Simple dual band dish feed for Es'hail-2 / QO-100

Mike Willis G0MJW, Remco den Besten PA3FYM, Paul Marsh M0EYT *February 2019*

Abstract
An easy to build 2.4 and 10 GHz dish feed, using commonly available materials, for Es'hail-2 / QO-100 deployment is presented. The feed consists of a LHCP patch antenna for 2.4GHz and a waveguide feed for 10 GHz, to be placed in the focal point of commonly available and cheap offset satellite TV dishes with f/D's of around 0.6.

Design
The 2.4 - 10 GHz dual band feed was designed and modelled with CST Studio (student edition) and comprises of a LHCP patch feed with a circular waveguide passing through it. Because the (free) student version of CST Suite has limitations there initially was some concern if the modelled results could be realised in practice. Modelling and optimising the patch feed meant adjusting the patch size, patch spacing, cut-out size and feed point location. All variables were iterated towards the final dimensions to let the patch generate LHCP and a sufficient match to Z = 50Ω resistive at 2400MHz. Figure 1 depicts the final impedance response (red line) on a Smith Chart.

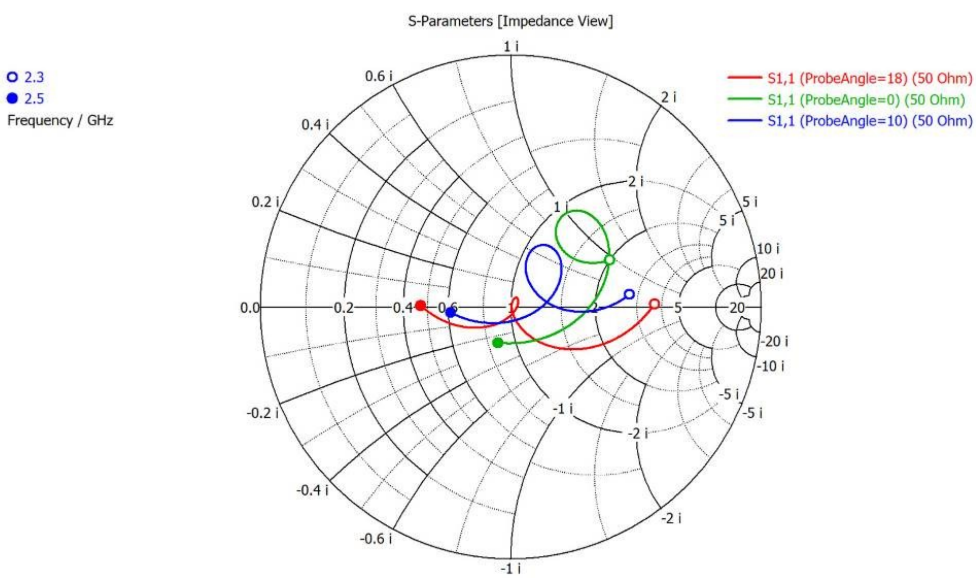


Figure 1 - Smith chart of various feed point positions.

Getting good LHCP depends on two resonances being properly set up through the geometry of the patch. The patch may be considered as two antennas having resonant frequencies lagging and heading 45° in phase to produce the desired 90° phase difference at the design frequency (2400 MHz).

Dimensions
Figure 2 displays the dimensions of the dual band feed. It contains a 105 mm diameter circular reflector but a square reflector with cropped edges (25mm) is also suitable. The patch itself is square with two opposite corners cropped. Material is ca. 1mm thick copper or brass plate. The waveguide is made from standard copper 'plumbing' tube (22 OD / 20 mm ID), ca. 120mm long and protrudes ca. 5mm above the patch surface. The centre (green dot) of the construction is marked as (X=0,Y=0) and the feed point position (red dot) is at (X=8mm, Y=28mm), thus 8mm right and 28mm above the centre.

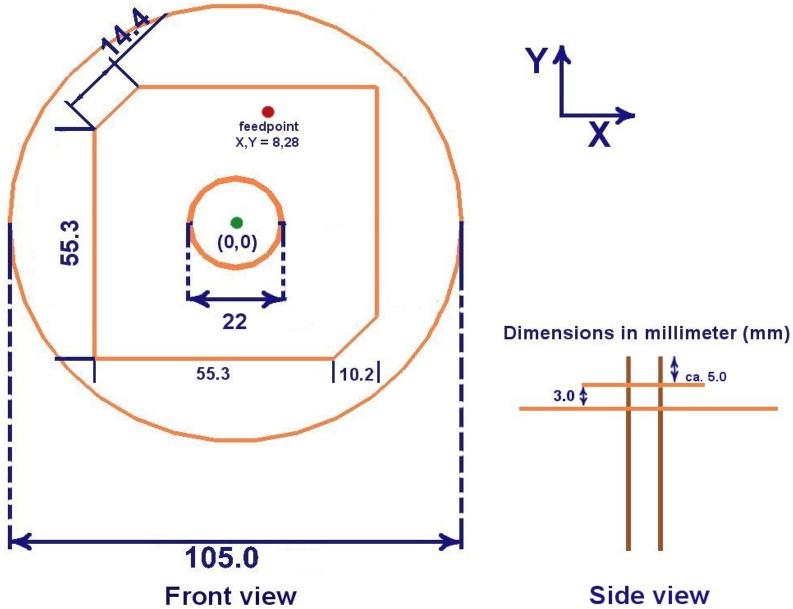


Figure 2 - Dimensions of the 2.4 – 10 GHz dual band feed. The patch is spaced 3mm from the reflector.

Construction

Cut the material according to the dimensions given in Figure 2. Drill or punch 22mm holes in the respective centres of the plates. Cut the waveguide with a pipe cutter and deburr the ends. Position the plates onto the waveguide so that they are centred. Drill a 1 mm diameter hole through both plates at the feed point position (X=8mm, Y=28mm). Mark out, drill and tap the mounting holes for your chosen connector on the reflector

Prior to soldering, degrease all parts with hot soapy water and clean with Scotchbrite or wire wool to ensure the surface will solder perfectly. First solder the reflector on the waveguide, see Figure 3. Keep the plate aligned at 90° to the 22mm tube at the right place (e.g. with an olive or clamp ring underneath), hold the assembly in a vice, taking care not to crush the copper tubing and ensure 9 - 10mm of 22mm tube is protruding above the reflector. Don't use excessive solder. Flux paste will aid the process.

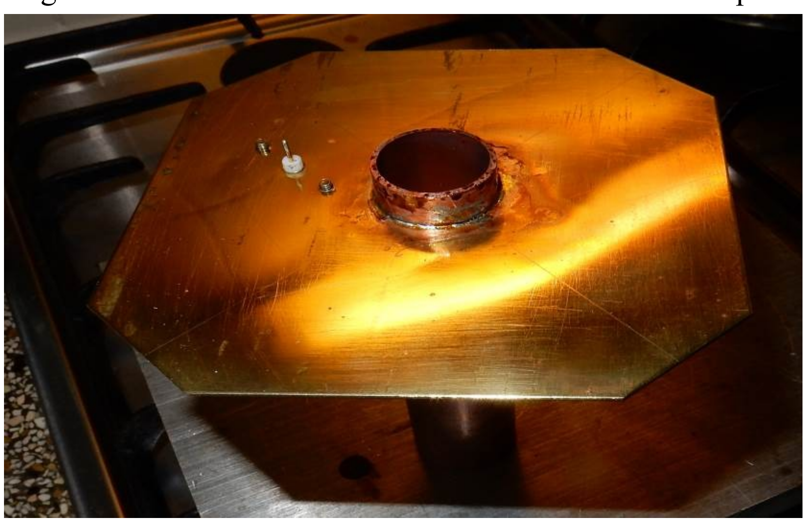


Figure 3 - Reflector soldered on the waveguide.

Next, attach the feed connector. Connector mounting screws should not protrude above the reflector surface or they will act as unwanted tuning screws. If they protrude, grind them down or they will affect the matching of the patch.

Finally, press the patch itself around the waveguide and use 3mm thick metal spacers to solder the patch and feed point, see Figure 4. It is important to get the spacing accurate. Aim for 3.0mm, not “about 3mm”.

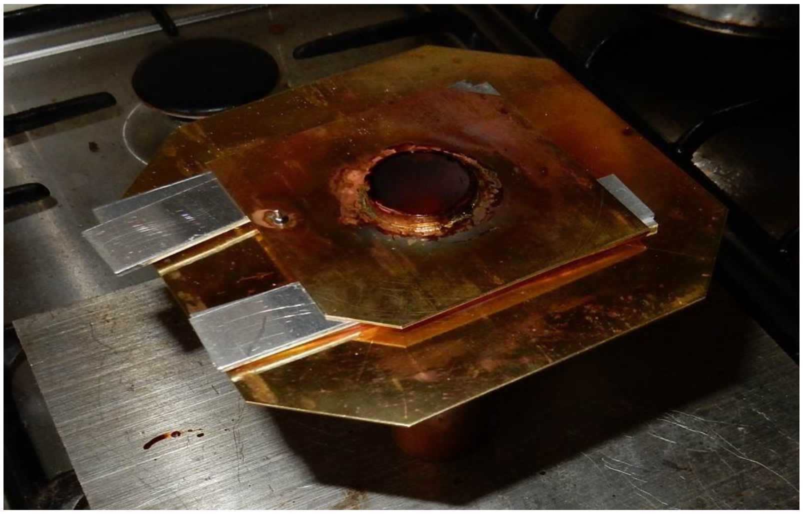
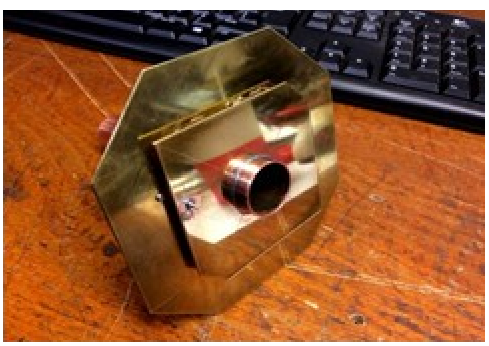


Figure 4 - Soldering the patch using 2 x 1.5mm thick aluminium plates as spacers.

Clean and deflux the feed and your result should look like the examples below.



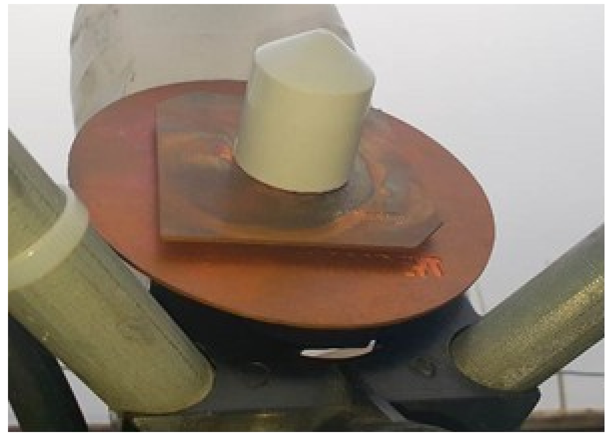
PE1JZQ

PE9RX

GI7UGV

PE1CMO

PA3FYM



M0EYT

G0MJW (note olive/clamp ring behind reflector)

OE8HSR

Mounting the LNB

How to mount the LNB to the waveguide depends on its inner or outer diameter. If the LNB has a horn (like most do) this horn has to be cut off. LNB's having an outer diameter of 20mm are also available. Using some sandpaper it can be squeezed into the waveguide. Most LNB's have a somewhat larger outer diameter. In these cases the waveguide internal diameter of the copper pipe has to be increased (e.g. swaged out on a lathe) prior to soldering the plates. As alternatives a 22 – 22 mm solder 'socks' or compression couplers can be used, or even another olive/clamp ring, see Figures 5 and 6.

Figure 5 – Compression fitting for a decapitated LNB

Figure 6 – Mounted LNB

Adjustments

If the patch is made precisely enough it should show two resonances just below and above 2400MHz. When the overall maximum return loss is too low or too high in frequency, bending the distances of the patch corners from or to the reflector plate helps centering the maximum return loss around 2400MHz. In practice, there will probably be only a single shallow dip of around 20 dB. Any higher is suspicious as it implies that both resonances are the same frequency, which will not give good circular polarization. Figure 7 displays modelled return loss and Figure 8 measured return loss of a sample.

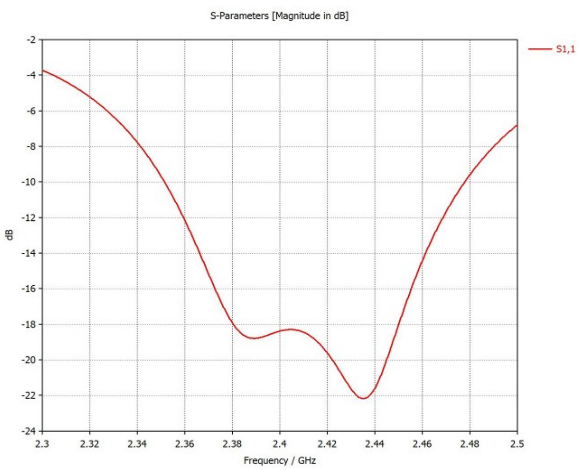


Figure 7 - Modelled return loss

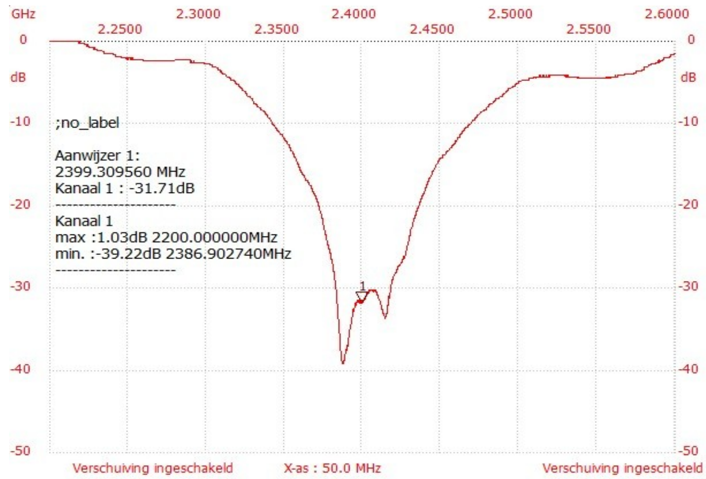


Figure 8 - Measured return loss of PE9RX's feed

Waveguide 10 GHz dielectric lens

The waveguide alone over illuminates a standard f/D = 0.6 offset dish and also presents a poor match. In order to illuminate properly most LNB's have horns. However, there are LNB's on the market destined to be placed close to each other so that with multiple LNB's multiple satellites can be received simultaneously using a single dish. These LNB's are known as 'rocket LNB's' because their shape resembles a rocket. These LNB's use a dielectric lens and are useful in this application as they do not disturb the 2.4 GHz patch. They are complex structures designed to optimally illuminate the dish. Options are to buy a (cheap) rocket LNB and use the lens only, or to buy a PLL rocket LNB (rare).

Figure 9 – Rocket LNB

Figure 10 – Rocket LNB lens on patch

Another approach is to produce a lens yourself on a lathe. In Figure 11 an experimental lens is depicted, made from 20mm diameter Nylon-6 (PolyAmide 6, or PA6).
The final dimensions of the lens is still work in progress. Figure 12 shows a sample.

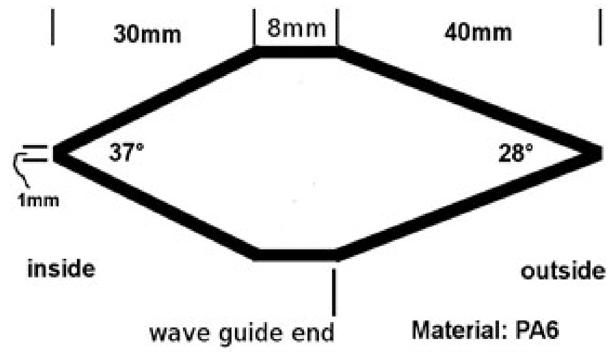


Figure 11 - Experimental lens dimensions

Figure 12 - Prototype of Figure 11

Conclusion
One month after the first succesfull prototypes were built and measured, almost 100 of this dual band dish feeds have been sent out and/or made by a large diversity of persons. The design is reproducible and strikingly simple. Although precision is the main virtue, this dual band feed already serves as the *de facto* standard for a single QO-100 dish. The modelled -10 dB opening angle of the 2.4 GHz LHCP patch amounts ca. 105° and illuminates standard/comsumer satellite dishes with f/D's of around 0.6 (which require ca. 90°) sufficiently, bearing in mind the patch is only used to transmit.

Appendix / hints and tips
Connectors
Use panel mounts with flanges and PTFE (teflon) dielectric as depicted in Figure 13. Don't use chassis connectors which protrude the reflector plate (too much)..

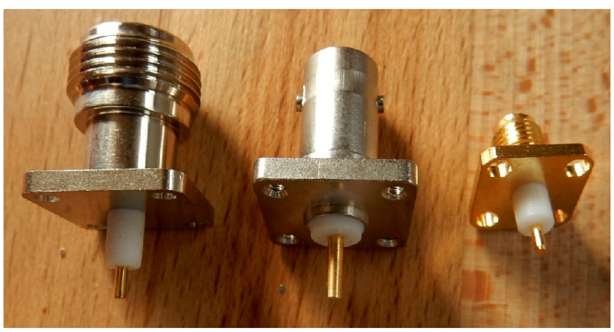


Figure 13 - Examples of suitable panel mount flanges

Figure 14 - A more weatherproof setup

Radomes
We leave it up to the builders creative imagination how to construct a suitable radome to protect the feed against weather influences. It is important that the (plastic) material does not heat up in a microwave oven. Test before usage! Figure 14 shows an example.

Materials
Copper and brass give similar results and performance. Double sided FR4 PCB has not been tried (yet).

Aligning feed/phase point
When the feedpoint of the waveguide is in the optimal position (tweak the dual band feed for maximum signal or SNR listen to the QO-100 beacon on 10489.550 MHz) the 2.4 GHz LHCP patch is also in the focal point of the dish. A convenient method to optimise the feed position is to use a SDR and maximise the transponder noise floor by looking at the waterfall.