

Satellite Radio

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Amateur Satellite Radio (AMSAT) is basically a repeater or transponder in orbit around the earth. There are several satellites in Low Earth Orbit and several satellites in High Earth Orbit.

There are four basic categories of satellites:

1. Low Earth Orbit – Analog (CW and Voice)
2. Low Earth Orbit - Digital
3. High Earth Orbit
4. Occupied Spacecraft

Most of the amateur satellites and occupied spacecraft are in Low Earth Orbit (LEO). Low Earth Orbit satellites orbit the earth many times a day. Because Low Earth Orbit satellites have low orbits, and sensitive receivers, omni directional antennas can be used without substantial amounts of power. However, their passes are short and communications must consequently be short. Low Earth Orbit satellites typically have an approximate 90 to 100 minute period of evolution (time to make one orbit around the earth). Your communications window is approximately 8-20 minutes. Low Earth Orbit satellites typically have orbits of approximately 250 km to 1,000 km. The orbits of occupied spacecraft are typically below 500 km.

High Earth Orbit (HEO) satellites require beam antennas, azimuth/elevation rotators, computer tracking, and higher power radios. High Earth Orbit satellites will have longer passes and consequently longer communications capabilities. High Earth Orbit satellites typically have orbits of approximately 11 hours. High Earth Orbit satellites typically have orbits of 35,000 km at apogee and 4,000 km at perigee.

There are currently several analog satellites including RS-12, UO-14, RS-15, FO-20, AO-27, FO-29, SO-41, and the occupied spacecraft in orbit. The equipment required to communicate with these satellites are: an HF radio and/or a 2m / 70 cm radio. Packet equipment is required for digital work. Receiver preamps may also be needed.

Sending a transmission to a satellite is called an "uplink." Receiving a transmission from a satellite is called a "downlink." Uplink and downlink frequencies are different. Oscar is an acronym for "Orbiting Satellite Carrying Amateur Radio."

Working a satellite is very similar to working "split" on HF or "cross-band" repeat on repeaters, where you transmit on one band and listen on another. For example, if you chose RS-12, it will accept a signal anywhere from 145.910 MHz to 145.950 MHz and retransmit between 29.410 MHz and 29.450 MHz. These are known as the uplink and downlink passbands, and there is a direct relationship between them. A signal you transmit at 145.920 MHz will be retransmitted by the satellite at about 29.420 MHz and 145.930 MHz comes down as about 29.430 MHz, etc. This is because RS-12 (as well as RS-15) uses what is known as a "non-inverting linear transponder". The international space station uses uplink and downlink in the same (2 meter) band.

The following is a list of common satellite modes:

Dual Band Modes

A	2 meters uplink	10 meters downlink
B (UV)	70 cm uplink	2 meters downlink
J (VU)	2 meters uplink	70 cm downlink
K	15 meters uplink	10 meters downlink
LU	23 cm (1.2 GHz) uplink	70 cm downlink
LV	23 cm (1.2 GHz) uplink	2 meters downlink
US	70 cm uplink	13 cm (2.4 GHz) downlink
LS	23 cm uplink	13 cm downlink
T	15 meters uplink	2 meters downlink

Single Band Modes

V	2 meters	2 meters
U	70 cm	70 cm
L	23 cm	23 cm
S	13 cm	13 cm
X	3 cm	3 cm

Uplink indicates the earth station transmit frequency. Downlink indicates the earth station received frequency.

Some satellites have dual modes that operate simultaneously. Satellites have 3 basic types of retransmissions: beacon, transponder, and repeater. Most satellites have a fixed Morse code beacon at the lower end of the satellites band-pass transponder. This is useful to detect when the satellite has crossed the horizon and is in range for operation. It can also be used to determine doppler shifts.

A transponder is similar to a repeater, but has a range of frequencies that are converted from one band to another. This range of frequencies is known as the passband of the transponder. There are two types of transponders: Non-inverting and inverting. A non-inverting transponder will receive an upper side band signal at the high end of the uplink passband and it will transmit it as an upper side band signal at the high end of the downlink passband. An inverting transponder will receive an upper side band signal at the high end of the uplink passband and it will transmit it as a lower side band signal at the lower end of the downlink passband.

A repeater closely resembles an earthbound repeater. It listens for signals on one frequency and transmits on another frequency. All satellite repeaters (and transponders) are full duplex, meaning one can listen to the signal on the downlink while transmitting. Headphones are often used to avoid audio feedback.

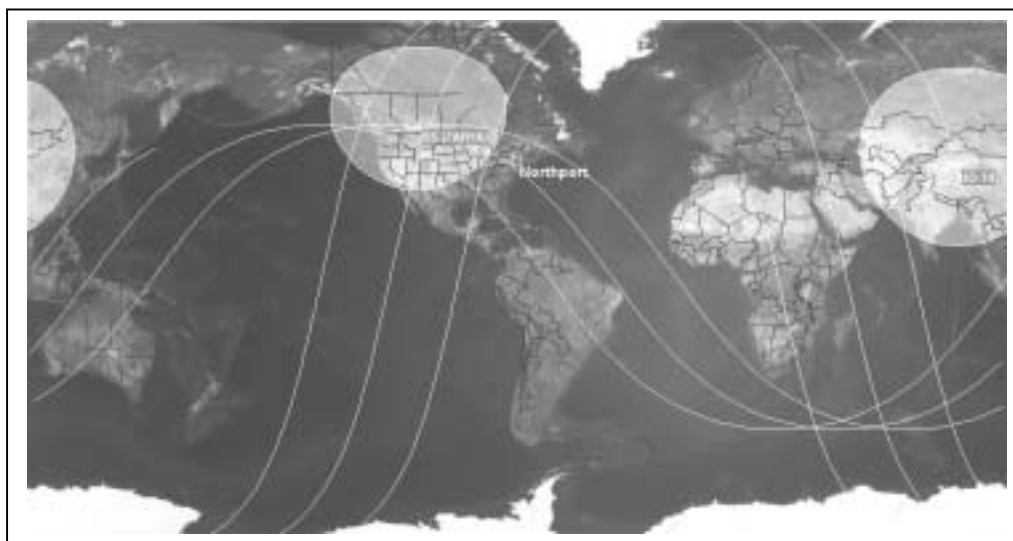
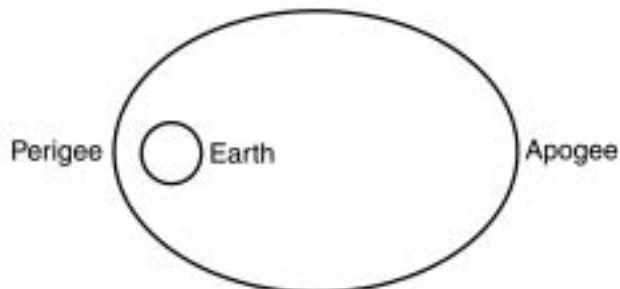
Unlike earthbound communications where it is possible to pick a frequency and stay there, there is a phenomenon known as Doppler Shift that satellite that must considered. An example of Doppler shift is hearing a train blowing its whistle as it passed by? The tone changes as the train comes close and moves away. The sound inside the train remains the same. The change in tone is a result of the Doppler Shift. Signals coming from space experience the same phenomena as the satellite moves at a speed of about 17,000 miles per hour. The operator have to constantly tune the receiver and transmitter to make up the difference. The frequency shift varies by band. On RS-12 with its 2 meters uplink and 10 meters downlink, the change is about +/- 2.5 kHz. On FO-20 and FO-29, where the uplink is 2 meters and the downlink is 70 cm, the shift is about +/- 10 kHz.

Satellites travel in an elliptical orbit. Apogee is the point in a satellite's orbit where it is farthest from the earth. Perigee is the point in a satellite's orbit where it is closest to the earth. Inclination is the

angle of the orbital plane with respect to the earth's equator. A node is the point where the orbital path crosses the equator. The ascending and descending pass is the south to north or north to south communications opportunity. These are also the points of Acquisition of Signal (AOS) and Loss of Signal (LOS). A footprint is the area of the earth's surface, which is visible to the satellite at one time. The lower the satellite's orbit, the smaller the footprint. Keplerian Elements (KEPS) are a set of numerical data that represents a satellite's orbital characteristics. The use of this information allows tracking programs to determine where that satellite is at any one time, to predict passes, and plot ground tracks. Keplerian elements should be updated every few weeks for stable orbits and more frequently if the object's orbit is altered. The AMSAT format is the most user-friendly format of Keplerian elements. However, the NORAD Two-Line Element (TLE) is the indigenous format available from NASA.

The AMSAT format looks like this:

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Satellite: AO-27
Catalog number: 22825
Epoch time: 03177.89093483
Element set: 590
Inclination: 98.2597 deg
RA of node: 200.9638 deg
Eccentricity: 0.0007455
Arg of perigee: 236.0777 deg
Mean anomaly: 123.9698 deg
Mean motion: 14.28984247 rev/day
Decay rate: 4.2e-07 rev/day^2
Epoch rev: 50820
Checksum: 344
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Some communication satellites stay stationary with respect to the earth so that TV signals can be received with small antennas. To achieve this stationary position, a satellite must have a one-day orbital period like earth. The satellite to earth distance is calculated as 35,768 km. The satellite orbit must be circular with near zero inclination to stay stationary. If the orbit is closer to an inclined ellipse, the satellite projection to the earth surface will follow a skewed figure 8 pattern. This pattern is good for amateur radio because it can cover additional surface area of the earth and the satellite is closer to the earth at perigee.

Most of the time satellites are no higher than 35 degrees or so above the horizon. The closer the satellite is to the horizon, the greater the distance it is from the observer and the higher the path loss and the greater the transmit and receive gain that is needed. Vertical antennas will work well, especially ones with some gain, although some of the really high gain verticals are optimized for low angles of radiation and the signal strength falls off rapidly as the elevation angle increases. Another problem with verticals is that noise tends to be vertically polarized. This is not a problem with FM signals, but a big problem with SSB and CW. Dipole antennas also work well, but they often suffer a loss of gain off the ends. Beam antennas can be tilted up about 30 degrees to provide more gain toward the horizon. However, many satellite operators report excellent results in the standard flat horizontal orientation. When using beam antennas, the operator will need to continuously correct their direction as the satellite moves by. This becomes difficult to manage manually with the low earth orbit satellites because they have relatively fast velocities. Computer controlled antennas with azimuth/elevation rotators can track the satellites with ease. Azimuth/elevation rotators and computer controllers tend to be expensive.

A radio signal passing through the ionosphere changes polarization. A horizontally polarized signal transmitted from a satellite would change polarization when reaching earth. This phenomenon is called the Faraday Rotation. Circularly polarizing antennas are often used to deal with Faraday Rotation. Circularly polarized antennas will also minimize the spin modulation effect, which is caused by a satellites rotation of approximately 1 revolution per second.

Most satellites have an automatic transmitter at the satellite called the beacon. The beacon is usually located at the high or low end of the pass-band and will send out satellite identification and telemetry. Most beacons use CW.

When beginning satellite operation, try to get on one of the FM satellites, such as UO-14, AO-27, or ISS. These satellites are probably the easiest to work with a minimum amount of equipment. This can be done with an HT and a directional antenna. The antenna does not need to have much gain. It can be a 3-element beam that is held pointing at the satellite. Arrow antenna makes the 146/437-10 handheld antenna with a foam grip for about \$75. Satellites like FO-20 and FO-29 are easy to work, but require two beams with an azimuth/elevation rotator and a computer controller. More sophisticated equipment will allow you to transmit and receive simultaneously on 2 bands and make frequency shifting for Doppler correction easier. At the time of this writing, AO-27 is only available on weekends. UO-14 is probably the best satellite to start with. ISS is easy to reach since it is so low. However, the ISS crew are not always available. Check the NASA website site for "Crew Scheduling" to see what times are allocated for amateur radio.

There are a number of tracking software programs on the market. After much trial and error by this author, the NOVA software program appears to be the best. It works well with Windows XP and the operator can update the Keplerian elements with the click of the mouse, provided there is with an internet connection. Some programs were actually inaccurate as compared to the online tracking by NASA of the international space station.

Online resources include:

<http://www.amsat.org>

<http://www.amsat.org/amsat/news/wsr.html> (weekly satellite status report)

<http://www.amsat.org/amsat/ftp/keps/current/amsat.all> (Keplerian elements)

<http://www.arrl.org>

<http://ariss.gsfc.nasa.gov>

<http://spaceflight.nasa.gov/realdata/tracking/index.html> (tracking international space station)

<http://www.nlsa.com/index.html> (Nova satellite tracking software)

<http://www.orbitessera.com/> (N2WWD webpage)

Kilometer = Miles x 1.621388

Miles = Kilometers x 0.621388

Region 1: Africa, Europe, Russia, Middle East (excluding Iran), and Mongolia

Region 2: The Americas, including Hawaii, Johnston Island, and Midway Island

Region 3: The rest of Asia and Oceania

Low Earth Orbit – Analog Satellites (partial list)

<u>Satellite</u>	<u>Frequencies (MHz)</u>	<u>Transponder /Beacon</u>	<u>Mode</u>	<u>Notes</u>
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UO-14 (OSCAR-14 NORAD 20437)

Launched: January 22, 1990 by an Ariane launcher from Kourou, French Guiana.

Approximate height (varies) 798 km - 781

Downlink	435.070		J	FM Voice
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Uplink	145.975		J	FM Voice
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Operational as of June 8, 2003

RS-15 (NORAD 23439)

Launched: December 26, 1994 from the Baikonur Cosmodrome

Approximate height (varies) 2,160 km – 1,885 km

Downlinks	29.352	B		CW
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	29.354 - 29.394	T	A	CW / USB
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Uplinks	145.858 -145.898	T	A	CW / USB
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Semi-operational as of June 8, 2003

FO-20 (Fuji-OSCAR 20, NORAD 20480) (2)

Launched: February 07, 1990 by an H1 launcher from the Tanegashima Space Center in Japan.

Approximate height (varies) 1,745 km – 912 km

Downlinks	435.795	B		CW
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	435.800 - 435.900	T	J	CW / USB
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Uplinks	145.900 - 146.000	T	J	CW / LSB
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Operational as of June 8, 2003

AO-27 (OSCAR 27, AMRAD, NORAD 22825) (3)

Launched: September 26, 1993 by an Ariane launcher from Kourou,

Approximate height (varies) 804 km – 790 km

Downlink	436.795		J	FM Voice
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Uplink	145.850		J	FM Voice
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Semi-operational as of June 8, 2003

FO-29 (Fuji-OSCAR 29, NORAD 24278) (also see 1200 and 9600 Baud)

Launched: August 17, 1996, by an H-2 launcher from the Tanegashima Space Center in Japan.

Approximate height (varies) 1,333 km – 801 km

Downlinks	435.795	B		CW
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	435.800 - 435.900	T	J	CW / USB
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Uplinks	145.900 - 146.000	T	J	CW / LSB
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Downlink	435.910	B		FM Voice digitalker
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Downlink	435.795	B		12 WPM CW telemetry
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Operational as of June 8, 2003

SO-41 (SAUDISAT 1A, NORAD 26545)

Launched: September 26, 2000 aboard Soviet ballistic missile from the Baikonur Cosmodrome.

Approximate height (varies) 672 km – 614 km

Downlink	436.775		J	FM Voice
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Uplink	145.850		J	FM Voice
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Operational, but, intermittent as of June 8, 2003

SO-50 SAUDISAT-1C

Launched: December 20, 2002 aboard a Soviet ballistic missile from the Baikonur Cosmodrome.

Approximate height (varies) 650 km

Uplink	145.850 MHz (67.0 Hz PL tone)	T	J	FM Voice
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Downlink	436.800 MHz	T	J	FM Voice
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Operational as of June 8, 2003

Low Earth Digital Satellites (partial list)

<u>Satellite</u>	<u>Frequencies (MHz)</u>	<u>Transponder /Beacon</u>	<u>Mode</u>	<u>Notes</u>
<u>AO-16 (OSCAR 16, Pacsat, Microsat-A, NORAD 20439)</u>				
Approximate height (varies) 797 km – 780 km				
Downlinks	437.025	T/B	J	1200 bps PSK SSB
	437.051	T	J	1200 bps PSK SSB
	2401.14280	B		1200 bps PSK SSB - (usually off)
Uplinks	145.900	T	J	1200 bps AFSK FM
	145.920	T	J	1200 bps AFSK FM
	145.940	T	J	1200 bps AFSK FM
	145.960	T	J	1200 bps AFSK FM
Semi-operational as of June 8, 2003				
<u>NO-44 (PC-SAT, NORAD 26931)</u>				
Approximate height (varies) 800 km – 790 km				
Downlink	144.390		V	APRS
Uplink	145.827		V	1200 bps AX.25 AFSK
Operational as of June 8, 2003				
<u>FO-29 (Fuji-OSCAR 29, NORAD 24278) (see also Analog and 1200 Baud)</u>				
Approximate height (varies) 1,333 km – 801 km				
Downlink	435.910	T	J	9600 bps FM BPSK
Uplink	145.850	T	J	9600 bps FM
	145.870	T	J	9600 bps FM
	145.910	T	J	9600 bps FM
Operational as of June 8, 2003				

High Earth Orbit Satellites (partial list)

<u>Satellite</u>	<u>Frequencies (MHz)</u>	<u>Transponder /Beacon</u>	<u>Mode</u>	<u>Notes</u>
<u>AO-10 (OSCAR 10, Phase 3B, NORAD 14129)</u>				
Launched: June 16, 1983 by an Ariane launcher from Kourou, French Guiana.				
Approximate height (varies) 35,421 km – 4,026 km				
Downlinks	145.810	B		CW
	145.825 - 145.975	T	B	CW / USB
Uplinks	435.030 - 435.180	T	B	CW / LSB
Semi-operational as of June 8, 2003				

<u>Satellite</u>	<u>Frequencies (MHz)</u>	<u>Transponder /Beacon</u>	<u>Mode</u>	<u>Notes</u>
<u>AO-40 (OSCAR 40, Phase 3D, NORAD 26609)(8)</u>				
Launched: November 16, 2000 aboard an Ariane 5 launcher from Kourou, French Guiana.				
Approximate height (varies) 58,872 km – 943 km				
Downlinks	2401.650 - 2401.950	T	S	DIGITAL
	2401.225 - 2401.475	T	S	CW / USB
	24048.450 - 24048.750	T	K	DIGITAL
	24048.010 - 24048.060	T	K	CW / USB
Uplink	145.840 - 145.990	T	V	CW/LSB
	435.300 - 435.550	T	U	DIGITAL
	435.550 - 435.800	T	U	CW / LSB
	1269.000 - 1269.250	T	L1	DIGITAL
	1269.250 - 1269.500	T	L1	CW / LSB
	1268.075 - 1268.325	T	L2	DIGITAL
	1268.325 - 1268.575	T	L2	CW / LSB
	2400.350 - 2400.600	T	S1	CW/LSB
	2401.323	B	S	
	24048.035	B	K	
Operational as of June 8, 2003				

Occupied Spacecraft (partial list)

<u>Satellite</u>	<u>Frequencies (MHz)</u>	<u>Transponder /Beacon</u>	<u>Mode</u>	<u>Notes</u>
<u>ISS (International Space Station)(NORAD 25544)(6)</u>				
<u>ARISS (Amateur Radio on the International Space Station)(NORAD 25544)(6)</u>				
The ARISS initial station was launched September 2000 aboard shuttle Atlantis.				
Approximate height (varies) 402 km – 391 km				
Downlink	145.800	T	V	Worldwide voice/packet
Uplink	144.490	T	V	Region 2 & 3 voice
Uplink	145.200	T	V	Region 1 voice
Uplink	145.490	T	V	Worldwide packet
TNC callsign: RS0ISS-1				
U.S. callsign: NA1SS				
Russian callsigns: RS0ISS, RZ3DZR				
Operational as of June 8, 2003				