Newcomers and Elmers Net: Operating Satellites AK3Q
Sept 22,2013

Of all the hobbies I have enjoyed over the years, I believe the radio hobby has been the most rewarding overall, and continues to stimulate my curiosity like no other. Radio offers an almost endless opportunity for exploration and creativity, and I find myself continually amazed at what folks have accomplished in this field.

For example, did you know folks regularly bounce signals off the moon to talk with other hams around the world? Think about this for a moment: a signal originating here on earth travels almost half a million miles round-trip and is received a few seconds later around the world. Wow! Now that's impressive! I doubt even Marconi could have imagined such a feat!

Not long ago an even more impressive feat was accomplished by German Amateur Radio operators as signals were bounced off of Venus at a distance of almost 100 million kilometers! The RF trip takes about 5 minutes and uses very high tech equipment in the process.

Maybe I am still just a kid at heart, but feats like this just fill me with wonder. I found out quite recently a local club has a station capable of EME work and I can't wait to see it in action, or to, dare I say it, work a station or two myself! The site is undergoing some repairs and is therefore off the air, but when it's back up I am *sooo* there!

Working Amateur Satellites
If you are an Amateur Radio operator, chances are you have heard about working satellites or the International Space Station (ISS), if only as you studied for your radio license. You may also have heard about Amateur Radio satellites built for and by Amateur Radio operators launched into space specifically for use by hams around the world.

What you may not have realized, however, is just how easy it is to listen to and make contact with these "birds" as they are affectionately known. One does not need expensive equipment at all to listen to or contact some of these satellites, and even contacts with the space station are possible using rather meager equipment.

The main difficulty with contacting the ISS is not the complexity of the process involved in making the contact, but rather the limited amount of time astronauts can spend on the air. Hearing the ISS or one of the many satellites as they fly overhead is fairly easy—it just requires some patience, technique, and an ever-present spirit of adventure! While I will talk about the necessary equipment and techniques below, let me start by giving just a brief overview of the history of amateur satellites and some of the radio theory involved. (I'll be brief, I promise!)

Satellite History

One does not have to stretch the imagination much to realize almost as soon as objects were being sent into space Amateurs around the world were thinking "Boy, would it be cool if we could figure out how to use a satellite to talk with other people around the world?" When Russia launched the first satellite in October 1957, Amateur Radio operators around the world monitored its transmissions. Four short years later the first OSCAR (Orbital Satellite Carrying Amateur Radio) launched on December 12th, the 60th anniversary of Marconi's first radio transmission across the Atlantic. What an exciting time to be in ham radio!

This first *hamsat* only had enough power to transmit its Morse code message "Hi" for about three weeks since it did not use a rechargeable battery, but hundreds of Amateurs in 28 countries sent in reception reports. This was the start of many more Amateur satellites to come.

By 1965 Amateurs had launched the first repeater satellite allowing two-way communications, and over 1,000 hams had contacts during its 18 day life cycle. This satellite also had two beacons which were used for telemetry and propagation information. The beacons were actually powered by solar cells, and they far outlasted the transponder.

Fast-forwarding to 2004, AMSAT-OSCAR 51 (AO-51) was launched in June of ‘04 and is probably the best known of the satellites for making contacts. By comparison to the early satellites of the 1960’s, AO-51 offered a wide array of features (active until 2011):

* telemetry at 435+ MHz
* analog FM voice communications
* digital communications with APRS
* two UHF FM downlink transmitters for the downlink that can be operated simultaneously
* four miniature VHF FM receivers weighing less than two ounces each for communications and command-and-control
* two downlink transmitter channels
* simultaneous voice and data,
* wide-coverage multi-mode receiver covering 100 KHz to 1.3 GHz

One of the more exciting aspects of Amateur Satellite work is the role Hams have played in their development as well as the truly international cooperation of the AMSAT community. Many nations have built and launched satellites, and this spirit of cooperation represents the best of the Amateur community.

Satellite Transmission (Lite)
While communicating with a satellite might seem highly complex, it really is rather simple, thanks to advances in computers and radio equipment. As one might imagine, merely tracking where a satellite is at any given time can be quite a challenge for the mathematically and/or time challenged among us! Fortunately there are a number of programs, many of them free, which will track any number of satellites right on the computer screen, as well as Internet sites which do the same thing.

With some basic information such as one’s longitude/latitude position, these software programs can quickly give you a visual representation of a satellite’s current position, as well as projected times for flyovers at your location. Within minutes I can find out which satellites will pass over my house on a given night, grab a few pieces of gear, and start tracking a bird to catch its signals.

Knowing where a particular satellite is going to be is 90% of the battle, while finding it with your radio is the other 10%. The rest is just having the right frequencies punched in and a clear path to follow the bird's movement along the sky. While tracking a satellite does not require expensive computer-controlled antennas (don't get me wrong, they <u>are</u> the ultimate way to work satellites!), understanding a bit of what happens to the satellite signal as it moves along the sky is very useful regardless of the equipment in use.

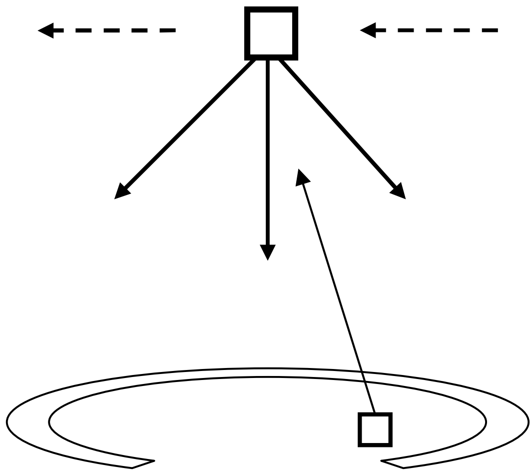
The *Doppler Shift*

One of the topics which falls under "theory" is the *Doppler Shift* (or effect), named after the scientist who first discovered this phenomenon. The Doppler shift, as you may remember from your science class days, is where the frequency of a wave changes as the source and destination change in relationship to one another.

The most common example of this is when one listens to a siren approaching from an emergency vehicle. The frequency is higher as the sound approaches, and lower as it moves away. The siren itself is always the same, but our perception of it changes as it moves in relationship to us.

The same effect happens when listening to radio signals transmitted by a satellite. As the satellite approaches it is best received on one frequency, but as it comes directly overhead it is on another, and when moving away it moves to another frequency. Base radios which are designed for listening to satellites often have some means of continuously adjusting for this Doppler Effect, but when using handheld radios one must make these adjustments manually.

On the plus side, neither the satellite nor the ground station needs to use much power to communicate with one another due to the nature of Earth-Space communications. Where one might assume, based on the great distances involved large power would be required, satellites can use 1 or 2 watts of power (or less!) to effectively communicate, as can folks on earth who are sending their signal skyward.



Think of the satellite as an antenna mounted way up high and you will get the idea. Just as an antenna mounted on a high mountain reaches far greater distances than one at sea level, so too an antenna in space reaches far more areas with less power than an earth-bound antenna.

As the satellite moves across the face of the earth its coverage is broad, while the earth-bound station merely points toward the moving satellite. Both can use low power.

Also, since much of the distance involves the vacuum which is space, signals are not obstructed or bounced, again lowering the power required to transmit.

Finally, since satellites operate primarily in the VHF or higher range, the normal RF issues apply here as they do with any VHF or higher transmission. The same weather conditions which affect 6-meter and above contacts may also affect satellite contacts, as well as other atmospheric and ground-based interference.

While this means trees and other obstructions can prevent line-of-sight communications, the higher frequencies are less prone to static and other interference common in the lower bands. This makes satellite contact a fairly reliable means of communication, all things considered.

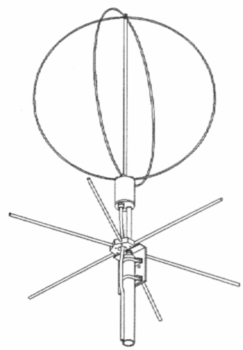
Polarization
A bigger issue, as it relates to antennas for satellite work, is the issue of polarization. As I mentioned above, an advantage to satellite work is the relatively direct line of sight between receiver and transmitter: antennas pointed toward space have a pretty clear path to the satellite orbiting above. This does have a bit of a downside however, in that because signals are not bouncing along the atmosphere the way they do with HF signals, matching polarization does become an issue. The receiving antenna needs to match the orientation of the transmitting antenna or a significant signal loss might be encountered. Since we have no control over the antenna placement of the satellite, we need to use the proper polarization on our earth-bound antennas.

Just by way of quick review, generally speaking, an antenna oriented parallel to the surface of the earth has horizontal polarization while a vertical antenna has vertical polarization. As a satellite moves overhead and changes position relative to your location, fading may occur because the polarization has changed. This is one of the bigger challenges faced by satellite chasers. Fortunately there are several solutions depending on one’s budget and methods of satellite tracking.

A simple solution is to use a handheld antenna and change its position relative to the moving satellite. Because low power is sufficient to work most satellites, this is a very viable option and it is the one I use. For those with the budget to do serious “bird” watching, there are antennas designed to be rotated while at the same time changing elevation angles. These options allow for computer controlled tracking of a satellite and extremely accurate placement in relationship to the bird’s orbit. For our purposed here I will focus on the freehand method of tracking a satellite, but just be aware this is an area of the hobby which offers a lot of room to grow!

Circular Polarization

Another solution to the problem of changing antenna polarization is to use what are known as "eggbeater" antennas, so-called because their shape resembles the kitchen utensil by the same name.



These antennas are designed to deal with the problem of fading by having two loops at a 90° angle to one another. This somewhat replicates an antenna with both vertical and horizontal polarization, so fading is reduced. This is a good solution particularly if you desire to have a station with fixed antennas.

While most of my satellite work is done with a handheld antenna, I have listened to the ISS with my regular 2-meter log periodic antenna because I happen to have it angled at about 45° anyway. This allows me to hear some of the flyovers if the space station elevation is high enough. Almost any 2-meter antenna will work for at least a few moments. Even the rubber duck of a handheld will hear for a couple of minutes if the signal is coming in from a high enough elevation. A higher gain antenna will hear much better and for longer periods of time, but don't be afraid to give a listen with your HT for starters—any satellite you hear is a real thrill!

Equipment

I doubt back in 1961 folks who listened in on the satellites would have ever dreamed they could work a bird with nothing more than a handheld radio and a basic telescoping antenna. Many folks, me included, have labored under the mistaken belief that to work a satellite or the space station one needed complex antennas or a satellite dish like those popularized in space movies. Every day of the year folks make contacts with satellites using very minimal equipment, so don't let a lack of a sophisticated antenna farm stop you from having a great time with this activity!

I recommend starting out fairly simply and building up your capabilities as your interest and/or budget allows. Make use of your handheld radio as nothing beats its portability. Depending on the bird you are listening to, a single- or dual-band radio will be required along with an antenna which has a bit of gain. A handheld antenna like the tape measure antenna will work quite well, or a similarly styled dual-band antenna as needed.

I use a dual-band Arrow antenna, a commercial unit and one that has garnered a great reputation for working satellites (see photo at left). While I would not hesitate to build my own these days, I got this soon after getting into Amateur Radio because I knew working satellites was one of my major goals in the hobby. The antenna does work well, and I have had good customer service from the company.

There are also other manufacturers who put out a good quality antenna, so don't hesitate to buy a decent antenna if you are not ready to build your own.

Radios

Some satellites broadcast their uplink and downlink frequencies on the same band, while others receive on UHF and transmit on VHF, and so on. A dual-band radio with built-in diplexer can be useful, but two mono-band receivers work well also. This is the setup I use most often as the antenna I use has dual connectors for VHF/UHF. I like the simplicity of such a setup as it makes it easy to hear the receive while transmitting. It is a bit more awkward to handle two radios, but I built a platform which mounts to a tripod to hold the radios while I focus on pointing the antenna (see photo at right).

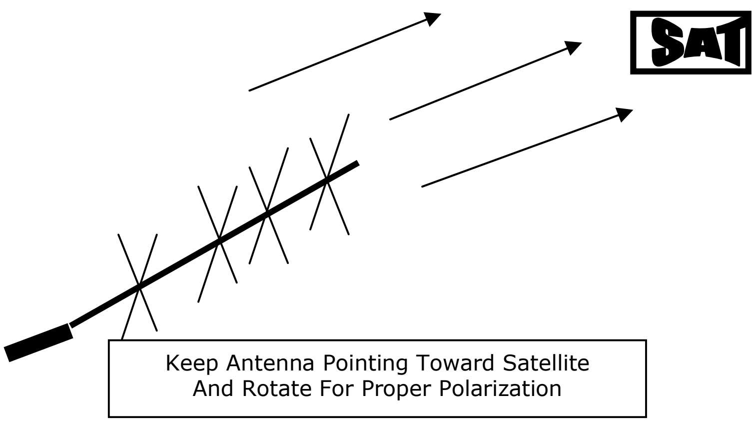
Technique

After determining where and when a desired satellite is going to pass over your location, the hardest part of the process is locking to the signal. I would recommend spending a few evenings practicing this part of the process as you will be surprised at how easy it is to miss the signal. I was quite lucky my first time out as I locked to the signal pretty quickly, only to lose and reacquire it a number of times.

By just focusing on the receive portion of the contact for a few times, not only will your movements get more fluid and your ability improves to keep the bird in range, but you will also be able to listen to the manner in which contacts are made. Unless you are listening to simplex transmissions on the ISS, most of what you will hear will be repeater contacts between folks back on earth. These contacts are quick and precise, so for the sake of all the other folks wanting to make contacts, follow the lead of those who are already working the birds. If the ability comes up some day to have a short QSO with someone longer than an exchange of ID and grid location, great! Just make sure you are mindful of others trying to make their own first contacts. Save the “ragchewing” for terrestrial contacts!

By the way, make sure you keep the squelch open to hear the transmissions. While many of the satellites are using a repeater, the low power requires the squelch be open wide so the signal gets through—otherwise the relatively weak signal will not open the radio.

When pointing an antenna toward a satellite contact keep in mind the polarization issues I mentioned earlier. Unless the satellite is very low on the horizon, point the antenna at the bird and follow it while rotating the antenna as needed to match polarization.



Here again I will mention the importance of practice. Learning how to smoothly move your antenna is very important, not to mention learning how to adjust your radio(s) as required for the Doppler Effect mentioned above. All of this can get rather nerve-wracking when trying to also make a contact on the satellite, so take your time and become comfortable with the process. The birds are flying overhead multiple times each day!

Preamplifiers
Due to the low power nature of satellite transmissions (lower power equals longer battery life, less weight, and more efficient solar cells) sometimes preamps are used to boost the received signal strength of a particular satellite. These are most commonly used on base stations or stationary antennas since the preamp requires a power source of its own to increase the signal strength. While these are not necessary, they do make hearing and hanging on to a signal a bit easier and well worth the investment.

If using a dual-band antenna, make sure the preamp has an RF sensing circuit in it to protect it from overload when transmitting. If using two separate coax lines for uplink and downlink, then the sensing circuit is not required.

Practical Antenna: The Cheap Yagi
As I mentioned earlier, you may want to build the tape measure antenna if you haven't already, as it will serve you well for both foxhunting and satellite work. Another great do-it-yourself antenna and one which has been copied endless times, comes from Kent Britain, WA5VJB, and may be found at:
http://radio.obarr.net/downloads/cheap_yagis.pdf

There are many frequency variations available for this antenna, along with charts for calculating the various dimensions required for each band. The idea behind this antenna is something which is simple to build with materials available as scrap or for dirt-cheap cost. Kent was challenged by a Cuban ham to come up with something not dependent on a local electronics store, since there are few such shops in Cuba. The result is this design which works extremely well, and should serve as a reminder that antennas do not have to cost an arm and a leg to get the job done!