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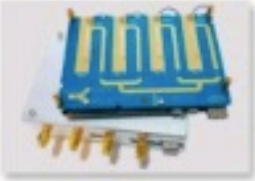

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My First Steps with Satellites

Daimon Tilley G4USI describes his journey into satellite operation.

One of the things I love most about the hobby of amateur radio is the sheer variety of new things to experiment with. For any amateur with an enquiring mind and a willingness to learn, there truly is no excuse to ever get bored with our hobby.

Having been licensed a while now I had, of course, been aware of amateur satellite working but I had never seen it in action, known an amateur who did it, or tried it for myself. In fact, while I always considered it interesting, my lack of knowledge shrouded the subject in a bit of mystery, and I suppose I always felt it was a bit specialised or out of my reach.

However, in June last year, I had a conversation with **Stuart GM7VEC** via Yaesu Fusion and CQUK. During our conversation Stuart mentioned his interest in satellite working and we discussed this at some length. Stuart very kindly followed up on this conversation with an e-mail outlining various commercial and home-brew antenna options, websites for further information and a 'screen shot' of how he had programmed FM satellite frequencies into his handheld.

I was intrigued and decided to do some more research. The school holidays were fast approaching, however, so I did not have time during the summer, but I revisited the subject in the autumn and began more detailed research.

While I found a number of websites on the subject, including the UK and American AMSAT sites, among others, I could not help but feel that there was not a single site that really provided everything I needed to know as a beginner in a single place. I did manage to cobble together various bits of information from around the web, but it was a slow laborious process. Even getting a definitive 'beginners' guide to what satellites were actually available was tough!

Interestingly, almost at the end of the journey I describe here, I did come across what I consider to be an excellent book providing many of the answers I sought – *Amsats and Hamsats* by **Andrew Barron ZL3DW**, and this book is subject of an accompanying Book Review.

Starting Out

I began by seeking out some satellite prediction software, so that I knew when to listen. For other reasons of necessity (to use my favoured SDR transceiver software) I was making the transition in the shack from Linux to Windows 10, and I think I must have downloaded all of the free satellite prediction software I could find. However, I didn't really like any of it, until I discovered that it was possible to run GPredict on Windows as well as Linux. I had been using GPredict on Raspberry Pi for a little while and liked it. Having got that working in Windows and having identified the satellites I wanted to start with, I loaded them into the software. I began with the FM amateur satellites and the ISS, as I intended to operate, at least initially, by using my handheld with a homebrew handheld Yagi, from the garden.


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Having identified the FM satellites I wanted to try, and their frequencies, I began listening on 2m FM to some of the satellite downlink frequencies. The FM satellites have uplink and downlink frequencies on different bands, typically 2m and 70cm. As can be seen from **Table 1**, most downlinks are on 2m FM with the uplink on 70cm. One notable exception is SO-50, which reverses that.

I quickly became aware that the satellites are really quite busy. Exchanges are quite perfunctory and businesslike, as a satellite is often only overhead for less than ten minutes or so, and many operators want to use it. Callsigns, signal report and Maidenhead squares are often the only information exchanged. Extensive listening from the shack on my vintage TS-700 using the homebrew 5/8th-wave vertical ground-plane antenna mounted on my eaves, was time well spent.

Having listened for a while to 'get the feel' of the nature of use, my interest was sufficiently piqued to want to have a go for myself. I wasn't set up for operation from the shack, with no desk-based 70cm rig and no beam antennas. In order to operate I was going to have to use my handheld FT-70D and a handheld beam, operating from the garden.

The Rig

I will deal with the rig first. Many sites recommend a full-duplex facility where you can hear both your uplink and downlink. This can either be achieved through a full duplex rig, or by perhaps using two handhelds. This makes a lot of sense – you can be sure you are accessing the

Fig. 1: Drilling the tubing to take the extension.
Fig. 2: The extended tubing, with join.
Fig. 3: Bending the tubing.
Fig. 4: The completed dipole end.
Fig. 5: Drilling the boom.
Fig. 6: Using copper tape for the joint.

satellite, because you can hear the net result. While I had access to a second handie, I decided to keep things simple, just using the one. Now the first issue that arises here is dealing with Doppler shift.

Doppler shift is an effect caused by the relative velocity between your location and the satellite. A common example often cited is that of a police car with sirens. Although the frequency emitted by the siren is constant on each tone, as it approaches you, the frequency of the siren sounds higher, and it sounds lower (relatively) as it moves away from you. The same happens with radio frequencies used when talking through satellites, and the higher the radio frequency, the greater the Doppler effect observed. An interesting side effect of this, is that, of course, the Doppler effect at 70cm will be more pronounced than that on 2m. So, to keep things simple, what most people do for FM satellite work is to merely adjust the 70cm frequency for Doppler shift, leaving the 2m frequency alone. Note that on SSB work, the Doppler effect is more important and both uplink and downlink frequencies on SSB satellites must be adjusted.

Let me use AO-92 (also known as Fox-1D) as an example, as I am listening to that downlink as I write this article.

AO-92 has an uplink frequency of 435.350MHz and a downlink frequency of 145.880MHz. In practice we tend to ignore the Doppler effect, which is less noticeable, on 2m FM, and use that single frequency for the downlink. For the uplink however, the Doppler shift is more noticeable and if you do not change your transmission frequency to match the passing of the satellite overhead, you will not maximise your use of the window of opportunity above the horizon nor have a great deal of success.

So, for programming the handheld, I set up some memories for this particular satellite. The memories looked as shown in **Table 2**.

Memory 3 holds the published uplink frequency. We start transmitting at Memory 1. Remember that Doppler shift means that, to the satellite as it is approaching us, our frequency sounds higher than it actually is, so we transmit

lower to accommodate this, then after the relative velocity between us has come close to nil, and it moves away, our frequency sounds lower from the satellites perspective, so our uplink frequency is adjusted higher to compensate.

What you are trying to achieve, as you track the satellite through the sky, is a change in your uplink frequency to compensate for the Doppler effect. You will start transmitting on the first frequency, be on the published frequency when the satellite is at the mid-point of its pass, and end with the last frequency. It is purely a matter of judgement when to change, and the full duplex facility suggested here should help with that, but I have not personally tried that. Some experimentation is required, along with a dose of experience, which I am still trying to gather!

Antennas

Once we have the handheld sorted, it is sometimes possible (although I haven't tried it) to communicate with the satellite with a whip type antenna. There are examples of this being done on YouTube, for example. But results will generally be much better and reliable with some form of gain antenna.

These fall into two broad camps – a crossed element dual-band Yagi or a log periodic antenna. Two very popular commercial antennas for this purpose are available from Arrow Antennas and Elk Antennas, respectively.

I like building stuff, both for the satisfaction and learning, as well as the

money saved. I had never built a Yagi before, so I opted to build an 'Arrow Style' Yagi. There are quite a few designs on the internet but having reviewed them, I decided on the design by **Bertrand Zauhar VE2ZAZ** and available here:

https://tinyurl.com/vfk65e3

This has three elements on 2m and six on 70cm, and is fairly easily built as long as you can measure and cut accurately. The basic antenna consists of a length of PVC conduit as the boom, approximately 30in long and in his case, Bertrand made the elements from 1/8in brass rods. In my case, I had a number of 6mm aluminium tubes (from a UK DIY store) left over from another project and decided to use those. I noted that using thicker elements can tend to lead to the need for making adjustments to the published element lengths, although a number of Yagi calculators I tried didn't seem to show a difference at these frequencies, but more of that later.

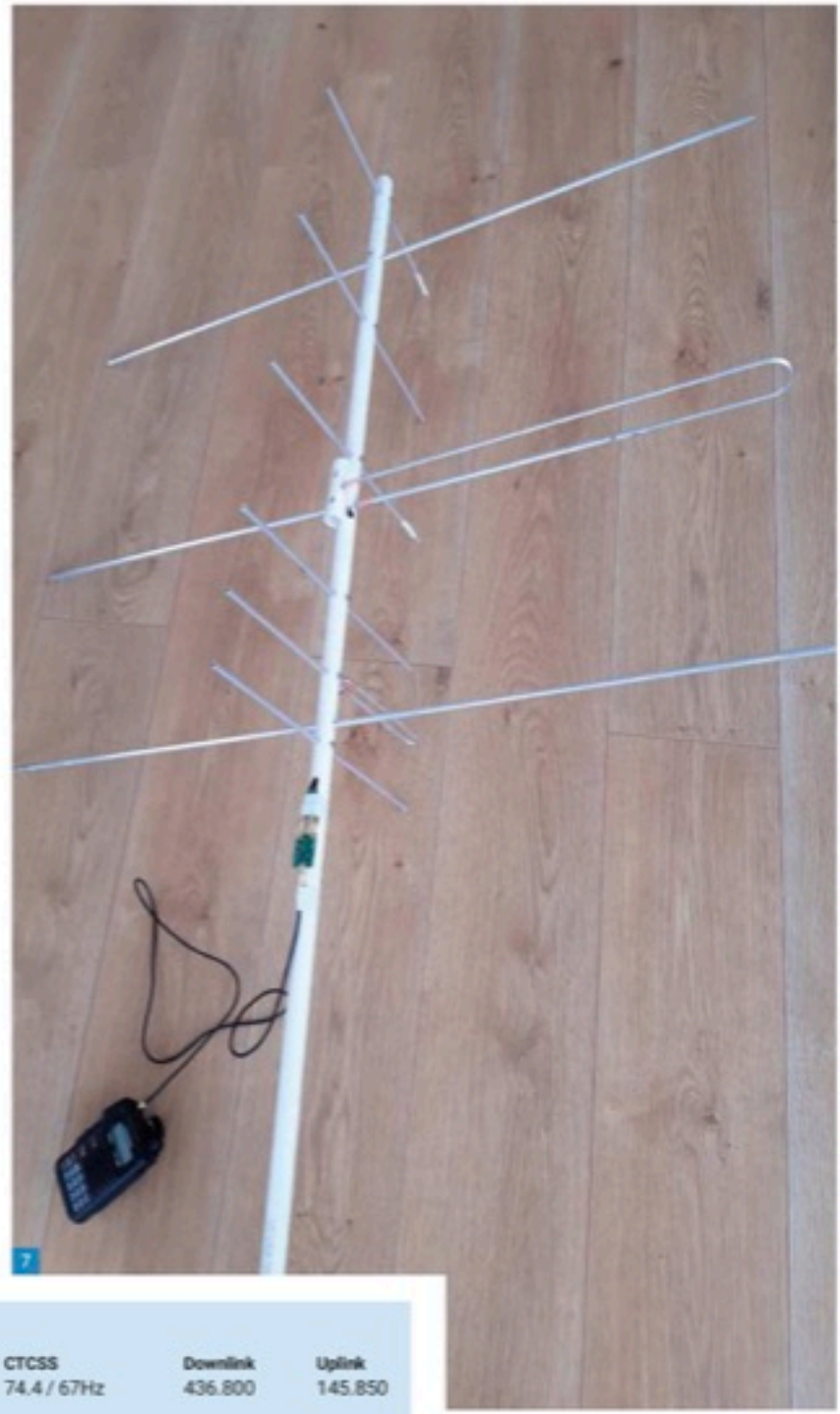
I won't reproduce his excellent instructions here, but I did make a couple of modifications to make my own design work. Most lengths of rod and tube at

these diameters come in 1m lengths, but the reflector and driven element for 2m are a bit longer than 1m so the tube needs extending. In my case I did this by inserting a solid aluminium rod into one end of the tube. To do this, I had to very slightly widen the tubing aperture with a drill, **Fig. 1**, file a taper on the rod, and connect with a fair bit of pushing and twisting, **Figs. 1, 3 and 4**. The materials are too delicate to risk a hammer, so I used brute force and then used a centre punch on the tube at the overlap with the rod to add a crimping effect in two places 90° apart. The result appears robust.

Having cut to length each of the reflectors and parasitic elements, I then carefully bent the two driven elements, **Figs. 2** and **4**. These elements are straight on one side and folded back on themselves on the other, in a semi-folded dipole approach.

The single most difficult part of the build was drilling the circular tubing so that the holes were parallel and in the same plane. I followed Bertrand's suggestion of screwing the tubing to a wooden batten and using a drill press. Even despite this, the results were not perfect, but they were close enough that with minor tweaking, all elements could be properly aligned. The elements slid through the boom neatly but despite careful drilling, **Fig. 5**, I considered the interference fit was insufficient to stop the elements moving, so I then used self-tapping screws, one per element, to secure through the boom into the individual elements.

Another hurdle to overcome was the connection between the coax and the aluminium tubing, which is notoriously difficult (is it even possible?) to solder to. Bertrand's solution is to solder his coax to his brass rods but that would not work for me. I considered mechanical connection using 'choc-bloc' electrical connectors,



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Satellite	Mode	CTCSS	Downlink	Uplink
SO-50 SaudiSat	FM	74.4 / 67Hz	436.800	145.850
AO-85 (Fox-1A)				
Daytime only	FM	67Hz	145.978	435.180
AO-91 (Fox-1B)	FM	67Hz	145.960	435.250
AO-92 (Fox-1D)	FM	67Hz	145.880	435.350
PO-101	FM	141.3Hz	437.500	145.900
Taurus-1	FM	67Hz	436.760	145.820

Schedule for PO-101 at https://twitter.com/Diwata2PH Note that for SO-50, the 74Hz tone is for opening up the transponder, and once open (by you or someone else) the 67Hz tone keeps it open during the pass.

Table 1: Some readily available satellites.

Memory	RX Freq	TX Freq	CTCSS
1	145.8800	435.3400	67Hz
2	145.8800	435.3450	67Hz
3	145.8800	435.3500	67Hz
4	145.8800	435.3550	67Hz
5	145.8800	435.3600	67Hz

Table 2: Programmed memories for AO-92.

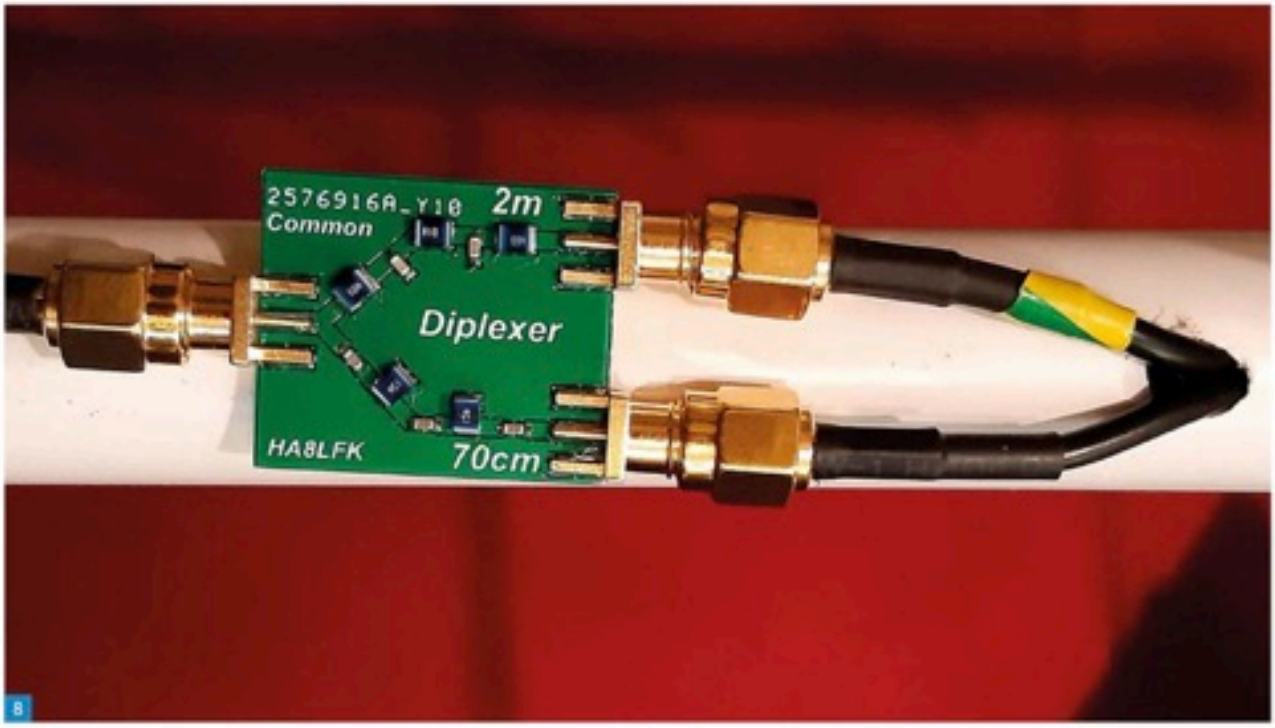

Fig. 7: The completed antenna.
Fig. 8: A view of the diplexer.

but in the end discovered that there is self-adhesive copper tape available with conductive adhesive. I promptly ordered some and tested it out and it worked beautifully with a good electrical connection made. Soldering to the tape was easy too. So, I wound some tape on the elements and soldered up some lengths of RG174, **Fig. 6**.

The final step was how to feed the antenna (shown complete at **Fig. 7**). If I used two handhelds, I could merely connect one antenna to each radio, but I just wanted the one so a diplexer was required. I did consider making one of these too. Designs are available on the internet, but I settled on a commercial one by HA8LFK for only $15. This is beautifully made, **Fig. 8**, small, neat and professional, and can be found here:

https://tinyurl.com/rcxhnvg

If I were to operate outside in the rain, I should take steps to waterproof my coax connections and the diplexer, but I don't like the rain so I didn't bother! The diplexer was fitted to the boom using cable ties and has SMA connectors for connection to the rig and antenna(s.)

On connecting my Nano VNA analyser, SWR for the 2m band was good to go, but it was high on 70cm and the driven element needed trimming to compensate – perhaps that was the impact of the larger diameter elements? A slight trim solved the problem.

Time to Operate

So, I had my FT-70D programmed for the FM satellites, taking account of Doppler, and I had my homebrew Arrow-style Yagi – time to go into the garden!

I used GPredict and looked at the time of passes that day. There were passes coming overhead for SO-50 and AO-92 in the next hour or so. I double-checked my frequencies, watched the clock tick by, and made a mental note of where in the sky the satellites would rise, reach maximum elevation, and recede.

For the first few passes, I listened only, to try to get the feel of the operating style and the antenna tracking. The next day, I set out to operate for real. I identified the relevant passes to me and headed out into the garden. At the appointed hour I was able to acquire a satellite and within a few minutes had made my first ever satellite QSO with a station in the Spanish territory of Melilla, just on the Eastern Moroccan coast. A few short minutes later and a second satellite was acquired and this gave me an Italian station.

It was when I ventured into the shack, I realised that I couldn't put these station 'firsts' in my log because I had already forgotten their callsigns! One of the issues with this style of satellite operating is that you just don't have enough hands to write things down. Many amateurs therefore record the audio of a pass, and their QSOs, to aid later logbook entries. You could use your mobile phone but I have a tiny digital dictaphone I haven't used in ten years or more, and a fresh battery soon saw this back in action, hanging unobtrusively around my neck.

Sadly, it was around that time when the British weather took a turn for the worse, so since then I have not made any further contacts, with the odd fine day being taken up with any outside chores that had been stacking up.

I definitely enjoyed it though and will be back for more as soon as I can. If I continue to enjoy it, I may well take the plunge and invest in a shack-based setup in time for the winter, but that will require a reasonably significant investment in time and money to purchase a dual-band duplex rig (essential for SSB satellites) and a Yagi antenna system. If I go ahead, hopefully you will read about it here!

Reflecting back to my initial conversation with Stuart GM7VEC, it really is easier than you might think – why not give it a go yourself?

Additional Resources

https://amsat-uk.org
www.amsat.org/two-way-satellites
www.work-sat.com/Home.html
Book: *Amsats and Hamsats*, Andrew Barron, ZL3DW, RSGB

Amsats and Hamsats

Daimon Tilley G4USI recommends a very handy starter book on the topic of working through the amateur satellites.

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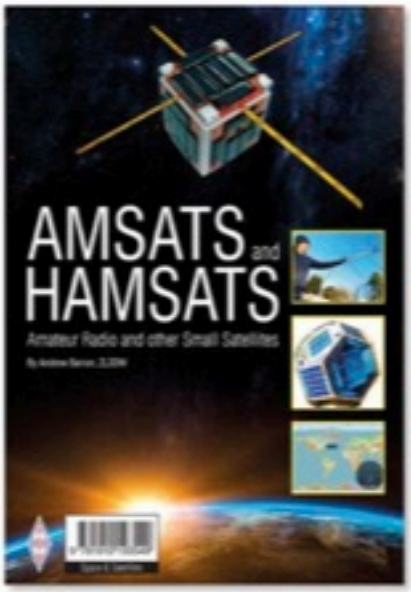
As I began to want to take my first steps into working satellites, I resorted, as usual, to the internet and conducted lots of searches. I found a good amount of information from various sites, but I came across two key issues. It didn't all seem to be particularly up to date, and there were still plenty of gaps in my understanding. I was completely unable to find a single authoritative source of information, despite lots of research.

I resorted to the RSGB bookstore and found a few titles. The one that caught my eye as being close to what I needed was the one reviewed here, so I duly ordered it just before Christmas, and spent hours poring over its every word.

Wow! This is a really good book, that did exactly what I needed – gave me all the information I could possibly want, and more, in one place. The book runs to a little over 350 pages. It really does live up to the blurb - *"This book is simply the most comprehensive guide available....."*

HAMSATs

Let's take a look at the title first, as it may be slightly misleading. Andrew defines an 'AMSAT' as those constructed by amateur (not necessarily radio amateur) teams, and even though some may carry radios, they are not designed for use by the wider radio amateur community. Examples might include satellites built by University teams for scientific purposes. 'HAMSAT' on the other hand, refers to those satellites that can be used by amateur radio operators to communicate with others on amateur radio frequencies.



The range of subjects covered is extensive, and there are over 40 chapters. It is not possible to list them all here but I found the book very well written. It gives you a limited amount of information to start off with, so that you can get on the air quickly and with the minimum fuss, and then fills in the knowledge gaps to a quite deep level of understanding.

Contents

The first chapter or two set out very clearly how to get started on the FM satellites in a detailed checklist format, and then moves into the use of linear (SSB/CW) satellites. It then touches on the biggest satellite of all, the moon, working the International Space Station (ISS), how transponders and repeaters work in space, monitoring weather satellites, and very helpfully covers the mistakes that Andrew himself has made, to help us not repeat them!

Then he really starts delving into details. Topics such as Doppler shift, feeder lines, link budgets, antennas and masthead preamplifiers are covered in a good depth. Also included are sections on satellite tracking and prediction software, CAT control of your radio, automated rotator control, differing types of spacecraft orbit, history, satellite designations, and even sections on vector mathematics, if you are feeling brave.

I found myself gobbling up the information, and even though some of it was not relevant to my intended use of satellites, I still felt compelled to read it and really felt that I learnt a lot.

To be honest, some of what I learnt was stuff I partly knew already, reasonably basic amateur radio concepts about coax cable losses, noise levels, etc, but all explained in a way where, even then, I found myself gaining a new insight on an old subject.

What more can I say? Well, only one thing really – if you want to learn more about working or listening to satellites, then buy this book – it is brilliant!

Amsats and Hamsats is available from the RadioEnthusiast bookstore for £14.99. https://tinyurl.com/y9hyly39