



Milton Keynes ARS

Amateur Radio Society




Es-Hail2 QO-100

Amateur radio on Geostationary Orbit

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What is it?



Launched on 15th of November 2018, Es' Hail 2, positioned at 26° East on GEO is a commercial satellite delivering DTH television and military broadcast services to the Middle East and north Africa.

However, there is more to it...

500KHz bandwidth
Narrowband transponder
(SSB, FT8, CW, NB Data)

8MHz bandwidth Wideband
transponder
(DATV)



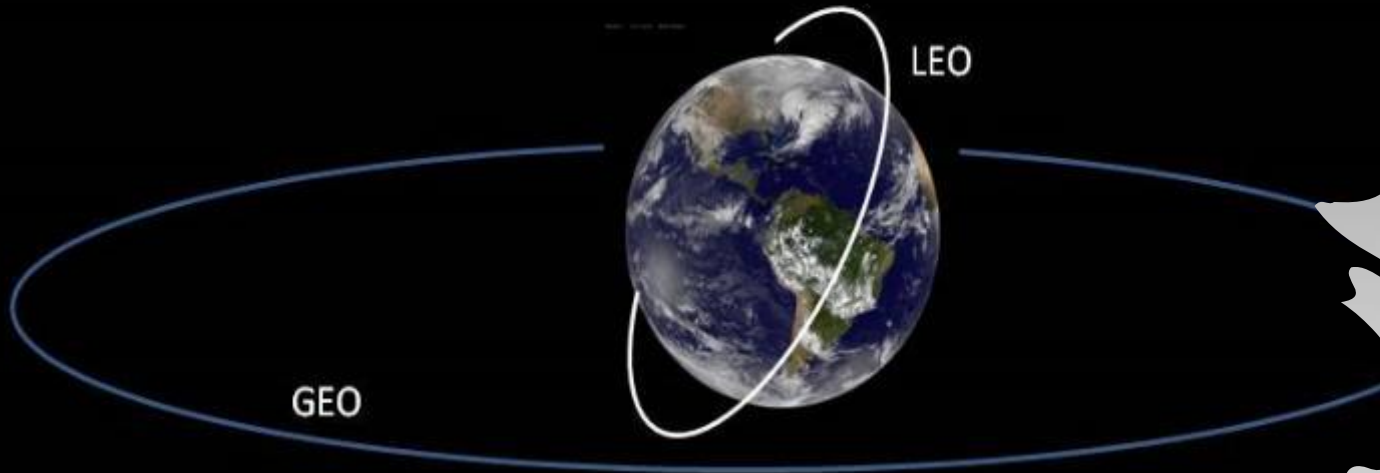
What's intriguing about it?

Alongside commercial services, with the help of Qatar Amateur Radio Society (QARS) and international organisation AMSAT, Es' Hail 2 has been gifted with 2 amateur radio transponders for us to enjoy!

**Being the 100th satellite carrying amateur radio, it has been named:
Qatar OSCAR 100 (QO-100)**

Where is it?

Low Earth Orbit (LEO)
Satellites travel faster than Earth rotation
Altitude between 150 - 2000 km (88 -127 min/orbit)



Geosynchronous Orbit (GEO)
Satellites orbital speed equals Earth rotation
Altitude = 35,786 km (24 hours/orbit)

At 36000km (22000m) on geostationary orbit (**GEO**) around the **equator**, the satellite travels at the same pace as the Earth's rotational speed, giving earthlings a stationary perspective.

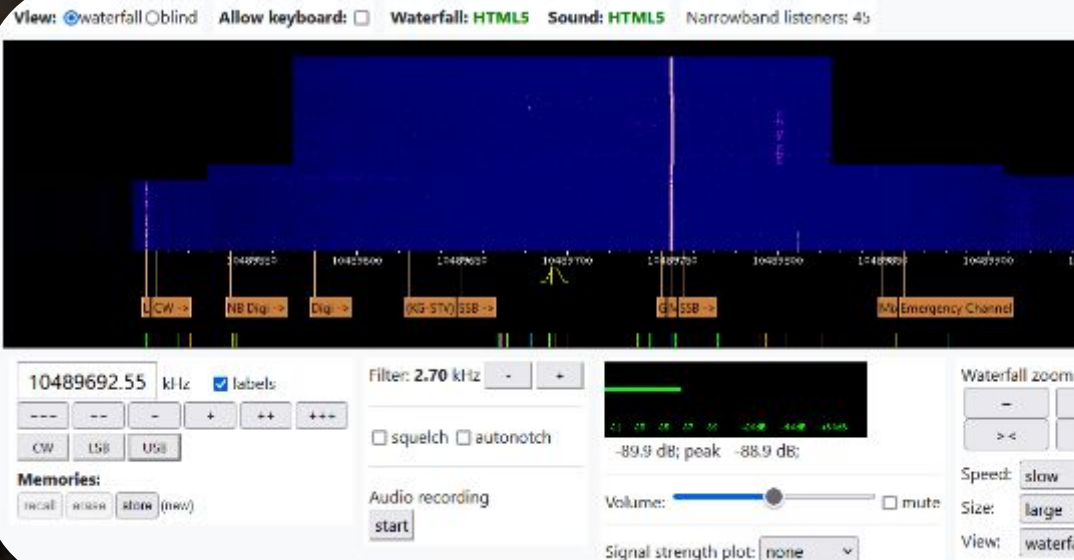
First steps

The first step into our journey with QO-100 is to receive the NB transponder.

We have no dish yet! But we can listen on the BATC WEBSDR located at Goonhilly Earth Station in Cornwall:

<https://eshail.batc.org.uk/nb/>

... or on the Sardinia WEBSDR:
<http://websdr.is0grb.it:8901/>





Es'hail-2 (QO-100) Dish Pointing

Click on the map or drag the marker to your station location.

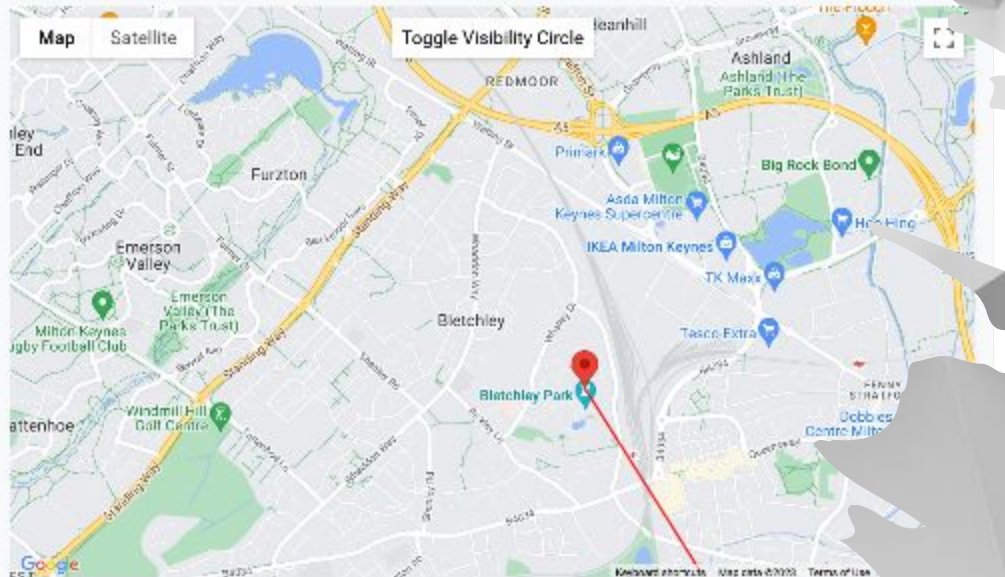
Ready (loaded 1LE: 2023.200)

Ground Station Location

- Latitude: 51.9987°
- Longitude: -0.7407°
- Locator: IO91PX
- Use my device location

Pointing

- Azimuth: 147.7° (147.2° magnetic)
- Elevation: 25.6°
- LNB Skew: -19.2°
- Current Sun-Earth-Satellite Angle: 36°

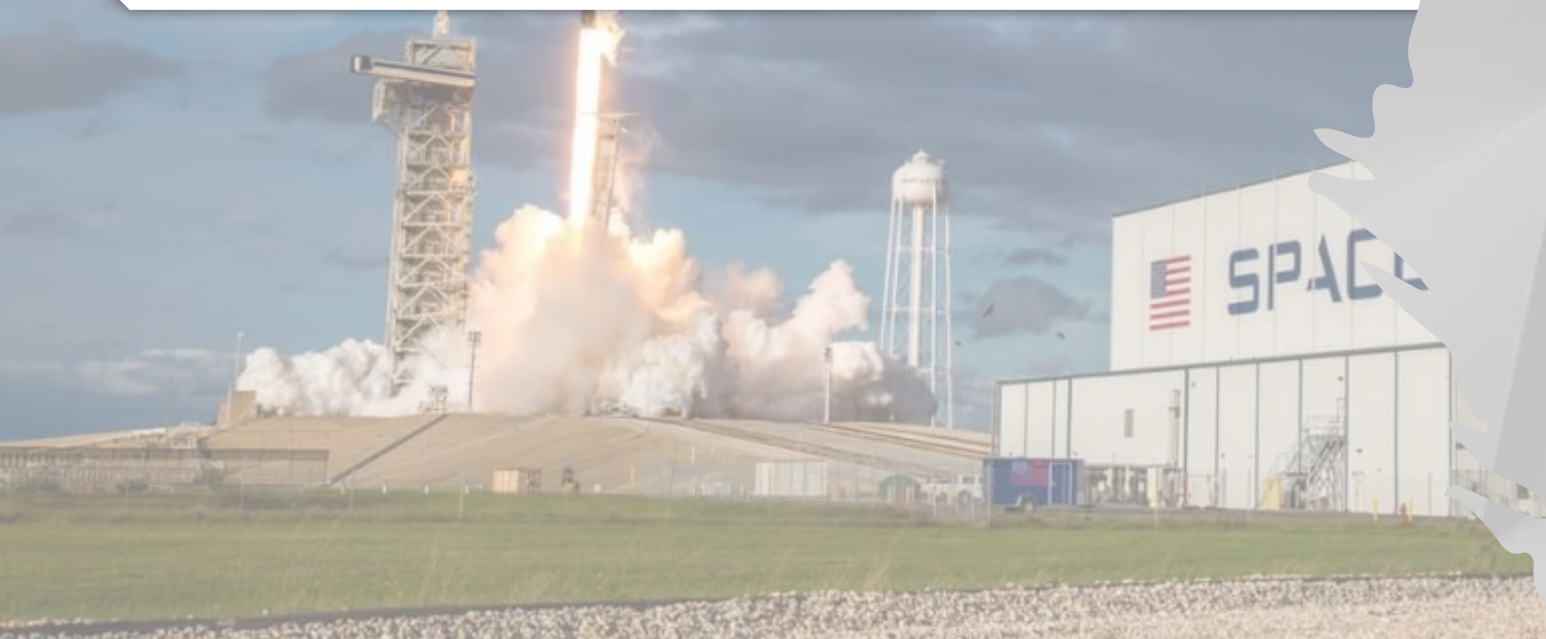


Got the virus? Let's locate the bird!

Looking up to the sky, it is positioned just 2 degrees “to the right” from where UK’s SKY TV provider Astra satellite is. No, you won’t be able to see it but is very easy to pinpoint with any satellite tracking app on your phone.

**Dish Pointer
Satellite Pointer**

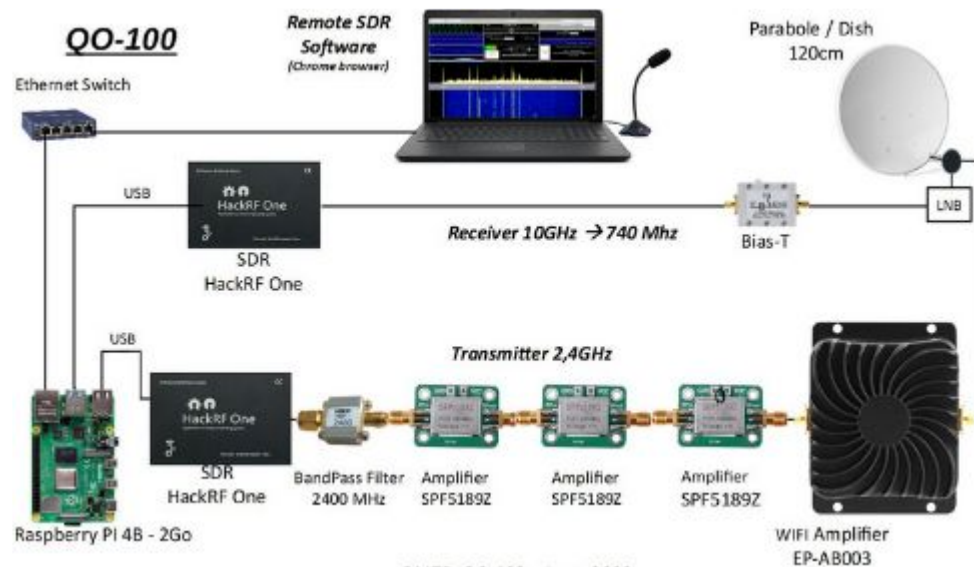
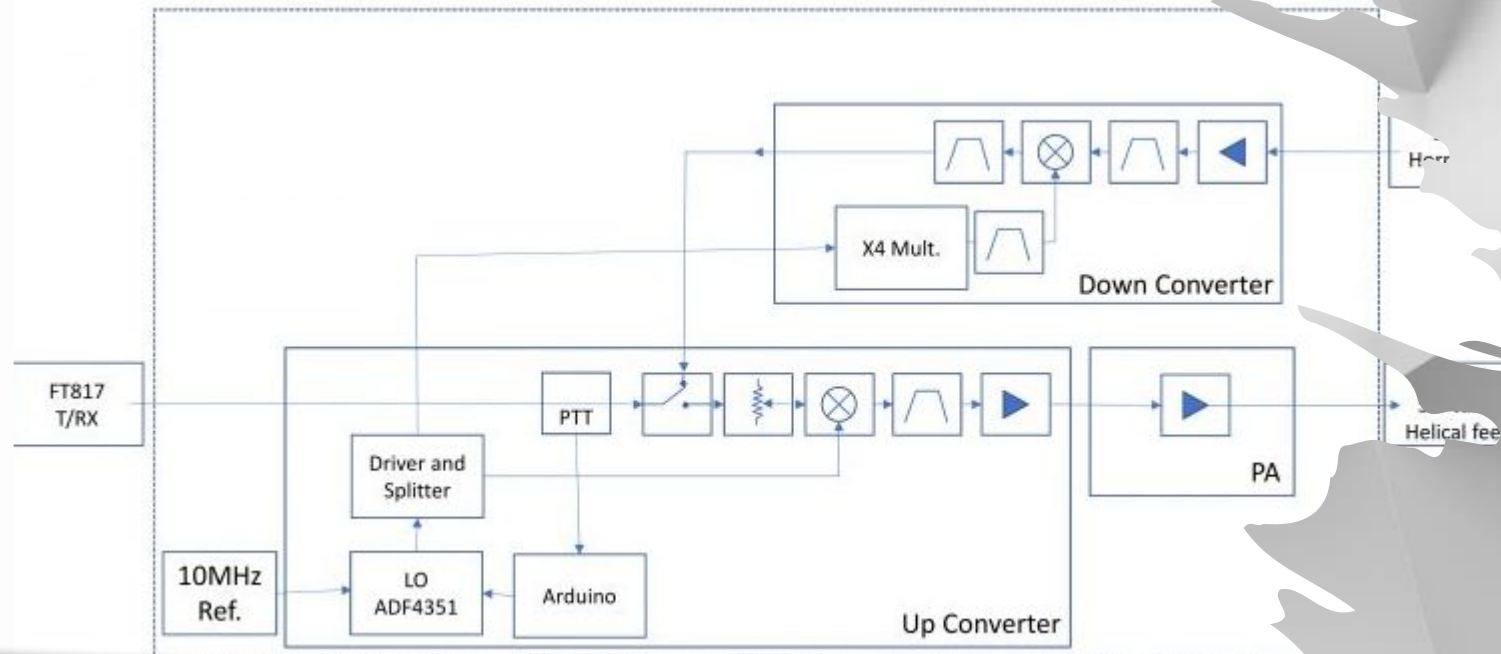
<https://eshail.batc.org.uk/point/>



How to start?

I did my homework, googled all the details but it is way too complicated!

Too many decimals in frequencies, split mode, IF, LO offsets, drift, beacon lock, downconverters, upconverters, stability, GPS disciplined reference oscillators ... Nah!



Let's start with some basics...

In order to receive stations, we need to know the frequencies to look for and adhere to the band plan.

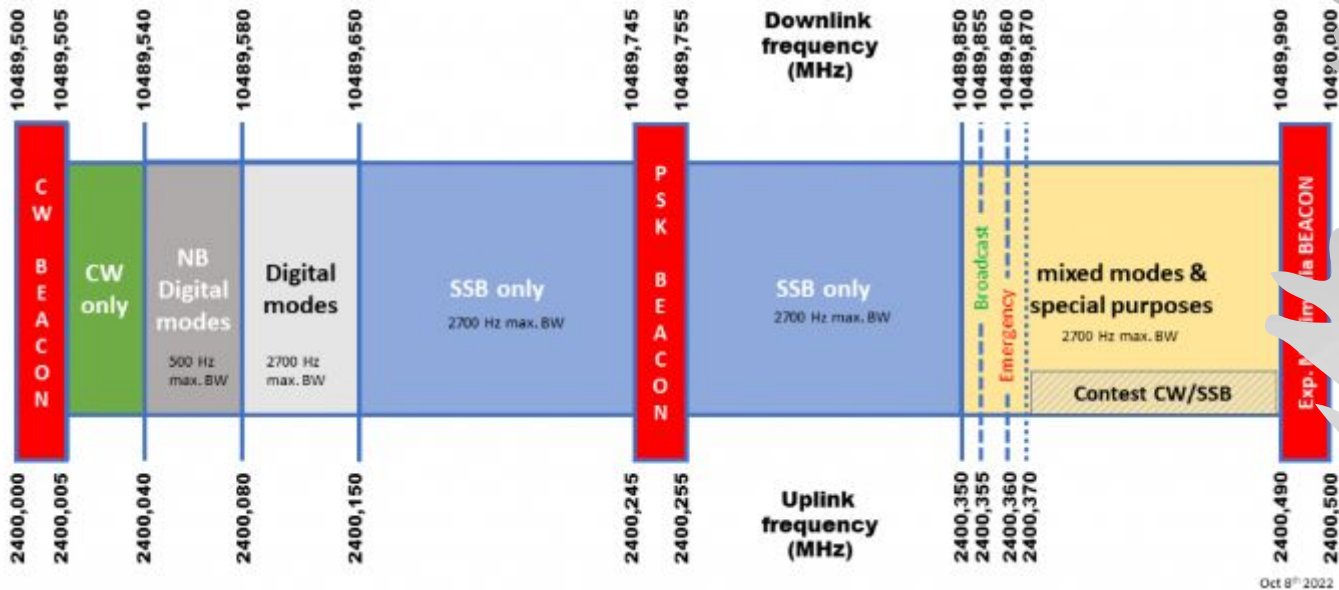
Initially a 250KHz bandwidth this was extended in 2020 to 500KHz.

AMSAT QO-100 / P4A NB Transponder Bandplan



AMSAT-DL
Satelliten für Kommunikation, Wissenschaft und Bildung
Satellites for Communication, Science and Education

EshailSat
شهاب سات
Social Satellite Company



Uplink: Right Hand Circular Polarised
Downlink: Vertically Polarised

Narrowband TP

10.489500 GHz Rx

2.400000 GHz Tx

This is a non-inverting linear transponder in the **S/X** band. It expects your uplink to be on S band (**2.400GHz**) and will output on X band (**10.4895GHz**) for earthlings to receive.

The **PSK beacon** is centred at **10.489750 GHz**

For later:

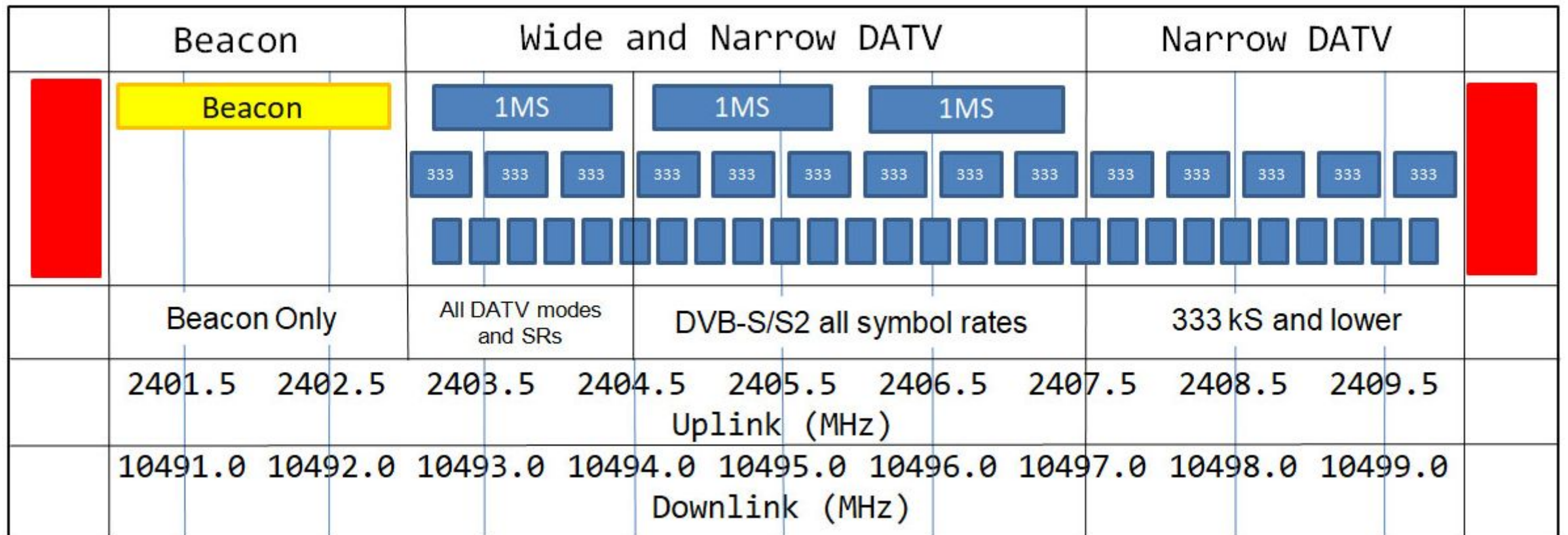
To link TX with RX, use the difference between RX and TX:
 $10.489500 - 2.400000 = 8.089500$

The wideband TP allows for Wideband and Narrowband DATV transmissions in DVB-S/S2

When we do this, we will need to provide the LNB with 18V to switch polarization to horizontal.

More on this in a future club night!

Wideband TP
10.491000 GHz Rx
2.401500 GHz Tx



1. Repurposed small satellite dish



2. PLL Low noise block
An LNB is a downconverter with integrated low noise amplifiers for the 10GHz band



3. Bias tee

4. 12V 500mA PSU



5. RTL SDR or similar stick



6. Laptop or PS with your favourite SDR software



The receiver!

Start by understanding and building a simple receiver. Then, tune to receive on the correct frequency.

To do that, we subtract the LNB's **LO** frequency from the **REAL** frequency of the **PSK beacon** we want to find:

Real frequency: **10.489750** GHz

LNB LO: **9.750000** GHz

LNB LO frequency is given by the type of LNB and is usually specified on the label

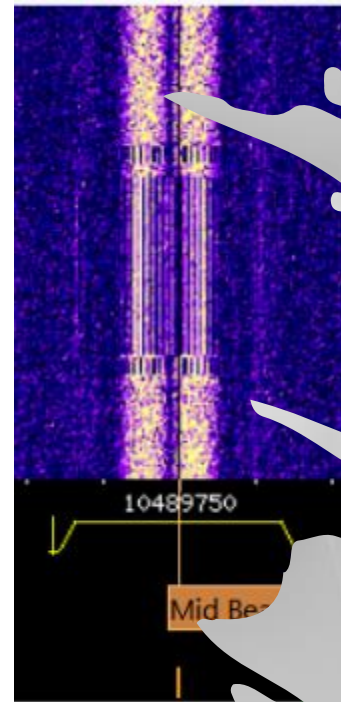
Tune in frequency:

$10.489750 - 9.750000 = \mathbf{0.739750}$

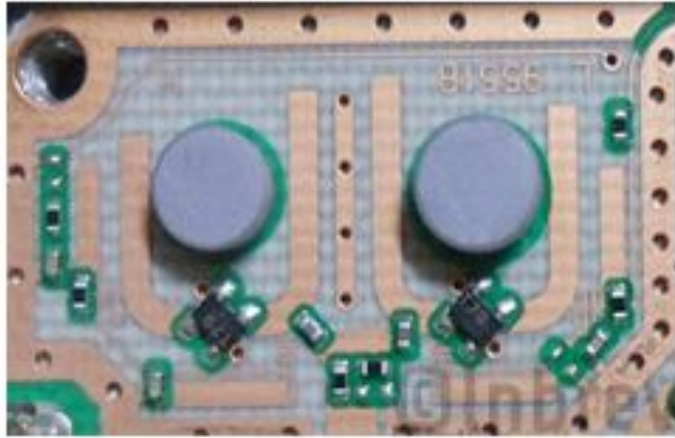
That is **739.750MHz**
(for the PSK beacon)

Align the **dish** and find the beacon!

The receive frequency might be slightly offset due to LNB LO drift!



DRO Oscillators



PLL Oscillators



LNB stability

DRO oscillators have a drift of 50-100KHz and they are temperature dependent. In an 8MHz+ bandwidth TV TP this is not a problem.

PLL oscillators have a drift of 1-20 kHz, and they are less unstable. This is still a problem for SSB but easier to stabilise with external sources or by software.

The bandwidth of an SSB transmission is 2.7-3KHz. In order to receive this the LNB's LO must be stable.

Imagine a drift of 10Hz in the LO. This is common in normal radios where the IF is close to the oscillator frequency.

In an LNB however, an LO of 9750MHz is created by multiplying a low clock frequency by a factor of 390x.

$$9750\text{MHz} / 390 = 25\text{MHz.}$$

That's our local oscillator.

Now, a drift of 10Hz would be:

$10 \times 390 = 3900\text{Hz}$, causing us to be far away from our SSB signal.

GPSDO are a good way of keeping your PLL on a leash within 1Hz of drift.

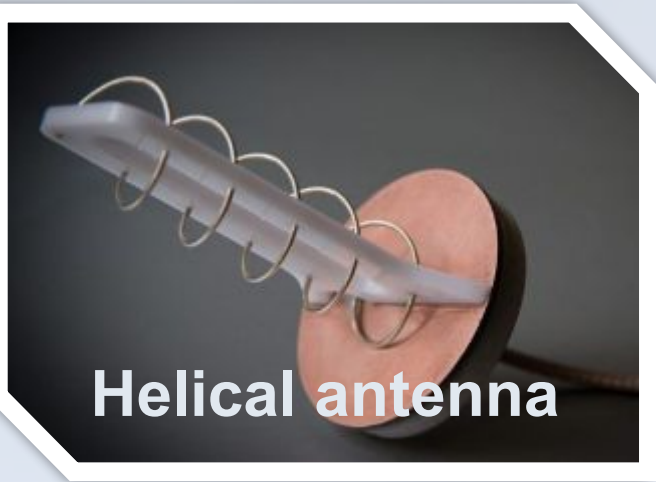


Let's build it!



YOU KNOW YOU GOT

**YERSELF A FANCY RIG WHEN
IT COMES WITH A FLASHLIGHT**



Helical antenna



Bamatech patch



POTY



Dual feed LNB + POTY

Still interested? Let's make a QSO!

In order to make a contact we need to be able to transmit to the satellite.

Some say this is the complicated part.
Let's (try to) make it simple!

Few things are required to transmit:

- An antenna for S band (2.4GHz) capable of **RHCP**.
- An upconverter or TX capable SDR.
- An amplifier for this frequency 1-10W

Note:

In order to achieve **RHCP** using a dish as reflector for the transmitted signal, we will need to build a feed that is capable of **LHCP**!

TX feeds can be COTS or homemade.

Easy to build are helical antennas but they only work well standalone on a separate dish for transmit.

RHCP – Right hand circular polarisation
LHCP – Left hand circular polarisation

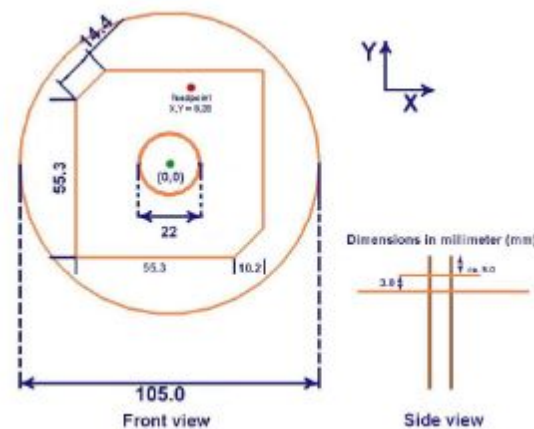


Easy to build, POTY or Helix, there are numerous HOW TO's on the Internet!
Pick your poison and build one!

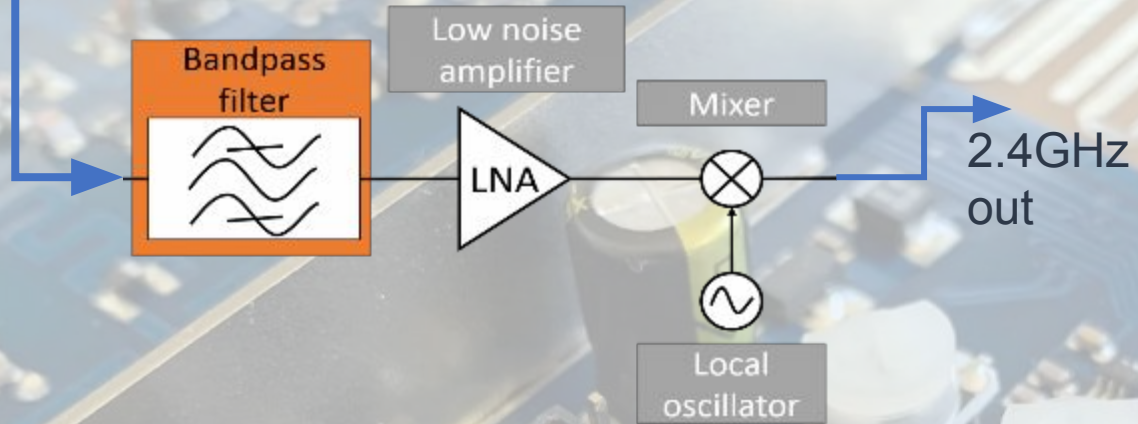
Helical antennas are good stand alone because in a combination with an LNB they will attenuate about 3-4dB of the X band receive signal.

POTY feeds are much better on dual feeds (with **LNB**), but they will need a microwave **lens** in the form of a cone to properly guide the signal reflected by the dish into the waveguide.

Cavity backed antennas are commercially available, and they can make a good TX antenna without a dish! Make sure they are **RHCP** in this case!



IF In (2m or
70cm)



2256MHz
(1968MHz
z)



DX Patrol

The upconverter!

An **upconverter** is used to mix a fixed frequency signal (generated in a PLL) with an external signal (IF) provided from a radio to create a higher frequency signal (the sum of the two).

To allow transmission on 2.4GHz the upconverter mixes our IF signal, with a fixed signal of 1968MHz for 70cm IF or 2256Mhz for 2m IF.

Upconverters are not difficult to build but many good ones are available to purchase.

An alternative is to use a TX capable SDR...



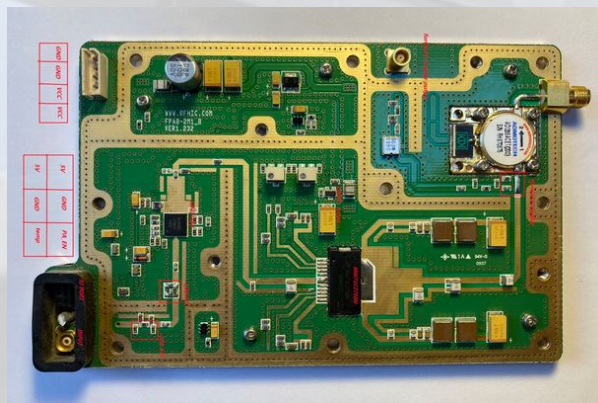
Edup chinese “8 Watts”



SG Labs 20W amplifier



DX Patrol 20W



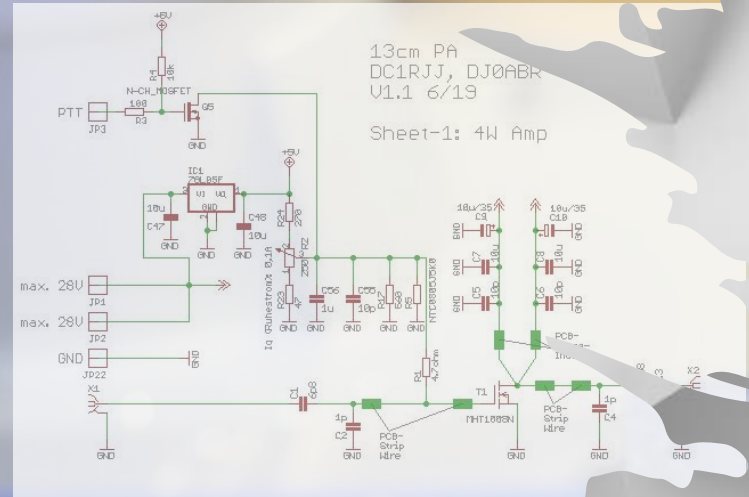
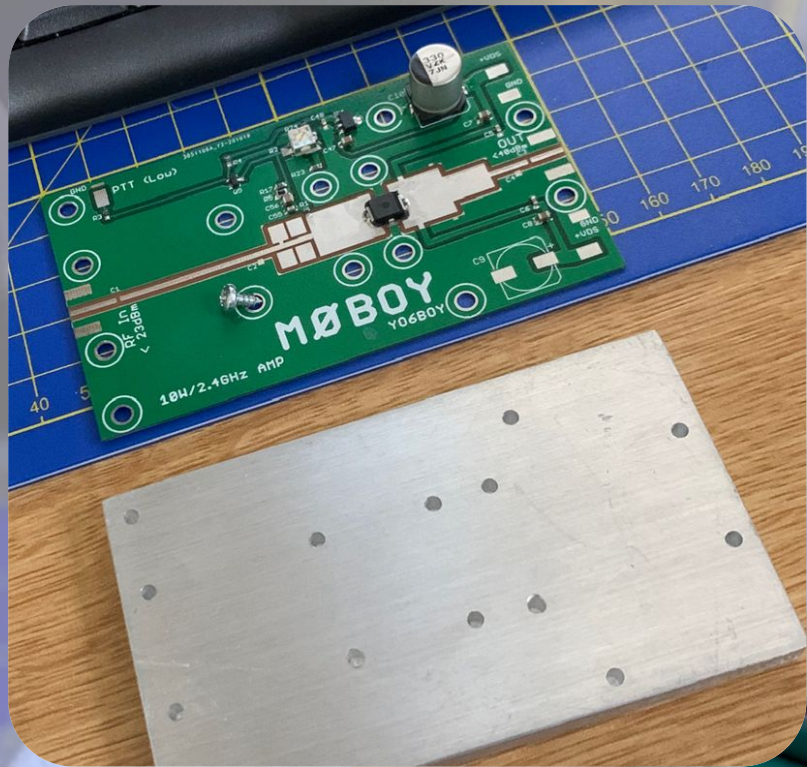
Repurposed UMTS amp.

The amplifier!

The signal provided by an upconverter is not too strong. On an SDR, it is even weaker. The signal will need to be properly filtered to eliminate the harmonics and the undesired intermodulation products. After this we must amplify the signal to then put it out to the satellite through our transmit feed.

I promised to keep things simple, so let's just buy one! Many COTS options on the market.

But I'm sure you can...



...build one!

Various designs are available online...

https://www.dj0abr.de/index_english.html

Prices for LDMOS transistor skyrocketed and availability is limited.





...but the coax!

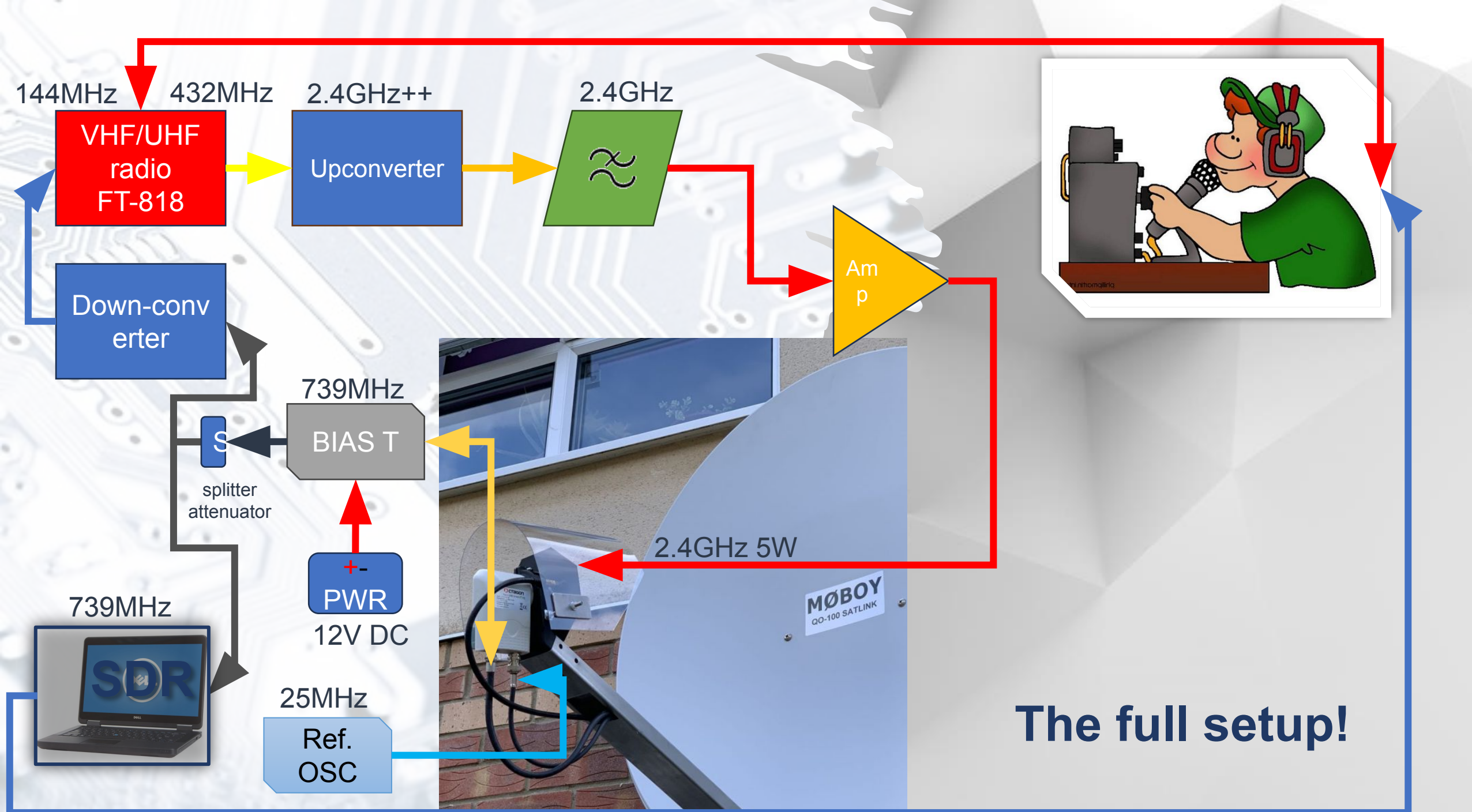
When we build things at these uplink frequencies the loss of the coax cable reaches unexpected levels.

To minimise our losses and transfer most of the signal to the feed, use only short runs of good coaxial cable. The better the coax, the less power you need from your amplifier.

Best option is LMR-240 or RG-420 semi rigid but any high-quality coax would do.

For patch leads and very short runs even RG-316 or Mini-8 could do.

Because of the very high output level from the **LNB** you don't need to worry about this on the receive. By the way, most of the time it is good practice to attenuate the signal coming from the LNB to avoid overloading the AGC inside the receiver.





ADALM Pluto



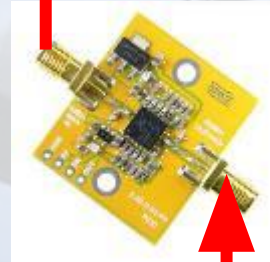
Lime SDR Mini



Hack RF One



12V PSU



The SDR solution

Instead of using an upconverter and downconverter solution we can use a transmit capable **SDR** platform.

This is usually the more expensive solution, but it has the advantage of doing both transmit and receive jobs for us and is much more compact and simpler to build.

AND is FULL duplex!

The frequency offsets?

When building the equipment, you need to set up your frequency offsets for downlink and uplink to see the real frequency in your SDR software or to tune in on the LNB IF.

For down-converting from the LNB we **subtract**:

Real frequency: **10.489750** GHz

LNB LO: **9.750000** GHz

LNB LO frequency is given by the type of LNB and is usually specified on the label

Tune in frequency: **10.489750 - 9.750000 = 0.739750** GHz

That is **739.750MHz** (for the PSK beacon)

To link TX with RX, use the difference between **RX** and **TX**:

10.489500 - 2.400000 = 8.089500

We then add **8.089500** to the exact TX frequency to display the correct one:

Example:

2.400250 + 8.089500 = 10.489750 GHz (for the PSK beacon)



Questions?

HAVE ANY QUESTIONS

DO YOU?

Let's operate!



Goonhilly WebSDR for NB:

<https://eshail.batc.org.uk/nb/>

Sardinia WebSDR for NB

<http://websdr.is0grb.it:8901/>

Dish pointer based on your location:

<https://eshail.batc.org.uk/point/>

QO-100 band plans:

<https://amsat-dl.org/en/new-qo-100-band-plan/>

<https://amsat-dl.org/en/p4-a-wb-transponder-bandplan-and-operating-guidelines/>

POTY build instructions:

<http://www.hybridpretender.nl/patch.pdf>

Helix calculator:

<https://www.everythingrf.com/rf-calculators/helical-antenna-design>

DJ0ABR's amplifiers:

https://www.dj0abr.de/english/technik/sat/sat_concept.htm

SDR Console

<https://www.sdr-radio.com/Console>

The links....

**Here is a list of the links
used in this presentation**