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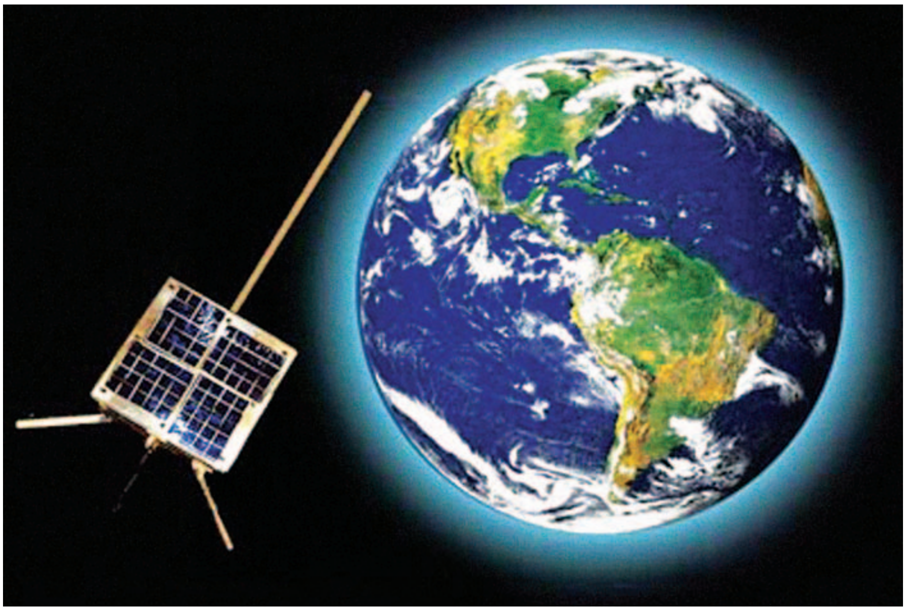
Getting started on amateur radio satellites

It is impossible to cover the subject fully, so you will find plenty of personal recommendations for information sources and suggested reading, based on experience.



Argentina's first amateur satellite, Lusat-1 (LO-19) – details at www.lusat.com.ar

WHY SATELLITES? As a class-B licensee under the old rules, I did not have any HF privileges at all. Satellites offered a technical challenge and the possibility to work some serious DX using 2m and 70cm. My first trans-Atlantic contact was achieved on the now-defunct *RS-10* using 10W to a small Yagi for the uplink, and a sloping dipole to receive the *RS-10* downlink signal in the 10m band. It took several months to achieve this first trans-Atlantic QSO as I needed to build up my operating skills and make improvements to my receive set up. To minimise noise pickup from the house, the antenna went at the bottom of the garden and a homebrew RF pre-amp overcame the cable loss and boosted the signal. It was a great sense of achievement to send and receive signals to and from space and to make that contact via an orbiting satellite. I still get a buzz from communication via a spacecraft.

The satellite community is quite small compared with the number of HF users. When you become a regular on a particular satellite, you quickly make friends on air which makes operating very enjoyable. Some HF old timers tell me that it's like it was on HF many years ago.

If you are new to satellites, you probably have the impression that it's very complicated, needs a degree in science or engineering and costs a small fortune. Whilst it's certainly true that you will be venturing into new territory, satellite operating looks more difficult when explained on the printed page than it is in practice. Keep in mind that satellites are like terrestrial repeaters, with four fundamental differences.

- They are constantly moving, so we need to know where to point our antennas.
- The input and output will be in two different bands.
- Their signals are always drifting rapidly in frequency – the Doppler Shift.
- Communications are full duplex – you must be able to hear your own transmission coming back from the satellite

On the non technical side, but of great importance when you start out, are the following.

- Listen to a few satellite passes to get the hang of how things are done and to check that your receive side is working properly.
- When you try your first contact, be patient, it may take you numerous passes of the satellite before everything comes together for you. Once it does it's like riding a bike.

SATELLITE GROUPS. There are three basic kinds of satellite, defined by their orbital paths.

LEO – low earth orbit, typically 1000km altitude in a near-circular orbit that passes over the poles

HEO – high elliptical orbit, typically a few hundred kilometres altitude at its closest to Earth, and 40,000km or more at its furthest point. The orbit describes an ellipse.

GEO – geostationary or, more accurately, geosynchronous, typically 37,000km orbits in synchronism with the Earth's rotation, so appearing stationary.

Many of our amateur radio satellites are LEOs and typically take about 100 minutes to complete each orbit. The *International Space Station* is a special case being a super LEO at only 300km altitude and an orbital period of 91 minutes. Without a regular boost from the supply vessel's rocket motors, the ISS would fall back to Earth.

WHAT'S UP THERE? There are various kinds of satellites to keep in mind.

Amateur Radio Satellites – CW, SSTV, voice, packet, PSK31, APRS and FM – only single-channel satellites for voice.

The International Space Station – voice (with crew members), packet, APRS, (SSTV coming soon).

Cube Sats – Telemetry and scientific data, and possibly a voice transponder on future satellites.

Suit Sat – a discarded space suit equipped with radio gear and deployed from an airlock. SSTV, telemetry, pre-recoded message and possibly a transponder. *SuitSat 2* will be probably be launched later this year.

Most amateur radio satellites have beacon transmitters and most send telemetry. Cube Sats also send spacecraft telemetry and scientific data.

COMMUNICATING VIA SATELLITE. The principal bands used are 2m and 70cm. FM satellites are generally phone and/or packet. The SSB satellites carry CW, phone, SSTV and PSK31. The newer generation of satellites can operate on various modes and bands, controlled by the ground station. Most satellites have a beacon transmitter which gives the satellite ID and in general, data about the condition of the satellite and its on-board systems. This is called Telemetry and capturing and studying it can become a major interest.

WHAT RADIOS DO I NEED? Whether you intend to operate portable with a handheld, or from a base station, it's essential that you have full duplex capability. That means that you can hear your own signal coming back from the satellite whilst you are transmitting. This feature is *not* available on all dual-band radios. An FM radio will enable you to operate through several satellites, *AO-51*, *SO-50*, *AO-27*. A multi-mode transceiver will give capabilities for the SSB satellites as well: *AO-7*, *FO-29*, *VO-52*. Several modern rigs have true dual-band capability on 2m and 70cm. Rigs with a VHF heritage seem to have good features for satellite operating. If you are planning a portable operation, using a dual-band hand-held radio, your choice will be limited, as duplex capability is not a common feature of hand-helds. The Kenwood TH-D7 with built-in TNC is full duplex and very useful for satellite voice, packet and APRS. Andy Thomas, G0SFJ, has mounted several mini-DXpeditions with a Kenwood and had good results.

Full duplex can be achieved easily of course by using two radios, one for transmit and the other for receive. This may be a cost-effective option and avoids the complication of learning your way around a fully-featured multi-mode. A good receive rig for 70cm and a second-hand 2m rig will get you going and enable you to get some valuable experience before you buy an all-bells-and-whistles radio. This solution is particularly valid for the FM satellites when working portable. The transmit radio on 2m can be set to the uplink frequency, and not adjusted throughout the pass. With 5W to a small hand-held Yagi or quad antenna, it will be easy to access the satellites. Check out the advertisers in *RadCom*; older style single-band 2m FM handhelds can be purchased new for around £80.

OPERATING HINTS – FM SATELLITES. *AO-51* has several operating modes, so you need to know which transponder is on.

TABLE 1: Uplink and downlink frequencies for VO-52.

Beacon 1 145.936MHz carrier

Rx (MHz) USB	Tx (MHz) LSB
145.930	435.220
145.928	435.222
145.926	435.224
145.924	435.226
145.922	435.228
145.920	435.230
145.918	435.232
145.916	435.234
145.914	435.236
145.912	435.238
145.910	435.240
145.908	435.242
145.906	435.244
145.904	435.246
145.902	435.248
145.900	435.250
145.898	435.252
145.896	435.254
145.894	435.256
145.892	435.258
145.890	435.260
145.888	435.262
145.886	435.264
145.884	435.266
145.882	435.268
145.880	435.270
145.878	435.272
145.876	435.274
145.874	435.276
145.872	435.278
145.870	435.280

At *zero* Doppler Shift

Check the operating schedule on the AMSAT NA website. *SO-50* needs a 67.0Hz CTCSS tone in your transmission to access the satellite. One of the commonest causes of frustration for beginners is the wrong use of the squelch. Keep it fully open, the satellite signal may not be strong enough to open it for you. Use an earpiece or phones, thus preventing you from creating a feedback loop out into space and back. It also makes operating easier. Use a recording device of some sort for logging. On busy single-channel FM satellites, make one or two short contacts then leave the channel for others. With only a 10 – 15 minute operating window, it's antisocial to dominate the satellite. During weekends, the satellites carry a lot of traffic. When starting out, choose satellite passes where mainland Europe is not in the footprint. I have had some very enjoyable contacts with GM and LA under these quieter conditions. Try working the satellite late at night or weekdays during the daytime.

OPERATING HINTS – SSB SATELLITES. *AO-7*, *FO-29* and *VO-52* all use SSB and have a pass-band covering several kilohertz. By convention, the lower one-third of the band is used for CW and data modes, leaving the remainder for voice and other analogue modes. Looking at the frequencies for *VO-52*, the uplink band is 435.220 – 435.280MHz and the corresponding downlink is 145.930 – 145.870MHz (see **Table 1**). The convention on SSB satellites is to receive on USB and transmit on LSB.

DEALING WITH DOPPLER. The Doppler Effect is usually illustrated by referring to the change in tone of the siren as a police car speeds by. As the vehicle approaches, its speed shortens the wavelength of the signal, so the note seems high. As it goes away the speed of the vehicle increases the wavelength and the note becomes lower. The magnitude of the effect depends on the speed of the vehicle relative to the observer, and the frequency of the signal. The orbital speed of satellites is such that Doppler Shift is very marked, creating the effect of a constantly drifting signal. This affects the signal we receive from the satellite, *and* the signal we send to the satellite. During a contact, we will be adjusting transmit, and receive frequencies constantly by small increments so that we keep our contact on frequency. With a bit of practice this can easily be done manually. With radios that have CAT computer ports, the control can be done by computer and the satellite tracking program. A satellite that orbits at 1000km altitude will be about 1000km away when it passes overhead. On the other hand, the same satellite, if it's near the horizon, will be around 4,000km. If it's that much further away, its speed will appear to be much less; think of an express train viewed in the distance compared with one passing you on the platform. It's all about speed relative to observer. Use this to advantage by practising on low-elevation passes where the effect of Doppler Shift will be less.

With a bit more room to spare on SSB satellites, it's possible to find a quiet spot near the top end of the band and try a few test transmissions. Wear headphones for satellite operating, it makes life easier and avoids creating feedback to the satellite. Whistle [your call sign] and say "Test, test", is perfectly acceptable and can go in the log as a test transmission. This is very useful way to practise operating and staying on frequency. A useful trick is to set the transceiver and receiver to CW and send a few dots, rather than whistle. On my FT-847, I have a footswitch plugged into the key jack. A brief press on the switch gives me a nice CW note to tune up with. Switch to sideband and follow up with your call sign to give that final adjustment.

Table 1 is useful when working the

TABLE 2: Memory settings for AO-51.

	Memory	Rx	Tx
AOS	1	145.890	435.250
	2	145.885	453.275
TCA	3	145.880	435.300
	4	145.875	435.305
LOS	5	145.870	435.310

AOS = Acquisition of signal
TCA = Time of closest approach
LOS = Loss of signal

satellite; we can quickly see that if we are listening on 145.900MHz we will need to transmit on roughly 435.250MHz. I say roughly, because the table is constructed at zero Doppler Shift. A few test calls and small frequency adjustments should get you on frequency quickly. Draw up a table for all of the satellites you want to work through. Satellite operators are very tolerant, welcome newcomers and expect a few mistakes, we were all beginners once. You can do your bit by following these suggestions. Please don't whistle like crazy whilst whizzing your transmit frequency up and down the pass-band trying to hear something. It's very antisocial and will trample over other people's contacts. Use the table, pick low-elevation passes for practice and try at less-busy times.

For FM satellites *SO-50* and *AO-51*, Doppler correction is much more straightforward. Since the signal is FM, the onboard receiver's pass-band is wide enough to compensate for Doppler Shift, and the frequency could be set to the nominal frequency for the satellite and not adjusted for Doppler Shift. For the receive frequency, you could program some memories with 5kHz steps. As the satellite comes over the horizon, it will be higher in frequency so the steps might look like this: +10kHz, +5kHz, Nominal Frequency, -5kHz, -10kHz, satellite out of range. When operating, it's a simple matter to click through the memories during the pass to keep a good receive signal.

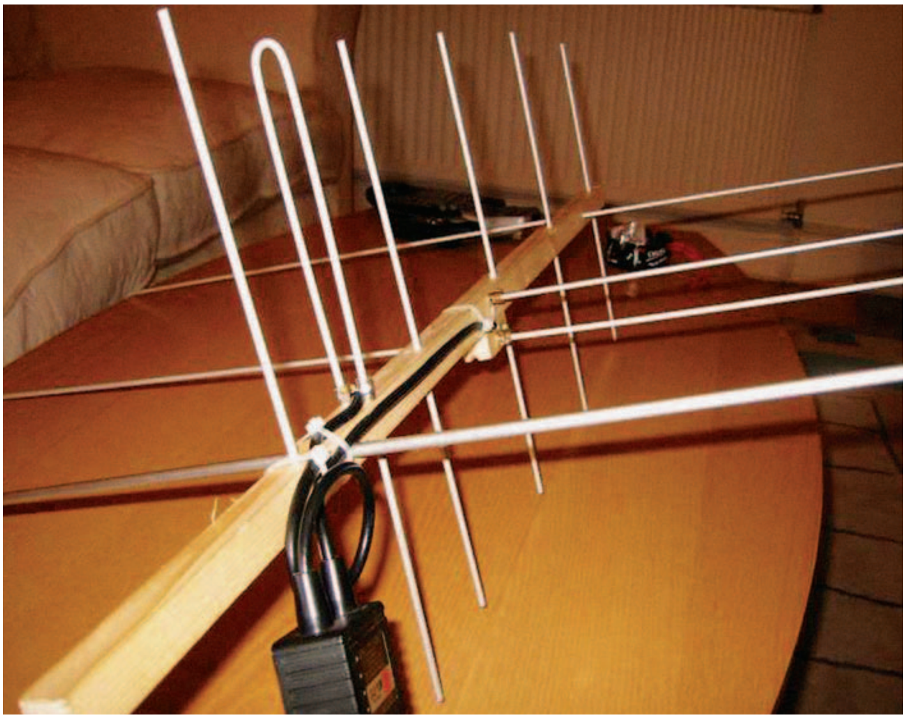
Table 2 shows the memories for both uplink and downlink.

ANTENNAS AND FEEDERS. A frequently-asked question is 'What antennas do I need for a home station?'. Here are some hints and tips based on my own operating experience, and from fellow enthusiasts. One of the best pieces of advice is to put money and effort into the receive part of your satellite ground station. It will pay off handsomely.

The main frequencies in use for the Satellite Service are:
144 – 146MHz, ground stations and satellites
435 – 438MHz, ground stations and satellites
1260 – 1270MHz, Earth to Space only
2400 – 2450MHz, ground stations and satellites

Several satellites, either in orbit or in the planning/building stages, will carry experimental payloads using higher frequencies. See 'Web Search' at the end of this article for URL's that give full details.

The ground station system should be looked at as a whole, not just the antenna. Careful consideration is needed to decide on the most suitable feeder and



Homebrew 2m/70cm Yagi by G6LVB.

Antennas at G7HIA.

connectors. If you anticipate having long runs of feeder cable, you will need to make some estimates of signal losses. Here are some typical loss figures for 30m of cable expressed as attenuation in dB.

Cable	Loss at 100MHz(dB)	Loss at 1000MHz(dB)
RG-213	2.26	8.0
Westflex 103	0.85	2.7
EchoFlex 15	0.28	2.9

(*Source: RSGB Radio Communication Handbook 8th Edition, Appendix A*)

The transmit side is seldom a consideration. Modern rigs have plenty of power available at 146 and 436MHz so a few dB cable loss can easily be made up by increasing the transmit power. Also in our favour, receivers on the satellites are very sensitive, so just a few watts to a small beam antenna will produce plenty of contacts.

Feeder loss is particularly important on the receive side as the relatively weak signal from the satellite will be attenuated in the feeder leaving you with a very little signal at the shack, and consequently a very poor signal-to-noise ratio. The practical consequence of this is that stations are difficult to hear and what would have been a pleasant contact with a 56 signal report is spoiled. If you have >30m feeder runs, you will probably need to install a masthead pre-amplifier (see below).

Use good quality connectors. N-type is preferred as it is low-loss, mechanically strong and, if fitted carefully, is watertight. Take extra time and attention to fit connectors very neatly, spreading out the braid evenly and taking care to cut everything to the recommended lengths. A well set-up system will last 10 years or more. For receive-only applications, low-loss satellite TV cable saves cost and performs very well.

Combined azimuth and elevation control for the antennas is far from essential; you will be able to do some space radio with simple fixed verticals, but results will be much better with small beam antennas that can be rotated in azimuth. Tilt the antennas so that they point upwards by about 15°, and you will be able to work all but the highest-elevation satellite passes.

Recently, I checked 100 consecutive passes of *AO-51* from my home.

34% did not rise more than 10° above the horizon. 42% were between 10° and 30°. Only 8% were above 70°. Keep in mind that the best DX is available when satellites are low to the horizon. The situation will be different when the HEO satellites – AMSAT NA's *Eagle* and AMSAT DL's P3E – are in orbit. For these satellites, some elevation capability will be an advantage.

Avoid very high-gain antennas as used by terrestrial DXers. The high-gain figures are attractive, but this comes with a correspondingly large antenna and narrow beamwidth. A narrow beamwidth antenna must track the satellite very accurately across the sky, otherwise the signal will be lost. Smaller, lower-gain antennas have benefits. A four-element cubical quad, or a quagi, is easy to make, will have about 10dB of gain and can be used with a low-cost TV aerial rotator costing about £40.

If using masthead pre-amplifiers on 2m and 70cm, don't pay a lot of money for amplifiers with very high gain figures. You only need enough gain to offset losses in your coax feeder and improve the system noise figure. If static doesn't fry the first device in the pre-amp then it's almost certain that at some stage you will accidentally send RF up the wrong feed-line. Simple pre-amplifiers, in which you can replace the front end device yourself, are ideal.

A problem often faced by satellite newcomers is receiver de-sensitisation (commonly called 'de-sense').

Here is what happens. When working satellites, we are using full duplex. We can hear our own signal coming back from the satellite while transmitting. For some satellites – *FO-29* is a good example – the uplink frequency (our transmit) is in the band 145.900MHz – 146.000MHz. The signal received from the satellite is between 435.800 – 435.900MHz. The third harmonic from our transmitter will be at 3 x 145.950MHz, ie 437.875MHz.

With, say, 20W to a beam which is in close proximity to our receive

Texas Potato Masher

antenna its easy to see that even with a third harmonic at -60dB the sensitive front-end of the receiver can easily be overloaded, making it very difficult to copy the signal from the satellite. De-sense can affect pre-amps as well as receivers. There are several remedies, some or all of which may be needed and will require some trial and error as the circumstances of each station will be different.

The first, and simplest, is to reduce your transmitter power. Satellite operators are often guilty of running more power than necessary. Secondly, try increasing the separation between the transmit and receive antennas. If an even more robust solution is needed, there are several good designs for small cavity filters made with copper tube and N-connectors. If you have workshop skills, these will give a good rejection figure.

An even simpler solution uses coax cable stubs as filters, with the simplest method of all being to use a commercial duplexer (diplexer) at the antenna. The Common port is connected to the 70cm receive antenna. The 2m port is terminated with a 50Ω load. The 70cm port goes to a pre-amplifier or to the shack. This is fully explained on the AMSAT NA website together with the diagram shown in **Figure 1**; the COMET CF-416C duplexer is said to work well. Duplexers are not waterproof, so you will need to arrange some sort of cover or box.

FIGURE 1

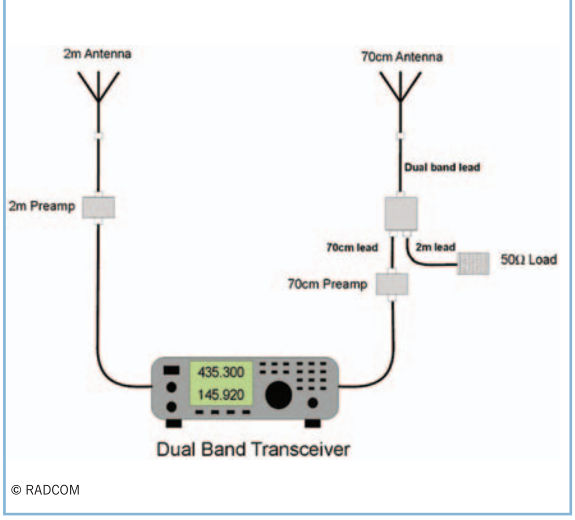


Figure 1: Desensitisation filter using a diplexer.

Text books recommend circular polarisation for space communications as it helps to reduce fading caused by reflections. Many of the satellites have transmit antennas which produce circular polarisation. Having the corresponding circular polarisation at the ground station is the ideal to aim for, but it's not essential. Most of the stations I work on the satellites are using linearly-polarised antennas. If you do use circular polarisation, make sure your antenna is compatible with the satellite – right hand (RHCP) or left hand (LHCP) – otherwise you could have 60dB of loss. For transmitting to the satellite, and receiving the downlink, circular polarisation is generally used at the higher frequencies of 1.2GHz, 2.4GHz and upwards. Take care with RHCP and LHCP when making dish feeds. The polarisation of the signal reflected from the dish will be the mirror image of the incoming signal.

You can homebrew some great antennas for satellite working. Quads, Yagis and quagis for 2m and 70cm are easy to make and are reproducible. A simple two-element quad for 436MHz made with thick wire will receive the downlink from a whole range of satellites. Helical antennas and patch antenna are good for 1.2GHz and 2.4GHz and there are plenty of good homebrew designs around.

Put any of the following call signs into your browser to find good practical designs that have been tested on antenna ranges or live on satellites: G6LVB, K5OE, W0LMD, G3RUH.

G6LVB's site has a very good construction article for building a hand-held dual-band Yagi designed for working the FM satellites with a 5W hand-held transceiver (final product shown in the photograph).

K5OE's site has some easy-build 'Texas Potato Masher' designs based on PVC pipe (see the photograph).

Other interesting antenna construction sites include WA5VJB and VE3CVG. Check out the design frequencies for the antennas on these sites. Many of the Yagi designs are optimised for terrestrial DX at 432MHz. For satellite use, a design frequency of 436MHz is best. Quads are less frequency-critical. For

VHF/UHF homebrewers, the quagi is well worth looking at as it combines the simple mechanical design of the Yagi with the increased bandwidth of the quad.

An important point for home construction when making Yagis and other multi-element antennas. A design may give the spacing between elements, don't be tempted to mark it out from element to element. Work from a fixed point such as the driven element, otherwise your measuring errors will accumulate and reduce the performance.

GOOD OPERATING PRACTICE. I regard my licence and the access it gives me to the bands as a privilege. I also feel a duty to uphold the fine amateur radio traditions of gentlemanly conduct when operating. After all, this is a shared resource, and especially so on satellites. The easy-to-work FM satellites do get rather chaotic at weekends as everyone is trying to make contacts on just one channel. I am happy to say that, in contrast, operating manners are good on the other satellites and we can all play a part in keeping it that way.

WHAT NEXT? Log on to the AMSAT-NA website and get the frequency details for FM or SSB satellites depending on your available equipment. Find the information by clicking on 'Sat Status' in the top navigation bar. When you get the status page click on the name of the satellite in which you are interested.

Have your latitude and longitude (or your grid locator) ready and go to the 'Passes' section of the website, (it's in the navigation bar along the top of the home page) or go to the Heavens Above website. This will give you the next few passes for the satellite of your choice.

Study the passes and pick those that look favourable for your location. Check to see which direction gives the best view of the sky for your antennas. Look to see if the satellite will be obscured by trees or buildings. Probably go for passes with about 20 – 30° of elevation.

Check that your shack clock is accurate to about 20 seconds or better. Make sure the time zone is right. All satellite work is done in UTC.

A few minutes before the pass, point your antenna towards the direction of the satellite and tune your receiver to the satellite beacon frequency +10kHz (approximately). Tune gently back and forward around this frequency until you hear the beacon (or contacts in the case of FM satellites, squelch fully open). Remember to move your antenna as the satellite comes over.

Having heard your first signals from space you are on your way to your first contact. Have a celebratory cup of tea and join AMSAT-UK so that you can be part of the international AMSAT community which designs, builds, funds and launches satellites for all radio amateurs to enjoy.

TIPS FOR COPYING SATELLITES. Here are my tips for working satellites, divided according to the equipment you're using.

- **FM hand-held or base station that can tune 137 – 138MHz**. This is the downlink for the NOAA series of American weather satellites. Signals are strong and have a distinctive tick-tock sound like a clock. There are several, and they pass over the UK several times a day. They are easily copied, even with 2m-band antennas. More information at the GEO website.
- **FM hand-held with 70cm**. *SO-50* and *AO-51* should be easy to copy with a small hand-held Yagi outdoors. *AO51* is sometimes switched to other bands, so check the AMSAT website for the current operating schedule.
- **Hand-held with wide-band receive**. Try some of the suggestions below for base station multi-modes, Listening outdoors with a hand-held antenna.
- **2m and 70cm Muti-mode**. Assuming that you have steerable antennas for terrestrial work, you should copy most satellites at low elevation. Check the predictions for suitable low-elevation passes that won't have the satellites signal path obscured by trees or buildings.

The *VO-52* beacon is a strong carrier on around 145.936MHz. Contacts will be heard around 145.900MHz USB.

FO-29 has a CW beacon on 435.795MHz, with contacts around 435.850MHz USB. Signals are weaker than those of *VO-52*.

LO-19 has a CW beacon on 437.125MHz. It runs at about 750mW and should be easy copy with any small outdoor Yagi.

If you have a suitable radio but only a VHF/UHF 'white stick' colinear or other omnidirectional antenna, don't give up. It's worth listening, although signals will be well down on what you could expect from a small Yagi. Look for passes that put the satellite signal in the best part of the maximum lobe of your antenna. Two UK stations with omnidirectional antennas received the recent test transmissions of SSTV from the *International Space Station*.

TO RECAP. All the frequency tables show the nominal frequency. Tune above that frequency at the start of the pass, as the satellite approaches. As it passes you tune slowly LF to follow the signal. This frequency drift is the sure sign you are listening to a signal from a fast-moving source (a spacecraft). If the signal is steady, it's probably terrestrial or a spurious signal in your receiver. Be patient, it may take you a few attempts to hear your first signals from space. If you don't seem to be succeeding make sure you have accurate time in your shack. Be prepared to listen carefully and tune around on either side of the anticipated frequency; the signal may be weak on your setup.

AND FINALLY. As a raw beginner, I had lots of advice from experienced satellite users, for which I was most grateful. Similarly, I will be happy to answer any e-mail or postal request from *RadCom* readers for advice on any aspect of setting up a satellite station.

RECOMMENDED READING

Guide to OSCAR *Operating* by Richard Limebear, G3RWL, published by AMSAT-UK.

The Radio Amateur's Satellite Handbook by Martin Davidoff, K2UBC, published by ARRL.

WEB SEARCH

AMSAT-NA
www.amsat.org

Satellite predictions
www.heavens-above.com

AMSAT–UK
www.uk.amsat.org
Weather satellites
www.geo-web.org.uk

Andy Thomas, G0SFJ, satellite-portable from Riga.