By Ed Krome, K9EK

Getting Started with AMSAT-OSCAR 40

After months of anxiety about the health of Amateur Radio's most advanced satellite, hams worldwide may soon be rewarded with access to AO-40. Here's how to get started.

The long-awaited AMSAT Phase 3D satellite roared spectacularly into space on November 16, 2000. The launch into a geosynchronous transfer orbit by the Arianespace AR-507 launch vehicle from Kourou, French Guiana, was completely "nominal"; in other words, perfect. Initially, the 70-centimeter beacon was supposed to turn on within a few hours of launch, but did not do so. However, the 2-meter beacon turned on and worked well. The new satellite, christened AO-40, was heard worldwide.

On December 11, after the first 400-Newton bi-fuel engine burn, P3D/AO-40 became silent. The command stations, Karl Meinzer, DJ4ZC, Peter Guelzow, DB2OS, James Miller, G3RUH, Stacey Mills, W4SM, Graham Ratcliff, VK5AGR and others began recovery attempts immediately. The satellite was completely unresponsive. Amazingly, NORAD, which tracks thousands of space objects, was able to radar image AO-40 well enough to determine that it appeared to be in one piece.

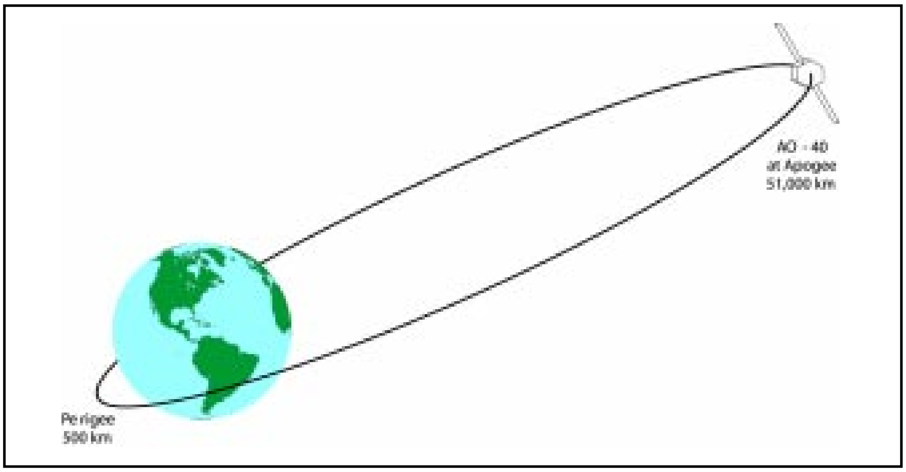
At least two automatic resets passed without hearing from the spacecraft. Then, on Christmas Day 2000, the second attempt to activate the S-band (2.4 GHz) transmitter was successful. AO-40 was still alive!

The good news—and there is really quite a bit of good news—is that the remaining satellite systems appear to be functioning normally. And although OSCAR 40 did not reach the inclination the team desired, its current orbit is stable and very useful. At the highest altitude of its orbit (the *apogee*), AO-40 seems to "hover" in the sky for hours at a time. We may have indeed lost our *downlinks* (satellite-to-ground transmissions) on 2 meters and 70 cm, but OSCAR 40 still has two fully-functional downlinks on 13 centimeters, as well as 2-meter and 70-cm *uplinks* (ground-to-satellite). This means OSCAR 40 still has the potential to be a fantastic DX satellite. The only difference is that you will need to set up equipment to receive on the microwave bands, which isn't nearly as difficult as you might think.

Before we start talking about hardware, however, one of the first purchases for your OSCAR 40 station should be satellite tracking software. You can't talk through the satellite until you know where it is! AMSAT's inexpensive PC- and Mac-based tracking software is highly recommended. In fact, these programs are tremendously interesting and instructive to "play" with—even if you never use them to track a satellite. Software sales provide a significant portion of AMSAT's operating and satellite-building funds, so when you purchase tracking software you'll know that you're doing your part in making AO-40 (and follow-on satellites) a reality. Just cruise on over to the AMSAT-NA Web site at **www.amsat.org**.

Communications Possibilities

Despite the damage, AO-40 still has a wide variety of operating frequencies and modes. Each individual transmitter and receiver has a common intermediate frequency of 10.7 MHz. All are connected to a central distribution network called the IF matrix. The IF matrix can be commanded to pair any uplink(s) with any downlink(s), providing the crossband, full-duplex modes that make satellite operation so different from terrestrial



AO-40's orbit is elliptical, which will give the satellite an outstanding "view" of much of the Earth. For hams on the ground, this means that we will have access to AO-40 for hours as it approaches every apogee.

AO-40 Ground Station Requirements

By Frank Sperber, DL6DBN

Uplink

Band	*EIRPc* [5]	*TX-power*	*Antenna*
435 MHz	21 dBWi	10 W 40 W	10-element X-Yagi[2] Crossed Dipoles over Reflector Plane[1]
1270 MHz	23 dBWi	10 W	12-turn Helix
2400 MHz	27 dBWi	5 W	60-cm Parabolic Dish[3]
5670 MHz	34 dBWi	10 W	60-cm Parabolic Dish

Downlink

Band	*GND-PEP/QSO* [4]	*Antenna*	*S/N*
2400 MHz	–167 dBWi	60-cm Parabolic Dish 14-turn Helix	26 dB 18 dB
24 GHz	–197 dBWi	60-cm Parabolic Dish	13 dB

Note: These are estimated values taken from the AMSAT-DL (AMSAT-Germany) Web site. The following are notes on the various types of antennas and terms:

(1) "Crossed dipoles over a reflector plane" is a pair of center-fed dipoles, mounted at 90° to one another, fed 90° out of phase, to produce right-hand circular polarization, suspended over a reflective sheet. This is a simple circularly polarized antenna with a predominantly vertical radiation pattern. Tracking is not required.

(2) "X-Yagi" ("crossed Yagi") is a right-hand circularly polarized Yagi antenna made with 2 sets of elements at right angles to each other. These elements are fed in a phase relationship that produces circular polarization. A "10-element X-Yagi" has two 10-element Yagis on a common boom. It is a relatively small directional antenna that requires tracking.

(3) "60-cm parabolic dish" is a 24-inch-diameter parabolic dish antenna with an appropriate feed for the band in use. Satellite tracking is required.

(4) "GND-PEP/QSO" is the signal strength of the satellite's signal on the ground.

(5) "EIRPc" is Effective Isotropic Radiated Power, circularly polarized, in decibels (dB) relative to 1 W. This is effective transmitted power from a combination of actual transmitter watts and antenna gain, referenced to an "isotropic" (point source) radiator.

communications. Theoretically, any uplink(s) can be paired with any downlink(s), though there are technical reasons why some pairings will never be used. Also, there can never be uplinks and downlinks in the same band at the same time. AO-40 isn't a repeater; it is a cross-band transponder. Because this allows so many combinations, a new mode naming convention has been adopted. Each band has an alpha designator. Both band designators, in the order of uplink/downlink, refer to a complete up/down schema. For example, the popular "Mode B," with its 70-cm uplink and 2-meter downlink, will now be referred to as "Mode U/V."

As of this writing, mid-May 2001, the following items have been found to be working: the 2-meter (V), 70-cm (U) and 23-cm (L) receivers (uplinks), both 2.4 GHz (S) transmitters, the magnetorquing (satellite orientation) system, the YACE (Yet Another Camera Experiment) camera, IHU-2 (Internal Housekeeping Unit – 2), both RUDAK (digital communications experiments), LEILA (the alligator-killer) and the high-gain antennas. The following items are believed not to be working: the 2-meter and 70-cm transmitters (downlinks), the 10-GHz (X) transmitter and the omnidirectional antennas. Status of the 5.7 GHz (C) receiver, the 360-THz IR laser transmitters and the 24 GHz (K) transmitter appear favorable. The power and battery systems appear to be working well.

Where Do I Start?

My suggestion is that you start by assembling the components you'll need for a Mode U/S station—transmitting on 430 MHz and receiving on 2.4 GHz. Unless the command team manages to recover the 2-meter and 70-cm transmitters, this is likely to become the most popular configuration. OSCAR 40 is transmitting telemetry on 2.4 GHz now and some limited 2-way operation is already taking place.

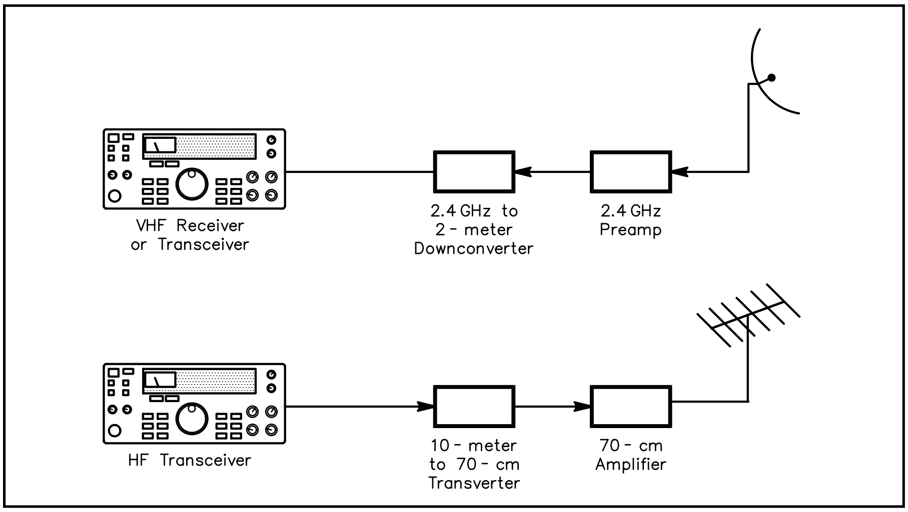
Antennas

There are a number of 2.4 GHz receive antennas available to you. Check out the Down East Microwave Web site (**www.downeastmicrowave.com**) and take a look at some of their 2.4 GHz loop Yagis and helixes. Other excellent choices include the Andrew 26T-2400 grid-style dish antenna and AirLink parabolic dishes. Both assemble in about 15 minutes—no tuning or other adjustments required. PC Electronics sells the Andrew dish. You'll find them online at **www.hamtv.com**. The AirLink antennas are available from SSB Electronic (see the "Resources" sidebar).

Also, Phillips-Tech offers grid-style MMDS dishes, complete with feeds, that are reasonably priced and work well. Find them on-line at **www.phillips-tech.com**.

For transmitting on 430 MHz, you don't need a monstrous antenna; it depends on how much transmitter output you can generate. The less transmitter output you have available, the bigger the antenna you'll need. For example, if you run 100 W output on 430 MHz, you will probably be able to get away with a small 6- or 8-element Yagi for your uplink antenna. Don't worry too much about antenna polarization at this point. Yes, it would be nice to have a circularly polarized antenna for your uplink, but AO-40 is so sensitive, you aren't likely to notice the 3-dB loss you'll incur by using just horizontal or vertical polarization.

What about an antenna rotator? Satellite tracking requires the ability to adjust the antenna in both the azimuth (measured in degrees clockwise from North) and elevation (measured in degrees up from the horizon). A new, off-the-shelf Az/El rotor can be expensive. If all you have is an azimuth rotor, you can use the characteristics of both the satellite itself and of your antenna to operate over a significant part of the satellite's orbit. First, use your tracking software to follow AO-40 through typical passes. Notice that the satellite is never directly overhead and spends most of its time in mid-elevation. Also, notice that, except around perigee (the point of closest approach to Earth), the orbit changes relatively slowly. Then, remember that an antenna's receiving pattern capability is not needle-sharp. It has a beamwidth over which it will provide satisfactory reception. If you set your antenna to 10-20 degrees elevation and lock it there, then follow the satellite in azimuth only, you will enjoy quite



A Mode U/S station could look something like this. A 24-inch parabolic dish antenna receives the 2.4 GHz downlink, which is amplified and then converted to 2 meters. Almost any receiver capable of listening to 2-meter CW or SSB could be used to monitor the converted signals. To transmit at the 70-cm uplink frequency, an ordinary HF transceiver could drive a 10-meter-to-70-cm transverter. A 70-cm RF power amplifier gives the necessary boost and the small 70-cm Yagi antenna sends the signal on its way.

a bit of "talk time" before the satellite disappears from your window.

Receiving and Transmitting

To operate Mode U/S remember that you need to transmit to the satellite on 70 cm and receive on 2.4 GHz.

The uplink is straightforward. You can use a 70-cm multimode rig as your uplink transmitter (possibly paired with a "brick" amplifier to generate a little more "oomph").

To receive on 2.4 GHz you will need to convert the signals from microwave to something lower in frequency—such as 2 meters. For this you'll need a *receive converter* (sometimes referred to as a *downconverter*) such as the Down East Microwave 2400RX or the SSB Electronic UEK-3000. You install the unit at your antenna so that the signal is converted right away before making the trip through the coaxial cable to your station (more about this in a moment). Most 2.4-GHz receive converters convert to 2 meters. So, you'll need a 2-meter all-mode receiver at your station. A number of HF transceivers now include 2 meters and these will work just fine in this application. Another alternative is an all-mode-scanning receiver. If you have only HF receive capability, you can obtain a 2-meter to 10-meter converter. The 2-meter output of the 2.4 GHz converter routed to the shack, where it is fed into the 10M-2M converter, then to the HF receiver, where it is received in the 10-meter band.

The same approach is used for reception on the higher bands.

As long as we're talking about hardware, another popular approach to setting up the foundation of a microwave satellite station is to simply buy a multiband (2 meters/70 cm or even HF through 70 cm) transceiver that includes satellite features. These rigs take a lot of the guesswork out of the whole operation. The ICOM IC-910H transceiver generates all the output you'll need to uplink on 70 cm and includes the 2-meter receiver for use with a downconverter. The same is true of the Kenwood TS-2000 and the Yaesu FT-847. If you prefer to buy used gear, check out the ICOM IC-821H, Yaesu FT-736 or Kenwood TS-790. Note that none of these radios cover the 2.4-GHz downlink, so you will still need to use a converter to receive.

More About Converters

As frequencies increase, frequency converters become the method of choice for a variety of reasons, both economic and technical. The complexity of a receiver or transmitter is in the interface between the RF world and the audio/digital world. By adding a receiving converter to a good quality receiver, the receiver's usage may be easily extended for a fraction of the cost of a complete radio. Older Drake and Collins radios, with their crushproof vacuum tube front ends and high selectivity, can be attached to converters to provide exceptional microwave performance. You can also generally plug one receive converter into another. For example, a 2.4 GHz to 10-meter converter is difficult to find, but you can plug a 2.4-GHz to 2-meter converter into a 2-meter to 10-meter converter. In my own weak-signal station, I have never owned a radio that would tune above 30 MHz. I simply plug one converter into another and eventually wind up somewhere in the 10-meter band. The frequency readouts aren't always exact, but it all works just fine.

The technical reason, which becomes more important as frequencies increase, has to do with noise. Overall receiving system performance is determined by the signal to noise ratio. For a given signal level, we can make a big difference in the quality of our received signal by lowering the noise part of the equation. And the most significant contributor to overall system noise is front-end noise. On UHF, natural noise from space (caused by electron motion) is very low. Man-made noise is also low. The noise comes from our amplifying devices and from the degradation of the signal between where it is received (the antenna) and where it is first amplified. Coaxial cable is the most common connection medium, and it is far from ideal. As frequencies increase, coaxial cable becomes progressively (and amazingly) lossy. If this loss occurs between the antenna and the first stage of RF amplification, it looks like noise and degrades the performance of the overall system. How do you prevent cable loss? The best way is to eliminate the cable. This is why mounting a low-noise preamplifier in the shack is nowhere near as effective as mounting the same preamp at the antenna.

By using converters, the highest-frequency amplifiers and conversion gear can be mounted remotely, right up at the antenna. Then the lower frequency output can be routed to the shack through inexpensive cable. High-quality commercial converters incorporate weatherproof construction and low-noise front ends and are designed for antenna mounting.

Digital Operation

AO-40 has a variety of digital experiments in dedicated subbands. There are two hard-wired 9600-baud modems (these require the same ground modems used for the 9600 baud LEOs) and 16 "agile" (programmable) modems attached to the RUDAK computers. Operation of both RUDAK CPU's with the 9600-baud modems and both 153.6 kBit/s high speed PSK downlinks has also been verified on the 13-cm downlink. Beacon telemetry, currently being transmitted on the 13-cm Middle Beacon, is 400 baud BPSK, the same as that on AO-10 and AO-13. W4SM's *P3T* (**www.cstone.net/~w4sm2/software2/P3t_AP.zip**) is the telemetry demodulator and analysis program. There is also a

Transponder Frequency Band Plan for AMSAT-OSCAR 40

Note: Frequencies shown are for transponders that were known to be functional when this article went to press. See the ARRLWeb at ***www.arrl.org*** *for updates. All signals are digital, SSB or CW. FM is not permitted on AO-40.*

Uplink Frequencies

Band	*Digital*	*Analog Passband*
70 cm	435.300 - 435.550 MHz	435.550 - 435.800 MHz
23 cm(1)	1269.000 - 1269.250 MHz	1269.250 - 1269.500 MHz
23 cm(2)	1268.075 - 1268.325 MHz	1268.325 - 1268.575 MHz
13 cm(1)	2400.100 - 2400.350 MHz	2400.350 - 2400.600 MHz
13 cm(2)	2446.200 - 2446.450 MHz	2446.450 - 2446.700 MHz
6 cm	5668.300 - 5668.550 MHz	5668.550 - 5668.800 MHz

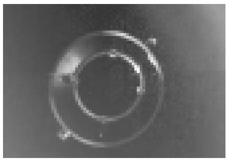
Downlink Frequencies

Band	*Digital*	*Analog Passband*
13 cm(1)	2400.650 - 2400.950 MHz	2400.225 - 2400.475 MHz
13 cm(2)	2401.650 - 2401.950 MHz	2401.225 - 2401.475 MHz
1.5 cm	24048.450 - 24048.750 MHz	24048.025 - 24048.275 MHz

Telemetry Beacons

Band	*General Beacon (GB)*	*Middle Beacon (MB)*	*Engineering Beacon (EB)*
13 cm(1)	2400.200 MHz	2400.350 MHz	2400.600 MHz
13 cm(2)	2401.200 MHz	2401.350 MHz	2401.600 MHz
1.5 cm	24048.000 MHz	24048.150 MHz	24048.400 MHz

The YACE camera aboard AO-40 captured this dramatic photo as the satellite moved away from the Ariane V rocket.



In this view, courtesy of *Nova* tracking software, you can see a typical example of AO-40's huge footprint. With this kind of coverage, the DX possibilities are fantastic!

popular sound-card demodulator program called *AO40RCV* (**www.qsl.net/ae4jy/ao40rcv.htm**) by AE4JY.

The satellite also has several cameras for the SCOPE and YACE (Yet Another Camera Experiment) experiments. The YACE camera has already taken pictures of the second stage AR-507 (launch rocket) separation. YACE is still functional although degraded since the December incident.

Let's Summarize

There isn't a "best" way to get into the satellite scene, but if you have no prior satellite experience, I recommend the following:

- Read the satellite chapter of *The ARRL Handbook*. You can buy it from your favorite dealer or order direct from the ARRL on-line at **www.arrl.org/shop/**
- Study the tables in this article. One lists frequencies. Another is a projection of uplink and downlink requirements. This gives you a pretty good idea of antenna size and transmitter power required for satisfactory communications.
- Get a good sat tracking program from AMSAT and learn how to use it. Play with it and get a feel for satellite motion.
- Subscribe to the AMSAT e-mail reflector. Read everything on the **amsat.org** and **amsat-dl.org** Web sites. These are the best sources of current AO-40 information.
- Visit the Web sites listed elsewhere in this article. Look at commercial offerings. Compare and contrast. Study. Think.
- Learn more about AO-40 and its capabilities. Decide what turns you on and what you want to do.
- Start at the beginning. Don't get too adventurous on your first foray into satellite operating. The better you understand the basics, the more sense the advanced stuff makes. This is fun, but can appear rather complex. After all, this *is* rocket science….

Resources

AMSAT-NA
850 Sligo Ave, Suite 600
Silver Spring, MD 20910-4703
301-589-6062
www.amsat.org
Tracking software: **www.amsat.org/amsat/catalog/software.html**

AMSAT-DL (Germany)
Lots of AO-40 information. English is available for many sections.
www.amsat-dl.org

Down East Microwave Inc
954 Rt 519
Frenchtown, NJ 08825
908-996-3584
www.downeastmicrowave.com

SSB Electronic USA
124 Cherrywood Dr
Mountaintop, PA 18707
570-868-5643
www.ssbusa.com

Phillips-Tech
PO Box 737
607 Parker St
Trinidad, CA 95570
707-677-0159
www.phillips-tech.com

Hamtronics
65 Moul Rd
Hilton, NY 14468-9535
716-392-9430
www.hamtronics.com

Postscript

AO-40 was first opened for general 2-way communications on May 5, 2001. The S2 (2401 MHz) downlink was paired with the U (435 MHz) and L1 (1269 MHz) uplinks. Although signal strength was highly dependent on squint angle, transponder performance was excellent. Many QSOs were completed with almost 80 different call signs noted during that first period of operation. At least a dozen stations were using L band uplinks, some with less than 10 W to a single Yagi or helix. Small "barbecue grill" truncated-parabola dishes seemed to be the most popular type of receiving antenna. Several stations reported good results with 16-turn helix antennas. That's a tiny antenna! Receiving converters ran the gamut from commercial (SSB, DEMI, Parabolic) to homebrew. Stock and slightly modified MMDS TV receiving converters were in wide usage. Overall performance, operation and satisfaction level was excellent. This is going to be a great satellite!

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