Lab Notes - Limited Space Antennas

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Satellite-Tracking Software

With all the Amateur Radio satellites in orbit today, more hams are becoming interested in satellite operating. As a result, the ARRL Lab has seen a substantial increase in requests for information about satellite-tracking programs. In this month's Lab Notes, we'll describe how to use satellite-tracking software—and where to find it.

Q: Why do I need a satellite-tracking program and a computer to work the satellites?

A: Technically speaking, you don't. Before the advent of affordable personal computers, hams used manual methods to predict when satellites would be in range. The ARRL *OSCARLOCATOR* was a popular tool for manual tracking. If you knew when the satellite was crossing the equator during its orbit—and where (east or west longitude)—you could use the OSCARLOCATOR to determine when you could access the bird. The equatorial crossing is determined through the use of an *orbit calendar*. Although the OSCARLOCATOR is no longer available, we still publish the orbit calendar each month. It's available *free* by sending a self-addressed, stamped, business-size envelope to: ARRL Technical Secretary, 225 Main St, Newington, CT 06111. Be sure to ask for the latest orbit calendar.

Manual tracking is great if you want a better understanding of orbital mechanics, but it is tedious and prone to inaccuracy. When personal computers hit the scene, one of their first Amateur Radio applications was satellite tracking. Within seconds a computer can tell you when a satellite will be in range, how high it will be in the sky, its direction of travel, and much more. Computers also have the capability to predict the position of a satellite over the earth at any point in its orbit—even weeks or months in advance.

Q: Are there any particular software features I should look for?

A: A bare-bones program will tell you when the satellite will appear at the edge of your local horizon, its *elevation* at various times during the pass, and its compass heading, or *azimuth*, relative to your station. This is the minimum information you'll need.

Q: Before you go any further, can you explain what you mean by elevation and azimuth?

A: The elevation of the satellite describes its *vertical* position above your local horizon in degrees relative to your station. If the satellite is at an elevation of 1°, it's just grazing your horizon. If it's at 90°, it's directly overhead (see Fig 1). Just like the moon, amateur satellites rise to a peak elevation and then "set" as they drop back below your horizon. (Geosynchronous satellites are the exception. Unfortunately, there are no Amateur Radio geosynchronous satellites—yet.) For communications purposes, the higher the elevation figure, the better.

Azimuth refers to the *horizontal* position of the satellite in the sky relative to your station. It is also measured in degrees. An azimuth of 0° is north (true north, not magnetic), 90° is east, 180° is south and 270° is west (see Fig 2). Azimuth information is very important if you are using directional antennas and rotators. To determine where to point your antennas during the pass, all you need to do is look at the azimuth data provided by the program. Most hams who use directional antennas have azimuth/elevation rotators that allow their beams to move up and down, as well as left to right. When tracking a satellite, these hams use the azimuth *and* elevation information to keep their antennas on target.

Q: How does the program know where my station is located?

A: It doesn't—unless you tell it. All programs have a means for you to enter your station location in latitude and longitude. Many also request your approximate height above sea level. No, you don't need a sextant or an expensive global-positioning receiver to determine your location. Just go to your local library and ask the reference person to steer you to an almanac or geographic index. Every town in the US has its latitude, longitude and height above sea level on record. Another alternative is to telephone

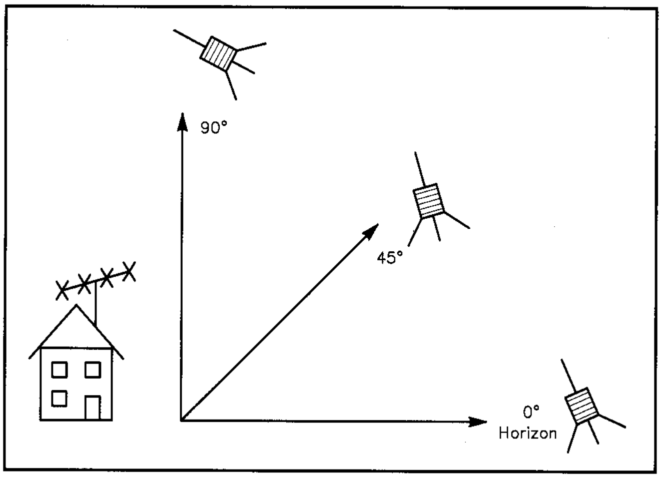

Fig 1—*Elevation* describes the vertical position of the satellite in the sky relative to your station. It's expressed as degrees from 0° to 90°. An elevation of 0° is right at your horizon. A 90° elevation is directly overhead.

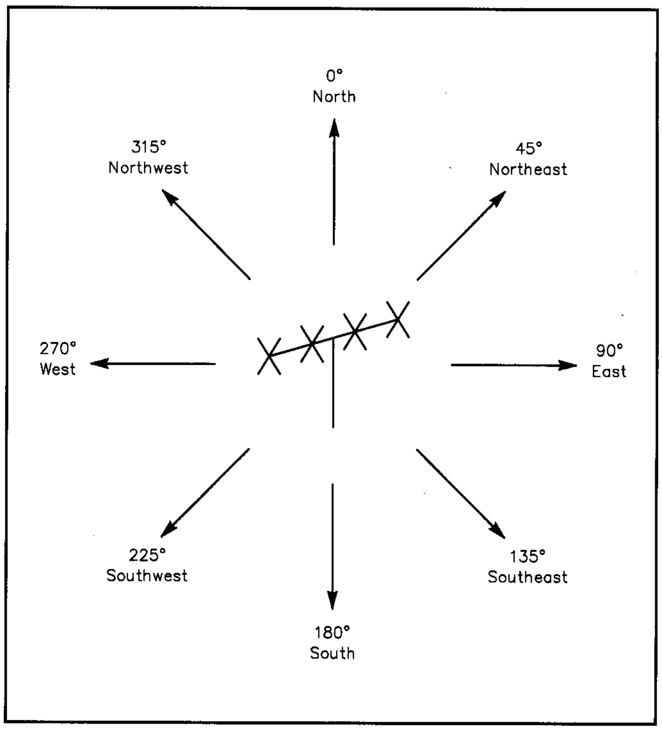

Fig 2—A satellite's *azimuth* represents its horizontal position (in degrees) relative to your station. This information is important if you own a directional antenna. If you know the azimuth of the satellite at any moment during the pass, you'll know where to point your antenna.

your nearest airport. They know their precise location and can provide this information. Even if the airport is 20 or 30 miles away, its position is accurate enough to use at your station.

Q: What other features do satellite-tracking programs offer?

A: Well, that depends on the software. Many offer *real-time* map displays. The computer predicts where the satellite is at the moment and displays its position on a map. As the satellite moves, its position on the map is updated. Some tracking programs take this function a step further. In addition to displaying the position, the programs draw a circle around the satellite known as the *footprint*. Theoretically, any stations within the footprint circle should be able to communicate with the satellite.

Programs will often calculate your range to the satellite, the exact latitude and longitude of the satellite over the earth, the amount of Doppler shift (in Hz) you can expect on the downlink signal, and more. This information is not critical for working amateur satellites, but it's handy.

Most satellite-tracking programs display their prediction data in an *ephemeris* table. Here is a basic ephemeris table calculated for an OSCAR 20 satellite pass near my station on December 1:

Date/Time UTC	*Azimuth*	*Elevation*	*Range*
01 DEC 93 09:58	159	0	3884
01 DEC 93 09:59	158	3	3488
01 DEC 93 10:00	158	7	3093
01 DEC 93 10:01	157	12	2700
01 DEC 93 10:02	156	17	2314
01 DEC 93 10:03	155	24	1939
01 DEC 93 10:04	152	33	1587
01 DEC 93 10:05	146	46	1280
01 DEC 93 10:06	130	64	1059
01 DEC 93 10:07	59	75	986
01 DEC 93 10:08	9	58	1093
01 DEC 93 10:09	358	41	1336
01 DEC 93 10:10	354	28	1657
01 DEC 93 10:11	351	20	2018
01 DEC 93 10:12	350	13	2401
01 DEC 93 10:13	349	8	2794
01 DEC 93 10:14	349	4	3194

You can learn a great deal by looking at this table. You can see that OSCAR 20 will reach my local horizon at 09:58 UTC at an azimuth of 159° (roughly southeast of my station). At this point it is 3884 kilometers away. As the minutes pass, the satellite rises higher in the sky. By 10:07 UTC, it's reached an elevation of 75°. At a range of 986 kilometers, this is as close as the bird will get during this pass. After 10:07, the satellite heads away from me. It sinks rapidly in the northwestern sky until it plunges below the horizon at about 10:14 UTC.

This is an excellent pass for my location. If the maximum elevation was only a few degrees, it would be a poor pass (just skimming my horizon). With tracking software and a proper set of *orbital elements* for your favorite satellites, you can easily determine when they should be available to you.

Q: Wait a minute. What are orbital elements and how do I get them?

A: Orbital elements—also called *Keplerian* elements—are sets of numbers used to mathematically describe the orbit of a satellite. Before a satellite-tracking program can predict a satellite's position, it must have this orbital data. A typical orbital element set is shown below:

Satellite: AO-16
Object number: 20439
Epoch Time: 93 200.2634796
Epoch Rev: 18202
Mean Anomaly: 272.16490
Mean Motion: 14.29841825
Inclination: 98.62100
Eccentricity: 0.00124870
Arg Perigee: 88.09640
RAAN: 285.09490
Decay: 4.70000e-007

This is called an "AMSAT format" element set. You may also find two-line "NASA format" elements. Here is an example:

AO-10
1 14129U 83 58 B 93261.37176135 -00000099 00000-0 99999-4 0 354
2 14129 27.1985 5.5050 6025636 115.1006 317.3712 2.05882714 77182

Two-line elements must be decoded with a "key" that is sent along with the elements.

In any case, don't let the words and acronyms intimidate you. We don't have space in this column to define each one and you don't need their definitions to use the data. Just consider the verbiage as labels for the numbers that appear beside them. Your satellite software will require you to enter this information for every satellite you wish to track. (Some programs will do the entry for you automatically if you have the orbital elements on disk in an ASCII file.)

Orbital elements are available from a number of sources. If you're a packeteer, you'll probably see orbital-element bulletins on your local PBBS from time to time. There are also telephone bulletin boards that carry orbital elements for satellites. Among the more popular ones are:

Dallas Remote Imaging Group: 214-394-7438
N8EMR BBS: 614-895-2553
ARRL BBS: 203-666-0578

If you're a CompuServe subscriber, check the HAMNET group.

W1AW transmits orbital elements on Tuesdays and Saturdays at 6:30 PM Eastern time on RTTY and AMTOR FEC. Check a recent W1AW schedule for frequencies. Orbital elements are also printed in the AMSAT Journal and the OSCAR Satellite Report (see addresses below). To ensure accurate predictions, you must update your program with new orbital elements about once a month.

Q: Now for the obvious question: Where do I find the software?

A: That's the easiest question to answer! Here is a list of satellite-tracking software suppliers along with the types of computers they support. Please note that these are not the only sources, just the ones I could find at press time. In addition, the ARRL does not necessarily endorse these suppliers or their products. No warranty is expressed or implied. I recommend that you contact any suppliers that interest you and request more information before ordering.

AMSAT (publisher of the *AMSAT Journal*)
850 Sligo Ave
Silver Spring, MD 20910
tel: 301-589-6062

IBM-PCs and compatibles, Commodore, Amiga, Macintosh, Tandy Color Computer, TRS-80 Model 4, Atari. Free catalog with SASE.

AMSOFT Ham Radio Software
408 Hillsdale Ave
New Cumberland, PA 17070
tel: 717-938-8249
fax: 717-938-6767

IBM-PCs and compatibles. On individual disks, or as part of their CD-ROM library. Catalog $1.

Buckmaster Publishing
Route 4, Box 1630
Mineral, VA 23117

IBM-PCs and compatibles. More than a dozen different tracking programs on *HamCall* CD-ROM. No catalog available.

Renaissance Software and Development
Killen Plaza
Box 640
Killen, AL 35645
tel: 800-525-7235

IBM-PCs and compatibles. Free catalog with SASE.

R. Myers Communications (publisher of the *OSCAR Satellite Report*)
PO Box 17108
Fountain Hills, AZ 85269-7108
tel: 602-837-6492

IBM-PCs and compatibles, Macintosh. Free catalog with SASE.

We welcome your suggestions for topics to be discussed in *Lab Notes*, but we are unable to answer individual questions. Please send your comments or suggestions to: Lab Notes, ARRL, 225 Main St, Newington, CT 06111.