A Portable 1.3GHz Dish Antenna

Continuing his fascinating introduction series on microwave operation – John Cooke GM8OTI describes a dish antenna for 1.3GHz and (eventually) 2.3GHz.

Welcome to my continuing series as I share the enjoyment I'm discovering as I progress on the microwave bands – and this time I'm concentrating on antennas. There's a lot of fun to be had experimenting with different forms of antenna, a key part of any radio system.

However, as wavelengths get shorter in the ever higher frequency bands, it becomes harder to make an antenna to the necessary physical accuracy. Even at 1.3GHz the elements for a Yagi antenna need to be cut to an accuracy of about one millimetre!

Another problem is that to make a significant increase in the gain of a single Yagi antenna, it needs to be made a lot longer. Roughly, to double the gain the length must be more than doubled. Alternatively, two Yagis could be stacked over one another, but then there is the additional problem of balancing the feeds from a single source.

The gain of an antenna is defined either relative to a theoretical isotropic source (which doesn't really exist for radio systems – as all have some directionality) or relative to a dipole. The gain figure is usually expressed in decibels with the units dBi or dBd respectively. An antenna is considered to have gain over a dipole if the radiation pattern it produces is more directional than that of a dipole.

Mirror Physics

Before retirement I was an Astronomer, and so I'm familiar with the physics of mirrors used to collect radiation – whether at X-ray, ultraviolet, visible, infrared or radio wavelengths – Astronomers use mirrors. Mirrors are nice and simple – a mirror collects the radiation over its area, and (if built properly) concentrates the radiation at the detector. If the diameter of a circular mirror is doubled, it collects four times as much radiation.

The mirror needs to be big enough – preferably many wavelengths across. At a frequency of 1.3GHz the wavelength is 230mm, so a 2m dish is nearly nine wavelengths across – rather low, but enough for it to work, although the beam width is about 8°. In comparison, at visible wavelengths a 100mm mirror is about 200,000 wavelengths across, with a beam width of about 0.00035°!

The radiation beam width for a mirror describes how directional the mirror is. In other words how concentrated the radiation is into a particular direction. The beam width decreases linearly as the mirror diameter increases, and also as the wavelength decreases. So, for a given size of dish the gain increases as the wavelength gets shorter.

Of course, everything depends on the dish being constructed accurately enough. For it to work well, deviations from the desired parabolic shape should be no more than about a tenth of a wavelength (λ/10) for the frequency in use. This means that the surface of a dish intended for use at 1.3GHz (23cm wavelength) should be accurate to 23mm, and preferably better. In radio terms, a dish antenna is simply a curved mirror for radio waves.

Portable Dish Design

Most of my operating is portable (/P) as I cannot set up a permanent large antenna at home. So any dish I build has to be portable – which, for 1.3GHz, means a dish that can be dismantled.

There is an excellent design in the *International Microwave Handbook* (second edition, page 76) by **Michael Kohla DL1YMK** which is well engineered.

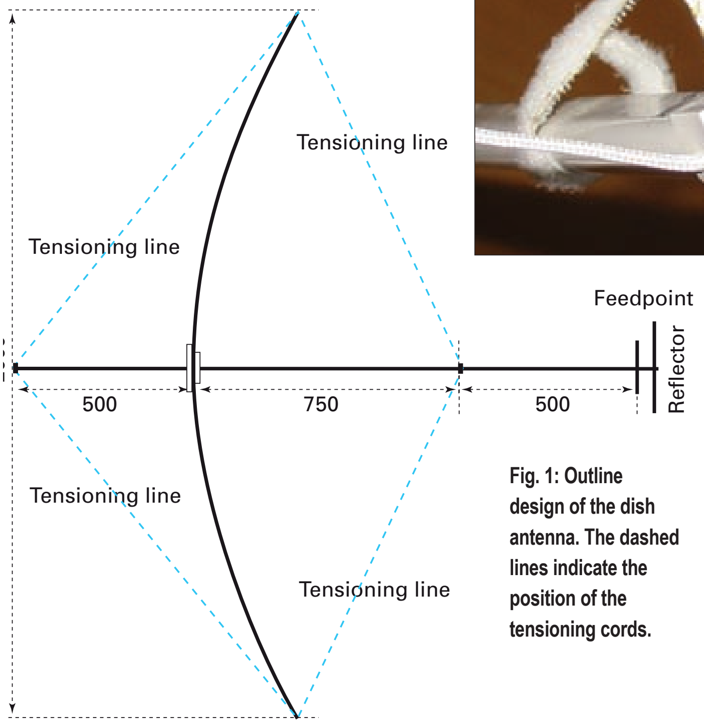

Fig. 1: Outline design of the dish antenna. The dashed lines indicate the position of the tensioning cords.

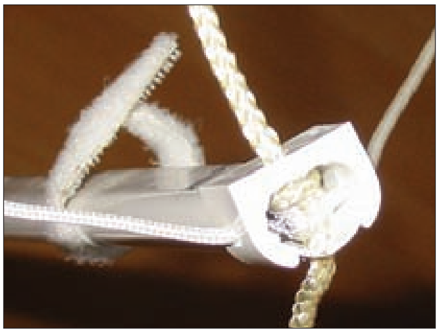

Fig. 2: The tensioning (thicker) and circumferential (thinner) cords are located in the end of the oval conduit using 'figure of eight' stopper knots. One of the Velcro tapes for attaching the dish panels is also visible.

But I needed to build something simpler which did not require metal working facilities. My home-brew Yagi antenna structures use plastic water pipe and electrical conduit, so I decided to try a design using more of these items.

The outline design in shown in **Fig. 1**. This dish is quite shallow, which makes a reasonably accurate shape easier to achieve with bent ribs, rather like an umbrella.

The shape of the paraboloid section is described by the parabola $y = 0.2\,x^2$ where y is the distance along the axis from the hub, and x is the perpendicular distance out from the axis to the dish surface, both in metres. Clearly at $x = 1$ (the dish radius, 1m), $y = 0.2$ so the depth of the dish from the rim is 0.2m (200mm). The focus of this paraboloid is a distance of 1.25m along the axis from the hub, so the feed is designed to be adjustable around that distance for the best signal.

I calculated the difference between the shape of a dish formed from bent ribs and the ideal paraboloid; for the dish described here, the error is no greater than ±7mm. This means that a perfectly constructed dish will only have errors of up to about 1/20 wavelength even at 2.3GHz. Of course, constructional errors (or setting up errors for a portable dish) are very likely to be somewhat worse than this, but the dish should still perform well.

The reflector does not have to be made from sheet material – it can have holes that are small compared with the wavelength of the radiation being reflected. Clearly once the wavelength gets small enough then it goes through the holes – you can see through wire mesh! A good rule of thumb is that a mesh size of no larger than a tenth of a wavelength will reflect practically all the radiation falling on it.

At 1.3GHz, this antenna should have about the same gain as four 44-element, 4m long Yagis in a single array!

The Components

The components used for the dish (listed in **Table 1**) are all easily available from a do-it-yourself store like B&Q, or a more general builder's merchant. The plywood hub pieces and the aluminium cord attachment plates have centred holes cut to take the 21.5mm pipe. The two plywood pieces are glued and screwed together with the holes accurately located. The front and rear aluminium plates each have 12 holes drilled to take the end of the cords.

The tip of each rib has a conduit clip fitted, then holes are drilled to thread the cords through. These holes are across the rib short axis (to take the tensioning cords) and across the long axis (to take the cord threaded around the circumference of the dish).

The 12 oval conduit clips are spaced equally and screwed around the circumference of the larger plywood disc. The ribs then clip into these, the inner ends in contact with the smaller disc.

The front tensioning cords are set up first. Thread a cord through the holes in the tip of a rib, with a stopper knot inside the rib (**Fig. 2**). A figure of eight knot is best since it can be adjusted along the cord fairly easily.

Using an additional reference cord held taut from the tip of one rib to the tip of its opposite across the dish, the distance along the dish axis from the hub (the dish depth) can be measured. The rib tensioning cords are all adjusted to the same length, so that the dish depth is 200mm. The cords are tied off at the front attachment plate again using a figure of eight knot to act as a stopper.

The procedure is repeated for all six pairs of ribs. Once the ribs are all tensioned correctly, the cord joining the rib tips around the circumference of the dish can be added; it should be knotted inside each rib tip so that they are held an equal distance apart.

The rear tensioning cords can now be added; they act to stop the dish being pushed out of shape from behind. In the prototype I used just four rear cords, spaced equally around the dish, though I intend to increase this to six or even the full set of 12.

The mesh panel shape is shown in **Fig. 3**. This was designed so that panels can be cut from a 900mm wide roll of mesh. The panels are bent slightly to fit the dish then fastened to the ribs using *Velcro*® hook and loop tape (visible in Fig. 2., and **Fig. 4**.) taken around the rib and through holes in the mesh, using three fastenings on each rib.

Feed Construction

For the feed I decided to use a 'bi-

Table 1

Components for 2m dish
(excludes a tripod and the fittings to mount it on the tripod).

Ribs: four 3m lengths of 16mm oval wiring conduit, cut to twelve 1m lengths.
Reflector: one roll 6m by 0.9m of galvanised wire mesh, 13mm square mesh size.
Reflector fixing: about 2m of Velcro hook and 5m of Velcro loop are needed to make three attachment points on each rib.
Hub: two circles of 9mm plywood, 75mm and 135mm diameter
Rib fittings: 24 16mm oval conduit clips (12 for hub, 12 to attach cord at free ends); 12 screws to attach hub fittings.
Feed and tension cord support pole: overflow pipe 21.5mm; round electrical conduit 25mm.
Cord attachments: two circular aluminium plates 50mm diameter (preferably about 3mm thick but thinner would do), with 12 holes around the circumference to take the cords.
Cord: about 45m of 3mm or 4mm artificial fibre cord (nylon is okay, less stretchy materials are better, though the tension is not high).

Components for feed
Quad elements and stub: 3mm brass rod or tubing (DIY store or model shop)
Feed coaxial cable: semi-rigid, about 3.5mm diameter, 50Ω (RS components)
Feed connector: SMA 50Ω solder fitting for semi-rigid co-axial cable.

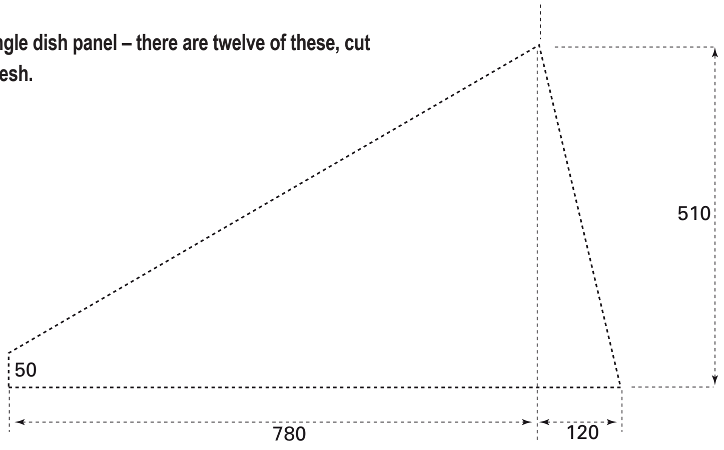

Fig. 3: Outline of a single dish panel – there are twelve of these, cut from 13mm square mesh.

Fig. 4: Rear view of the hub of the dish with the panels assembled.

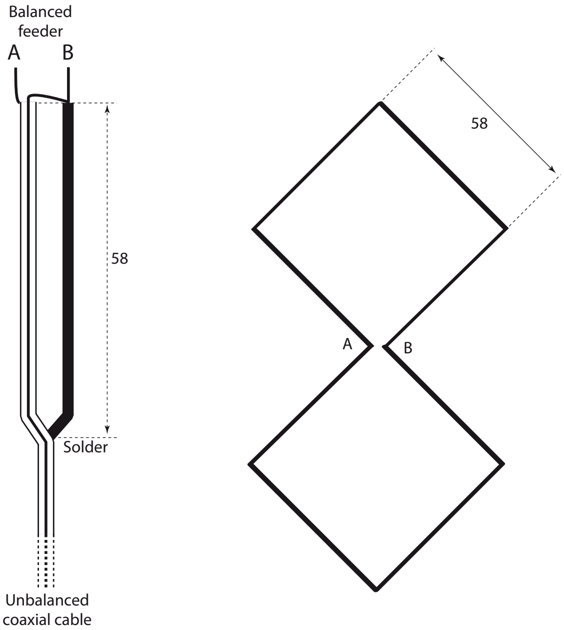

Fig. 5: Design of the 'bi-quad' or 'bow-tie' feed element and its matching balun transformer.

quad' or 'bow-tie' driven element with a removable reflector – since this has a wide enough beam width to illuminate the dish fully. There are many articles on the internet giving designs for this type of antenna, especially for use with WiFi at 2.4GHz.

The dimensions of a bi-quad for 1.3GHz are shown in **Fig. 5**, along with the balun ('balanced to unbalanced') matching arrangement. Each side of the quad sections is a quarter wavelength long, as is the balun stub (also known as a 'Pawsey stub'). The quad element and the solid stub are made from 3mm brass tube; the feed coaxial cable is semi-rigid (about 3.5mm diameter) so that the stub can be soldered to the outer of the coaxial cable at the feed end (**Fig. 6**).

Fig. 6: The 'bi-quad' as constructed.

The reflector is made from the same mesh as the dish panels, and is about 200mm by 240mm in size. The reflector is spaced from the bi-quad element using 21.5mm plastic pipe and a pipe connector (**Fig. 7**).

The feed end of the semi-rigid coaxial cable has a soldered SMA connector fitted. I obtained this short length of cable with the connector attached at a rally, but semi-rigid coaxial cable is available in short (1m) lengths from RS Components, it's rather expensive though.

Setting Up

I found that putting the dish together took around half an hour; with practice it will be quicker! The centre support tube has a core of 21.5mm pipe, with two pieces of 25mm conduit (a sliding fit) over it to act as spacers between the plywood hub assembly and the front and rear cord attachment plates.

My dish is mounted using a metal plate on a small tripod; 25mm electrical conduit clips attach the support tube to the plate. The means of attaching the plate depend on the tripod available. A

Fig. 7: The feed with a mesh reflector – the reflector is removable, which adds a wide but low sensitivity beam, with an associated loss in sensitivity to the main beam.

counterweight is needed to balance the weight of the feed; mine is a plastic bag containing old snooker balls that hangs from the rear end of the centre support tube! (**Fig. 8**).

The feeder cable is pushed through the centre support tube and attached to the bi-quad feed and reflector assembly. Measurements of the match to the feed using my home brew reflected power meter suggested that the optimum spacing between the bi-quad and reflector is about 70mm.

The exact point to place the feed along the dish axis will depend on the exact shape of the dish. If built to plan, the position should be approximately as shown in Fig. 1, and I found this to work well for my first QSO. However, I would like to do further experiments to optimise the focus position for best gain; this is easy to do since the support tube for the feed slides inside the support tube between the hub and the front cord attachment.

The bi-quad feed is set up for horizontal polarisation using the orientation shown in Fig. 5.

Field Day

Does it work? Of course it does! I eventually used the dish (**Fig. 9**) during the **Radio Society of Great Britain** (RSGB) VHF National Field Day in July 2011, at a site with a reasonable take-off to the south. I only managed one contact on 1.3GHz. It was set-up with the **Lincoln Short Wave Club G5FZ** contest group north of Lincoln in a 432MHz contact. But using single sideband (s.s.b.) we exchanged 5&8 both ways over 310km, my best DX on 1.3GHz to date! Using about 5W, I was very pleased with this – many thanks indeed to the operators at **G5FZ/P** for my first contact using the dish.

I had set up in a flat calm, but my session was curtailed when a gust of wind gently blew over the dish and tripod, leaving the 'bow-tie' feed rather bent and disconnected. Next time everything will be tied down properly!

What's Next?

I now have a good sized dish antenna that I should also be able to use at 2.3GHz with a suitable change of feed. So, off we go – to build a 2.3GHz transverter. I look forward to letting *PW* readers know how I get on! Cheerio for now! ●

Fig. 8: The counterweight mounted on the end of the support pole; the four rear tension cords are visible.

Fig. 9: The dish antenna in use for VHF National Field Day.