USING AMATEUR RADIO SATELLITES.
ZL3CU

INTRODUCTION

Satellites are objects that orbit a planet.
To achieve an orbit two things need to be considered. First the gravitational effect of the planet which attempts to pull the satellite towards it and second that the object wants to travel in a straight line due to its momentum. With sufficient speed the object will orbit the planet as it is in continuous free fall, because the planet's surface is continually curving away from underneath it.
The Moon is our natural and largest satellite.
There are many man made satellites of course.

The following web site provides up to date status of Amateur Radio satellites as reported by users around the world:
https://www.amsat.org/status/

There is an AMSAT Bulletin Board in which people, usually operators, post questions/comments etc. regards Amateur Satellites activities. There is no requirement to be a member of AMSAT to subscribe to this open forum. To subscribe click on the following link:
https://www.amsat.org/mailing-list-faq/

USING FM AMATEUR RADIO SATELLITES

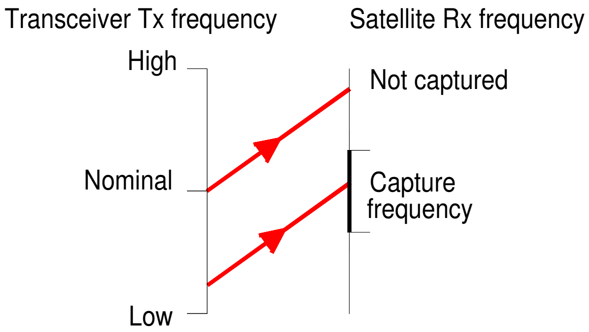
One activity is receiving slow scan television broadcasted from the International Space Station which, of course, does not involve an operator to transmit and therefore can be done by anyone.
The following link demonstrates this activity using only a handheld and a cell phone:
https://www.facebook.com/848975366/videos/480508006859552

FM satellites are the simplest to use, can be accessed using VHF and UHF hand helds with a small sized hand held antennas, and overall is not too expensive for the operator. Therefore it is a good way of seeing if satellite operation it is of interest.
Like a terrestrial FM repeater, just one operator can transmit though it at a time, (single channel) and often requiring CTCSS.
Unlike a repeater they do not have, or need, a tail, as the operator listens for their own signals on the satellite's downlink while they are transmitting.
(NOTE (a) If the uplink is on VHF, the downlink will be on UHF or vice versa. (b) Not many hand helds have this function. It may be cheaper to beg, borrow or even purchase a second handheld. One for Txing, the other for Rxing).
The squelch setting on the receiver is disabled. In other words it is open even if no signal is present.
Headphones are usually used to minimise feed back.
UHF section may need to be altered during a pass due to Doppler. More information about this later in this article.
Due to de-sensing issues, a filter blocking the commercial radio FM transmissions may be needed especially if the operating location is near these transmitters. Also SDR dongles are susceptible to these transmissions.

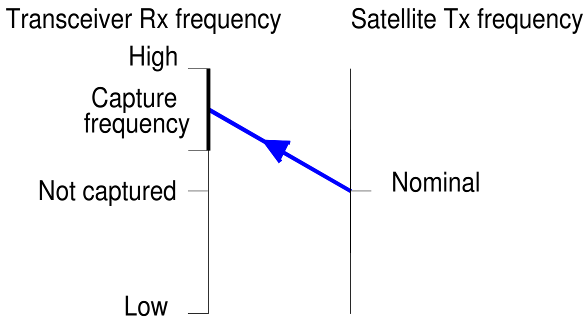
The following link first shows suitable radios, however there is a practical demonstration near the finish which shows an actual activity using an Arrow antenna:
https://www.youtube.com/watch?v=yFqqlAUvYj4&t=86s

Note in our neck of the woods there is not so many operators so there is more likely hood of getting aboard the satellite here.

Doppler:
When a satellite is rising (AOS) it is coming towards the operator. Due to Doppler, this has the effect of increasing the signal frequency coming from the satellite to the operator, and also increasing the frequency of the signal coming from the operator to the satellite.
To compensate for this the operator must appropriately (a) **increase** the transceiver's **receive** frequency and (b) **decrease** the **transmit** frequency from the nominal frequency,
During the pass the Doppler reduces until, at the operator's highest point in the sky, both receive and transmit frequencies become nominal for a very short time. After that the satellite moves away from the operator and the operator's receive frequency becomes progressively lower while the transmit frequency becomes progressively higher.
The following figures may help with the explanation:

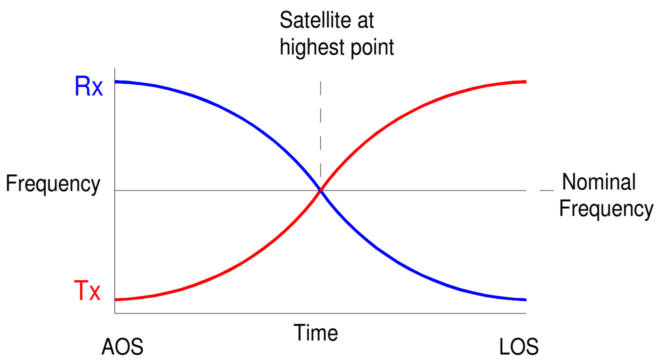


Uplink showing the effects of Doppler
when the satellite is heading towards the operator



Downlink showing the efffects of Doppler
when the satellite is heading towards the operator

These figures show that the signal frequency is increased when a satellite is heading towards an operator. If the transceiver transmits on the nominal frequency then it may be too high for the satellite's capture frequency so therefore the transceiver must use a lower frequency. Also the transceiver's receive frequency may need to be higher than the nominal frequency during this time.
The following figure shows an approximation of how the frequencies change during a pass from an operator's point of view.



An approximation of changing frequencies during a pass

The UHF FM frequency may need altering during the pass due to Doppler. For Rx, approx 8kHz high at the beginning of the pass (often termed AOS (acquisition of satellite)) reducing to approx 8kHz low at the end of the pass (often termed LOS (loss of satellite)). (Opposite for Tx)
It is unlikely that the VHF section of the FM radio needs to be altered during a pass as the Doppler is a third that of UHF.

There are a number of FM satellites. The following link provides updates:
https://www.amsat.org/fm-satellite-frequency-summary/

A good satellite to try is the International Space Station as it has a reasonably strong signal. However as it can be switched to other activities so its status needs to be checked beforehand.

The following frequencies are currently used for Amateur Radio ISS contacts (QSOs):

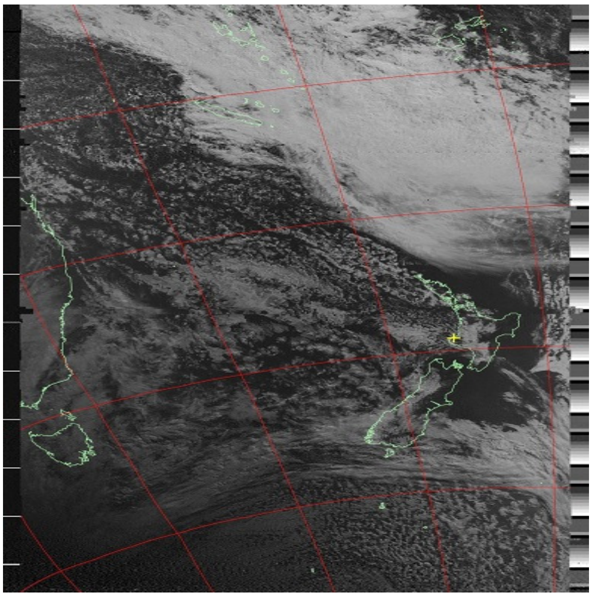
Voice and SSTV Downlink: 145.80 (Worldwide)
Voice Uplink: 144.49 for ITU Regions 2 and 3 (The Americas, and the Pacific and Southern Asia)
Voice Uplink: 145.20 for ITU Region 1 (Europe, Russia and Africa)
VHF Packet Uplink and Downlink: 145.825 (Worldwide)
UHF Packet Uplink and Downlink: 437.550
VHF/UHF Repeater Uplink: 145.99 (PL 67 Hz)
VHF/UHF Repeater Downlink: 437.80

ISS status link:
https://www.ariss.org/current-status-of-iss-stations.html

Also the following is useful as it has posts from people interested in ISS activities.
https://www.facebook.com/groups/195430590089

The picture on the right shows the antenna set up that was used on an extended caravanning holiday in the North Island.
There is an azimuth rotator, however the elevation is fixed at 15 degrees which is considered a good compromise. This arrangement using 4 elements on VHF and 10 elements on UHF gave very good results. One issue, due to the use of a single coax between the TS2000 and the Arrow antenna, along with the required splitter/combiners, was when the VHF Tx exceeded 10W there was de-sensing of the UHF Rx.

On the right, using the set up as shown above, (4 elements on VHF) is an image received from a NOAA weather satellite broadcasting on 137MHz. (The image has been squashed to fit the page better). An SDR dongle was used for receiving the signal and wxtoing was the software that produced the image.
The NOAA satellite is in a Sun synchronous orbit. More details about this orbit will be mentioned later in this article.

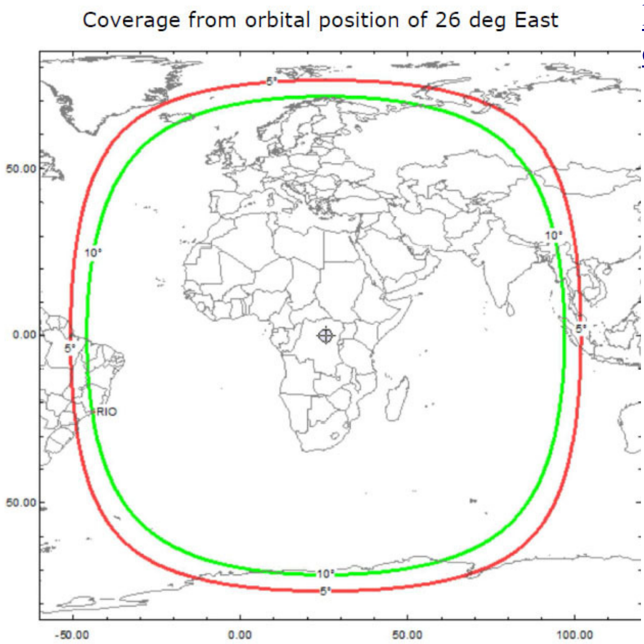


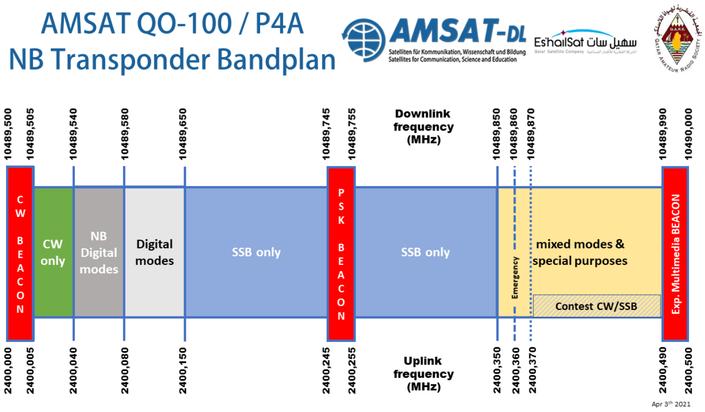
ORBITS

The purpose of satellites will determine their orbital path. These include:

(a) Low Earth orbit (LEO) Examples included (i) The Space Station, (ii) Sun synchronous satellites which is a common orbit as the satellite passes occur around the same time each day for an observer. Most Amateur Radio satellites are LEO's
Sun synchronous satellites, orbits are inclination to the equator is approximately 95 to 105 degrees. (90 degrees is a polar orbit) so their orbit is slightly retrogressive.   The following link illustrates the principle of Sun synchronous orbits.
https://www.youtube.com/watch?v=ylvgxNF3C0c

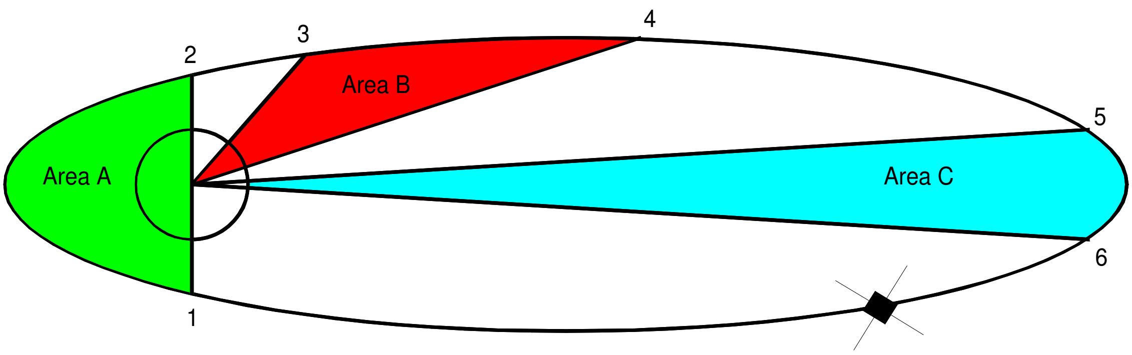
(b) Geostationary orbit HEO). There is only one of these satellite, (Es'hail-2), with Amateur Radio on board. The Amateur radio transponder is a small part of a the communication satellite and was professionally build. Qatar kindly sponsored it all. It's transponder is 500kHz wide with an uplink frequency of 2.4000 to 2.4005 GHz and a downlink of 10.895 to 10.490 GHz. With respect to Amateur Radio, this is known as Oscar 100 (QO -100). The downlink antenna is shaped so that all of the Earth's available footprint is illuminated which is unlike other downlink antennas, that are shaped to focus on specific areas.
For more information regards Es'hail-2 try:
https://spacewatch.global/2019/03/eshail-2-in-commercial-service/





(C) Medium Earth Orbit (MEO). At the time of writing, GreenCube (IO-117) is the only active satellite with Amateur Radio on board in this category. The orbit is nearly circular and has a height around 5840 km. The Amateur communication mode is a digipeater which includes store and forward. The operating frequency is 435.310 MHz (USB) for both uplink and downlink. More information about GreenCube is mentioned later in this article.

Previously there have been other MEO Amateur Radio satellites launched all of which a Molniya orbit was attempted. This is very elliptical (0.74), orbit with an inclination of 63.4 or 116.6 degrees. The distance above Earth's surface is 600km at perigee and 39,700km at apogee. The orbital velocity varies throughout its orbit. The period is 12 hours. Russia used this orbit with 3 satellites spaced throughout it's path so that at least one could be received at any given time in Russia. This gave the Russian people 24 hour TV etc. without the need to track their antennas, as each satellite, in turn, appeared to hover in the same place in the sky for a number of hours.
Three Amateur Radio satellites were place in an orbit similar to that used by the Soviet Union for their Molniya satellites. The first being AO 10. It did not quite achieve the Molniya orbit but none the less was very useful. It would stay at around about the same place in the sky for hours around it's appogee. Not only this but it gave a very large footprint. After AO 10 failed, most likely due to battery problems, AO 13 was launched into a similar orbit. However again the orbit was not prefect and it entered the Earth's atmosphere after only a few years due to it getting to close to the Earth at perigee. The next to be sucessfully launched was AO 40, however it achieved a reasonable orbit but ended up closing down due to a battery and leaking fuel issues. Most likely due to the cost of putting a satellite in this orbit these days all Amature Radio satellites launched since are LEO except for GreenCube and QO 100. Note: Amateur Radio is not the primary purpose for both of these the satellites. There is some activity from AMSAT (North America) to indicate that a high orbit satellite could be.... feisable.... sometime in the future. Fingers crossed.



Kepeler's second law.
If Area A, B, & C are all equal, then the time taken to go from 1 to 2 equals the time taken to go from 3 to 4 and also equals the time taken to go from 5 to 6.

Molniya orbit information:

https://www.daviddarling.info/encyclopedia/M/Molniya-type_orbit.html

Addition information:

Types of orbits are shown in detail in the following link.
https://www.youtube.com/watch?v=BvjlBpP4zU8&t=17s

For geostationary orbits launching at or near the equator is an advantage as it gives the launcher extra velocity in the right direction due to the Earth's rotation.

Sun synchronous orbits are common. As they pass near the poles during each orbit, command/monitoring stations for them are usually located in places having high latitudes.
For example the following link provides brief details of an interesting station in Southland:
https://en.wikipedia.org/wiki/Awarua_Tracking_Station
Web site:
https://spaceops.nz/

SUMMARY

Orbit type	Distance above Earth's surface.	Orbital Velocity.	Period.
Low Earth orbit (LEO)	100 to 2000km	7.84 to 6.9km/s	86 to 127minutes
Geostationary (GEO)	35,862km	3km/s	24h from Earth's point of view. *(Space POV. 23h 56m 4.0905s (1 sidereal day))* *
Medium Earth orbit (MEO)	Between LEO & GEO	Between LEO & GEO	Between LEO & GEO
Moon	356,500 to 460,700km	1.022km/s Mean	Earth ref. 29.531days Sidereal. 27.322 days

* A sidereal day is the actual time that it takes the Earth to complete 1 full rotation.

USING LINEAR AMATEUR RADIO SATELLITES

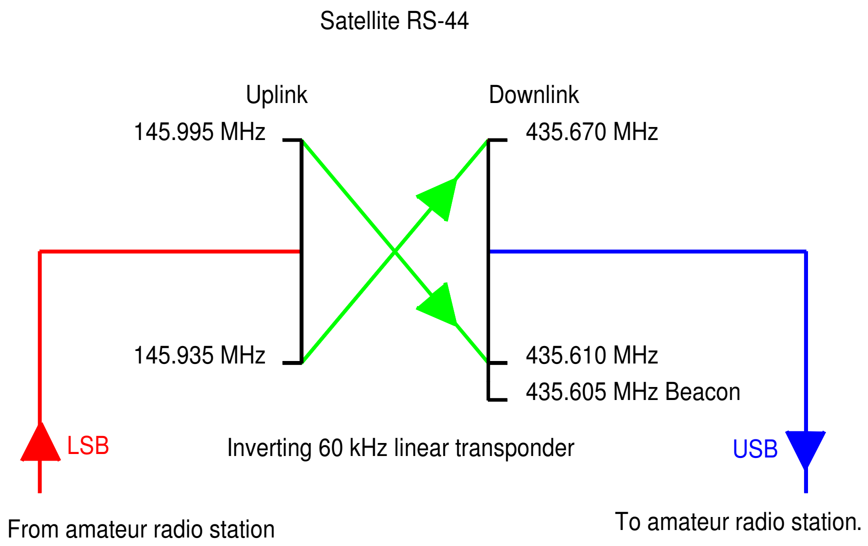
The downlink on these satellites is somewhat like an HF band with several stations able to transmit throughout it's bandwidth at the same time. FM is not used. Usually SSB and CW.
Operators need to take care that they do not uplink too much power as this may desence the satellite's receiver which will affect other users. Care also has to be taken to ensure that an operators signal does not drift into another users frequency due to Doppler. Therefore computer control of both the tranceiver's uplink and downlink frequencies is a practical requirement.
Most linear satellites use VHF and UHF transponders, however HF and SHF are also other options.

Tranceivers required to use linear satellites:

These are very much more expensive than a hand held (s). The transceiver needs to have full duplex and computer controlled capabilities. A bonus is that the transceiver is very likely to also have FM. Some of these types of transceivers also have HF bands, so it may be worth considering a transceiver with the satellite option when considering purchasing an HF rig.

Current linear satellites are:
AO 7
RS44
FO29
There are also some Chinese satellite.

The following diagram shows the inverted transponder arrangement for RS-44:



The diagram above shows the LSB uplink is transponded to USB. It also shows that an uplink signal in the higher end of the bandpass is transponded to the lower end of the downlink's bandpass, and vice versa.

USING PACKET DIGIPEATER STORE AND FORWARD AMATEUR RADIO SATELLITES

This method of communication involves the use of a computer connected to the radio. The message is first typed into the computer which the operator then uplinks to the satellite. (The uplinked/downlink information is termed a packet as the message is bundled in with other data that is required to run the system). The satellite repeats this packet at a time determined by the sender. Of course a computer is also needed to decode packets downloaded from the satellite. As the uplink and downlink frequency is the same, an uplink packet will not be received by the satellite while it is transmitting.

Store and forward has been around for a while. With this method, the packet can stored and at a later predetermined time, transmitted by the satellite. The advantage of this is that the packet can be transmitted long after the satellite finishes its pass over the sending station, therefore extending its coverage. Also the stored packet can be transmitted to the operator receiving the packet during their sociable hours

An example of a satellite with a Digipeater is GreenCube (IO117) (MT-CUBE-2)

This satellite's digipeater store and forward communication frequency is 435.310MHz (USB).
The satellite's approximate altitude is 5800km, which enables a very good coverage.
To access it, a 10dBi or greater directional antenna is recommended.

Computer software and instructions required to use GreenCube can be found at:
https://drive.google.com/file/d/13ysdRU0FYVwHzsWUKL9-iFYVAYpCQPXY/view?usp=sharing

Although store and forward can be used, only contacts that occur when both stations have access to the satellite simultaneously are “officially” recognised for distance.

Maximum distance for ZL3CU is 12,876km (VE6WQ).

GreenCube is an Italian satellite that was launched by the European Space Agency on the 13 July 2022. Its main purpose is/was environmental monitoring and control to allow the cultivation of the microgreens, (*brassicacae*) seeds in microgravity as well as having a significant radiation environment.
In the last few months it’s digipeater seems to have been enabled practically full time.
More details can be found at:
https://www.s5lab.space/index.php/greencube-home/

SATELLITE PASS TIMES AND TRACKING PREDICTIONS

Examples of Internet options:

(A)
https://www.heavens-above.com/?lat=-43.5034&lng=172.5799&loc=Christchurch%2c+New+Zealand&alt=17&tz=NZST

This is set up for Christchurch so no need to sign in.
Click on ISS under the 10-day predictions for satellites of special interest line. Then click in the, Passes to include all, circle. If you wish to track the satellite then it has an excellent function which can be accessed by clicking on the date at the pass of interest. This displays the azimuth with respect to time. (Also try ground track in this window) During a night pass it will show the stars etc. (It is worthwhile clicking on a date for a pass just to see what is available there. It may be a useful function for you to use in the future)

(B)
https://www.n2yo.com/

You will need to sign in and put in your location, say your address. After clicking on the location button it should show you where you are on a map. If OK click on the select button. Back at the main menu (it should default to the ISS) click on 10 day pass predictions. Then click on the All passes button just underneath the info that displays your location details etc. (Click on the Map and details to give a bit more info)
This is a very good website as, for example, it gives you a link to the live down streaming of the ISS (If it is available at the time) etc.
This is very useful to tell the operator where to point the antenna during the pass.

(C)
I thank Nicholas Lynch ZL3NLA for the following information that provides a link to Look4sat by Arty Bishop, for Android devices which Nicholas prefers it to Heavens Above.

https://play.google.com/store/apps/details?id=com.rtbishop.look4sat&hl=en_NZ&gl=US

Examples of options using software on a computer:

(1) Orbiton:
http://www.stoff.pl
Is free and has some good features. Tutorial:
https://.youtube.com/watch?v=AqPpdpdbERw

(2) Instant Track:
https://www.mustbeart.com/software/it/index.html
Is now free and has been used for many years.

Instant Track has a couple of disadvantages. (a) DosBox needs to be installed on the computer to run it. (b) Every so often the latest Keplerian elements for the satellites need to be installed into the program as it does not do it automatically like other programs.

For DosBox:
https://www.dosbox.com/wiki/Basic_Setup_and_Installation_of_DosBox
This gives very good details for its set up and a link to download it.

For Keplerian elements (Two line elements (TLE)):

https://www.celestrak.com/NORAD/elements/

(There are also other web pages that proved the latest TLE)
Click on the name of the group of satellites that is to be updated. Example; Amateur Radio. Clicking on the icons to its right will not provide the TLEs.
A .txt document will appear showing a number of satellites along with their TLEs. Right click on this document and save it along with a suitable file name, eg. 12Feb22a.txt into the same folder as the Instant Track software.
Then starting at Instant Track's main menu, type; 6, then A, then 3. At the file name prompt type in the file name, eg. 12Feb22a.txt. After the updating go back to the main menu.

(3) Gpredict:
https://sourceforge.net/projects/gpredict/

Gpredict is free. A lot of features including control transceivers for Doppler correction and automatic control of tracking of antennas.

(4) AMSAT products:
https://www.amsat.org/product-category/software/

An example is SatPC32. It is fully featured for satellite activity. This includes automatic control of transceiver's Doppler and automatic control of tracking of antennas. (Costs $US45 - $US50 which is used to support AMSAT)

(5) Ham Radio Deluxe:
https://www.hamradiodeluxe.com/

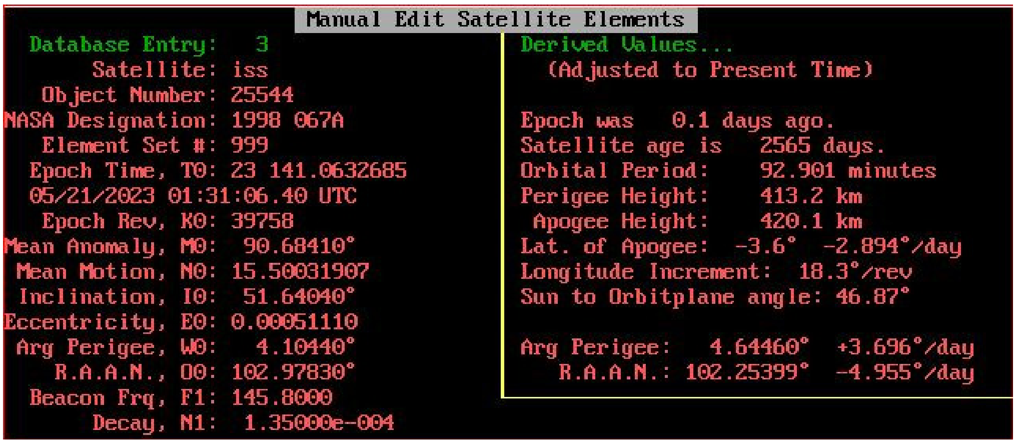
Again fully featured including features for non satellite activities. Examples are control of most of the radio's functions, and display of its front panel, digital modes and contacts logging. (Costs $99.95)

Keplerian elements:

Keplerian elements are required by the tracking program to provide information about a satellite's orbit. This is used to calculate the passes and tracking data for the operator's location. Satellite tracking software programs require reasonably updated Keplerian elements.
Keplerian elements can be found at a few web sites including AMSAT and https://www.n2yo.com/
Most programs automatically download Keplerian elements. (Instant Track does not).
The following shows the two line elements set for the International Space Station that was provided by Celestrak:
https://celestrak.org/NORAD/elements/

```
ISS (ZARYA)
1 25544U 98067A   23141.06326854  .00013500  00000+0  24379-3 0  9991
2 25544  51.6404 102.9783 0005111   4.1044  90.6841 15.50031907397584
```

The following shows the above TLE converted by a tracking software program. (The beacon frequency was manually edited in.)



The following provides details about elements:
https://en.wikipedia.org/wiki/Orbital_elements Kepelarian
Also:
https://www.spaceacademy.net.au/watch/track/orbspec.htm

ANTENNAS

Note. The adage "If the antenna did not blow down during last winter's storm, then it's too small." is not necessarily correct for satellite communication. A modest installation that is placed as high as practical will furnish very good results. A large array has to be pointed accurately at the satellite to get its benefits. Significant off pointing will give a poor result that would be worse than if a modest antenna was in its place.

Once the path of the satellite has been established then directive antennas need to be pointed correctly during its pass.

(A) Non rotatable: These should be installed as high as practical, (the higher the better) as the satellite spends more time at/near the horizon than it does going in the near over head quadrant. The J Pole is a very good non rotatable satellite antenna. Of course 2 will be needed. (VHF and UHF). Very good success has been achieved using a J Pole antenna for receiving ISS SSTV images. There are a number of good web sites for J pole antennas. Here is one:
https://www.hamuniverse.com/jpole.html

Super J pole for 70cm:
https://vk6ysf.com/superjpole.htm

(B) Portable hand held directive antenna:
There are a few manufactures of portable hand held antennas. An example is the Arrow:
https://www.arrowantennas.com/sub/arrowiiyagi.html
Building your own antenna is an option. There are a number of websites of how to construct VHF and UHF antennas. Please be aware the bigger the array the harder it is to hold in the air! (If somewhat heavy then a vertical support pole to enable the ground to take the weight would be an advantage).
Try:
2m/70cm-Yagis ultralight
From:
https://www.qsl.net/dk7zb/start1.htm

(C) Permanent directive antennas:
Some publications mention using circular polarise antennas. This will give the best results, however a linear polarised antenna will usually provide good results and is not as complex.
Obviously the bigger the antenna the stronger the signal, however as mentioned, it needs to be pointed more accurately to achieve this benefit.
An Azimuth rotator is required when using directive arrays. An elevation rotator will provide the best results, however if there is no elevation rotator, setting the antennas at 15 degrees is a good compromise.
There are a number of commercial VHF and UHF antenna manufactures to be found on the Internet.
There are a number of web pages on the internet detailing how to build 2m and 70cm antennas.
An example is: (Look for the options on the left hand side of the page)
https://www.qsl.net/dk7zb/start1.htm

As previously mentioned using a single coax in conjunction with combiner/splitters between the transceiver and the antennas, will likely cause desensing of the UHF Rx if the VHF Tx is running 10W or more. If the Tx is UHF and the Rx is VHF then this is not an issue. However, if practical, it is better to run separate coaxes.

ROTATORS AND ELEVATORS

I THOROUGHLY RECOMMEND VISITING THIS WEB SITE
https://www.sarcnet.org/rotator-mk1.html

The following are links to a couple of rotor elevator manufacturers:
http://www.alfaradio.ca/index.php
https://www.yaesu.com/indexVS.cfm?cmd=DisplayProducts&ProdCatID=104&encProdID=79A89CEC477AA3B819EE02831F3FD5B8

HINT. STORING TRACKING INFORMATION FOR LATER USE.

Take a photo, using a digital camera or preferably the camera option of a cell phone, of the tracking information displayed on the computer screen, as there could be a lot to write down. After the event trash the photo. If a portable activity is planned, also take a photo of the Sun's/Moon's tracking information that starts before the satellite is due. Use this, in conjunction with a 360 degree protractor, to calibrate the azimuth alinements at the portable location before the pass begins.

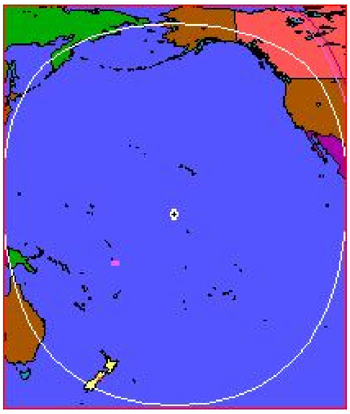
NOTABLE SATELLITES

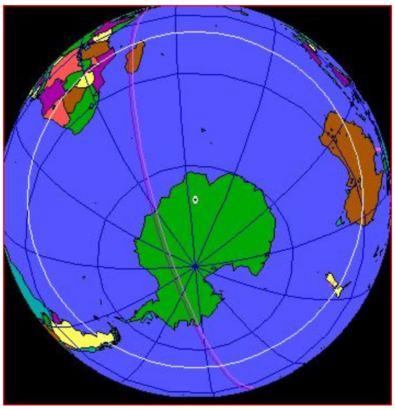
(A) GREENCUBE (IO-117) (MT-CUBE-2)

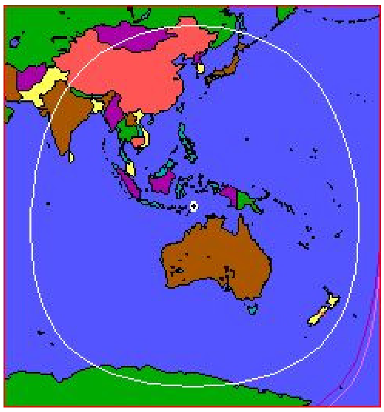
Although store and forward can be used, only contacts that occur when both stations have access to the satellite during the same time are "officially" recognised.

It is a bit of a challenge as it has a low power output and needs to be followed in frequency accurately. Therefore a computer is required to control the operator's radio frequency. Note, even though the satellite transmits and receives on the same frequency, the frequency for transmitting and receiving at the operator's radio, except for a brief period at maximum elevation, is different.
As it is not in a low orbit, therefore changing the direction of the antenna during a pass can be easily achieved manually.

The following provides some idea of its coverage when, at different times, it is approximately 4 degrees elevation in Christchurch.







(B) AO-7 .Launched in 1974, AO-7 became non-operational in mid 1981 due to battery failure . In 2002 one of the shorted batteries became an open and now the spacecraft is able to run off solar panels. For this reason it is not usable in eclipse and may not be able to supply enough power to the transmitter to keep from frequency modulating the signal. When continuously illuminated, the mode will alternate between A and B every 24 hours.

(C) AO10. Due to battery failure it is hoped that like AO7 an open circuit will occur

FINISH.

Thank you.
73
Starr ZL3CU

Updated 28th May 2023.