise ships and made contacts from the outside deck of their ship ... after, of course, obtaining the appropriate permission from the captain of the vessel!

Putting it All Together

Now is a good time to visit the AMSAT Web site (if you haven't already) and download a set of current online pass predictions for AO-51 from www.amsat.org/amsat-new/tools/predict. Select the satellite for the prediction (AO-51) and then enter either your Maidenhead Grid Square or your latitude and longitude into the online prediction tool. Then, click on "predict" icon and, presto! A list of satellite pass dates and times (in UTC) and directions (in degrees) will pop up. You can also click the view the current location of AO-51 link for a snazzy map-based view of AO-51's next few orbits.

In the table, the acronym AOS stands for Acquisition of Signal which is the time when the satellite will first come over your horizon. The acronym LOS stands for Loss of Signal which is when the satellite will fall back below the horizon at your location. Both azimuth and elevation headings are expressed in the degrees of a 360-degree compass from your location.

You will also note that AO-51's satellite passes at your location follow a repeating



The AO-51 satellite launches on a converted Russian ICBM rocket on 29 June, 2004 from the Baikonour Launch Complex in Kazakhstan. (AMSAT Photo)

pattern. As the satellite is in a near polar orbit (which means it orbits over the Earth's north and south poles) this means the satellite will be in view of every spot on the planet several times each day as the Earth (and you!) slowly rotate underneath. For AO-51, and most other polar orbiting satellites, you'll usually observe a string of three passes ... one moving from north to south (or south to north) off to the east, one nearly overhead, and then one off to the west, with each pass spaced about 90 minutes apart. A similar string of passes will repeat some 12 hours later in the opposite north/south direction.

When you are first starting out, it's probably also best to pick a satellite pass that will put the satellite close to being nearly overhead (90 degrees) of your location. So, look for those pass elevations in the table that are well above 45 or 50 degrees. These will be your targets of best opportunity.

What to Listen For

Now, it's time to actually listen for the satellite. At the appointed AOS time, step outside, turn your radio(s) on and set it (or them) for one of the frequencies on the upper side of what's published for both the uplink and downlink. Then, wait for the satellite to pop above your horizon. If you are using a Yagi antenna of some sort, aim it at the horizon in the direction of the AOS prediction and start sweeping the antenna back and forth horizontally. Be sure to turn the radio's squelch on the



downlink frequency off and (carefully!) listen for the radio to quiet. Once it does ... congratulations ... you'll be listening to AO-51 in orbit some 500 miles above Earth!

You may want to practice tracking the satellite with your antenna and simply listening for the rest of that satellite pass (or a few more) to get a better idea of how the conversations flow on the bird. It is important to remember that, not only is the satellite rapidly moving toward and away from you, which is causing the observed Doppler shift in frequency, the satellite is *also* slowly tumbling in orbit. So, at multiple times during each pass, its transmit and receive antennas will be cross-polarized with yours, which, in turn, will create a significant loss in signal strength. If the satellite signal fades (or the down link gets garbled) try switching downlink frequencies on your radio up or down. Twisting or moving your antenna around to better match the satellite's changing antenna polarization with yours should also help.

During the pass, you'll probably hear one or more hams simply saying hello or exchanging their Maidenhead Grid Square numbers. Indeed, most conversations on AO-51 are usually very brief "hello – and – goodbye" exchanges similar to an HF DX exchange so as to give the many others listening in, a chance to work the bird. As you might guess, long-winded rag chews are *not* welcome on the FM birds.

It's Showtime!

When you've gathered up enough courage to actually try your hand at making a contact (and if you are using the same radio in full duplex mode on the uplink and downlink) you also need to make sure you are using a speaker separated from your microphone. This can be an earpiece or an external speaker of some kind. In full duplex mode, using a microphone and a speaker located right next to each other (such as on a handheld) will cause howls of feedback ... through the satellite! Needless to say, such activity will *also* not make you a popular camper on the bird, either!

However, once you are ready to try your luck at actually making a contact, simply wait for a pause in the action and then (quickly!) drop your call sign in between contacts. Hopefully, you will immediately hear your own signal on the downlink, a discovery that will provide immediate confirmation that you are, indeed, getting in. But, please refrain from calling CQ because, just like

causing long distance feedback and rag chewing, calling CQ on the FM birds is considered another amateur satellite protocol no-no.

But, regardless of how, where and when you do it, the first time you hear your own voice coming back down from a satellite (or someone answers your call), the thrill will be much like your very first ham radio contact, shaking hands, sweaty palms and all! It was for me.

See you on the birds!

About the Author

First licensed in 1976, Keith Baker, KB1SF/VA3KSF, holds an Extra Class license in the USA and an Advanced Class license in Canada. He is a Past President and the current Treasurer of AMSAT-North America and also served as AMSAT Executive Vice President from 1994 to 1998. Keith was also a member of the AMSAT Board of Directors from 1994 to 2003. Besides *The AMSAT Journal*, his amateur satellite-related articles and photos have appeared in *The ARRL Handbook*, *The ARRL Satellite Anthology*, *QST Magazine*, *CQ Magazine*, *CQ VHF*, *CQ Ham Radio (Japan)*, and *OSCAR News (UK)*. Keith was the author of *How to Use the Amateur Radio Satellites*, a work that was published in several editions by AMSAT-North America throughout the 1990s. He later donated that work to several other AMSAT organizations around the world where it was eventually translated into five different languages. Currently, Keith writes the quarterly "Sky Surfing" column about amateur satellites for *Monitoring Times* magazine. Some of his other more recent creative projects include writing portions of the AMSAT-NA publication "*AMSAT: The First Forty Years*," as well as serving as an editor for the ARRL's new *Satellite Handbook*. Keith currently makes his home in the small town of Corunna, Ontario, Canada with his wife, Kate (KB1OGF/VA3OGF) and daughter Emily. 📡



Getting the Right Antenna

As with any radio installation, the more money you put into it, the more versatile it will be. Still, you don't have to break the bank to get started. Here are some antenna tips to help give you a better chance for working AMSAT's so-called "EZ sats" with success.

The output power of these satellites is usually little more than a watt. Most often, the satellite's handlers will have the bird's downlink transmitters powered back into the 500 milliwatt range to help extend the life of the satellite's batteries. This means that any antenna you can muster on the ground to listen to the UHF downlinks from these satellites will help.

On the other hand, a somewhat more useful arrangement consists of a higher gain, externally mounted VHF/UHF vertical antenna such as that used for Amateur Radio repeater operation. This antenna installation will usually provide a bit more success if you want to hear satellite passes, for example, near the horizon.

Another very reliable antenna arrangement that many FM satellite enthusiasts have used consists of an externally mounted, dual-band, rotatable VHF/UHF, three or four element Yagi beam antenna set up for terrestrial operation. This approach allows users to aim their beam antenna at the horizon and work through the satellite as it rises. Then, as the satellite passes overhead, they swing their beam antenna around in the opposite direction and catch the satellite as it sets. Such an arrangement is useful for contacts on satellite passes up to about 45 degrees in elevation. Now, of course, the ultimate satellite antenna for full pass coverage is a high gain, three or four-element set of VHF/UHF Yagi beam antennas mounted on an altitude/azimuth rotator. But, you don't need that just to work the "EZ sats."

(Left) Until its successful launch, AO-51 was called "Echo" as it was the fifth satellite built entirely by AMSAT-North America. The AO-51 moniker (which denotes it as the 51st AMSAT OSCAR satellite successfully launched) was awarded once the satellite achieved orbit and transmitted from space. (AMSAT Photo)

