A SDR-based receiver for Es’hail-2 and the BACAR 6, 10 GHz beacons

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Introduction

If all goes according to plan the Qatar Satellite Company (Es’hailSat) will place its second satellite, Es’hail-2, in a geostationary orbit with the help of a Space-X Falcon-9 rocket. The launch was originally planned for the second half of 2016 but has since been postpone numerous times. Latest indications are that it may happen before the end of 2018. Es’hail-2 will carry an AMSAT linear transponder with a 2.4 GHz uplink and a 10 GHz downlink as a secondary payload, giving amateurs for the first time access to a geostationary satellite.

A suitable 10 GHz beacon implemented as a BAlloon Carrying Amateur Radio (BACAR) payload will be very handy in providing a 10 GHz test signal and will also offer radio amateurs the opportunity to join the BACAR fun.

Radio amateurs do not need to wait long as BACAR 6 will be launched from the Trichard Radio Controlled Aircraft Club’s airfield on 11 August. The primary aim of the balloon flight is to give the 80 international Youngsters On The Air (YOTA) 2018 delegates a near space experience. Among the many payloads planned for BACAR 6 will be two, 10 GHz beacons. A high precision CW beacon will operate on 10.489,680 GHz and a wideband FM beacon will operate on 10.490 GHz. In both instances the output power will be around 8 mWatt.

The beacons will provide radio amateurs with the opportunity to gain experience with microwave equipment and to hone their skills in aiming and tracking the balloon. It will also serve as good motivation to prepare equipment for Es’hail-2.

10 GHz Receiver

The 10.4898 GHz signals from Es'hail-2 or the BACAR beacons need to be down converted to a much lower frequency for filtering and demodulation. It is possible to construct your own 10 GHz down converter but a much easier (and lower cost) option is to make use of a commercial Ku-band satellite Low Noise Block (LNB) down converter such as used for DSTV reception. The IF output of the LNB is fed to a suitable UHF receiver than can demodulate CW and SSB.

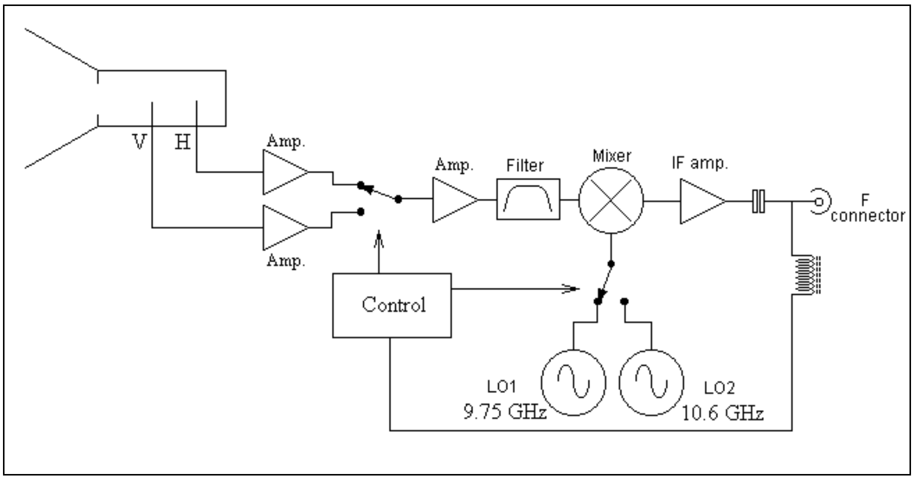

Figure 1: Universal Ku-band LNB block diagram.

The Universal LNB incorporates a circular waveguide to effectively illuminate the offset-feed parabolic dish antenna. Inside the waveguide are a vertical waveguide to coax and a horizontal waveguide to coax converter. These converters are simple waveguide probes directly connected to very low noise, GaAsfet amplifiers (LNAs). (Never touch these probes as the amplifiers will probably be destroyed by the static charges on your body.) The noise figures of these LNAs are typical very good with values of <0.8 dB being common. Supplying the LNB with 12 V will select one of the polarizations and 18 V will select the other.

Although the LNB is designed for an input frequency range of 10.7 to 12.5 GHz, the filter preceding the mixer is usually wide enough to enable reception of signals as low as 10.250 GHz with minimal loss. This is very useful for operation on the 3 cm (10 to 10.5 GHz) amateur band.

A 22 kHz tone imposed on the supply voltage selects the 10.6 GHz local oscillator (LO2 in Figure 1). With no tone present, the 9.75 GHz local oscillator (LO1 in Figure 1) is selected. In the past, a Dielectric Resonator (DR) was used for the local oscillator. Measurements have shown that although the DRO is stable enough for wideband TV or FM signals, it is not be suitable for the reception of narrowband CW and SSB signals. The lack of stability of the DROs disqualified these units for any narrow band modulation schemes such as CW and SSB.

A recent discovery by Alex, ZS6EME, changed all of that. High stability DSTV LNBs are now freely available at a very reasonable cost (typically less than R200.)

ELSAT High Stability DSTV LNB

The ELSAT Universal Ku-band LNB, part number LNBU10.6, features high stability phase locked loop 9.75 (LO1) and 10.60 GHz (LO2) local oscillators.

Figure 2: High stability, ELSAT Universal Ku-band LNB, part number LNBU10.6.

An ELSAT Universal Ku-band LNB was disassembled to confirm that the DROs were replaced by high stability PLLs. It is amazing to think that PLL circuitry is now the most cost effective option for Ku-band LNB manufacturers.

Figure 3: Disassembled, high stability, ELSAT Universal Ku-band LNB, showing a very compact PCB with the two waveguide probes.

For DSTV applications the exact LO frequency is not critical, with the result that the accuracy (precision) of the LO signal may not be that good. This is not a problem as it is an easy matter to compensate for this fixed IF offset using ZS6EME's very accurate, GPS disciplined CW beacon operating on a frequency of 10.489,680 GHz.

To ease the ground station's power supply requirements a single 13.8 V supply can be utilised. The 9.75 GHz LO is then selected. When Es'hail-2's 10.489.7 GHz signal is mixed with the 9.75 GHz LO signal, an IF of 739.7 MHz is obtained. The LNB is designed for an IF output of 950 to 2,150 MHz but once again the losses associated with working outside the official frequency range are acceptable. 739.7 MHz is not near any of the amateur radio bands but fortunately modern, low cost RTL based USB SDR dongles cover this frequency range. Using a SDR solution brings all the benefits of spectrum and waterfall displays as well as "click and tune" operation. The spectrum and waterfall displays also make finding the beacon transmissions infinitely easier. The higher performance FunCube+ dongle is also an excellent choice.

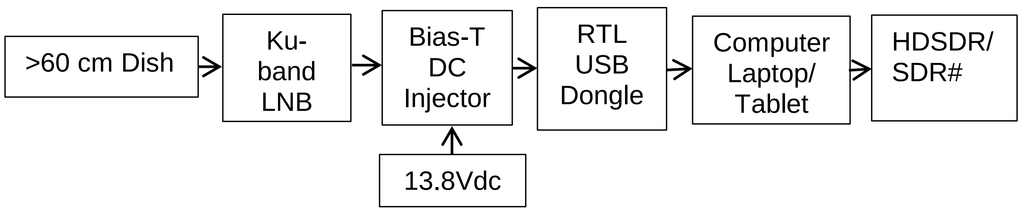

Figure 4: Possible Es'hail-2/BACAR beacon receiver chain block diagram.

<u>Bias-T or DC Injector</u>

The only component not easily, commercially available is the Bias-T or DC Injector required to supply 13.8 Vdc via the coax to the LNB. Fortunately it is a simple matter to homebrew one on a piece of Vero board.

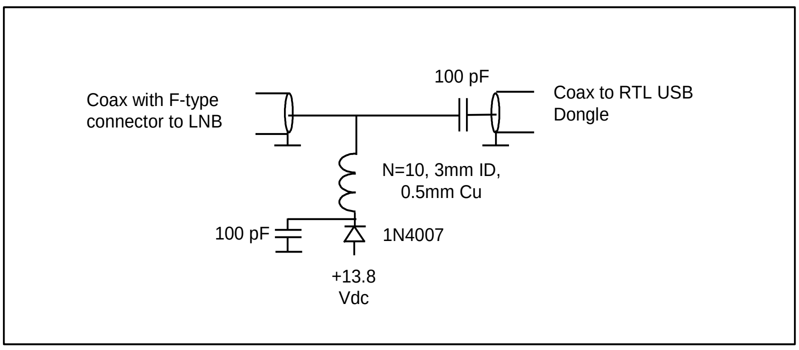

Figure 5: Bias-T or DC Injector schematic diagram.

An inductor or radio frequency choke (RFC) is required to isolate the DC from the RF on the centre conductor of the coax. The inductor is made by tightly winding 10 turns of 0.5 to 1 mm diameter, enamelled copper wire on a 3 mm drill bit. The enamel is removed from the ends of the inductor to enable easy soldering. It is good practise to include a diode in the supply line to protect the LNB from accidental polarity reversals. A small, 100 pF capacitor between the inductor and the coax feeding the RTL dongle prevents any DC from reaching the dongle. Another 100 pF capacitor at the "cold side" of the inductor decouples any RF before it can reach the power supply.

Conclusion

It is a simple matter to put together a 10 GHz receiver for the beacons that are planned for the BACAR 6 flight on 11 August. This receiver chain can also be used for Es'hail-2, amateur radio's first geostationary satellite due to be launched before the end of 2018.

A dish reflector should not be required to receive the BACAR beacons although a small, camping DSTV dish may considerably boost the received signal strength when the balloon is at its maximum expected altitude of around 27 km. Aiming the dish will of course be much more critical than simply holding the LNB in your hand.

At an altitude of 27 km the line-of-sight footprint is extensive with a theoretical radius of more than 600 km, allowing radio amateurs from far-and-wide to be able to receive the beacons.

Figure 6: DSTV camping dish equipped with an ELSAT high stability Universal Ku Band LNB, ready for the 10 GHz BACAR beacons.

Invest a small amount of time and money and join the BACAR microwave fun on 11 August. You will also gain the extra benefit of being ready to receive the 10 GHz signals from amateur radio’s first geostationary satellite, Es’hail-2, due to be launched before the end of the year.