Chapter 3

Antennas

Antenna Measuring Notes

Kent Britain WA5VJB

Since 1987 I have set up my portable antenna range at 14 Conferences measuring well over 1000 antennas, mainly in the .9 to 24 GHz range. G4DDK has asked me to list some of my observations.
The Feed is not at the focus of the dish:

First off, I have NEVER been able to calculate the focal point of my dish, mount the feed, and have the antenna optimised. NEVER! It always seems I have to move the feed in towards the dish a bit to tweak things up.

But out of the antenna range things are far worse. About half of the dishes have the feed off by as much as 50% in distance!

A chap comes up with a 2 ft. dish and about a .35 f/d. The feed is sticking out 3 ft from dish! "But that's where I calculated the focus to be!" is always the answer. I haven't found out what in the d sq/16c equation throws them but we see it all the time. Another problem is the rounded edge on most dishes. They measure the physical diameter of the dish, not the diameter of the actual parabolic surface.

That outer cm or so is not usable and should not be used in the F/d calculations. And I won't even start on the complications of calculating the actual phase centre of the feed. I have always been able to pick up a dB or two tweaking the focus and 6 dB or so has been the typical improvement at the conferences when the feed is movable and we can optimise it's position. Finally come the 25% or so really bad ones. The "dish" was not parabolic, the feed wasn't resonate in the ham band, the focus was miscalculated by 3 feet (on a 2 ft dish!), using a grid dish on 3cm (and 3cm spacing on the wires), and so on. As I said, typically 25% or so of the dish antennas tested at these conferences are just air cooled dummy loads.

Most of these really bad ones are usually the prime focus dishes. With the offset dishes, you usually have a pretty good idea where the feed was for a starting point if you had saved all the parts. But the ham feeds will usually have a different phase centre, so we're back to seeing several dB of improvement moving the feed around a few millimetres. The antenna range is also a good spot to figure out where the antenna is pointing. Build up some kind of mechanical sight, or mount a telescopic sight on the edge of the offset dish. (Top edge works well too) Peak up the signal, and sight in on the source. An optical sight can be very useful when portable.

On Yagi and Quad loop type antenna, the builder has often used a different diameter boom, or different size elements, or even replace a round boom with a square boom. In each case there was no attempt to use corrections factors. (50/50 chance they would have gone in the wrong direction anyway!) Again a large percentage of these antenna are not close to what the owners are expecting in the way of performance.

If you tested all the microwave antennas in England, I am sure very few of the antennas would have the dBs you have been optimistically using in your range calculations.
Interestingly both the UK and ZL groups left the Microwave Update

antenna range saying, "This antenna measuring is not all that hard" and are both looking at setting up antenna ranges back home.

Next month I will go more into the details of measuring antennas and some of the pitfalls that have given me extended headaches. It really is not all that difficult to set up a practical UHF + antenna range. Last month we discussed the value of an antenna test range, now we will explain how it is not necessarily complicated to set up an antenna range.

Equipment:

RF Source
Source Antenna
Reference Antenna
Detector
Open Space

RF Source 1000Hz vs. CW:

Many of my first antenna range setups was just a CW source, a reference horn, and a power meter.

Hold up the power sensor and horn, measure power, attach the antenna to be measured, and the difference is dB power is the difference in dB gain. This works, but you really have some dynamic range problems. The power sensor is not very sensitive, so you have to run a fair amount of power and use a short range. But it does work. Just make sure you have at lease 1 dB more power that the noise floor of the power meter, otherwise you run into (Signal + Noise) / Noise problems. I have been able to make pretty good measurements with 10 to 30 milliwatts sources into 20dB gain antennas on 6cm and 3cm. Horns were measured at about 5 Meters, dish antennas at about 10 Meters from the source.

Generating 1000 Hz:

I have a Wavetek 3001 50MHz synthesised signal generator I haul to the antenna range. Most RF generators already have a 1000Hz AM setting. So up to 50MHz I just set the generator to max output, 100Hz AM and drive a source antenna with it. On 902MHz, I set the generator to 45 MHz and drive two sides of a mixer, this doubles to 902MHz which goes through a filter and into a 20dB gain amp. This gives me about 100 milliwatts to work with. On 1296MHz I set the generator to 432MHz, horribly overdrive a small brick amp, filter the 3rd harmonic, and drive a second brick amp.

Again about 100 milliwatts to work with. On 230 MHz, I set the generator to 384MHz, again horribly overdrive a small brick amp, filter the 6th harmonic, and drive a second brick amp. This gives me about 75 milliwatts to work with, and there is a second similar unit for 2400MHz. For 3456MHz I again use a brick amp (Hand picked this one) driven with 432 MHz and run the 8th harmonic through an interdigital filter. A second brick amp brings this up to 10 milliwatts or so. On 5.7GHz, 10.3GHz, and 24.1GHz I use Gunn sources driving PIN Diodes. Sometimes I use a 555 timer circuit AA5C built up for me, other times I just drag along a function generator and directly drive the PIN Diodes. On 47GHz I have a 23.5GHz Gunn source driving a doubler out of an old HP 940A . I modulate a PIN diode on the 23.5GHz source.

So there are a lot of ways to generate a 1000Hz modulated RF source. Of course if I had a Signal Generator actually on these frequencies, or even a sweeper with an external modulation input, I would use it.

Source Antenna

You will need an antenna at the source end. It's nice if the antenna has a fair amount of gain and over the years I have used everything from Coffee Can horns, to 2 ft dish antennas on 3 cm. Over the years I have migrated to multiband antennas at the source, just to speed set-up and less stuff to haul about.

Ridged horns work well, some the multiband dish feeds work well too. While it is nice for the source antenna to have gain, it is not necessary and I am a firm believer is using what works. More on the type of antenna to use under Open Area.

Detectors/terminations

At the receiver end we need a simple diode detector to demodulate the 1000Hz AM signal. I normally use a standard Type N Input diode detector. Now, most of these detectors in the US do not contain any kind of terminations. So they don't look like a 50 ohm load, but rather have a very complex input impedance. Just put a 6dB pad on the input of the detector. 10dB works better, 20dB has too much loss, and the input is pretty much 50 ohm. For the higher bands, the simple diode detector mounted in WG works well.

Receiver:

If you are using CW and a Power Meter, then this is your receiver. If you are using 1000Hz, then you need an HP-415, HP416, or the Marconi Type 6593A. Many other companies also make these 1000 Hz "SWR Indicators". These are simply an audio meter tuned to 1000 Hz with a high accuracy meter scale. I have also used General Microwave and NARDA versions of the HP415 and they work just as well.

Note: The HP415E needs 9 Volts to run, 16 volts to run in the expanded scale mode. It only pulls about 5 ma, so I will wire in two 9volt dry cell batteries and can run it for hours and hours on the antenna range.

Reference Antenna:

The most important part of the antenna range is an antenna you know the gain of.

The hand of God, or someone with a crayon, has written the gain of the antenna on a calibration sticker, or Post-it-Note. We measure how much signal the Reference antenna collected, and if the antenna being tested collects 3.2dB more signal, then it has 3.2dB more gain than the Reference. On all bands above 1.3 GHz, I use horn antennas as the reference. In several cases I was fortunate to acquire Std. Gain Horns, and the gain of a horn antenna can be easily calculated with high accuracy.

But like any ham activity, absolute gain numbers are not as important as optimising the antenna. We will spend hours tweaking the output of a power amp, or the NF of a Pre-amp, and we

know the equipment is not calibrated for the frequency we are using but Max Power Out is still Max Power Out wether it is 68 Milliwatts, or 92 Milliwatts, it's all we can squeeze out of that circuit. Same for the antennas. You move the feed around, try several feeds, and so on, even if the range errors are a dB or 2, we have maximised the performance of the antenna and been able to compare the relative performance of different antennas. Again if the real gain of the antenna is 29.6 dBi or 30.4 dBi is all academic, we have squeezed everything we can out of the antenna. (Or thrown it in the rubbish bin!)

Audio out:

The HP-415 has a "Recorder Out" connector on the back. I usually connect a small audio amp with a speaker to this connector. The raw 1000 Hz can be amplified to drive a speaker. Several good reasons to listen to the audio signal. It's nice to peak the antenna on a audio signal, especially when you're holding the dish with one hand, moving the feed with another hand, and holding the detector with the third hand .... you know what I mean. And it is especially good when there might be interference Some time back I was testing an L-Band Helix for possible use on Phase 3-D. The meter was jumping all over the scale, there were several peaks away from the source, an a constant erratic noise floor on the meter. After some time I
connected the audio amp and figured out the problem in nano seconds. Loud video buzz! The long helix was acting like a 1/4 wave whip on TV Channel 4! All further testing included either a 1269 MHz filter or an isolator. I have had similar problems testing Log Periodics that do not have the back ends of the booms terminated. At our Central States VHF Conference we typically have the 50-450 MHz and the 900+ MHz ranges running at the same time. Listening to the tones lets us easily tell when of the English lads were looking at me pretty funny while I was waving a horn antenna all over the parking lot at Microwave Update. (The US guys had seen me do this before.) Up, Down, Left, Right, Back up a bit. The antenna range is not preplanned geometry, I am just looking for an area about 1 meter by 1 meter where the signal level varies less than 1 dB. When I find it, I put some kind of marker on the ground, then tell everyone how high to hold their antennas. Over grass I will usually set the source antenna 2 or 3 meters off the ground. If the source antenna has 20 dB or so of gain, very little of the RF hits the ground at the 1/2 way point. And what does hit the ground is higher than Brewster's angle, so the bounce is attenuated 10 to 15 dB. If I am on a parking lot, I will set the source on the ground and make a ground reflection range. Although there is no hard fast rule here, I just use what ever works best and it's a quick test just setting the source antenna on the ground. If there is a nice consistent signal area, we start measuring antennas!

Measurement technique:

Substitution: Measuring itself if simple and quick. Hold up the reference antenna, set the meter to a convenient sport, attach the sensor to the antenna to be tested, hold it at the same spot, take a reading, calculate the difference. I normally carry some kind of marking pen and write the results on the antenna. We usually have someone else standing around with pen and paper making a more complete record, but the guys seem to like having an "Official Result" right on the antenna rather than trying to remembering it, or waiting a month until someone publishes the results.

Dynamic Range: One pitfall is the dynamic range of the SWR Indicator or power meter. You like to keep less than 10dB difference between the antennas under test. So don't use a dipole as the reference for a 30dB gain antenna measurement. First of all the meters have errors the farther you stretch them.

Second, the capture areas of the two antennas will be quite different. A large number of secondary problems testing antenna with vastly different capture areas. With the 415's or 6593's you want to keep them down in the 30,40 or 50 dB ranges. Higher than 30 usually means the diode is driven out of the square law region, in the 60's the signal will be pretty noisy. These meters will also work with bolometer mounts. Now you could use all the scales with a bolo, but the bolo is less sensitive than a diode mount and you will need more signal. The 6593 can be used to directly compare 2 antennas, but this means you will need to find a larger measurement area, bigger than both antennas, to make your measurements. This is easy enough on 50 MHz - 432 MHz, but much more difficult on the microwave bands. I haven't used a 6593, but going over one in G4DDK's garage, it sure looked like a natural for antenna ranges.

Results: Oh it was fun in the early years deflating egos. "Well, a 5 element Yagi would have 12dB gain, using quad elements adds 2dB, and a corner reflector would have 10dB, so by combing a Yagi, Quad, and corner reflector, my super antenna has 2 dB GAIN!" Yea, sure, here's the detector. (6dBi if he was lucky!).

Over the years the wild claims have died down, and better, more consistent designs are showing up. And we have developed a bit of a tradition of seeing what kind of strange antennas we can show up with and still get good results. And a sprit of experimentation has developed where guys are not afraid to show up with a dish, 8 feeds, and find out which one works best. Typically at the CSVHFS antenna contests we will measure 100 to 125 different combinations of antennas. There have been a few fun ones, I particularly remember KB0HH spending several years trying to optimise a scalar feed. With excellent form, his cowboy boot set the feed over 30 meters down the range!

Circular Polarisation: We usually get a few CP antennas to test. Normally I just measure the gain, rotate the antenna 90 degrees, measure the gain, average the numbers add 3dB, and label the gain dBiC. Ideally, the gain does not change as the test antenna is rotated. If gain only varies 1 dB I'll congratulate the builder, if it varies 3 dB I'll still call it CP, more than 3dB and we'll start looking at ways to fix/repair/improve the antenna. This is especially a problem with some of the "Short" Helix dish feeds that have become popular lately. It is very difficult to properly generate a CP wave in only 2 turns of wire. At an AMSAT Conference we set up the antenna range and only 4 of the 8 Helix antennas had gain along the axis of the antenna! Of the 4 with gain, only 2 were within 3dB of that 1296 rhombic also working as a 144 MHz antenna. (Our 1000 Hz tones are hardly phased locked)

Open Area:
30 Meters is nice, but I have often set up in more confined areas of 10 to 20 Meters. But try to avoid areas near walls that might cause reflections. Given a choice, I set up on grass (easier on my feet) but parking lots can also be used. The whole idea is to find an area where you have a consistent signal about the same size as the capture area of the antenna. i.e. a bit bigger than the biggest antenna you plan to test. Our greatest source of error is have the signal level on one edge of the dish stronger than on the

other edge of the dish. Some circularity. And yes, 1 of the 2 had been brought by James Miller G3RUH. The AMSAT lads have been passing around the idea that Helix antennas are easy to build and fool proof. Test of dozens of Helix antennas says they are WRONG. AMSAT writers perhaps have the worse habit of copying articles. A guy writes an article about a Helix, that is copied from and article, that was copied from and article .... And over the last 5 generations of this design, each writer/builder has substituted materials, slightly changed dimensions, and NEVER tested the antenna.

Log Periodics: LP's can also be difficult to test, especially the ones that do not terminate the back of the booms. The antenna pick up fundamental and harmonic frequencies equally well. They also tend to pick up more local interference. A clean source, and monitoring the 100 Hz audio will usually keep you out of trouble. The unterminated LPs tend to act like a big capacitor and pick up noise from the mains and a lot of other garbage. All my current LP designs terminate the back of the booms, it just cleans up so many problems.

Higher Bands: In my job, we have been doing some radiometry work between 90 and 110GHz. Yes, I modulate the Impatt amp with 1000Hz and do all sorts of tests with the HP 415. It's a system that works well for antenna testing on all bands.

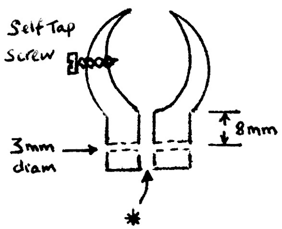
Yagis and Helixes

A 'Do it yourself' Yagi for 23cm

Sketches and notes by Peter Blair, G3LTF

Editor's comments:
This is not a complete constructional article in that the numbers of elements and their dimensions are left to the individual to decide. The beam is based on the DL6WU design (for which there is DOS-based software freely available) and on the article by Rainer, DJ9BV, in Dubus 2/94 and Dubus Technik V page 96. One departure from the printed article is the use of fully insulated elements, mounted underneath the boom rather than on top of it. Anyone with access to a drill press, hacksaw and callipers should be able to make themselves a high performance 23cm
Yagi at low cost, if these diagram (and the DJ9BV articles) are carefully followed.

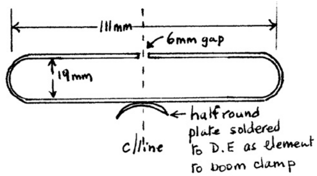
Boom diameter: 19mm O.D round section tubing
Elements: 3.6mm O.D aluminium rod
Driven Element (D.E.): 4.5mm copper rod
Element supports: 15mm plastic pipe clamps (from DIY or plumber)
Each pipe clamp is drilled with a 3mm drill, 8mm from the boom, in the position shown in Fig.1
The clamps are secured to the boom by means of a self-tapping screw.



Each element is a tight, push fit into the 3mm hole and is secured with window sealant injected into the original screw hole in the end of the clamp (see * in fig.1)

The directors should be made 9mm shorter than the dimensions given in Dubus. Lengths should be accurate to +/- 0.3mm. Elements end should be filed flat across the rod end cross section. The Reflector length is 113mm.

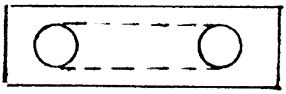
A jig to shape and bend the driven Element (Figure 2) to the correct size is easily fashioned out of two pieces of 19mm OD round bar, mounted on a small piece of aluminium plate as shown in Figure 3.

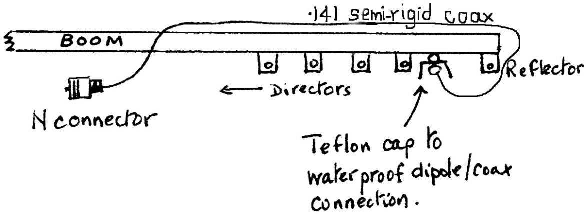


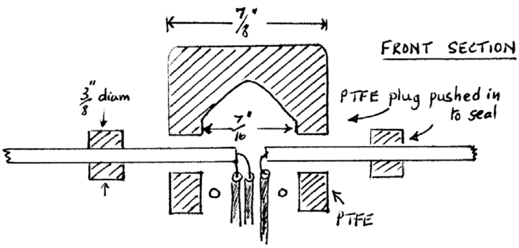
All the elements, including the driven element, are mounted on the underside of the boom. The balun is as the Dubus article fig. 3. The feeder is 0,141" semi-rigid coaxial line, approx, 1 metre long, taken directly from the driven element and back over the reflector as shown in Figure 4 A Teflon cap waterproofs the driven element feed point centre section, as detailed in Figs. 5 and 6.

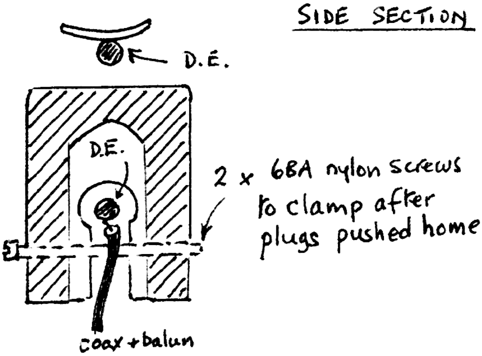
The completed Yagi should be supported about its centre by a "trombone" bracket section as used in UHF TV antennas. This allows the Yagi to stand clear of the supporting mast, which can be, for example, a 2 inch diameter pipe.

MANY THANKS TO RAINER FOR THE FINE BASIC DESIGN!









Heavy Duty Antenna Systems for Portable Microwaves

Peter Day, G3PHO

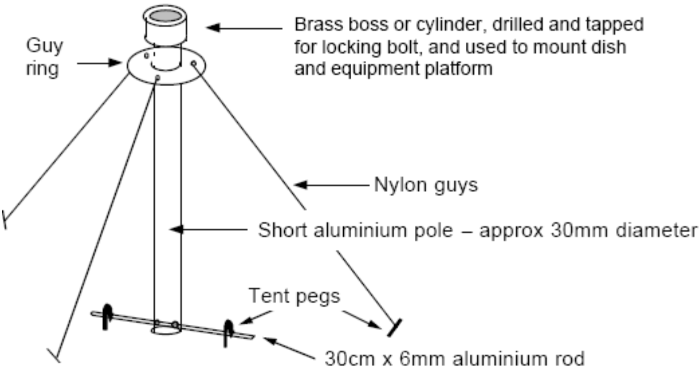
Have you ever had your microwave gear blow over in the wind when out portable? There can't be many portable operators who have not suffered in this way! Since ninety-nine percent of my microwave operating is out-of-doors (and has been for the past 25 years or so) I have gone through many different dish and Yagi support systems. Some have been moderately successful but others have been downright disastrous! The aim of this article is to pass along some of the lessons I have learned over the years, in the hope that they may be of help to others. While these support systems refer to a van rather than a car, there is no reason why a smaller vehicle cannot be used in the manner to be described …. just scale down the masts!

While tripods are still the most widely used dish supports in portable microwave systems, they leave much to be desired, in spite of their obvious advantages of ease of setting up, light weight and compactness. Good tripods are hard to find and are very expensive when purchased new. Few operators own the superb ex-BBC/ITV outside broadcast tripods use by operators such as G0HNW and G3KEU. My National studio tripod, while very sturdy, is not really safe with dish diameters greater than 40cm or so. The present-day tendency is to use offset dishes of 60, 90 or even 100 centimetres diameter. These put a tremendous strain on the average tripod (often not much more than a large camera type). Wind loading, in even light breeze conditions, can be enough to cause the tripod legs to lift off the ground. Unless the tripod is securely guyed, stronger winds can easily tip the whole system over, causing the equipment to crash to the ground and be damaged in the process. I have never really felt confident with tripod-mounted gear and so have tried a variety of other methods over the years. These have involved guyed masts, both short and tall and, more recently, guyless masts supported by the vehicle.

Guyed masts:

For lightweight, backpacking forays into the hills you can't beat a short length (say 1.5 metre or so) of aluminium tubing as a dish support. This can easily be guyed with three thin nylon cords and tent pegs. The base of the tube is drilled through to take a 60cm length of 5 or 6mm diameter aluminium rod which, in turn, is anchored to the ground with a couple of tent pegs. As this prevents the mast from turning, a dish-to–tripod rotating head mount needs to be fashioned to slip over or into the top of the short mast. A locking bolt tightens the antenna mount when the direction has been determined. **Figure 1** shows the essentials of the system. Of course the mast can be as high as you want it. The writer has used a 3 section, 4 metre mast, with a 48cm dish clamped at 1 metre and a small 144MHz Yagi at the top. Such a system was used extensively in the days of 10GHz wideband portable when it was thought essential to get to the highest summits possible! There is still a need for this type of lightweight portable today, with the advent of 47GHz and 76GHz activity. These bands need all the help they can get so "the higher the better" still applies.

FIGURE 1



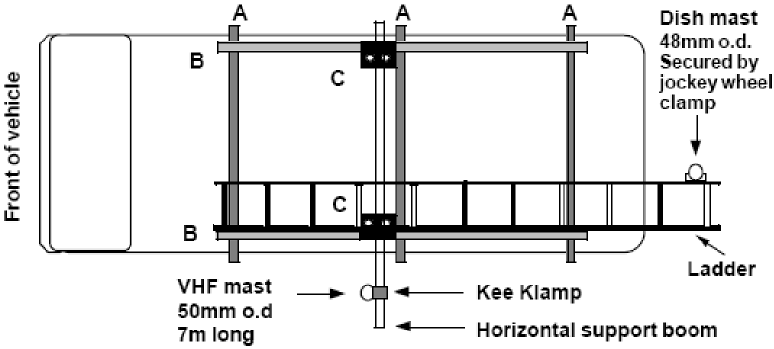
Such a mast weighs very little and can be easily strapped onto the side of a rucksack, along with a small dish. For these "high altitude" operations the 144MHz talkback equipment need be nothing more than an FT290 or IC202. Provided the output power of the microwave station is in the order of milliwatts rather than watts the battery requirements can be met with Yuasa type "dry fit" batteries rather than the large leisure ones used with high power car-based operations.

Vehicle supported masts

Over the past twenty years I have operated from a VW Campervan during the all-day microwave contests. This has the advantage of lots of storage room for equipment, a table and seat operating position and the satisfaction of remaining out of the wind and rain during bad weather. The idea of standing outside all day, by tripod mounted gear has never appealed to me, even though I am quite used to Scottish mountain winters! In February this year I acquired a new vehicle, a VW Transporter. It was a "bare" panel van when I received it from the dealer but I have since floored and carpeted it as well as lining the interior walls with fibreglass wool, plywood and carpet. Side windows were then fitted in the sliding door and the wall opposite. No rear seats have been fitted as this vehicle is for microwaves only! A small operating bench is bolted to the wall beneath the window. I fitted three VW roof bars to the vehicle and added two further longitudinal, square section bars down from the front to the rear roof bars, thus forming a very rigid frame (**Figure 2**). A metal plate, 19cm x 10cm, was then fitted midway along each longitudinal bar and drilled to take U-bolts for a 3 metre long, 50mm diameter, aluminium pipe that runs under the frame from one side of the vehicle to the other. This forms a horizontal support for a 7 metre, 2 section mast that holds the 8 element 2m beam for talkback.

No guys are needed as the mast as it has 3mm thick walls and is approximately 50mm diameter. I cut it into two sections and use a joining sleeve for full height. If conditions are extremely windy I can always use just one section but things have not yet come to that! The vertical mast hinges on its support boom by means of a Kee Klamp, a 90 degree joiner used in scaffolding and barrier structures (**Photo 1**).

Figure 2: showing roof bar structure and mast arrangements



A: Roof bars (spaced approx. 1 metre apart)
B: 20mm square section steel tubes, secured to roof bars with M6 bolts
C: Mounting plates, drilled for 50mm U-bolts and secured with M6 bolts to square section tube

The base of the VHF mast slots over an axle stand (I have two in my garage … they are rarely used for car servicing!) to allow for easy rotation. The mast is locked into position by tightening the hexagonal bolt in the Kee Clamp. The mast in the foreground supports the 144MHz beam. A further Kee Klamp holds a turning handle at a suitable height. The 1.2m microwave dish antenna is not fixed to this mast as it is on a separate mast fixed to the ladder.

The microwave antenna mast is supported at the end of a short, 4 metre ladder section which is clamped to the van roof bars. Here standard ladder clamps are employed. These allow a quick but secure attachment of the ladder to the roof bars. Around 1 metre of ladder projects beyond the back of the vehicle and a 3 metre high mast, consisting of 5mm wall aluminium, 48mm o.d., is attached to the side of the ladder, near the end rung. For this I use a caravan or trailer jockey wheel clamp, obtainable at low cost at any caravan spares supplier. The clamp is bolted to the outside of the ladder so that the ladder can still be used for climbing if need be. **Photo 2** shows the clamp in close-up. Note the sturdy locking handle and general rugged construction. The


Photo 1: VHF mast and support

jockey wheel clamp allows both a secure support for the 3 metre mast and a convenient means of locking the mast in position when dish headings have been set.
The mast stands in a further Kee Klamp fitting which is mounted on a wooden board upon which a 360 degree compass scale was carefully

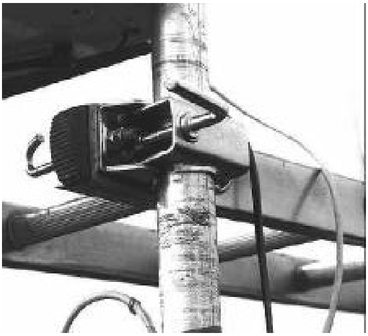


Photo 2: Microwave mast support

drawn and protected with clear varnish. The board is anchored to the ground by means of tent pegs pushed through holes in each corner (**see Photo 3).**

A simple direction pointer was made from a strip of aluminium , painted black and clamped to the pole as shown. The 1.2m dish has a mounting ring and this is used to attach it to the top of the support mast such that the dish can rotate through a full 360 degree arc, above the van roof. The 10GHz transverter is carried on a small platform attached to the mast, just below and behind the dish. A short length of WG16 flexiguide transfers the RF to a Chaparral" type feedhorn that came with the dish. Once the mast and dish are elevated into position and clamped to the ladder, the transverter is placed on its platform and secured with a couple of "bungies". A 3-way spirit level (local D.I.Y again!) is then strapped to the mast and everything is trued up. With 5 watts of RF output, a 1.2m dish and a HEMT receiver front-end, I now find that I can work 400km or more on 10GHz with relative ease, if conditions are anything like normal. I have the distinct impression that the dish performs better at the new height of approximately 3 metres above ground. Plans are now afoot to use the same dish on 5.7GHz with my newly constructed DB6NT 6cm transverter.

With a "bombproof" antenna support system and a roomy vehicle, I can now confidently face anything the British weather throws at me (says he, with fingers crossed!). I hope other readers might find some of this information of use and that we might see more dedicated portable microwave operators out and about in the various activity days and contests.

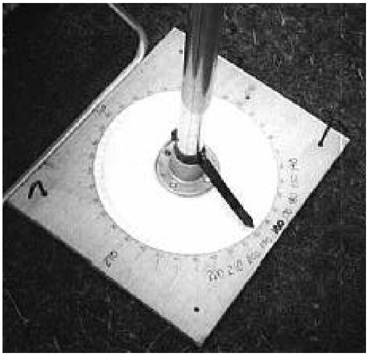


Photo 3: Microwave base board

HARDWARE RESOURCES:
4m ladder section: Local D.I.Y store. Look for light weight aluminium type,
Kee Klamps: Excellent catalogue (Fitting Manual) available from Beeley Fabrications Ltd., Niagara Road, Sheffield S6 1NH (Telephone 0114 234 3244 Fax 0114 2343063)
Roof Bars: VW main dealer.
20mm square section steel tube: Local B&Q.
Dish mast (48mm o.d/5mm wall):

Local scaffold supplier at £2 a foot.
VHF Mast (50mm o.d/3mm wall) and joining sleeve: Local TV antenna supplier at £1.25 a foot.
Jockey Wheel clamp: Local caravan suppliers. Approx £3.75 for large size.

Making Helix Antennas

some notes by Des Clift, VK5ZO

Over the last few years I've made quite a lot of helix antennas from 23cm up to 3cm on 2.4GHz, 3.3, 4.5, 5.7, 8 & 10GHz. I solved the problem of obtaining suitable wire by using capillary tubing service packs that are used by refrigeration people. They are made in Adelaide and are available in 12 or 13 sizes from 1.72mm to 3.54mm O.D, so you pick a suitable size for a particular frequency. They are annealed and very nearly keep their shape when wound on a wooden mandrel. Even buying them retail, I get about two 15T to 20T helixes from an $18 pack (about £6 pounds sterling) and many more 4T to 6T ones. Considering they work so well and are easily available, that's not bad. The ex factory price I got is less then half the retail price and they seem as though they would supply me with small quantities, which is a bit unusual.

The retailer also keeps dozens of copper cap and tapered sections like your dual mode feeds. Unfortunately, the factory does not have an agent in UK. He only seems to supply VK, ZL & S. E. Asian countries. I would imagine there are similar sources of tube made in the UK or Europe, so it may be worthwhile looking into. For your information the packs are 150mm diameter and the ODs and lengths of the type they make are as follows:-

PART No.	O.D. (mm)	USEABLE LENGTHS (mm)
SP1	1.72	3660
SP2	2.06	3660
SP3	2.18	3660
SP4	2.16	4270
SP4.5	2.26	4270
SP5	2.58	4270
SP6	2.70	3660
SP6.5	2.82	3660
SP7	2.94	3050
SP8	3.10	3660
SP9	3.06	2750
SP10	3.44	3050
SP11	3.54	3660

YAMSHA

Yet another Mode S Helical aerial

Martyn Kinder G0CZD

Whilst on a trip to the plumbing department of our local B&Q hardware store before Christmas to prepare for a new kitchen sink, I spotted some semi-rigid 42mm plastic waste pipe. A quick calculation.

42mm dia. x pi = 13cms = mode S

and I can fasten my newly converted Drake to this as well. End of design process!

Well, very nearly. Clutching a 2m length of the waste pipe (along with the rest of the copper bends and valves for the kitchen sink) I rushed home and attacked a calculator, the ARRL "Satellite Experimenters Handbook" (1st Edition –1984) and the contents of an extensive junk box. I then put it all away neatly and read pages 6-16 to 6-18 several times over. YAMSHA Mark 1 was conceived. Following many conceptions, nothing else happened for a couple of weeks (except the sink was installed).

One of the claimed benefits of Helical antennas is that they remain quite functional over a large bandwidth, typically 0.8*f*c to 1.2*f*c, with *f*c the "tuned centre frequency". This was just as well. The optimum frequency for an air spaced helical with an internal diameter of 42mm is 2273MHz. A little bit lower than the 2400MHz I really wanted. The remainder of the design parameters were calculated as follows:

The wavelength of an aerial with 42mm diameter helix is

? = 42 x 3.14 = 131.9mm

To achieve efficient circularity, a pitch angle of 12.5 degrees is required. The spacing between turns can be calculated as S = ? (tan 12.5) = 29.24mm.

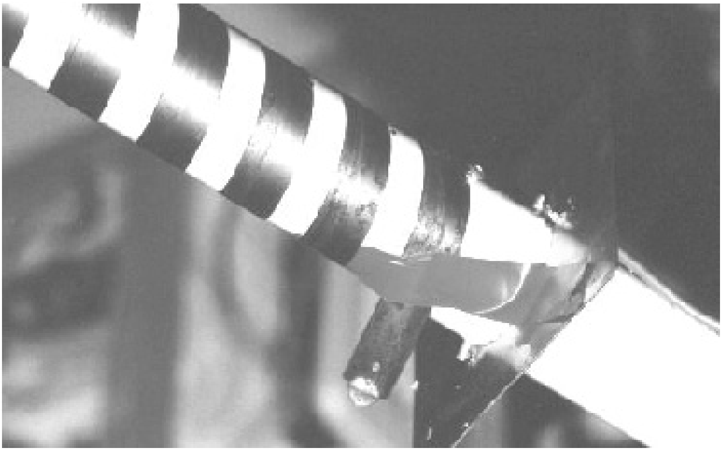
Finally the reflector had to be a reasonable size, a minimum side length of 0.6?? is recommended, I settled on a nice round 100mm. These numbers were starting to look silly. There was no way that I (or any other amateur) could measure 20 turns to an accuracy of 1/100mm. A little bit of creative thought was required. But firstly, the reflector had to be manufactured and secured. I decided to use a two hole gold plated SMA socket as the termination/ connection point. A 43mm hole was cut in the centre of the 24g brass sheet (available from your hobby shop or much cheaper from a scrap metal merchant), and the SMA connector mounted as near to the edge of the hole as possible, whilst still allowing an SMA plug to be screwed in.

The Plastic pipe was marked up with the reflector 250mm from the mount end. This allows adequate space to mount the Drake and also an aerial mounting clamp. The reflector was located by two short lengths of 3mm brass rod passed through the tube and soldered, one on each side of the reflector. This secures the reflector very solidly. Next, mark on the tube, on the same side as the SMA connector three small pen marks, one 29mm from the SMA, one 88mm from the SMA, the other 585 mm up the tube. Drill a small hole into the tube at this point and cut the tube neatly about 5mm beyond this. You will need a 3metre steel tape measure. Place the tape measure number side down at the first mark and wind two turns around the tube. Adjust the pitch of the measure so that both of the first two marks are on the same edge of the tape. Place some sticky tape over the start of the tape and wind out another 17 turns, keeping the tape absolutely flat against the tube. If you have got it right, you will use all 3 metres of steel tape and will terminate right on the final hole – and with no compound errors. Make sure that you wind the helix in the right direction. Phase 3D will have right hand polarised antennas, this means that in the direction of radiation, the helix should be wound in a clockwise direction.

hole. Pull tight with a pair of pliers, bend up and cut off any excess leaving about 6mmon the inside of the pipe. Now carefully cut the sticky tape securing the steel tape measure and unwind. Stand back and admire your perfect Helix. The original design had a slightly different feed point from this final aerial design.

At the time of writing (January 2000), there is only one active satellite with a Mode S beacon. (UO-11 transmits a weak, unmodulated beacon but uses left hand circular polarisation). A second prototype was built using Left Hand circular polarisation.

On the original design (following

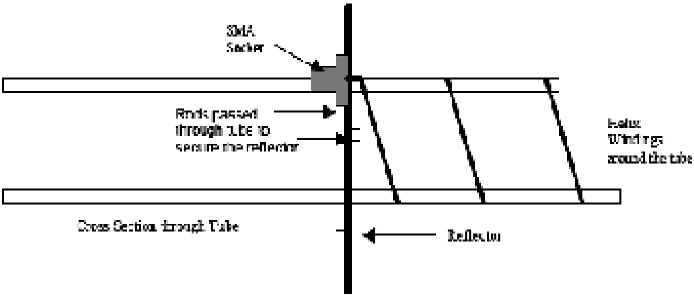


Have a look at the photographs if you are unsure. Now secure the other end of the tape in place with some sticky tape. I used just over 3m of 16g hard drawn copper wire for the "element". Clean the enamel off the end and solder to the protruding pin of the SMA socket. Now keeping the wire tight, twist the aerial one turn until the wire lines up with the correct edge of the tape. Keep winding for the remaining 19 turns using the tape as a guide and then finally push the wire through the

advice from the "Satellite Experimenters Handbook", the start of the first helix was delayed by 29mm, i.e. the wire came straight from the SMA for 29mm before the windings started. This feed arrangement was designed to improve the match to 50 ohms. I spent around a week trying to hear UO-11 with absolutely no success. The Drake had been tested at the last Adastral park Microwave Round Table in November 1999, and exhibited < 2.0dB noise figure and just less than

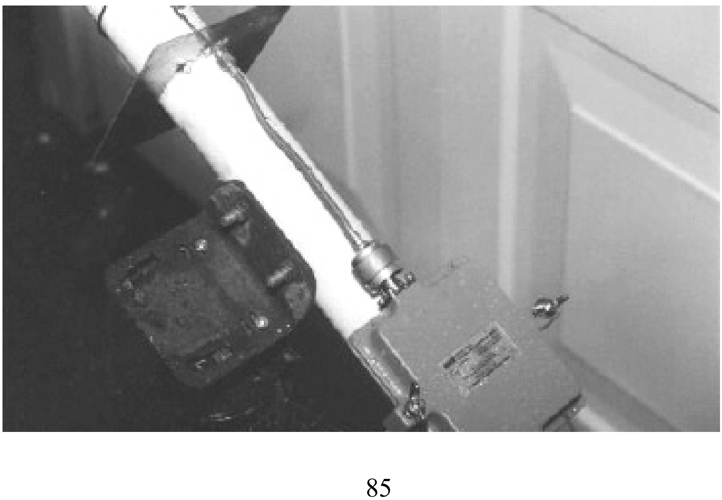
40dB gain. It was working OK!.

Eventually, I decided that the problem was likely to be related to the feed point (no rational reasons – it just didn't look right) of the Helix and so I extended the spiral back all the way to the SMA and tried again. Jackpot! The satellite was picked up on the first pass, with the signal rising to a peak of about 10dB above noise. Very satisfying. Note the photographs show the prototype Right Hand Circular Polarised antenna with the original and inefficient feed.



The claimed calculated gain figure for this aerial is about:
10 x log (15 x 20 (turns) x tan(12.5)) = 18.2dBi.
It is generally accepted that these calculated gain figures are in the order of 1 to 2dB too high. (However read Kent Britain's article – no guarantees implied!) 3dB beamwidth is about 30 degrees.

A few other constructional points. The aerial is attached to an 'L' shaped bracket using two 10mm diameter bolts. These were not tightened unduly, but the nuts were secured with Loctite and the bolts "Araldited" into place. A standard ''U' bolt arrangement can be used to secure the aerial either to a vertical or horizontal pole. The size of the aerial is comparatively small and is unlikely to be unduly stressed in high winds. The Drake is attached to the SMA via a 150mm length of UT141 semi rigid coax with the other end terminated in an N plug. When it eventually goes up on



the mast, the connectors will be weatherproofed, the rest of the unit including the Drake will remain out in the Elements.

Postscript: There has been some discussion on the AMSAT-BB mailing list about the feed impedance of helical aerials. The nominal VSWR of this aerial is approximately 3:1. Several suggestions for improving the match have been suggested which will be subject to further tests and experiments. This high SWR does not appear to affect the stability of the Drake 2880, however, some preamplifiers may be inclined to take off with this level of mismatch.

Dishes and feeds

Is Your Dish Doing What You Think It Is?

Richard T. Nadle, K2RIW

INTRODUCTION --
In his 4/15/03 submittal, Kent, WA5VJB quoted the Johnson & Jasik "**Antenna Engineering Handbook", 2nd edition, 1984,** page 36-9 as saying that the reference #16 article authors (Galindo-Israel, Mittra and Cha) are claiming that, "Their analytical techniques are reported to result in efficiencies in the 80 to 90 percent range". Kent is accurately quoting the Handbook, but there is a problem -- I believe the quote is being taken out of context. I'll supply 3 pieces of evidence of this, and I'll provide a further discussion of possible Dish Efficiencies.

(1) Chapter 36 of the Handbook is devoted to "Earth Station Antennas" that are 60 to 300 wavelengths in diameter. As you are about to find out, some great "efficiency magic" is possible when you have a lot of wavelengths to play with.

(2) The type of antennas being discussed on page 36-9 are Double-offset Geometry dish antennas. This means that the feed horn is offset from the hyperbolic-like sub reflector, and the sub reflector is offset from the parabolic-like main reflector. These are rather complicated geometries that our Microwavers may not be able to use, for some time to come (explained below).

(3) The "Analytical Techniques" being discussed are computer-modelled theoretical dish antennas that are using a Cassegrain-like geometry that employs a "shaped" reflector and sub reflector. This means that the main reflector is an intentionally distorted parabola, and the sub reflector is an intentionally distorted hyperbola. The intentional distortions are being used to simultaneously improve the "Illumination Taper" while still providing essentially no unintended "Phase Taper" The computer-modelling techniques had to use "Diffraction Optimization" techniques for which there is no exact Geometric Optics (GO) solution -- whew!

MAXIMUM DISH EFFICIENCY --
I wish we had access to 90% aperture efficient Dish Antennas, and Horn Antennas. We usually do not, and you will soon see why. "Aperture Efficiency" and Side lobe Levels are often misunderstood, and the detriment they cause is often misquoted. I hope the following material will help.

IT'S ALL IN THE FEED SYSTEM --
The requirements for high efficiency are easy to state, but quite hard to achieve. So, what's required for 100% efficiency -- no Phase Error (no phase taper), and no Amplitude Taper. If my great new "wizz-bang" feed horn system could provide exactly the same number of watts per square cm across my parabolic reflector, no spill-over energy at the edges, and no phase errors, than I'd have what's called a 100% Aperture Efficient dish antenna system.

TRANSMISSION & RECEPTION --
During transmit, almost every possible watt emitted by the antenna would be directed toward the target, and during reception, almost every "possible bit" of the signal hitting the antenna (from the correct direction and polarization) would be absorbed and sent down the feed line -- and it would often peg the S meter. If I had such an antenna, there would be no way that I could improve the transmission or reception,

without increasing the size of the antenna.

SIDE LOBES & SCATTERING --
However, newly-instructed antenna engineers are usually quite surprised to find that a theoretical 100% Aperture Efficient (round dish) antenna will still have 1st side lobes that are about 17.5 dB down, and on reception the antenna still has a considerable "Scattering Area" that will show up on a good Instrumentation Radar.

SIDE LOBE ORIGIN --
The side lobes are the result of the Diffraction Effect, caused by the abrupt fall-off of signal at the edge of the antenna. Simplistically, you could say that Mother Nature doesn't like a sharp discontinuity, and she responds by creating those pesky side lobes (they're almost always there).

SCATTERING ORIGIN --
A Free Space vacuum has an "impedance" of 120*Pi (377 ohms). The 100% Aperture Efficient, highly directional, dish antenna, will absorb the maximum signal if it also presents a matched impedance of 377 ohms. However, now there is a 377 ohm antenna across (in parallel with) the free space impedance of 377 ohms. The new local impedance is now 377/2 = 188.5 ohms. A free-space planar wave entering the vicinity of the antenna will "sense" the change in impedance, and a portion of the wave will become scattered at the impedance discontinuity.

MAKE IT DISAPPEAR --
There are ways to make the antenna side lobes as low as you like, and there are ways to lower the Scattering Area as much as you please. But, all of these techniques must be accompanied by an Aperture Efficiency that is considerably lowered -- you can't have it both ways.

IT'S ALL IN THE SIZE OF IT --
I can almost achieve that nearly ideal Illumination Taper (0.0 dB) and Phase Taper (0.0 degrees). However, to have that much control over the radiation characteristics (primary pattern) of the Feed will require the horn to be made from a very large number of radiating elements that have a carefully-controlled amplitude and phase at each element.

Such a "Cluster Feed" would really be an elaborate Phase Array Antenna, and I don't think you can come close to achieving the desired primary pattern with less than 1,000 elements -- a feed with about 38 wavelengths of diameter (43 inches [1.1 meters] at 10 GHz).

SMALL CASSEGRAINS -- I'm always amused when I encounter an enthusiastic, new Microwaver who becomes enthralled with a small-dish Cassegrain antenna system. Quite often they end up with a sub reflector design of 1.5 inch diameter at 10 GHz, and they start to worry about the accuracy requirement for the Hyperbolic shape.

There is a tried-and-true rule of thumb among informed antenna engineers, "don't even consider a Cassegrain system unless the sub reflector is at least 10 wavelengths in diameter". A 1.5 inch sub reflector at 10 GHz (1.3 wavelengths) is essentially a "Point Source" (almost isotropic). If your eyes functioned at 10 GHz, and you looked at an illuminated 1.5 inch sub reflector, it would look like a fuzzy white dot to you, and you couldn't tell if it was concave, convex, or flat -- they would all look the same. It take a large number of wavelengths of object size before your "vision system" begins to resolve the details. The 2 inch diameter of the sub reflector on my 8 inch Celestron Cassegrain telescope is 100,000 wavelengths in diameter -- that's a real sub reflector that can easily control the pattern it reflects!

CONCLUSION -- Concerning those super Aperture Efficiencies we sometimes hear about, they are possible, but difficult to achieve. And, I doubt we will see many of these in our back yards, unless we are talking about elaborate antenna designs that are hundreds of wavelengths in main dish diameter.

Maximum Dish Efficiency and the Best Antenna Side Lobe Levels

Richard T. Nadle, K2RIW

INTRODUCTION --
What follows is long winded but it is intended as a mini-tutorial that I hope will give some microwavers a better understanding about the highly misunderstood area of Maximizing Gain, Aperture Efficiency, Properly Feeding Parabolas, and the Proper Side lobe Levels that must be present in a properly operating, high efficiency, aperture-type antenna.

THE FORMULA --
The most important factor that determines the achievable Gain of a microwave antenna is it's area. The formula that is the bedrock of the antenna measuring/designing industry and science is:

Gain = (4*Pi*Ae) / (Lambda2)

Where:
Ae = Effective Area, often 55% of the Physical Area
Pi = 3.1416
Lambda = Wavelength in the same units as Ae

GAIN EQUALS AREA --
When you study that formula you can come to an interesting Conclusion; at a fixed frequency everything is a constant except the Ae. Therefore Gain equals a Constant x Area. If you want to double the Gain of your antenna (that's a +3.01 dB Gain increase) you have to double it's effective area.

ILLUMINATION --
All of the above assumes that you are properly illuminating that new area you added. In most Parabolic Dish situations (offset and centre fed) that Gain is maximized when you choose a feed horn that has the -10 dB pattern fall at the edge of the illuminated surface (including the extra path length to the edge). That will usually give you a Dish with an Aperture Efficiency of about 55 - 60%.

100% EFFICIENCY? --
You can almost achieve a 100% Aperture Efficiency. All you have to do is design a feed horn that illuminates every square inch of the dish with the same power and have that power abruptly fall off to zero at the edge of the dish (no spill over). To have that much control of the feeds Primary Pattern will require a properly-fed, Cluster Feed, Phased Array of about 1,000 elements, and that feed assembly will be about 30 wavelengths in diameter. If you are working with a Dish that is 120 wavelengths in diameter, this is almost 'doable' !

A REAL DISH --
Since many of our antennas are only 20 wavelengths in diameter, that approach is not practical. You would end up with more gain in the feed horn assembly than in the whole Dish antenna system. You would be better off just aiming the feed at the target and eliminating the Dish reflector.

APERTURE EFFICIENCY --
The subject of Dish aperture efficiency is highly misunderstood. amateurs (and engineers) believe that the lack of 100% Aperture Efficiency, or 100% Main Lobe Efficiency, represents a true Power Loss (it does not), and that the "lost power" is in the side lobes (it is not).

THERE IS NO LOSS --
In a reasonably-constructed 55% aperture efficiency Parabolic Dish antenna system, if you apply 100 watts

to that antenna, 99.9 watts will be radiated into space. Aperture Efficiency (surface efficiency) is a measure of the True Gain of your antenna versus the theoretically achievable Gain of an antenna of equal area. The desirable 100% aperture efficiency will only be achieved when:

1. The complete surface is illuminated with the exact same number of watts per square inch.
2. There is no phase error on any of those square inches -- this means no bumps in the reflector and no feed horn phase errors in the Primary Pattern.
3. And there is no spill-over energy being wasted.

WHAT'S PRACTICAL --
We can either loose a lot of sleep fretting over how you are going to make your aperture efficiency go from 55% up to 65%, or you can simply add another foot to the diameter to the Parabolic Reflector (and properly illuminate it) -- both may yield the same gain increase. The second approach is much faster, cheaper, and practical.

MANY ANTENNAS HAVE 100% ? --
The world is filled up with Parabolic Antennas that have an aperture efficiency of about 98% -- they are called "Diffraction Limited" Telescopes. My 8 inch diameter telescope has about that aperture efficiency. It achieves this because the Parabolic Reflector is 370,000 wavelengths in diameter, and the Feed Horn (the Eye Piece) does create the desirable Primary Pattern (it is 9,000 wavelengths in diameter) that allows it to do that.

SIDELOBES vs. EFFICIENCY --
Here is the real kicker concerning side lobes and Side lobe "wasted" energy. A Diffraction Limited telescope could be described as one where the Parabolic Reflector has about 1/20 wavelength accuracy, and the rest of the optical system is working properly. That telescope could easily have an Aperture Efficiency of 98%. That's the highest Gain you are ever going to get out of that available area. But now, lets see what it is really doing.

THE AIRY DISC --
As all astronomers know, every Diffraction Limited telescope creates a "picture" (the antenna pattern) that contains an Airy Disc. That means that around every star in the image you will see some dim rings (the side lobes). The Airy Disk is present in all diffraction limited optics systems (and in all antenna patterns). A proper Airy Disk does not represent a system error. However, if a system error is present, the Airy Disk will change in a characteristic way that's beautifully pictured in Suiter's book, "Star Testing Astronomical Telescopes: A Manual for Optical Evaluation and Adjustment" by Harold Richard Suiter, $29.95 at Amazon.com.

HOW MUCH POWER IN THOSE SIDELOBES? --
From my Melles Griot "Optics Guide 5" catalogue, in the section entitled Fundamental Optics, they say that the Diffraction Limited Airy disc will have a Central Maximum region relative intensity of 1.0 (that's the antenna's main lobe at bore sight), and 83.8% of the energy is located there. The first ring (I call this the 1st side lobe), will have a relative intensity of 0.0175 (I call this -17.57 dB), and will contain 7.2% of the energy.

The second ring relative intensity will be 0.0042 (I call this -23.77 dB), and will contain 2.8% of the energy. The 3rd ring intensity is 0.0016 (I call this -27.96 dB), containing 1.5% energy.

The 4th ring is 0.0008 (I call this -30.97 dB), containing 1.0% energy, and a bunch more dimmer rings with less and less energy (the remaining 3.7%).

100% APERTURE EFFICIENCY CHARACTERISTICS --
Now let's review those last statements. A Diffraction Limited 100% aperture efficient telescope has 83.8 % of the received energy located in the main lobe, 7.2% of the received energy located in the first side lobe, 2.8% of the received energy is located in the second side lobe, and 1.5% of the received energy is located in the 3rd side lobe, etc. These are the best numbers you are ever going to get from a perfect, round aperture, that is not an infinite number of wavelengths in diameter.

REMOVE THE SIDELOBES, NO WAY! --
There is an amazing number of amateurs and engineers out there who are dreaming about getting rid of ALL of those side lobes and their "wasted" energy. This is a VERY FUTILE EFFORT. When a circular aperture HAS 100% aperture efficiency, it WILL HAVE side lobes that are exactly that strong (-17.57 dB [1st side lobe], -23.77 dB [2nd side lobe], -27.96 dB [3rd side lobe], etc.) and the amount of energy in each of those side lobes WILL BE exactly the numbers indicated (7.2%, 2.8%, 1.5%, etc.).

REAL DESIGNS --
You can definitely design an antenna with weaker side lobes; but it WILL HAVE less Gain. You can design an antenna with stronger side lobes; and it also WILL HAVE less Gain. You can then design a low loss (no pads) circular aperture antenna with exactly those magic side lobe levels; and it will have the MAXIMUM GAIN for that size aperture.

IS THIS REASONABLE? --
Of course this doesn't seem to make sense, but that's the way "Mother Nature" and Diffraction Limiter 100% aperture efficiency antennas (and telescopes) behave. Those side lobes are the result of the abrupt change in the illumination taper at the edge of the aperture -- Mother Nature reacts to them by creating side lobes. You could slowly taper the energy as you approach the edge of the aperture; that will decrease the abruptness of the illumination taper and it will lower the side lobes but the available Gain will decrease when you do this. You can't have it both ways (maximum Gain and no side lobes).

SO LET'S STOP THE INSANITY
It's time we microwavers, amateurs, engineers, and interested scientists stopped seeking Maximum Gain antennas that have miniscule side lobes; it isn't going to happen! At least I can say, it's not going to happen in THIS universe, that operates with THIS SET of the Laws of Physics that determine our antenna patterns by using what the mathematicians call Window Functions -- that's the way you feed an aperture.

THE YAGI CONNECTION -- A well-tuned, long Yagi antenna has a nearly circular aperture with a nearly uniform aperture distribution. It is interesting to note that such a Yagi usually has a set of side lobes that are very nearly -17.5, -23.8, -27.9, and -30.9 dB. I think we have been looking at the Yagi antenna's "Airy disc" for a long time, we just didn't give that name.

DISH COMPARISON -- A well tuned Parabolic Dish antenna has weaker side lobes than these, simply because the best available feed horns need to use an Amplitude Taper of -10 dB at the Dish perimeter.

GOOD OPTICS BOOKS -- For those microwavers who wish to dig deeper and try to understand this material I recommend reading some of the better optics books. I soon recognized that the guys who have gotten the subject of High Aperture Efficiency down to a science are the optics people. They can easily do this because their "parabolic antennas" frequently are more than 100,000 wavelengths in diameter. Their "feed horn" is called the eyepiece. Their books can give us a lot of insight into what is really achievable with our microwave antennas.

THE REFERENCE --
Here is what I believe is one of the best books on optics. It's modern, well illustrated with computer-generated graphics and photos, and it's in it's 3rd edition: Eugene Hecht, "Optics", Addison-Wesley, 3rd edition, 1998. It's much nicer than the classic, Born and Wolfe, "Principles of Optics", Cambridge University Press, seventh edition, 1999.

AIRY DISC DEFINITION --
Chapter 5, page 228 of Hecht says: "Because an instrument can only collect a portion of the incident wave front to be reformed into an image, there will always be diffraction: the light will deviate from straight-line propagation and spread out somewhat in the image plane. When an optical system with a circular aperture receives plane waves, rather than there being an image "point", the light actually spreads out into a tiny circular spot (called the Airy disc, containing about 84% of the energy), surrounded by very faint rings. The radius of the Airy disc determines the overlapping of neighbouring images and therefore the resolution. That's why an imaging system that is as perfect as possible is referred to as Diffraction Limited. For a perfect instrument, the ideal theoretical angular resolution is given by the radius of the Airy disc, which is [1.22 x Lambda / D] radians (this is the Raleigh criteria). Another way to present the angular resolution is [2.52 x 105 x Lambda / D] arc-seconds." I added the parenthesis.

Dish Under-illumination, F/D, G/T, Phase Centre and Relate Topics

Richard T. Nadle, K2RIW

Introduction --
I have had a rather close and hands-on relationship with Parabolic Dish antennas since 1968, when I scratch-built my first 12 footer -- "A 12 Foot Stressed Parabolic Dish," (QST, August, 1972, page 16 and on the cover, by K2RIW)

On the WA1MBA Internet Microwave Reflector, Zack, W1VT, asked a simple but provocative question about under illuminating a dish as a method of beam broadening. I call this a "Zoom Control." I have used a Zoom Control for four and a half years, with great pleasure, on my 432MHz array of 16 Yagis (19 elements each = 304 elements total) on a 100 foot tower. The use of electronically selectable beamwidth broadening during a contest operation can greatly increase the fun and eliminate many of the azimuthal ambiguities. Zack's fascinating question kicked off a series of 19 Microwave Reflector responses by K2TXB, G4BRK, K5TR, WA5VJB, W0EOM, KD7TS, KJ4SO, W6CWN, K0CQ, WA2SAY, W7CS, and AL7EB, in that order! Each of the responses contained vital "pieces of the puzzle" but few of the responses would give a newbie a "warm feeling" for what is happening within that modified Parabolic Antenna.

Arguably, the most important and popular type of Microwave antenna is a Parabola. We all want more, new and skilled Microwave operators -- so as to preserve our valuable spectrum, as well as other reasons. For this to happen we must remove some of the mystery about this valuable antenna type. Once learned, many new and crafty operators will "see" new antenna possibilities within every hardware store (such as Home Depot). This memo is my attempt to fill some of that void. Please read also, W1GHZ's On-Line Microwave Antenna Book. The following seven sections try to explain:
(I) The Focusing Action of a Parabola (and its cousins, the Offset Parabola, Ellipse, and Circle),
(II) The two meanings of The Parent Parabola,
(III) The effects of Axial Horn Movement (Prime Fed Dish),
(IV) Axial Horn Movement (Offset Dish),
(V) Non-Axial Horn Motion (two types),
(VI) Gain Maximization
(VII) The W2IMU Horn Modification Problem.

(I) Focusing RF Energy -- During reception, every antenna we use has a certain "capture area" wherein the antenna gathers and focuses the RF energy onto a "driven element," "feed horn," or similar structure that supplies the "gathered RF energy" to the transmission line. In the case of a Parabola, that "gathering," and "Focusing" (if done efficiently) involves at least TWO coherent functions --
(1) having the correct surface orientation (angle of incidence equals angle of reflection), and
(2) obeying the correct phase length (path length). If used correctly, the so-called "conic sections" do this very well.

I'll first give three conic section examples (ellipse, circle, and parabola) to illustrate this, as a kind of thought experiment:
Example (1) Ellipse -- Assume I have

a (slightly isotropic) point source RF emitter that's located at the transmitter site, in my back yard, and I wish to capture all it's output at a receiving site, that's 10 feet away. There is one surface that does this perfectly, it's an ellipsoidal surface; it would look like a large, reflective, egg, that's placed around the two sites. That's a three dimensional (3D) ellipse, or an ellipse of revolution about the major axis. I'll boil this down to a 2D discussion.

Assume I have placed a vertical sheet of metal through the two sites and I'll analyse the shape of the ellipsoid that touches the sheet (it's a 2D ellipse). If the ellipse was placed at the coordinate centre, the equation of the 2D elliptical reflector would be $(X/a)^2 + (Y/b)^2 = 1$, where a and b are constants that define the shape and size of the ellipse.

The ellipse has two foci (focuses); each one is located at one of the sites (transmission and reception). The ellipse has a property called eccentricity, ($e = 1 - (b/a)^2$), which is less than 1 and somewhat proportional to the distance between the foci.

The magic of the elliptical surface is that it meets the TWO conditions --
(1) every square inch has the proper surface orientation to reflect the energy in the correct direction, AND
(2) every possible path taken from the transmitter site to the receiver site (with one bounce) has exactly the same path length. That means that the ellipse (ellipsoid) will gather ALL the transmitted energy (from all of 3D space) and focus it (all in phase) at the receiver site. To me, that's kinda neat. By the way, ellipsoidal reflecting surfaces have often been used to focus almost all of the exciter energy of a laser pump onto a laser rod.

Example (2) Circle (Sphere) -- Now let me slowly move the transmitter closer to the receiver, while continuously changing the reflecting surface, so that I can keep gathering all the RF energy. In the limit, the transmitter and receiver will be collocated and the reflecting surface will become a sphere (a circle on my sheet of metal), where a = b in the ellipse equation -- the eccentricity has gone to zero, and the two foci have moved together.

Example (3) Parabola -- Now let me move the transmitter site off to an infinite distance, while continuously changing the reflecting surface, so as to keep gathering all the RF energy. In the limit, that surface will be a Parabola, which is merely an ellipse where the (a) dimension has gone to infinity in the ellipse equation; the eccentricity is 1.0. With a little rearrangement, the equation takes on the familiar form, $Y^2 = 4(f)X$, where f equals the focal length and Y is the dish radial dimension. Notice that a parabola (for an infinite distance) and an ellipse (for a close distance) are related, but slightly different curves. This may give you some feeling for why there is such a thing as a "Near Field Range" for a parabola ($R=2D^2/\lambda$), where D is the dish diameter and R is the range. If you attempt to make Parabolic Antenna measurements within that range (or closer), the surface shape is sufficiently far from the correct elliptical shape that the RF energy starts focusing slightly out of phase and you start getting a noticeable degradations in pattern and gain. The first sign of this is that the first null in the antenna pattern (between the main lobe and the first side lobe) disappears.

Moving the feed focal length further away from the dish gives you a slight improvement in the Near-Field Focusing errors, but it does not accomplish a complete correction -- only reshaping the reflector into an ellipsoid would do a perfect job.

(II) The "Parent" Parabola -- This phrase has at least two meanings:

Meaning (1) -- Notice that the basic equation of a parabola always goes to infinity in the multiple directions (X and Y). When we decide to build a Parabolic Dish Antenna, we are deciding to build a reasonable portion of that complete Parabolic curve. By choosing the focal length (f) of our Parabola we are choosing whether the portion we build will be a deep dish or a shallow one -- each has it's advantages. Selecting the focal length (or the F/D) merely selects the radius of curvature (at the apex, for instance). If we cut away some of the reflector, or electrically do a similar function (by under-illuminating), we are not changing the true focal length (radius of curvature) of the Parent Parabola.

In all cases, a well-constructed Parabolic Reflector has ONE FOCUS for all frequencies and dish diameters (when using the same Parent Equation [focal length]). Many amateurs erroneously think that the focal length changes with the frequency or the portion of the surface that is constructed (or illuminated).

Meaning (2), Offset Reflectors -- When we construct a round shaped Parabolic Reflector with the Parabola Apex in the centre, this too can be called the "Parent Parabola." We can then choose to "cut away" an off-centred portion of the reflector, leaving a round (or slightly oval) "Offspring" that includes the apex and one side of the perimeter. That new surface is an Offset Parabolic Reflector. Notice that the Offspring now has a non-symmetric surface that's more curved at the position of the apex of the Parent Parabola (this difference is rather subtle to an unaided eye). Also, there is only one position (spot in 3D space) where the reflector focus is located; you can not rotate the Offset Reflector and leave the feed horn in the same position -- the non-symmetrically curved surface will not focus properly. One of the well kept secrets of almost all the manufactured Offset Fed Parabolic antenna systems, is that the Offspring Reflector includes the Parent Parabola's apex (centre of the original Parent Parabola. The result of this is that you can now easily determine the elevation aiming point. Merely sight from the apex edge of the dish (the part closest to the feed) through the phase centre of the horn; that's the antenna's bore sight. If that turns out to not be true, than most likely you are using the wrong focal position. This became apparent when a number of 10GHz operators started using the same 18" Offset Fed Dish on 24GHz. The dish efficiency was quite low, until they determined the "true" focal position; the shorter wavelengths made this more critical. When they then went back to 10GHz, they discovered a slight increase in efficiency with the "corrected" focal position.

An Offset Fed Parabolic antenna system has the feed horn phase centre placed at the same focal point as the Parent Parabola (it didn't change because of the off-centred cut away). However, the Primary Feed Pattern would now be illuminating areas where the Parent Parabola, was cut away (that would be wasteful). Thus, the feed is re-aimed (but, not translated) at approximately the centre of the remaining Offspring Reflector -- keep the phase centre in the same place. This gives the best (and a higher) efficiency, because now the feed horn is not causing a blockage and the spill over (and feed side lobes) are usually illuminating cold space, and thus not contributing much to the system's noise temperature.

III Shifting The Feed, Forward and Aft (Prime Fed Dish) -- When we move the feed horn along the axis of transmission (in a prime-fed Parabola) we are shifting the focal distance, but we are creating a spherical aberration (a kind of defocusing). Moving the horn outward causes the emitted signal to have a concave wavefront (viewed from a position that's in front of the dish system), and it "Focuses" at a distance closer than infinity (it becomes near sighted). I use the word "Focus" in quotes because, as previously explained (in Section I), this is only a partial phase correction. It makes an improvement for a close emitter, but the technique can only be carried so far. You can't use this technique to get a good focus on a 10GHz 3 foot dish at an emitter distance of 10 feet (mathematics to be supplied later).

Moving the horn inward of the calculated focal distance causes the emitted signal to have a convex wavefront and now the dish is "Focused" beyond infinity (it becomes far sighted). The horn inward moving technique is a coarse method of "Beam Defocusing," or "Beam Broadening" that could be used as a Zoom Control. It causes a more spherical wavefront (lowers the gain), and simultaneously causes the desired under-illuminating function required for a broader beamwidth. There will be some side-lobes developed, but they may be very tolerable; their magnitude is partially dependent on the system's F/D ratio, as well as the Feed Horn characteristics.

IV Shifting The Feed, Forward and Aft (Offset Fed Dish) -- However, the axial motion (along the bore sight) of the feed horn will have a different effect on an Offset Fed Parabolic system. It will simultaneously cause Squint. That's a fancy way of saying that the bore sight will shift. The direction of shift (squint) is fairly easily predicted (with slight inaccuracy) by knowing that (in general) the angle of incidence equals the angle of reflection.

V Shifting The Feed, Non-Axially (Offset & Non-Offset Fed Dish) -- I believe that there is a way of intentionally de-focusing an Offset Fed Parabolic system by moving the horn inward along the axis of the horn. This will slowly (because of the larger F/D ratio) cause a convex wavefront (front view) and, again, it will cause under-illumination -- both are in the desired direction for beamwidth broadening. There probably are past references on this subject but, even if there aren't any (for an Offset Fed system), microwavers are becoming quite proficient with fancy modelling programs; this would be a great place to do some pattern/gain modelling. Or, simply make a "Leap of Faith" -- go do it (try it, you'll like it)!

For a Prime Focus Dish, there is a considerable amount of beam steering that can take place by only moving (translating) the horn in a transverse manner. In the Radiation Laboratory Series of Books ("Microwave Antenna Theory and Design," #11, McGraw-Hill Book Co., NY, 1949, by S. Silver) the author states that the bore sight can be steered by six beamwidths, before the gain falls off by 1 dB, if a 0.6 F/D reflector is in use. The problem becomes worse for lower F/D ratios. **This suggests that a cluster of almost 6 horns, side by side, is possible if a 0.6 or greater F/D is in use.**

I believe that an Offset Fed Parabolic Antenna system will be even more forgiving, when transverse horn motion is used (in azimuth or elevation). This is because of the large F/D ratios that most of them posses. This suggests that a whole cluster of horns is possible, with a rather small gain sacrifice. The only disadvantage may be that a predictable amount of dish re-orientation will be required when a change in horns is initiated.

VI Gain Maximization --
Step One in the process of maximizing the gain of a parabolic Reflector

antenna system is understanding the Geometry. This means:

(A) Is the reflector the correct shape and smooth enough for the wavelength in use? If not, can it be re-shaped; can the dents be hammered out, etc.? The Johnson, "Antenna Engineering Handbook", McGraw-Hill, 1992, has curves that predict the rate of gain fall off versus reflector errors (bumps).

(B) Is the reflector's mesh fine enough for the wavelength in use? Should it be covered over with a finer mesh? Johnson (ibid) Handbook has prediction curves.

(C) Has the proper feed horn focal position been found for the reflecting surface in use? By measuring the diameter (D) and the depth (d), and applying the formula,

F = (D^2)/16d ,

This can be found for a Prime Focus Parabola. For an Offset Fed Parabola, the problem is a little more difficult. W1GHZ's web site will help. Even by pure experimentation, it can be found.

(D) Has the system's F/D been correctly determined (this is required to design/ build the proper feed horn)?

Step Two -- The next step is choosing the best Feed Horn to properly illuminate that Parabolic shaped Reflecting surface -- this is a slight compromise. Do you want the maximum Gain, maximum Efficiency, or best Gain to Temperature (G/T) Ratio?. Most of us want the first two (they're very close). An EMEer will want the best G/T. Well, where does the best Gain come from? If this was the best of all worlds, your Feed Horn design would apply an equal amount of RF energy (in phase) to every square inch (or square cm) of the reflecting surface (including the extra path loss to the dish perimeter). That Primary Feed Pattern would abruptly fall to zero at the edge of the dish -- there would be no spill-over energy. Such a Primary Feed Pattern would yield a reflecting surface with 100% aperture efficiency, and the G/T would be ideal.

Believe it or not, those feed horn characteristics are almost achievable. BUT, to have that high a Directivity and Pattern Control, such a horn (or a cluster of horns in a Phased Array) would be larger than most of the Parabolic Reflectors we have ever used. In a Prime Focus Parabolic System, that ideal horn would block out the whole reflector! Even in an Offset Fed Parabolic system, if your horn has more gain than the reflector, skip the reflector and simply aim the horn at the target!

So, for a bunch of reasons, we choose the best realistic horn we know of (Chaparral or Dual Mode [W2IMU] if your dish is near a 0.6 F/D) and adjust them for either a -10 dB, or -20 dB edge illumination taper. The two horn types (Chaparral and W2IMU) are really a multi-element type of feed that have a very desirable pattern, almost no edge currents outside the horn, almost no side lobes, and they have a nearly constant point source phase centre versus azimuth, elevation and diagonal observation angles.

Bear in mind that a subtle shift in the emitted phase from your horn, as a function of a change in observation angle, causes the same system degradation as if your reflector had a big dent in that area. It's hard to believe that some beautiful-looking Parabolic Dish Antenna systems can have a serious error that an untrained eye can not see.

A lot of experience has shown that the best gain occurs at about a -10 dB edge taper (nearly the best illumination taper), and the best G/T occurs at about a -20 dB edge taper (a kind of under illumination).

The gain changes rather slowly (at first) as the illumination taper is changed. The most sensitive characteristic is the first side lobe levels -- they can be as low as -25 dB (or better) with a -20 dB edge taper.

VII W2IMU Horn Modification Problem -- I have read of enthusiastic builders who changed the length or diameter of the large-diameter section, or the diameter of the smaller section, of the W2IMU Dual Mode Horn, as a way of controlling the horn's beamwidth, so as to adapt it to a dish that has an F/D that's quite far from (the designed) 0.6. This can be a disappointing endeavour. Yes, the Dish is not going to crash and burn but it may have a disappointing efficiency (or pattern) result. What Dr. Dick Turrin, W2IMU, did in that horn design was to set up the two circular waveguide modes (TE11 and TM11) in just the right amplitude ratio and phase relationship that the resultant at the horn throat has virtually no edge currents to cause side lobes and back lobes. This also causes the horn to have a constant point source phase centre versus all observation angles.

If you were to change the 30 degree flare angle or the larger diameter, that would change the amplitude ratio of the higher mode generation (TM11). If you change the diameter or length of the larger section, that will change the phase relationship between the modes, because they have different cut-off wavelengths and thus different phase velocities in the larger diameter section. The length and diameter of this section is really a phase corrector between the two waveguide modes.

I may be overly-conservative, but here is my opinion. If you are very skilled at 3D modelling of higher-order waveguide mode generation techniques, and if you are skilled at calculating Bessel-Neumann and Hankel Functions, than have at it and please let me know about your results. For the rest of us mere mortals, I recommend that you follow one of W2IMU's two designs exactly and only scale every dimension, proportional to your particular wavelength.

I hope these thoughts are helpful to those who were brave enough to read all of this.

Please feel free to correct the errors!

Focusing of Deep Focus Dishes

Paul Gaskin, G8AYY

This note is an attempt to show how accurately a deep parabolic dish needs to be focused.

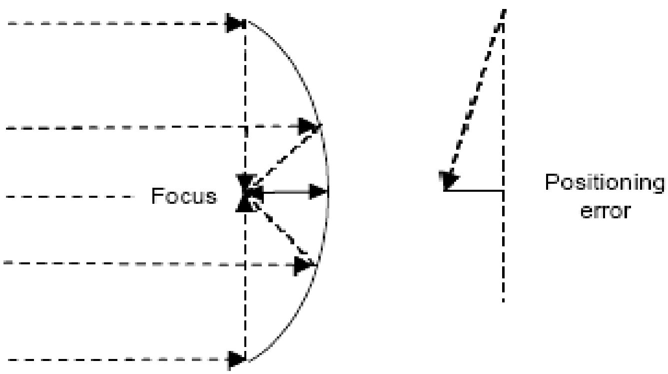
Consider the reception of a plane wave front by a focal plane dish (f/D = 0.25) which is large compared with the wavelength. At the edge of the dish an incoming wave is reflected through 90 degrees which means that the path length to the feed point will not vary significantly with small errors in axial positioning of the feed point.

In order to focus, there have to be equal path lengths from the front of the dish to the feed point and an axial positioning error of the feed point will give the maximum phase angle error between the waves from the centre and the edge of the focal plane dish. Loss of gain is related to cosine ((phase angle error)/2) and a phase angle error of over 30 degrees will give a noticeable loss of gain.

At 10 GHz a feed point positioning error of 5mm (1/5 inch) with a deep parabolic dish will have a phase angle error of up to 60 degrees and serious loss of gain which confirms measurements made by other people. If the feed point error was 2.5 mm (1/10 inch) or less then the loss of gain would be negligible.

Measurement of the path lengths from the front of my 45 cm PW dish (f/D = 0.28) to the centre of the disc of the G4ALN 'penny' feed gave a positioning error of only 2 mm (2/25 inch). This dish has a fixed feed point position but works well which confirms the accuracy requirement for the feed point position.

Another 45 cm PW dish was available for direct comparison but did not work so well even after adjustment and requires further investigation. There may be a problem with the dimensions of the G4ALN 'penny' feed.



Large Dish Cassegrain Development For Millimetric Bands & Practical Implementation Using CAD & Spreadsheet

by
Martin Farmer G7MRF

Introduction

The aim of this paper is to make available the design calculations and a spreadsheet program to enable microwavers to design their own hyperbolic sub reflector for a cassegrain feed system as well as a suitable W2IMU feed horn and to explain the implementation of quick band change on my portable set up.

After using flat plate type reflectors on both 24GHz and 47GHz portable systems to good effect, the decision was made to incorporate both of these bands into one box during a major rebuild over the winter months. The decision also included using one dish, with interchangeable bands contained within a quick-change system that could eventually end up with 5.7, 10, 24 & 47GHz as a possible combination on a portable expedition.

The decision to move away from the flat plate type reflectors was influenced by the small improvement in system gain but, more importantly, I wanted to use a W2IMU dual mode feedhorn, using circular waveguide, to feed the new dish (which has a f/D ratio of 0.38).

Looking at the reference books, the optimum f/D for the dual mode feedhorn is 0.8 but it can be used on parabolic dishes with f/D ratios as low as 0.5. The use of a cassegrain system and, in particular, the ability to slightly change values in the calculation makes it possible to modify the f/D ratio of the virtual parabolic dish to suit whatever f/D you require for your feedhorn, as in my particular case from 0.38. If I used a flat plate type reflector, the virtual dish would appear to be 0.38 and not suit the feedhorn type that I wanted to use. For details of the 24GHz and the 47GHz W2IMU dual mode feed horn see **figure 6**.

The original flat plate reflector used on 24GHz was constructed from double-sided PCB material and brazing rods for the supports from the WG20 dish feed. A similar approach was used on my original 47GHz transverter, using a 60mm circular disc reflector. Discussions with Dr Dennis Hawkins of Qpar Angus [1], at the end of one of the UK Microwave Round Tables during 1999, resulted in the exchange of correspondence on the subject of cassegrain feeds.

Armed with this information and calculations from a paper [2] regarding Microwave antennas derived from the cassegrain telescope, we started to lay out, in AutoCAD, the profile from the main dish that was going to be used and, by using geometry, we arrived at a shape for the reflector. This profile from the CAD system was sent to Dr Dennis Hawkins who compared what we had laid out with his commercial antenna software and confirmed it to be ok.

It was decided to go ahead with the manufacture. I found a machine shop that was willing to make the component for me using CNC technology and they had the ability to take the CAD profile of the sub reflector in to their computer system to generate NC code automatically. The end result (shown in **figure 1** below) is the 100mm-diameter sub reflector and support boss used on my new portable system.

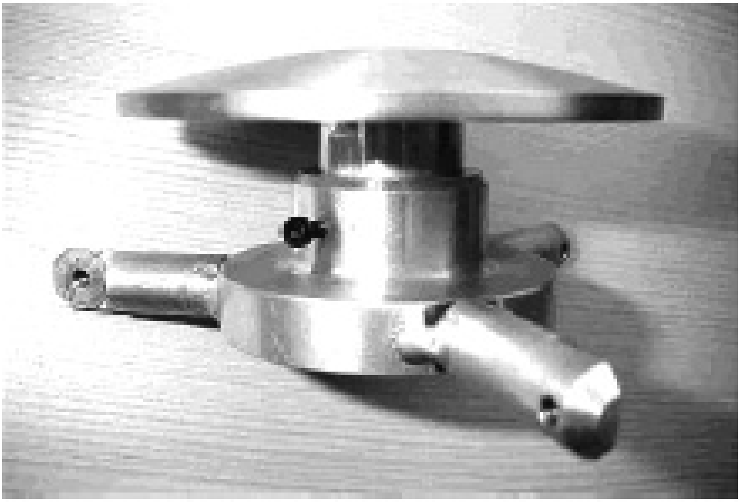


Figure 1: 100mm subreflector and supports

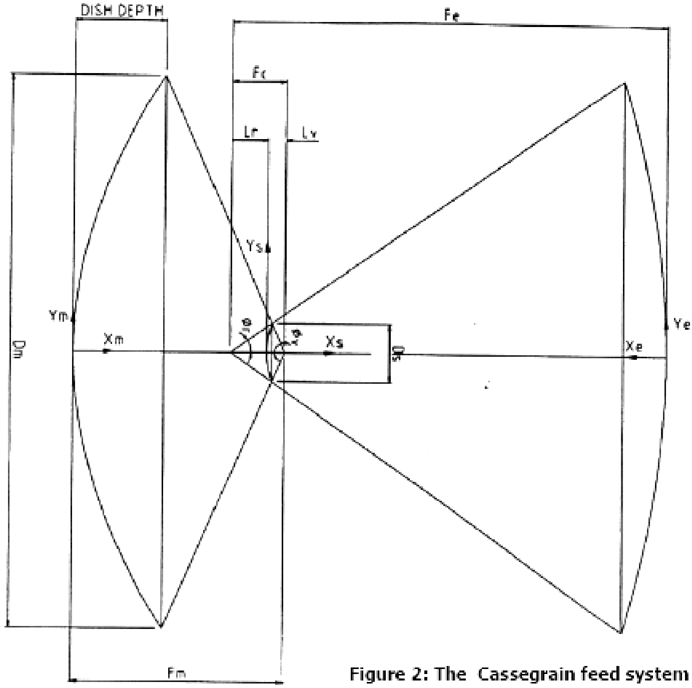


Figure 2: The Cassegrain feed system

Nomenclature

Dm = EFFECTIVE DIAMETER OF CIRCULAR MAIN DISH (TO EDGE RAYS)
Ds = EFFECTIVE DIAMETER OF CIRCULAR SUB DISH (TO EDGE RAYS)
Fm = FOCAL LENGTH OF MAIN DISH
Fc = DISTANCE BETWEEN FOCI OF SUB DISH
Fe = EQUIVALENT FOCAL LENGTH OF CASSEGRAIN SYSTEM
Lv = DISTANCE FROM VIRTUAL FOCUS (OR MAIN DISH FOCUS) TO SUB DISH
Lr = DISTANCE FROM REAL FOCUS (OR FEED) TO SUB DISH.
φv = ANGLE BETWEEN AXIS AND EDGE RAY, AT VIRTUAL FOCUS
φr = ANGLE BETWEEN AXIS AND EDGE RAY, AT REAL FOCUS
E = ECCENTRICITY OF CONIC SECTION.
A = TRANSVERSE HALF-AXIS OF CONIC SECTION.
B = CONJUGATE HALF-AXIS OF CONIC SECTION.
Xm = AXIAL CO-ORDINATES OF MAIN DISH.
Ym = RADIAL CO-ORDINATES OF MAIN DISH.
Xs = AXIAL CO-ORDINATES OF SUB DISH.
Ym = RADIAL CO-ORDINATES OF SUB DISH.
Xe = AXIAL CO-ORDINATES OF VIRTUAL DISH.
Ye = RADIAL CO-ORDINATES OF VIRTUAL DISH

Manual Calculation Method
Here is a worked example based on the following data:
Dm = 935 mm
MAIN DISH DEPTH = 152 mm
Ds = 100 mm
Fc = 94 mm

CALCULATING F/D RATIO
F/D RATIO = Dm/(16 x DISH DEPTH)
= 935/(16 x 152)
= 935/2432
= 0.3845

CALCULATING MAIN DISH FOCAL LENGTH
Fm = Dm x F/D RATIO
= 935 x 0.3845
= 359.5 mm

CALCULATING ANGLE φv
φv = INV TAN [(Dm ÷ 2) ÷ (Fm - DISH DEPTH)]
= INV TAN [(935 ÷ 2) ÷ (359.5 - 152)]
= INV TAN [(467.5) ÷ (207.5)]
= 66.0659°

CALCULATING ANGLE φr
(1 ÷TAN φv) + (1 ÷ TAN φr) = 2 (Fc ÷ Ds)
(1 ÷ TAN 66.0659°) + (1 ÷ TAN φr) = 2 (94 ÷ 100)
0.4439 + (1 ÷ TAN φr) = 2 (0.94)
(1 ÷TAN φr) = 1.88 - 0.4439
φr = INV TAN (1 ÷ 1.4361)
φr = 34.85°

CALCULATING DISTANCE Lv
1 - [SIN 1/2 (φv - φr) ÷ SIN 1/2 (φv + φr)] = 2 (Lv ÷ Fc)
1 - (SIN 1/2 (66.0659 - 34.85) ÷ SIN 1/2 (66.0659 + 34.85)] = 2 (Lv ÷ 94)
1 - (0.269 ÷ 0.771) = 2 (Lv ÷ 94)
0.651 = 2 (Lv ÷ 94)
Lv = (0.651 ÷ 2) x 94
Lv = 30.597 mm

CALCULATING ECCENTRICITY 'E'
E = SIN 1/2 (φv + φr) ÷ SIN 1/2 (φv - (r)
E = SIN 1/2(66.0659 + 34.85) ÷ SIN 1/2 (66.0659 - 34.85)
E = SIN 1/2 (100.9159) ÷ SIN 1/2 (31.2159)
E = 0.771 ÷ 0.269
E = 2.866

CALCULATING VALUE 'A'
A = Fc ÷ 2E
A = 94 ÷ 2 x 2.866
A = 16.4

CALCULATING VALUE 'B'
$B = A \sqrt{E2 -1}$
$B = 16.4 \sqrt{(2.866)\ 2 -1}$
$B = 16.4 \sqrt{7.213956}$
B = 16.4 x 2.6859
B = 44.05

CALCULATING CONTOUR OF MAIN DISH (PARABOLA)
Xm = Ym2 ÷ 4 (Fm)
FOR Ym = 50
Xm = (50) 2 ÷ 4 (359.5)
Xm = (50) 2 ÷ 1438
Xm = 2500 ÷ 1438
Xm = 0.017
REPEAT FOR VARYING VALUES OF Ym TO CALCULATE CORRESPONDING VALUE OF Xm.
EG. FOR Ym = 50 Xm = 1.739
Ym = 100 Xm = 6.954
Ym = 150 Xm = 15.647 Etc

CALCULATING CONTOUR OF SUB DISH (HYPERBOLA)
$Xs = A [\sqrt{1 + (Ys \div B)\ 2 -1}]$
FOR Ys = 5
$Xs = 16.4 [\sqrt{1 + (5 \div 44.05)\ 2 - 1}]$
$Xs = 16.4 [\sqrt{1 + 0.01288} - 1]$
Xs = 16.4 (0.006419)
Xs = 0.105
REPEAT FOR VARYING VALUES OF Ys TO CALCULATE CORRESPONDING VALUES Xs.
EG. FOR Ys = 5 Xs = 0.105
Ys = 10 Xs = 0.417
Ys = 15 Xs = 0.925 Etc

CALCULATING EQUIVALENT FOCAL LENGTH Fe
Fe ÷ Fm = (E + 1) ÷ (E -1)
Fe ÷359.5 = (2.866 + 1) ((2.866 - 1)
Fe ÷359.5 = 3.866 ÷1.866
Fe ÷ 359.5 = 2.072

Fe = 2.072 x 359.5
Fe = 744.88

CALCULATING CONTOUR OF VIRTUAL DISH (PARABOLA)

$Xe = Ye^2 \div 4Fe$
FOR Ye = 50
$Xe = (50)^2 \div 4\ (744.88)$
$Xe = 2500 \div 2979.52$
$Xe = 0.839$

REPEAT FOR VARYING VALUES Ye TO CALCULATE CORRESPONDING VALUES OF Xe.

EG. FOR Ye = 50 Xe = 0.839
Ye = 100 Xe = 3.356
Ye = 150 Xe = 7.552 Etc

After going through the above set of calculations a series of X, Y points are obtained. With this the shape of the sub reflector can be laid out onto paper to produce a template. This could then be used to check profile accuracy if manually turning the reflector in a lathe.

After searching the Internet for any programs to calculate the reflector's profile nothing could be found and also not everybody has access to a CAD workstation on their desk so the decision was made to make the calculations available to other amateurs by writing a simple Microsoft Excel spreadsheet to do this task.

Figure 3 shows the layout of the Excel screen. User data input is to the upper left hand side while to the rest are data tables for the sub reflector, actual dish parabola and virtual dish parabola profiles. The dish and virtual dish profiles tables are given to allow the user to draw out the whole scheme if required. I have written an AutoCAD Lisp program to take this data and draw a 1:1 layout within the CAD system. The Excel program is available to download from [3] but we are getting close to the limits of what we as a group are able to do within Excel. Please feel free to play with the routine and comment.

Figures 4 and 5 show the completed portable transverter in use. With using such a large dish, initial alignment when arriving onto the portable site is done by fitting a rifle site into the sub reflector boss on the front of the dish so that it looks back though a hole where the feed fits. By optically aligning the dish onto a visible landmark (180 degrees out) and then working out the beam heading to this point, the compass rose on the neck of the tripod can be altered to suit. After an initial contact, further refinement to the compass can be made.

After working someone with the 24GHz transverter, the head unit can be replaced with the 47GHz transverter, whilst still maintaining the correct beam heading, by the following method ...
I start with standard type die-cast boxes for the equipment and a three-point female conical mounting on the lid of every box that is to be used (see **figure 5**). This is done before any equipment is installed. The position of the waveguide feed is marked using a laser pen innards mounted inside a machined cylinder slid into position where the sub reflector is to be located. The laser light beam projects through a very small hole in the cylinder and the marking of the box entry is then quite straightforward. Mounted on the metal framework that supports the dish are three male conical points that allow the boxes to be repeatedly positioned with good accuracy.

DATA INPUT

Fc (mm)	94.0000
Ds Sub ref dia (mm)	100.0000
Dm Dia main Dish (mm)	935.0000
Fm Focal L Main Dish (mm)	359.4675
Dish Depth	152.0000
Phiv (rad)	1.1531
Phiv (deg)	66.0693
1/tan PhiV	1.4362
Phir (rad)	0.6082
Pgir (deg)	34.8484
Fe/Fm = Magnification	2.0719
Fe	744.7938
Fm/Dm Main Dish	0.3845
Fe/Dm Equivalent Dish	0.7966
Eccentricity of subref	2.8658
Lv (mm)	30.5996
Fc-Lv (mm)	63.4004

Button 10

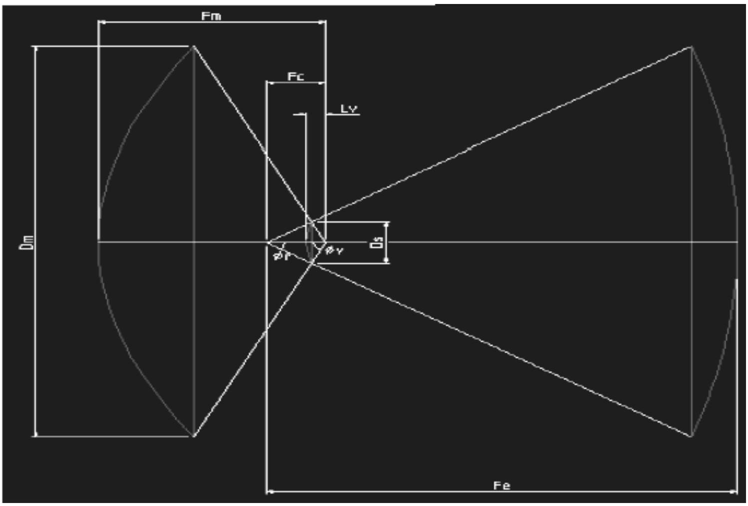
Figure 3: Excel Spreadsheet

SUB REFLECTOR

A	B	Xs (profile mm)	Ys (radius mm)
16.4004	44.0457	11.3141	-60.0000
16.4004	44.0457	9.8364	-55.0000
16.4004	44.0457	8.4106	-50.0000
16.4004	44.0457	7.0459	-45.0000
16.4004	44.0457	5.7537	-40.0000
16.4004	44.0457	4.5474	-35.0000
16.4004	44.0457	3.4428	-30.0000
16.4004	44.0457	2.4576	-25.0000
16.4004	44.0457	1.6116	-20.0000
16.4004	44.0457	0.9250	-15.0000
16.4004	44.0457	0.4174	-10.0000
16.4004	44.0457	0.1053	-5.0000
16.4004	44.0457	0.0000	0.0000
16.4004	44.0457	0.1053	5.0000
16.4004	44.0457	0.4174	10.0000
16.4004	44.0457	0.9250	15.0000
16.4004	44.0457	1.6116	20.0000
16.4004	44.0457	2.4576	25.0000
16.4004	44.0457	3.4428	30.0000
16.4004	44.0457	4.5474	35.0000
16.4004	44.0457	5.7537	40.0000
16.4004	44.0457	7.0459	45.0000
16.4004	44.0457	8.4106	50.0000
16.4004	44.0457	9.8364	55.0000
16.4004	44.0457	11.3141	60.0000

MAIN DISH PROFILE

Fm Focal L Main Dish (mm)	Xm	Ym
359.4675	156.9161257	-475
359.4675	140.8333095	-450
359.4675	125.6198347	-425
359.4675	111.2757013	-400
359.4675	97.80090938	-375
359.4675	85.19545883	-350
359.4675	73.45934971	-325
359.4675	62.592582	-300
359.4675	52.59515571	-275
359.4675	43.46707083	-250
359.4675	35.20832738	-225
359.4675	27.81892533	-200
359.4675	21.29886471	-175
359.4675	15.6481455	-150
359.4675	10.86676771	-125
359.4675	6.954731333	-100
359.4675	3.912036375	-75
359.4675	1.738682833	-50
359.4675	0.434670708	-25
359.4675	0	0
359.4675	0.434670708	25
359.4675	1.738682833	50
359.4675	3.912036375	75
359.4675	6.954731333	100
359.4675	10.86676771	125
359.4675	15.6481455	150
359.4675	21.29886471	175
359.4675	27.81892533	200
359.4675	35.20832738	225
359.4675	43.46707083	250
359.4675	52.59515571	275
359.4675	62.592582	300
359.4675	73.45934971	325
359.4675	85.19545883	350
359.4675	97.80090938	375
359.4675	111.2757013	400
359.4675	125.6198347	425
359.4675	140.8333095	450
359.4675	156.9161257	475



24GHz Scalar Feed and mount for the Direct PC or Prime Start Dishes

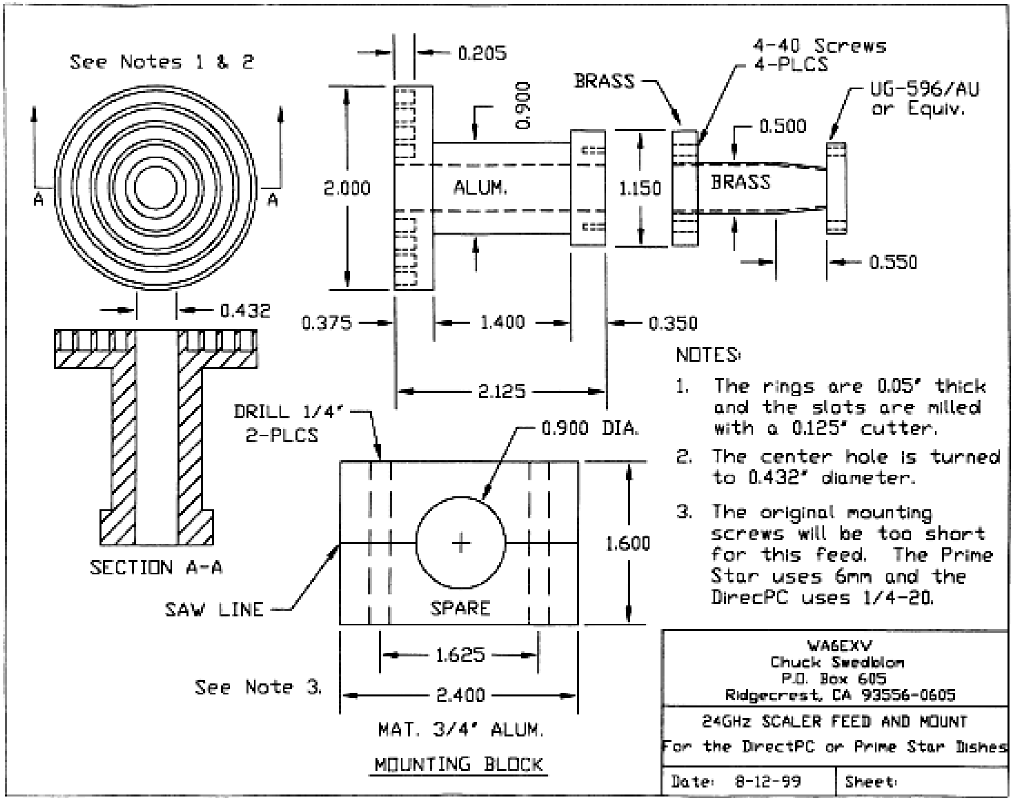
Chuck Swedblom, WA6EXV

Editor's comment: Chuck has very kindly allowed us to reprint this article, originally published in the July 1999 Newsletter of the San Bernardino Microwave Society. While the article refers to two specific brands of dish, the feed is eminently suitable for any prime focus feed with an f/dD of around 0.45 or so.

The existing feed on these two dishes* provided a measured efficiency of 60% at 10.368GHz. I decided to explore the possibility of using the dishes at 24GHz and built this feed to fit in place of the original one. Since my antenna range is too short (92 feet), WA6QYR and I located two sites about a half mile apart on two sides of a small canyon to conduct these test using an antenna of known gain. The results of the tests showed that the DirectPC antenna had an efficency of 59% using this feed at 24.125GHz. The original tests on the Prime Star dish did not perform this good, but the Prime Star dish was used and had been installed here in Ridgecrest for two years or more, whereas the DirectPC dish was brand new. Also there is some doubt in my mind that the Prime Star tests may be flawed. Further tests of the Prime Star will be conducted in the near future.

I built the Scalar Feed, as shown on the following page, since I have the tools and enjoy turning and milling metal. I have also built the scalar section using 1/16″ G10 or FR4 PCB material and thin hobby brass strips to form the rings with equal results. In this case the 1/2″ brass tubing (circular waveguide) would extend through the centre of the scalar and would have to be long enough to allow for mounting, a total of about 3.5″. Also the mounting technique has to be modified such that the centre of the feed will be at the same location as the present one. I used a brass strap soldered to the 1/2″ circular waveguide and bent such that the alignment was correct and then drilled two 1/4″ holes in the strap to bolt it to the mounting arm of the dish.

The engineering drawing for the feedhorn is on the following page …



See Notes 1 & 2
A
A
0.432
SECTION A-A
0.205
0.900
2.000
ALUM.
BRASS
4-40 Screws
4-PLCS
UG-596/AU
or Equiv.
0.500
1.150
BRASS
0.550
0.375
1.400
0.350
2.125
DRILL 1/4"
2-PLCS
0.900 DIA.
SAW LINE
SPARE
1.600
1.625
2.400
See Note 3.
MAT. 3/4" ALUM.
MOUNTING BLOCK
NOTES:
1. The rings are 0.05" thick and the slots are milled with a 0.125" cutter.
2. The center hole is turned to 0.432" diameter.
3. The original mounting screws will be too short for this feed. The Prime Star uses 6mm and the DirecPC uses 1/4-20.
WA6EXV
Chuck Swedblom
P.O. Box 605
Ridgecrest, CA 93556-0605
24GHz SCALER FEED AND MOUNT
For the DirectPC or Prime Star Dishes
Date: 8-12-99
Sheet:

Scalar Feedhorn For 24GHz

by Barrie, VE4MA

(reprinted with the permission of the North Texas Microwave Society)

This versatile scalar ring feed first appeared in the June/July 1999 issue of the NTMS newsletter "Feedpoint" and looks just the job for those 24GHz operators who are using dishes with an f/D of around 0.4 or so. For larger f/Ds, such as those found on offset fed dishes, it is suggested you use a dual mode horn of the W2IMU type.

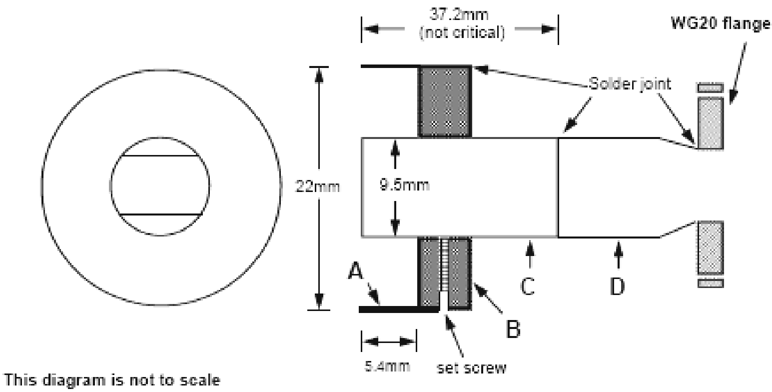
The diagram (fig.1) is largely self explanatory. Part A, the scalar ring, is formed from a pieceof copper waterpipe of an internal diameter that will be a snug fit over Part B, a brass disc(thickness not critical), and to which it is eventually soldered to provide a ring depth of 5.4mm as shown in the diagram. The brass disc is also a snug fit over Part C, a section of brass or copper pipe with an internal diameter of 9.5mm and an external diameter of 11.1mm.

Part D is a soft copper plumbing coupler or pipe of suitable diameter to enable it to be carefully butt jointed and soldered to Part C. Its other end is squeezed and shaped as accurately as possible to fit inside a WG20 flange and then soldered.

For an f/D of 0.4, the open face of the scalar ring should be flush with the open end of Part C. The whole scalar ring assembly (Parts A and B) can be slid back and forth over Part C to adjust for different f/Ds, after which it can be secured with a set screw. Part B is drilled and tapped as shown for the screw.

This design can, of course, be scaled for use on other microwave bands.

figure 1



Using the G3PHO Feedhorn with Coax Feed

by John Quarmby G3XDY

When my satellite system was upgraded to digital I kept the old Amstrad dish with the expectation of putting it to use when I got going on 10GHz. I chose to use the G3PHO "Plumbers Delight" dual mode horn, as this looked like it would illuminate the dish reasonably efficiently, although my dish appears to have a shorter focal length.

The G3PHO design uses waveguide feed with a transition from WG16 to the 22mm copper pipe at the rear of the feed horn. I wanted to build an entirely coax based masthead mounted system, as I already had a Sivers Lab coax relay and all the modules used SMA connectors. It also looked to be easier to engineer the feed to come to the rear of the dish with coax than waveguide, and saved having to find various bits of WG, bends, flanges and transitions. Losses in coax are higher but it looked feasible to keep the cable length short enough to keep within acceptable limits. I ended up using 70cm of Andrews FHJ2 cable for the feeder, with a measured loss of about 0.5dB.

The coax feed design is based closely on the W5LUA dual band feed horn design from Volume 2 of the ARRL UHF/Microwave Projects Manual, optimised for the dimensions of the G3PHO horn.

The diagram, **fig. 1**, on the next page should be self explanatory. Reference to the original article by G3PHO is recommended.

The shorting plate at the end of the 22mm diameter copper pipe is generally to be found in your pocket, and cost the princely sum of £0.01 each! The 22mm pipe is 60mm long and has 44mm exposed beyond the end of the Yorkshire reducer. A piece of brass about 10mm x 10mm x 15mm was filed with a half round file to fit the profile of the 22mm tube. This acts as strain relief for the semi rigid cable emerging from the horn. A 3mm hole was drilled through the middle of this brass block and through one side of the 22mm tube, and they were then temporarily bolted together with a plated steel 3mm screw. The 22mm tube, brass block, and end plate were then silver soldered in place. Silver soldering is more robust than standard tin-lead solder, and because it has a much higher melting point it means that subsequent soft soldering operations on the feed will not cause it to fall apart. When cool the 3mm screw was removed and the assembly cleaned up with wire wool. A 3mm drill passed through the block and tube was gently tapped with a mallet to make an impression on the far wall of the tube, and a 1.6mm hole drilled at this point, then tapped with an M2 thread for the tuning screw. The 3mm hole was opened up to 4mm to accommodate 0.141 inch semi rigid cable. Two examples of the horn were made, one with a cable mounted SMA socket soldered directly to the brass block, the other with a tail of semi rigid cable emerging from the brass block and formed to bring an SMA connector in line with a feeder running along the feed horn mounting arm. The semi rigid cable is soft soldered into the 4mm hole after checking that the feed probe dimensions are correct, with 1.8mm of PTFE dielectric extending into the tube, and

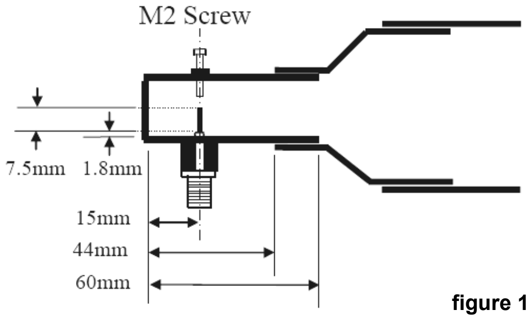


figure 1

7.5mm of inner conductor extending beyond the dielectric. Use plenty of flux to ensure the solder gets right down to the bottom of the hole. The 22mm tube, the Yorkshire reducer, and the 42mm coupler were then soldered in one operation over our domestic gas cooker. Once cool the assembly was cleaned up as far as possible and the outside spray painted to protect it and make it more neighbour friendly.

A 12mm long M2 screw is used to tune the horn, and should have about 5mm penetration into the tube. The two horns I built were tuned up courtesy of Sam G4DDK's excellent test facilities, but can be set up using a microwave power meter and a circulator and tuning for a minimum on the power meter, as per **figure 2** below. No matter how poor the initial match the TX will see 50 ohms thanks to the circulator. Take care not to look into the horn if using more than a few milliwatts for this.

The first feed horn achieved over 25dB return loss over about 200MHz, and could be easily tuned to 10368MHz. The tests were done before soldering the reducer and coupler so that these could also be optimised. The second horn was soldered to the same dimensions as the first before testing so the only adjustment was via the tuning screw, and achieved 20dB return loss at 10368MHz, with best VSWR slightly higher in frequency. I have not made any measurements of the overall dish gain, but the results obtained so far indicate that it seems to work well.

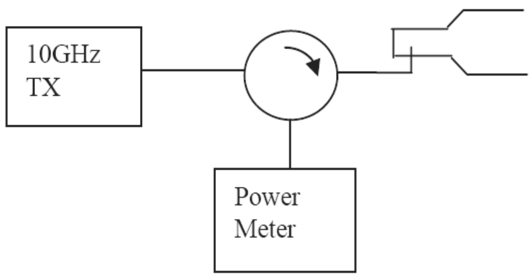


figure 2

3.4GHz Dual Dipole feed

by John Quarmby G3XDY

A description of a dual dipole feed for 2.3GHz suitable for dishes with an F/D ratio of 0.6- 0.7 appeared in Scatterpoint, the UK Microwave Group journal. I have now made a scaled version for 3.4GHz, based on the same principles.

It can be mounted alongside an existing 10GHz feed on an offset fed dish to make a multiband antenna with minimal interaction between the feeds.

On 3.4GHz the beam squint is about 10 degrees off bore sight. This offset has to be taken into account when aligning the dish. The loss due to the offset is about 1dB, so overall gain should be of the order of 24-25dBi for a 60cm dish.

The EIA dual dipole antenna performance as a dish feed is analysed in detail in Paul Wade W1GHZ's excellent online microwave antenna manual at:

http://www.qsl.net/n1bwt/preface.htm

The original 432Mhz feed design is documented in the ARRL UHF/ Microwave Experimenters Manual.
The balun design has been changed to make it more readily realised using UT141/RG402 semi-rigid cable, otherwise the design is scaled directly from the original.

The reflector is made from un-etched double sided glass fibre board, with the dipole elements made from 1.4mm diameter copper wire recovered from old cooker mains cable, and the phasing lines made from 1mm diameter copper wire, all soft soldered in place.
I found that the lengths of the dipole elements had to be extended slightly beyond a half wave to get a good match. With 22.5 mm lengths of wire, the return loss was only about 8dB. Extending them to 24mm improved the return loss to 17dB, equivalent to a VSWR of 1.3:1. No doubt this could be improved by further adjustment but the difference in performance would be hard to see.

I measured the return loss using a reflectometer made from 2 pieces of semi-rigid cable, as described on page 10.14 of the Microwave Handbook, but with an interaction length of about 8mm. In addition to adjusting the length of the dipole elements, the match can altered by squeezing the phasing line sections closer or further apart.

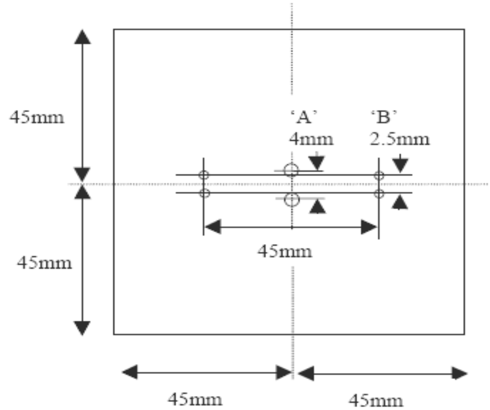
Weatherproofing the feed depends on which way up the dish is mounted. An "upside down" mounting of the dish with the feed support arm at the top means that most of the weather hits the back of the reflector. I just added a piece of Perspex about 60mm x 90mm to the upper edge of the reflector to prevent rain falling onto the upper dipole element. With the dish mounted the other way up then something needs to be mounted over the feed elements to stop water bridging the phasing lines and balun. I found a plastic jar that had contained 500g of mixed nuts that should do the job well.

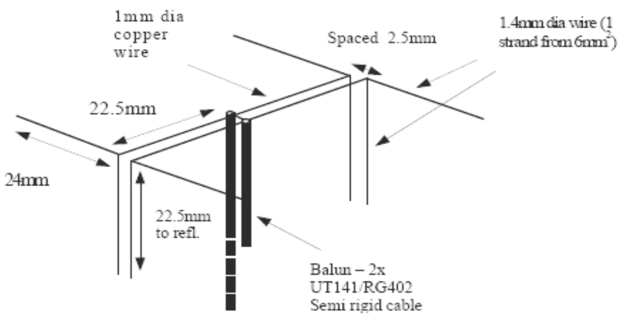
Results have exceeded expectations, with 11 QSOs in the recent UHF contest on one of the least used microwave bands. With the availability of surplus 15W solid state PA s and a new updated transverter design from DB6NT, perhaps we will see a welcome increase in interest in this band.

EIA Dual Dipole dish feed for 3.4GHz

Reflector – 1.6mm double sided copper clad FR4 board 90mm square

Holes A = 9/64" (3.6mm) dia
Holes B = 1.5mm dia





Analysis of the OK1DFC Septum Feed Horn

Paul Wade, W1GHZ

The septum feed[1] was described by Zdenek, OK1DFC, at the 10th International EME Conference 2002 in Prague. On-the-air results were promising, but, like any new antenna, there were questions as to how well it really works. Computer simulations suggest that this feed should work well, and also suggest some variations to allow use over a range of dish f/D. The septum polarizer may also be used to generate circular polarization in other feedhorns.

Description

The septum feed as described by OK1DFC is an unflared square horn, or simply a square waveguide, with an internal stepped septum to generate circular polarization. Figure 1 is a cartoon of a septum feed with one wall cut away. The horn is excited by inputs on either side of the septum, with the two sides exciting opposite senses of circular polarization. For EME, this provides separate transmit and receive ports of opposite polarization. The excitation may come from two rectangular waveguides, each matching the dimensions of one-half of the square horn, or from a perpendicular probe on each side of the septum acting as an integral transition from coax to the waveguide. The two methods should provide identical results provided that the waveguide section before the septum is long enough to suppress any spurious modes.

The radiating element, at the aperture, is simply a square horn. Rotated 45 degrees, it is identical to a diagonal horn[2]; if the diagonal horn is excited with circular polarization, then the radiated pattern should be identical. N7ART has shown[3] the diagonal horn to be a good feed, so we might expect the septum feed to be also.

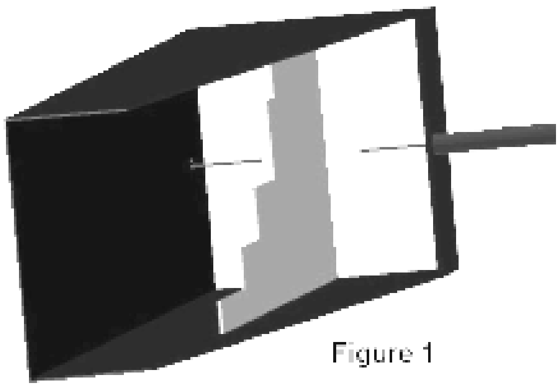


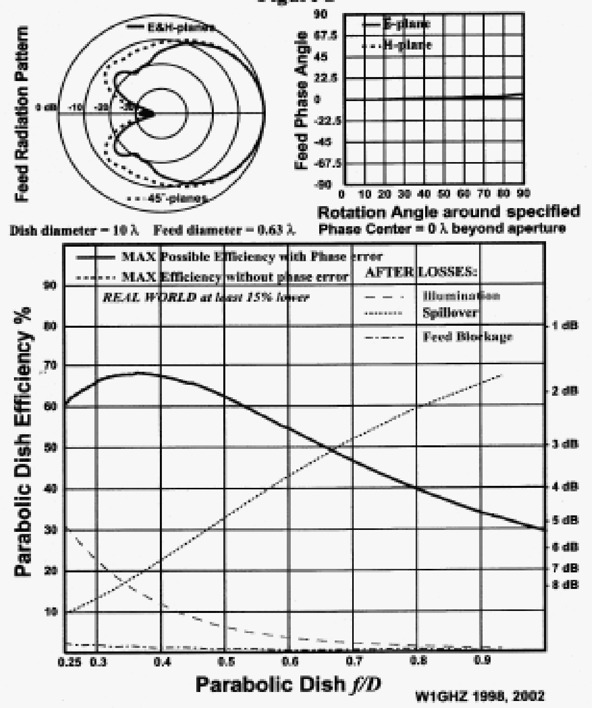
Figure 1

The version described by N7ART used phased crossed dipoles to generate circular polarization. The septum could be a better way to generate circular polarization.

The septum is a bit more complicated. A circularly polarized wave entering the aperture may be considered to have two polarization components with a 90º phase difference, one parallel to the septum and one perpendicular. The parallel component is divided equally by the septum and passes to the two rectangular input waveguides. The cut-off frequency for the perpendicular component is changed by the septum, so that the wavelength for the perpendicular component is shorter. Thus, the electrical length of the septum is longer for the perpendicular component than for the parallel component; if the difference in length is ¼ l, or 90°, then the horizontal and vertical components arrive in phase at the input. The components add together on one side and cancel on the other, depending on the sense of circular polarization, so that the two ports are isolated from each other. In order to achieve the difference in electrical lengths in a reasonable physical distance, the septum polarizer operates near the cut-off wavelength of the waveguides.

OK1DFC Septum feed for 1296, 0.63λ square, RHCP

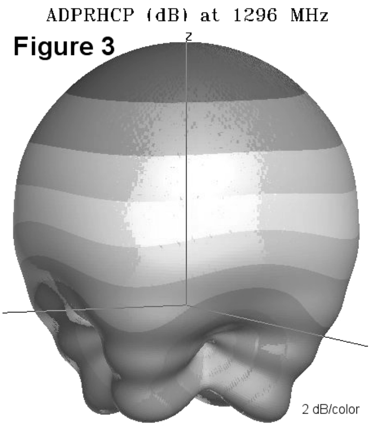
Figure 2



Simulations

A septum feed for 1296 MHz with dimensions specified by OK1DFC was simulated using Ansoft HFSS software[4]. The calculated radiation patterns in Figure 2 show the broad illumination expected of a small horn. Like other open waveguide feeds, the rear lobes are relatively large, only about 12 dB down, reducing the calculated efficiency to about 68% with best f/D around 0.35 to 0.4. Patterns for right and left hand circular polarization are pretty much identical. Patterns were calculated for both probe excitation and rectangular waveguide excitation; they were very similar, so the distance from the probe to the septum is adequate.

The circularly polarized pattern of the septum feed, shown in 3D in Figure 3, shows side lobes on the four corners like the diagonal horn, generated as the polarization vector passes through horizontal and vertical polarization in the square horn. The side lobes on the corners reduce the calculated efficiency by perhaps four percentage points compared to a calculation using only the traditional horizontal and vertical pattern cuts.



The circular polarization is quite good, with cross polarization about 21 dB down, and the pattern circularity is good. Isolation between the two ports is about 24 dB at 1296 MHz, with reasonable bandwidth, showing good isolation from at least 1.2 to 1.4 GHz. Note that reflection from the parabolic reflector reverses the circular polarization, so that the reflection coming back into the horn will reduce the isolation.

While the calculated efficiency of this feed is not as high as some, the better ones have a larger blockage shadow, so the septum feed may be the best performer on a small dish where circular polarization is required

Other f/D dishes

The diagonal horn may be tailored to illuminate a various f/**D** by varying the dimensions of the diagonal section, or by adding a flared section for larger f/**D**.

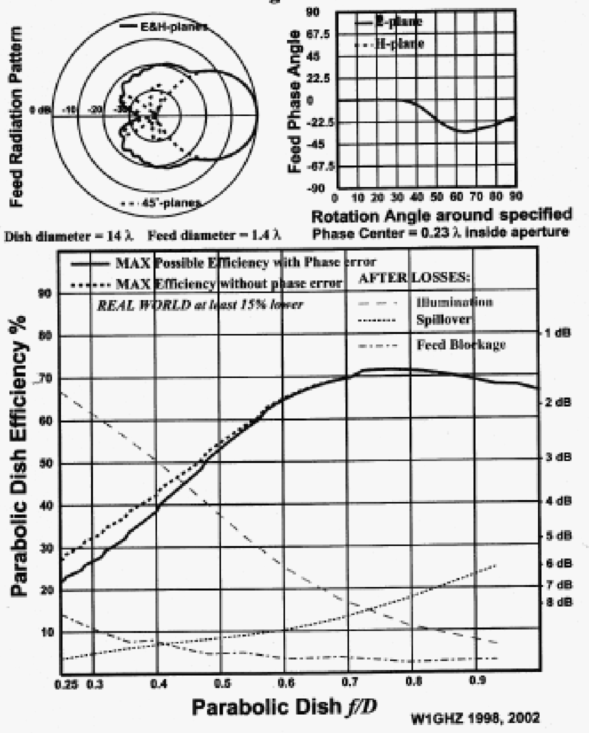
Since the operation of the septum in generating circular polarization depends on the guide dimensions being close to the cut-off wavelength, the square cross-section is fixed at 0.63l for a given operating frequency.

However, a flare section may be added to increase the aperture size to optimize the horn for any larger f/**D**, so that the septum feed may be used for any dish with f/**D >** 0.3. The flare section is similar to a rectangular waveguide horn, except that it should maintain a square cross-section with a gentle taper to prevent excitation of unwanted modes.

I first tried a adding a flare section with an aperture 1.4l square and a flare angle of 30° (15° half angle on each side of the septum), since this size diagonal horn with linear polarization is a good feed for an offset dish with an equivalent f/**D** around 0.7. With the septum feed generating circular polarization, the calculated efficiency in Figure 4 is high with best f/**D** is around 0.7 to 0.85, suitable for many offset dishes.

OK1DFC Septum feed with flare to 1.4λ square at 1296, RHCP

Figure 4



This horn also had high rear side lobes on the corners, so that the 3D pattern in Figure 5 looks like a rocket with fins. An intermediate size flare, with an aperture 1.1l square, produces the radiation patterns with high calculated efficiency at intermediate f**/D**, best around 0.5 to 0.6, and less pronounced corner lobes.

Both flared septum horns show good isolation and cross-polarization. Since horn beamwidth is inversely related to aperture size, we can choose an appropriate aperture for the flare for any f**/D** by interpolating between the results for the three sizes above, 0.63l square, 1.1l square, and 1.4l square.

For smaller apertures, the flare angle should be small so that the flare length is reasonably long.

Summary

The septum feeds are impressive — a feedhorn with good circular polarization performance with no adjustments and no phasing losses. The simple square cross-section described by OK1DFC is ideal for low blockage on small deep dishes, while a choke may be added for better performance on larger dishes. A flare section to increase the aperture will better illuminate shallow and offset dishes. The septum polarizer can also be used in cylindrical horns like the VE4MA feed. More information is available on the OK1DFC (www.qsl.net/ok1dfc) and W1GHZ (www.w1ghz.org) web pages.

References

1. Zdenek Samek, OK1DFC, "Feed for Parabolic Dish with Circular Polarization," 10th International EME Conference 2002, Prague, 2002. www.qsl.net/ok1dfc
2. A.W. Love, "The Diagonal Horn Antenna," Microwave Journal, March 1962, pp. 117-122. (reprinted in A.W. Love, Electromagnetic Horn Antennas, IEEE, 1976, pp. 189-194.)
3. R. Miller, N7ART, "A 23cm Diagonal Waveguide Feed," DUBUS, 2/1997, pp. 514.
4. www.ansoft.com

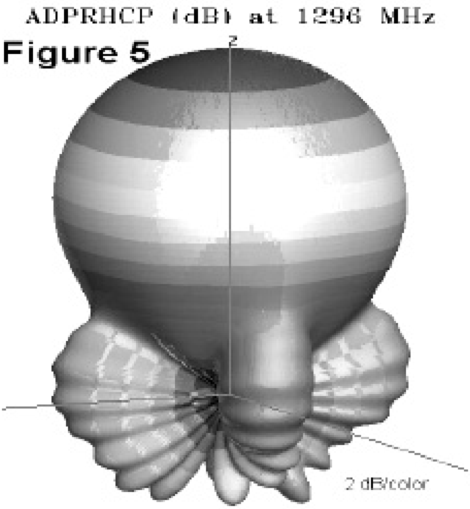


Figure 5

G4ALN Waveguide Feed ReVisited

Paul Gaskin, G8AYY

This popular feed was originally described in Radio Communication, October 1976, 'Microwaves' p757 and was intended for used with short focal length dishes with an f/D in the region of 0.25-0.3. The use of an old penny coin for the disc on 10GHz came later. The width of the ë/2 slots was specified as ~ ë/20. It was claimed that the length of the slots, and also the diameter of the disc, were probably not critical within a few per cent and the width of the slots even less so. This seems to overlook the fact the slots are located next to the reflector disc (splash plate) which theoretically has zero electric field strength at its surface in the waveguide. This could make the width of the slot quite critical. Matching screws or a sliding sleeve was suggested to improve the match but no thickness was actually specified for the disc which could be important.

The G4ALN 'penny' feed became popular with the 45 cm PW (Practical Wireless) dish, f/D 0.28, introduced in 1981 for a 10GHz project, and also other prime focus dishes, but did not always work as well as it should have done. I had two different versions of the 'penny' feed in 45cm PW dishes available for tests and found that one version did not work as well as the other with a Solfan head although it had the specified ë/20 slot width and an adjustable feed point position.

This 'penny' feed was modified as part of an investigation into its performance. The 1mm thick brass disc was replaced with a thicker brass disc which was silver plated and the width of the slots was increased. The new disc was soldered to the wave guide, with heavier soldering at top and bottom for strength but fillets of solder were avoided near the slots in the broad faces.

There was an improvement in performance which suggests that the problem could have been caused by the lack of matching screws and or the illumination of the dish.

My version of the 'penny' feed seems to work well, is capable of being sharply focussed and cannot be improved with matching screws. The 2.5 mm thick discs were cut from an old silver plated brass chassis and filed to match an old penny in diameter. The waveguide slots were experimentally increased to 5mm (~ëg/8) width which seems to give good illumination and matching. The clean silver plating on the 31 mm diameter discs probably improves their efficiency as reflectors.

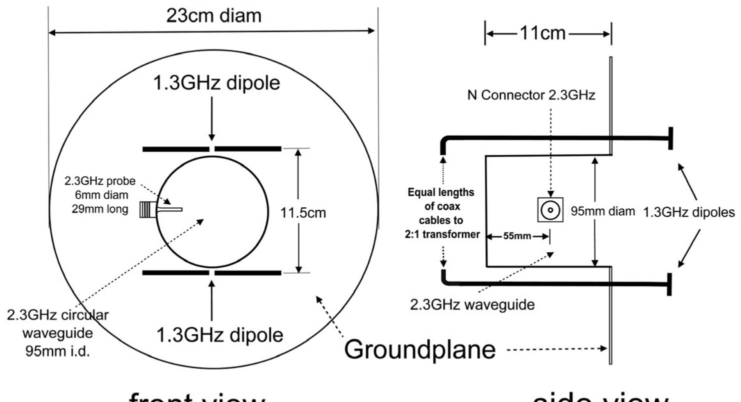
Versions of the G4ALN feed have produced for the 5.7, 24 and 47GHz bands also (reference RSGB Microwave Handbook Volume 3). They all use the ë/20 slot width and it is suggested that it may be worthwhile increasing these slot widths also. Incidentally if anyone is thinking of using an 'English' silver coin as a disc then he should be aware that British 'silver' coins have been made of cupro-nickel alloy since 1947.

A Dual Dish Feed for 23cm and 13cm

by Peter Blair, G3LTF

The diagrams that follow are self-explanatory. A copper or brass disc, 23cm diameter, is soldered to the outer lip of a 95mm i.d. copper or brass tube (or suitable soup can! ...editor). The tube forms a waveguide feed for the 2.3GHz amateur band while the disc becomes the reflector for a pair of 1296MHz dipoles. The rear of the copper tube is, of course, blanked off. A 29mm long probe made from 6mm brass rod or tube is soldered over the end of an N socket centre conductor and the resultant assembly is fixed to the 2.3GHz feed horn so that the probe is 55mm from the horn's back plate and in the horizontal polarised position as shown in the first diagram. That is the 2.3GHz (13cm) section of the dual feed completed.

The 1296MHz feed consists of a pair of stacked dipoles, each made as shown in the second diagram on the next page. They are mounted so that they are in front of the 2.3GHz feed-horn and critically spaced from the circular reflector or ground plane.

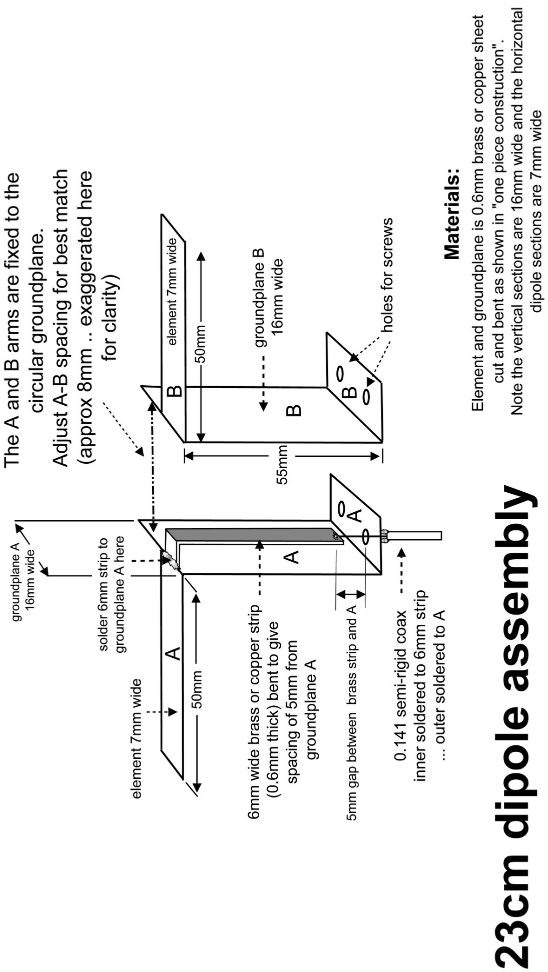


G3LTF Dual Band Feed for 23cm and 13cm

Identical lengths of UT141 semi rigid coax, terminated in sma connectors and fed from the main 1296MHz feedline (e.g. heliax or similar) via a 2:1 transformer (see final diagram), are fixed through the ground plane and rigidly mounted to it. By varying the centre spacing between each arm of each dipole, as shown in the third diagram, a good match can be obtained.

This feed has been very successfully used for several years on a 2m diameter dish whose f/D is 0.5.

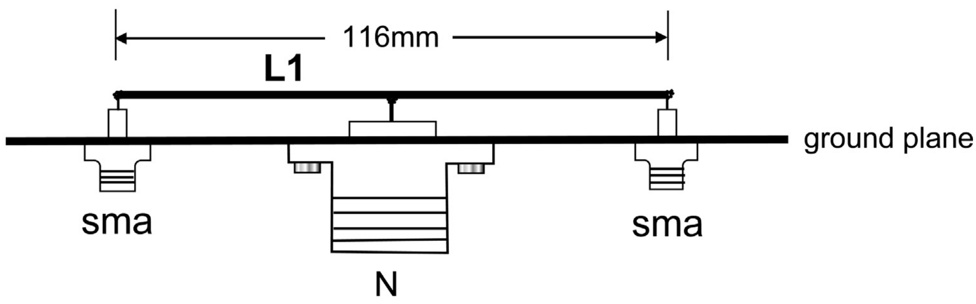
The feed can be suitably protected from the weather by the judicious use of plastic boxes and sealing compound.



2:1 transformer

(enclose in suitable waterproof box)

L1 : 13mm wide copper or brass strip spaced 5mm over ground plane



Analysis of the G3LTF Dual Band Feed for 23cm and 13cm

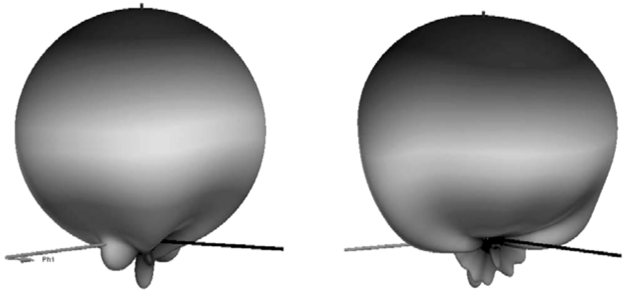
Paul Wade W1GHZ

G3LTF described has described **(1)** a dual band feed for the 23 cm and 13 cm bands. The feed is a combination of two proven designs: an EIA dual-dipole feed for 23 cm, with a cylindrical waveguide horn, or "coffee-can," feed for 13 cm. The dipoles are backed with a 1λ diameter GP (ground plane); the cylinder fits in a hole in the centre of the GP, so that the GP acts as a flange at the aperture of the cylinder. Each dipole is fed with a stripline balun arrangement from a remote power divider, and the cylindrical waveguide is excited by a probe.

Taken separately, each feed is known to work well; radiation patterns and calculated dish efficiency may be found in the W1GHZ Microwave Antenna Book — Online **(2)**. What remains to be seen is how well the combination works. Is the dual band feed as good as the individual feeds, or are there unexpected interactions that spoil the performance?

The radiation patterns were calculated using Ansoft **HFSS** software **(3)** and plotted in 3D in Figure 1. Performance as a dish feed was estimated using my **PHASEPAT** software **(2).** The calculated dish efficiency at 2304 MHz is very good, as shown in Figure 2. Best **f/D is around 0.5, just** right for the two-meter diameter dish at G3LTF. The phase centre is 0.07λ beyond the aperture of the cylindrical horn, or about 9 mm above the GP. Since the phase centre is most critical at the higher frequency, the 1296 MHz dish efficiency in Figure 3 is calculated at the same phase centre (best phase centre at 1296 MHz would be 0.14λ above the GP). Efficiency is also very good, with only a tiny phase error due to the phase centre compromise. Best f/D is again around 0.5, so this is a good feed on both bands for the G3LTF dish.

Figure 1

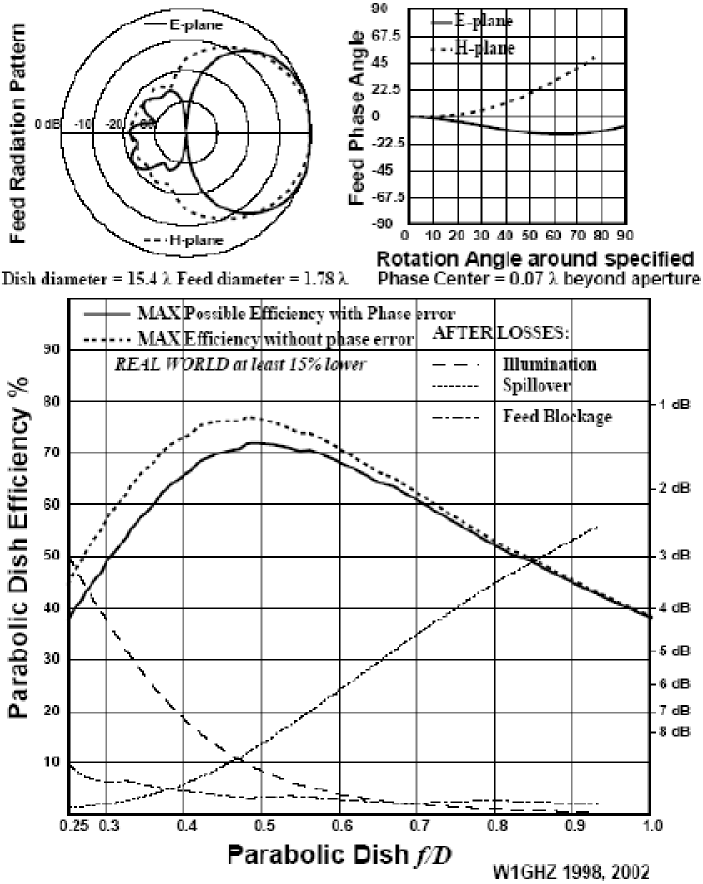


1296 MHz 2304

Since the two dipoles for 23 cm are fed separately, it is important to keep them in phase, by using a good power splitter and identical cables. Figure 4 illustrates the radiation pattern resulting from feeding the dipoles 180º out of phase — the beam splits into two lobes with a null in the centre.

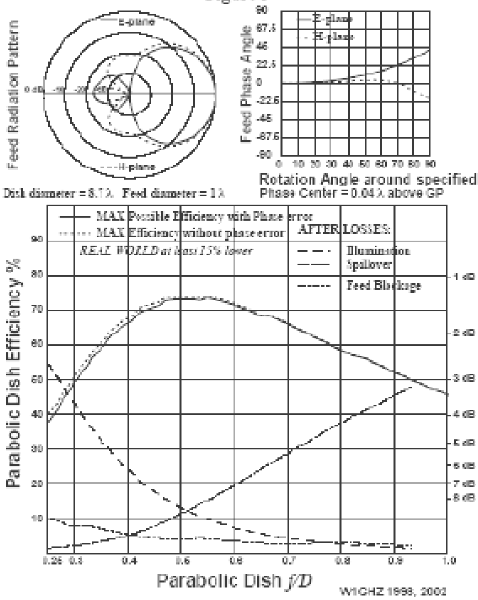
G3LTF L&S Dual Band Feed at 2304 MHz

Figure 2



G3LTF L&S Dual Band Feed at 1296 MHz, 13cm Phase Center

Figure 3



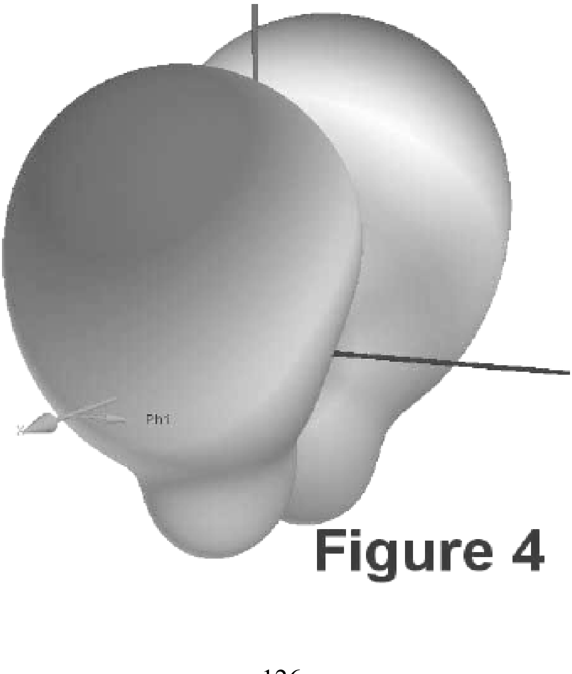


Figure 4

Isolation is always a problem with multi-band feeds. The 13cm cylindrical waveguide is beyond cut-off at 23cm, so isolation at 23cm is better than 30 dB. At the higher frequency, there is nothing to isolate the two feed except spacing, so the isolation at 13cm is on the order of 20 dB. At any reasonable power level, additional protection will be necessary.

References:

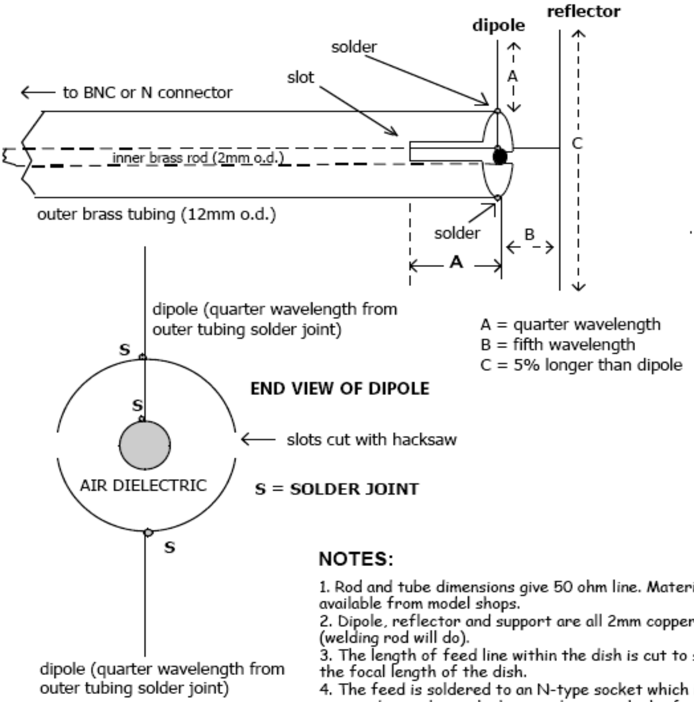
1. Peter Blair, G3LTF, "A Dual Dish Feed for 23cm and 13cm," RSGB Microwave Newsletter, March 2004, pp. 7-8.
2. www.w1ghz.org
3. www.ansoft.com

A Simple Dish Feed For The Middle Microwave Bands

by Mike Parkin , G0JMI

The feed shown in Fig.1 is used at this station on the 6, 9 and 13cm bands. Its most useful feature is its simplicity. The dipole driven element is merely soldered to the supporting brass tube, which in turn forms the feed line. The quarter wave slots form stubs that ensure the dipole is effectively mounted at the end of a quarter wave line.

Figure 1: Plan view showing tubular feedline and wire elements



NOTES:

1. Rod and tube dimensions give 50 ohm line. Materials available from model shops.
2. Dipole, reflector and support are all 2mm copper wire (welding rod will do).
3. The length of feed line within the dish is cut to suit the focal length of the dish.
4. The feed is soldered to an N-type socket which is mounted on a plate which is used to attach the feed to the dish (at its centre).

Improving the Dual Band 10 & 24GHz Feed Horn for Offset Dishes

Paul Wade, W1GHZ

Operating multiple bands in the 10GHz and Up contest is difficult with separate antennas … after locating a station on 10GHz and peaking the dish, we must start over on a higher band, usually with a narrower beamwidth. Using a dual-band feedhorn for 10 and 24GHz would very attractive; the dish may first be pointed and peaked up on 10GHz, then switched over to 24GHz with no repositioning required.

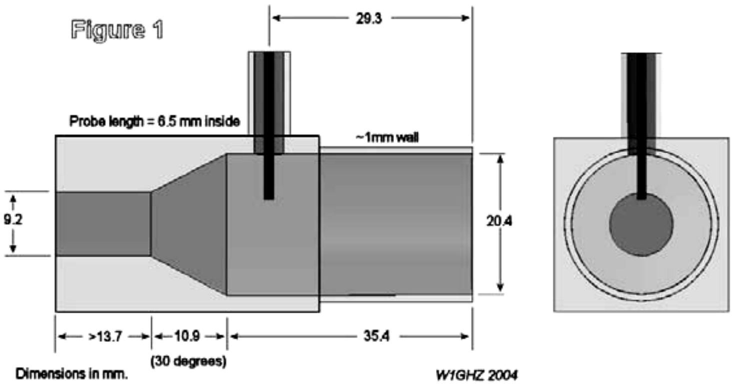
At Microwave Update 2001, Gary, AD6FP, and Lars, AA6IW, described (**1**) a dual-band 10 and 24GHz feedhorn for shallow and offset dishes. The design was based on previous work of W5LUA (**2**) and W5ZN (**3,4**) to develop a dual-band feedhorn more suitable for conventional deep dishes.

With the offset dish, we have a distinct advantage – the equipment may be located very near the feedhorn without being in the radiation pattern, minimizing the large feedline losses at the higher microwave frequencies without decreasing gain. Other advantages include higher efficiency feedhorns, less critical focusing, and the ready availability of modest-sized DSS dishes with good surface accuracy.

Gary and Lars included computer simulated radiation pattern plots which look like potentially good feeds, but did not do dish efficiency calculations. However, they did include more important results – sun noise measurements and on the air performance! To calculate efficiencies, I took the published dimensions and re-simulated. The results were good, so I wanted to make a feed.

Dual band feedhorn operation

The basis of the dual-band feedhorn design is the W2IMU dual-mode feedhorn (**5**), dimensioned to feed an offset dish at 24GHz and excited from the rear with a circular waveguide section. For 10GHz, an excitation probe fed by an SMA connector is added on the side



of the output section of the dual-mode horn. The tapered section of the dual-mode horn acts as a closed end at 10GHz, so that the output section behaves like a simple "coffee-can" feed at 10GHz. **Figure 1** is a sketch with the dimensions I used.

While the 24GHz dual-mode horn has a pattern suitable for an offset dish, the simple 10GHz horn has a much broader pattern**,** better suited to a deep dish, so it would have a lot of spill over feeding an offset dish. AD6FP improved the 10GHz performance by adding a conical horn to narrow the beam, and AA6IW enhanced it further by using a corrugated horn.

The dual-mode horn is intended to eliminate edge currents in the rim of the horn, so the addition of the conical horn outside the rim has a much smaller effect at 24GHz. By varying the horn dimensions, it might be possible to make the patterns and efficiencies very close on the two bands. I had four different corrugated horns on hand, so I tried simulating with each of them. Results were promising, so I bored out the circular waveguide end of each horn on my lathe so that it could be slipped over the end of the dual-band horn.

Construction

Gary and Lars built their horns with copper plumbing and hobby brass, soft-soldered together. I tried this construction, but wasn't happy with the dimensional accuracy, and it certainly didn't feel robust enough for rover operation. Then I experimented with turning the tapered section out of solid brass but found it difficult to get the taper right. Finally, I ran out of time before the 2003 contest and simply used a 25dB horn on 24GHz; at least it was easy to point.

Last fall, I was browsing through a tool catalogue from MSC (**6**) and found some 60º countersinks (normal is 82º or more). This would make a 30º flare angle for the tapered section, while Gary and Lars used my HDL_ANT program to calculate a 27.8º taper angle. The 60º countersink would be an easy way to machine a 30º taper, but is 30º close enough to 27.8º ?

I simulated the horn with 30º taper using Ansoft HFSS software (**7**). The rear lobe is a couple of dB worse than with the 27.8º taper, but the calculated efficiency of 76% is close, and the best f/D is about 0.7, just right for a DSS offset dish. At 10GHz, calculated efficiency is still good, about 70%, but best f/D is about 0.38. At the 0.7 f/D needed for an offset dish, efficiency is down to about 47%, or nearly 2dB worse. A few additional trials at 24GHz suggested that a slightly longer output section might be a little better, if the countersink were long enough, but the improvement was not significant.

Another problem is that the nearest countersink size is 3/4 inch, or 19.05mm. I simulated with the inner diameter of the output section reduced from 20.4 mm. This change did not work well at all — the larger diameter is required.

The other mechanical problem is robust feedline attachment: WR-42 waveguide for 24GHz and an SMA connector for 10 GHz. Using brass or copper for the feedhorn would allow soldering, but both are heavy and expensive. Turning the feed from aluminium rod was the best choice, but the size would have to be large enough for the WR-42 hole pattern: 7/8" square, or 1.25 inch diameter. I found that 1" square aluminium was readily available in short lengths, so I ordered some, along with a 3/4" 60º countersink. After a couple of hours with the lathe, my first attempt is shown **in Figure 2.** The machining was possible, but the 3/4" countersink diameter is smaller than the 20.4 mm inner diameter that a small shoulder was left. I fiddled with a

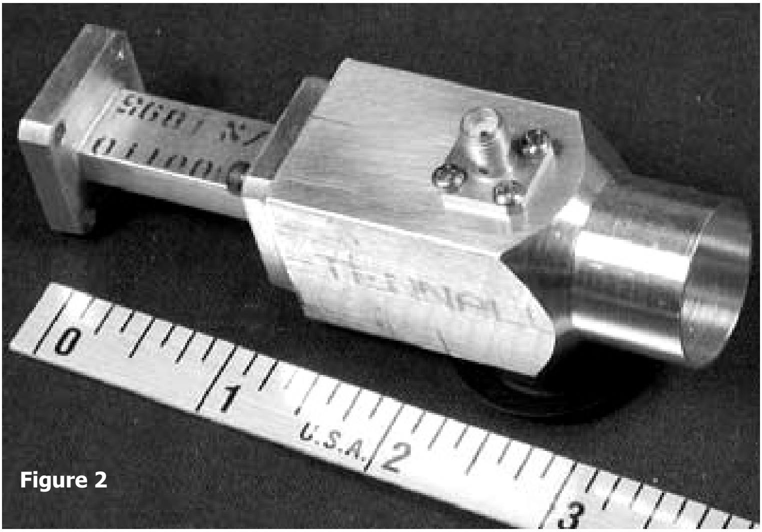


Figure 2

boring bar to minimize the shoulder so that I could at least measure the VSWR and make sure I was on the right track. Some improvement was necessary to make a proper taper. Matt, KB1VC, attempted to make a custom cutting tool, but the results were not encouraging – the counter-sink is clearly the right tool. I went back to the MSC catalogue and found a 7/8″ countersink, slightly oversized. The HSS tool steel is too hard to cut with ordinary tooling, so I used a tool post grinder to grind the countersink to the exact 20.4mm diameter.
Now we are able to machine the correct taper cleanly.

The basic machining procedure is:

1. Cut a piece of 1″ square aluminium to about 2.6″ long.
2. True up in 4-jaw chuck and face ends.
3. Drill a hole about 1/4″ diameter down the centre, all the way through.
4. Drill 3/4″ diameter about 35 mm deep.
5. Bore out to 20.4 mm diameter. This leaves a small shoulder at the taper.
6. Countersink with 20.4 mm, 60º countersink to form the taper.
7. Turn down outside diameter to leave about 1 mm wall, about 16 mm long.
8. Trim end to leave output section length of 35.4mm.
9. Drill out circular waveguide diameter to 9.2mm diameter.
10. Mark out WR-42 holes in back end, drill and tap 4-40 thread.
11. Mark out and drill SMA holes in one side, with centre 29.3 mm from open end.
12. Tap mounting holes for SMA 2-56 thread.
13. Clean up and degrease.
14. Fit SMA.

Figure 3: The countersink

Corrugated horns

The four corrugated horns I have ready to try are shown here in **Figure 4**.

I simulated the feedhorn with each of these, as well as with a plain conical

Figure 4:

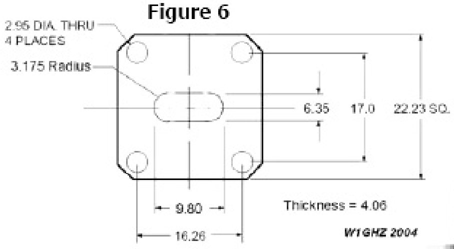
horn. Patterns and calculated efficiencies are shown in the following figures at 24GHz, and at 10GHz with the phase centre at the best location for 24GHz.

The calculated efficiencies and phase centres are summarized in the table below**. (Fig 5)** At 10GHz, efficiencies are listed at the 24GHz P.C. (phase centre) as well as the optimum, assuming that the feed position would be more critical at 24GHz. Phase centres are measured from the centre of the aperture; negative numbers are inside the horn. All of the horns improve the performance at 10GHz while maintaining high efficiency at 24GHz. However, the best f/D and the phase centres for the two bands are not the same. The best choice appears to be the Chaparral horn, with phase centre differing by only 1.3 mm, so that the optimum position for 24 GHz is only 0.04λ off at 10GHz. The result is excellent calculated efficiency for both bands, 76% at 24GHz and 74% at 10.368GHz. This is comparable to the best single band feeds – a dual-band feed that does not compromise performance.

To make machining easier, a radius was added at the corners, and increased until the ends are simply 1/4 inch diameter; a slight increase in the wide dimension was required for the same impedance. The matching section improves the measured VSWR to about 1.05.

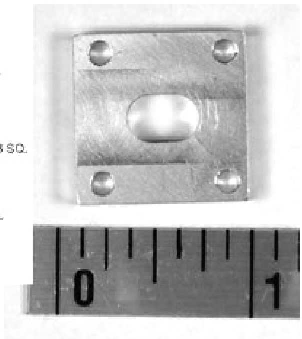
Figure 5:Dual band 10&24 GHz Feed - Calculated Horn Performance

	24GHz			10GHz			Offset f/D=0.7 at 24GHz P.C.	
HORN	Effciency	f/D	Phase Centre	Efficiency	f/D	Phase Centre	24 GHz	10 GHz
none	76%	0.72	1.2 mm	71%	0.38	0 mm	76%	47%
Conical	76%	0.8	-26	67%	0.7	-31.2	74%	66%
RCA	75%	0.93	-24.8	77%	0.7	-5.8	69%	68%
Chaparral	78%	0.81	-23.6	75%	0.65	-24.9	76%	74%
CD-80	77%	0.88	-29.1	78%	0.76	-4.9	68%	65%
Surplus	79%	0.8	-6.2	76%	0.7	-22	77%	70%



WR-42 Matching Section

Figure 6



I believe European 24GHz operation is at 24.048GHz; VSWR there is about 1.04. Adding the various corrugated horns to the basic feed has only a small effect on the VSWR on either band.

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2. Al Ward, W5LUA, "Dual Band Feed-horns for 2304/3456 MHz and 5760/10368 MHz,"
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3. Joel Harrison, W5ZN, "W5ZN Dual Band 10 GHz / 24 GHz Feedhorn,"
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4. Joel Harrison, W5ZN, "Further Evaluation of the W5LUA & W5ZN Dual Band Feeds,"
5. Proceedings of Microwave Update 1999, ARRL, 1999, pp. 66-73.
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(reprinted in A.W. Love, Electromagnetic Horn Antennas, IEEE, 1976, pp. 214-215.)
6. www.mscdirect.com
7. www.ansoft.com
8. www.w1ghz.org

EDITORS NOTE: Paul's article has been somewhat shortened for BackScatter purposes. The complete article, including computer analysis charts of the horns, can be downloaded from Paul's excellent website as listed in reference 8 above.

Using Surplus "Digi Dishes" at 10GHz

by John McCarthy, G7JTT

So far, using the G4JNT beacon, as a source, I get about an S1 signal with a 18" penny feed dish and a S5 with the digi dish shown in the photo on the left. I tried it with a G3PHO type dual mode feed but only got about an S1, the same as the penny feed. I then tried the 22mm open feed and got about S3 then tried various LNB feed horns and found one that got me an S5.

The feed is off an old, unbranded LNB . It is 63mm diameter at the open end down to 22mm copper at the other end.

There are 4 rings inside, with an average depth of about 6mm. The length is about 37mm and the copper feed enters about 5mm into the horn to give an SWR of about 1.4:1. As to the position of the feed, it is 330mm from the top of the dish to the centre of the horn's face and 230mm from the bottom. It is pointed to the centre of the dish.

The gain seems to be in the order of about 4 "S" points above an 18" penny feed dish and about 5 "S" points above a 20db horn. It's also much sharper than either the penny feed or horn, about 36 degrees from no signal to no signal. There seems to be at least two types of dish, I have one type (Channel Master) and my friend Noel, G8GTX, has the other (made by Grundig), so, over the next few months, we will see how they differ As to shape, the dishes differ quite a bit … mine had the LNB with a swept back elliptical horn where as Noel's is a straight forward round feed.

At the Adastral Park (Martlesham) Microwave Round Table meeting this month, the following measurements were made on the antenna test range. The dishes appear to outperform the ubiquitous PW type with 'penny' feed.

CALLSIGN	DISH TYPE	GAIN (dBi)	COMMENTS
G7JTT	Channelmaster mini-dish with tubular horn feed	30.3	One of the popular digital Sky dishes. About 42cm wide
G8GTZ	Grundig Sky mini-dish with G3PHO/ W2IMU feed	30.3	Also one of the popular digital Sky dishes. About 42cm wide

Other Antennas

Designing Log Periodic Antennas

Kent Britain, WA5VJB

Over the last few years, I have developed 4 Log Periodic antennas from 50MHz to 6GHz. I wish I could say I have a secret design process, but there were many variations and metal tape on the early models. And while there are software programs such as IE3D than can analyze a log periodic antenna on a dielectric surface, I do not know of any programs that can design such an antenna. And as commercial antenna go, this is a poorly performing antenna.

Instead of a flat -10 dB Return Loss, these antennas have dips, at 2.3, 3.4, and 5.7 GHz. As a radio amateur, I am willing to loose a little performance outside the call frequencies for better spot performance on the call frequency.

If you would like a copy of the PCB file in Tango format, just send me an email at WA5VJB@FLASH.NET I'm sorry, but I only have the PCB file in Tango.

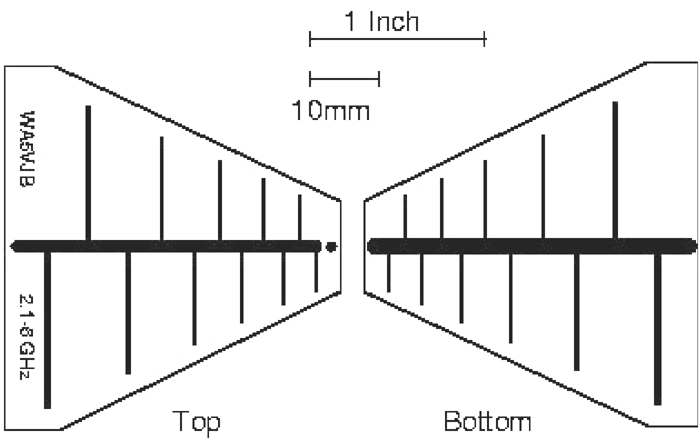
And now for a few of the problems designing PCB Log Periodics.

PCB Asymmetry

A Copper trace resting on a dielectric has a velocity factor. That is, a 1/2 wave dipole is shorter resting on Fiberglas than it would be in free air. While the textbooks give you the velocity factor for a stripline over a ground plane, this is not over a ground plane! But it turned out to be close to the velocity factor of a normal stripline, about 60%. However that is in just one direction. While the elements are about half their expected length, the element to element spacing is only reduced about 20%. So you cannot simply scale a free space Log Periodic by the PCB velocity factor and expect it to work well. As they say, "Been There, Done That"

PCB Dielectric Constant

I also learned the hard way that the dielectric constant of most PCB materials vary with frequency. So while FR-4 type materials have a dielectric constant (Er) of 4.2 to 4.4, it can drop to 3.9 at 2GHz, and even lower at



higher frequencies As you move up in frequency, the relative thickness of the material increased. At 900 MHz the PCB thickness (1.6 mm) is about .5% the length of the element. By the time I was up to 6GHz, the PCB material was up to 8% of the element length. So the Fiberglas dielectric has an ever increasing effect on the lengths of the elements, and companies just don't publish the Er of their non-Teflon PCB material above 1 GHz.

Booms

The velocity factor of a stripline varies with its impedance. That is, the wave travels at different speeds for wide lines and narrow lines. When the transmission line is soldered to the antenna, that side of the antenna effectively has less inductance and a higher velocity factor. You really don't want the waves travelling at different velocities on the opposite sides of the antenna! So the line trace on the transmission line side has been narrowed to allow for the effects of soldering on the coax.

Coax

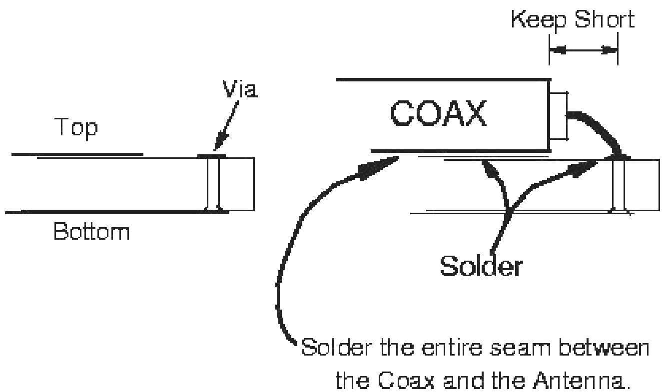
The 900-2600 MHz version works well with either .141" semi-rigid or the smaller .085" coax. But the 2.1 - 6GHz versions get unbalanced with a really thick coax going down the boom. I recommend using either .085" semi-rigid coax on the 2.1 - 6GHz antenna or one of the Teflon RG-174 style coax with a diameter of less than .1 inch, or 2.5mm. The coax only needs to be a millimetre longer than the antenna, then you can transition to 7/8" Heliax? if you like. Keep the free tip of the coax as short as possible, and the shield as close to the via as practical. This improves phasing, especially at 6cm.

Grounding via at the back of the Log Periodic

Designing a Log Periodic to be grounded at the back of the boom helps solve many problems.
The entire antenna is at DC ground and many low frequency response problems are eliminated. In high EMI areas, ungrounded LP's can allow many VHF signals to become intermodulation sources. Removing the via will lower the lowest usable frequency slightly, but introduce many new resonance's into the antenna. Removing the back grounding via is not recommended.

Power

I wish I could test one of these antennas to destruction, but I just do not have enough power. At 900MHz, the antenna has a relatively large active



area and could probably take 100 watts for short periods of time. As you go up in frequency, the active area gets smaller and smaller, and the dielectric loss goes up. At 6cm, the max power is probably in the 10 to 20 watt range. I am expecting some feedback from local EMEers.

Phase Centre

The phase centre is the point on the antenna that does the radiating. On an LP style antenna, the phase centre moves along the antenna as the frequency changes. Counting Elements from the small end, the 6 cm phase centre is about element #3. 9cm is about element #6, and 13cm is about element #9. One effect of the dielectric is the compression effect on the antenna, making it physically smaller. While the antenna has less capture area, the phase centre does not move as much as it would with a Teflon or air dielectric design.

Why didn't you build them on Teflon?

The short answer is money. If you know a PCB house that can make double sided PCBs with plated through holes from CAD files for less than $500 a panel, let me know! Also, I cannot use the current artwork. The elements will get about 20% longer, the element to element spacing will increase about 10%, and the asymmetrical booms would change. Both the 900-2600MHz and 2.1 - 6GHz versions went though the PCB house 3 times before I was happy, and a Teflon version would probably make several trips too. So a Teflon version would easily cost $2000 for me to develop.

As a Dish Feed

A Log Periodic is a compromise dish feed. How far down it is from an optimised feed depends on many factors, f/d, frequency, etc. But in general, a 3ft dish with an LP feed has about as much gain as a 2.5ft. dish with an optimised feed, and during contests you only have to carry one antenna. Mount the LP with the phase centre of the highest frequency you plan to use at the focus of the dish. The lower frequencies are slightly beyond the best focus point, but the loss is usually less than a dB. Also the dielectric compresses the antenna, so the phase centre does not move as much as it would with Teflon or an air dielectric Log Periodic.

The Flyswatter Microwave Antenna

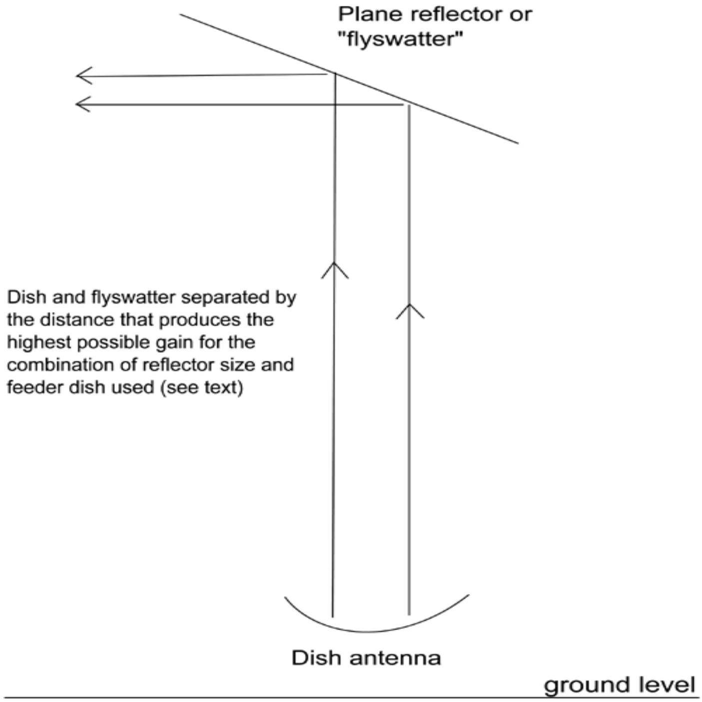
Peter Day, G3PHO

including notes from Doug, GW3ATM

In an effort to develop a decent 10GHz home station antenna system, Doug, GW3ATM, has turned to the Flyswatter Array. Pioneered many years ago in the UK by Mike Walters, G3JVL and Dain Evans, G3RPE, it does not appear to have received the attention it deserves. When correctly set up, the system offers a very good performance, often comparable to a moderately sized dish antenna at the same height.

Many of us have problems erecting a dish at a reasonable height because the most efficient way of feeding it usually involves having the microwave transverter either immediately behind or just below the dish and effectively out of reach for easy access.

The associated weatherproofing problems deter many folk from using this approach. Feeding the antenna via a long length of waveguide is another alternative but this usually means having some sort of rotary waveguide joint at the base of the waveguide and using a length of flexible waveguide or coax section to get around the rotator.



Losses are necessarily greater when this latter method is employed.

The flyswatter antenna uses a very low loss feeder … air!

Basically, the microwave transverter is placed at or near ground level, where it can easily be adjusted and even taken indoors during periods of non activity.

Some distance directly above the transverter is a plane reflector, angled so that the radiation from the transverter's antenna (which is conveniently a small dish or even a horn) is reflected out horizontally to the surrounding area (see diagram right). The lower antenna doesn't need to be exactly underneath the plane reflector as the angles involved can easily be adjusted to compensate for any deviation from the vertical.

Small offset fed dishes provide excellent feed antennas for flyswatter systems since the transverter and its feedhorn can be mounted so that they do not point up into the sky from where they might get an input of rain during bad weather. They also tend to be more efficient than rear fed dishes using, for example, the "Penny" feed. The distance between the dish and the plane reflector is effectively a compromise based upon the relative gains of both dish and reflector (which in turn are a function of their physical dimensions). Unfortunately there is not room here to discuss this aspect in the detail it deserves! Paul Wade, W1GHZ, presented a fascinating paper on the subject at Microwave Update , held in Philadelphia, USA in September 2000. The paper can be found in the Proceedings of Microwave Update 2000 (available from the ARRL) and on Paul's outstanding website at: **www.w1ghz.org** . Interested readers should refer to either of these resources.

GW3ATM's flyswatter system consists of a 48cm diameter, ex-BSB, offset fed dish, mounted just above gutter level on a rotary, guyed pole, next to his bungalow. The dish is fed with an ex-Amstrad, sat-TV feedhorn (widely available at rallies). The aluminium, plain reflector is 1mm thick and measures 23 inches by 33 inches. It is fixed 11 feet above the BSB dish. A Sat-TV screw jack, fixed on a bracket on the opposite side of the mast to the reflector, is used to vary the tilt angle of the flyswatter. The pole, dish, plain reflector and transverter are so arranged that they all rotate together. If the dish and reflector did not move together there would be a change in the polarisation of the reflected signal. This problem was clearly demonstrated in Paul Wade's Microwave Update talk, when he used a laser pointer and plain reflector to "beam" the light at the four walls of the lecture room!

GW3ATM places his 10GHz transverter on a small platform, mounted on the same pole and just below the dish, so that a short and easy connection can be made to the offset feedhorn. Results so far have all been in receive mode only but have been very encouraging.

From his home at Llandogo, Monmouthshire, he can hear the Cleeve Common 10GHz beacon, GB3CCX, at good strength from two directions, via reflections from nearby commercial towers. He cannot hear this directly at ground level. G4UVZ has also been heard and he believes he can just detect the new Dorset beacon, GB3SCX. Doug is looking forward to the coming microwave "season" when he hopes to work many stations several hundred kilometres away. Rain scatter propagation should also provide very interesting results now that the reflector's tilt angle can be remotely adjusted.

The Flyswatter antenna system offers the home station operator a convenient and efficient way of making the most of his or her location.

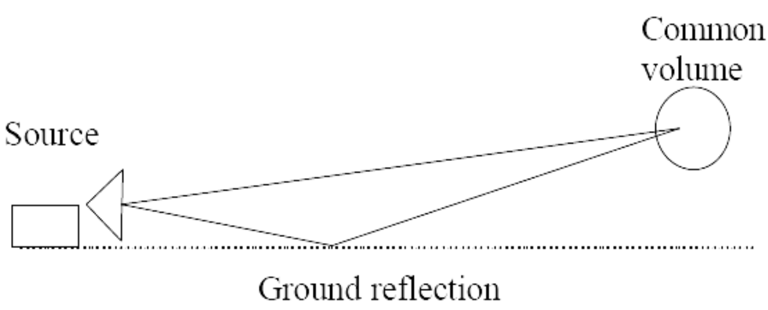
Antenna Measurements at Adastral Park 2001

A report by Sam Jewell, G4DDK

Introduction
Having discussed at RSGB Microwave Committee meetings for several years the possibility of setting up an antenna gain measurement facility I finally ran out of excuses as to why it couldn't be done. So at Adastral Park 2001 I finally got round to setting up a 10GHz antenna range with the help of Kent, WA5VJB, and the loan of some critical items from Simon, G3LQR. I had decided early on that it would have to be limited to just one or two bands because of the sheer amount of equipment needed for each individual band. In this case it would be 10GHz and, time and facilities permitting, maybe also 2.4GHz. By limiting the measurements to one or two bands initially I thought I would be able to manage the logistics better.

The principle of short range antenna measurements has been known for years and antenna gain measurement on all bands from 50MHz to 24GHz has been a regular feature of VHF and Microwave events in the USA for many years. The results of these measurements are often reported in various ARRL publications and specialist newsletters. The principles have also been explained in many of these same publications as well as in a notable article by WA5VJB here in Scatterpoint, issue 1. Instead of trying to fight ground reflections, the normal bane of antenna measurements, the ground reflection is used in the measurement.

When the source is set up close to the ground then a ground reflection will occur, as normal. The direct and reflected rays combine in phase at some distance from the source and an increase in signal level will be observed. The distance can be calculated and then verified by probing this volume of space with the reference antenna. The volume is not too difficult to find and is shown by a volume of approximately 1 metre sides where the signal level does not change by more than about 1dB. In practice it is usually possible to find a common volume where the change is much less than 1 dB. Obviously, the volume



changes with frequency but not enough to be a problem to our measurement set up. Figure 1 shows the ground reflection range with the source antenna close to the ground and the common volume in which the measurements are taken.

The source is set up on 10368MHz and set to an output level somewhere between 10 and 100mW. The signal in the common volume, which is found by probing with the reference antenna, is indicated on the measuring 'receiver'. This level is noted and represents the reference antenna gain. In the case of the 10GHz measurements, the reference antenna was a 16.5dBi gain horn. A horn is used because the gain can be accurately determined from the physical aperture, assuming the flare angle is reasonable etc. The gain of my reference antenna is known to be 16.5dBi at 10.4GHz, from the data sheet anyway!

By substituting the reference antenna with the antenna to be measured (taking care to ensure the feed point of the unknown gain antenna is in the same place as the reference antenna was located when the reference measurement was made) the increase or decrease in signal level can be read off the meter on the 'receiver'. The gain of the unknown antenna is then the reference antenna gain plus or minus the difference on the meter in dB. Simple!

The problems

As you might expect there are some catches….

A power meter such as the venerable HP 432 could be used to measure the level of the signal received from the source. And, indeed, often is used. With this arrangement a pure CW source is all that would be required as the transmitter. However, the drift free dynamic range of the average power meter is very poor and the usual virtue of broadband operation is a serious problem.

With this simple (but workable) arrangement any stray RF will be indicated on the power meter with no indication of whether it is the wanted signal from our test source or unwanted pick up of the local 10GHz beacon, or even someone on a GSM phone, 2m handheld or the local taxi. This can lead to some very peculiar results if care is not taken to check the readings!

These limitations can be overcome by using a 1kHz (the standard) amplitude modulated source as the transmitter and a diode detector connected to a VSWR indicator as the receiver. All this is explained far better than I can do in issue 1 of Scatterpoint so I won't take up space by repeating it all, again. Suffice to say the modulated signal is not easily mistaken by the receiver and the use of a detected audio signal allows relatively drift free, highly repeatable measurements with a surprising dynamic range of nearly 50dB under optimum conditions.

For the 10GHz range I used a borrowed Marconi 6058B tuneable Gunn source. These were originally made as sources for driving slotted line measuring systems. As such they already have facilities for internal 1kHz amplitude modulation. The receiver was also a borrowed Marconi instrument. I used a Marconi 6593A VSWR indicator. These narrow band 1Khz tuned amplifiers with log detector are (subjectively) better than the better known HP415E VSWR indicators. I can confirm they are better as I had to give mine up to a well know American who insisted he needed it for measurements in the USA! Hence I had to borrow one to replace it. The second catch is that the accuracy of the range can depend on how close the gain of the unknown antenna is to that of the reference antenna. As the gain difference increases, so the possibility of errors increases. There are several reasons for this. A higher gain antenna is usually physically larger than our reference horn. This means it may not accurately 'capture' all the common volume because part of the antenna may be outside the common volume. However, this isn't too much of a problem because the contribution from the outer areas of the dish to overall gain is usually decreasing due to lower edge illumination. Also the bigger antenna should ideally be further from the source than our small reference horn. What this means in practice is that a 10dB gain difference is OK, 15dB is getting to be a problem and 20dB is asking for trouble. You will note that I asked in the original call for antennas for people not to bring 4 foot dishes to measure as these would (if working properly) be more than 20dB above the reference gain antenna of 16.5dBi. These larger antennas would probably show lower gain than actually achieved due to this effect of the range gain compression described above.

The results

So, now you know how the range works on 10GHz, the results. Please note, that these have already been published in both the RSGB Microwave Newsletter and the North Texas Microwave Society newsletter. In one of these fine publications the table was incorrectly formatted, prior to publication, and some information was lost. Hopefully, this is the definitive version.

2.4GHz

So, what about 2.4GHz and why 2.4? The first range I set up was at the University of Surrey, Amsat Colloquium 2001, I was assisted with the range by Dave, G0MRF. Dave arranged for a reference horn antenna to be made specially for the measurements. The antennas measured were all for use with AO-40 satellite and featured circular polarisation. The measurements went well and we had many converts to the technique of the measurements and I'm sure the range will re-appear at next year's Colloquium by public demand.

Probably most important, several very important lessons were learnt about helix antennas. How not to build them featured strongly!

The measurements were all published on the Amsat UK web site. Unfortunately, the reference horn antenna was not available for use at Martlesham Adastral Park and so a patch antenna was substituted. Although we knew the gain of the patch quite accurately, the broad beamwidth of the patch together with its low gain caused some problems and I am not too confident of the results obtained. For this reason I won't re-publish the figures in Scatterpoint although they have appeared in the previously mentioned publications.

Analysis of the results

The results are quite interesting. I am confident that up to about 30dBi, the gains measured are quite believable.

Above about 30dBi the results look to me like there is some slight (~0.5dB) gain compression. I base this on the expected gain of the Andrew dish which should have been closer to 34dBi than the 33.1dBi measured. The loss of the coax to waveguide adaptor accounts for the missing fraction of a dB.

The PW dish and penny feed surprised me with how good it could be after years of believing that this arrangement was less than optimum. ?? I am impressed by the efficiency of the dual mode feed on the Amstrad 60cm dish. I'm definitely going to try this arrangement myself.

10GHz			
Callsign	*Antenna measured*	*Results (dBi)*	*Comments*
G3PHO	60cm Amstrad dish with W2IMU feed and extension	35.2	G3PHO version
G3PHO	As above without extension	34.2	
G8PSF	80cm Amstrad dish with W5LUA dual band feed	30.5	10 + 5.7GHz feed
G3LYP	BSB 35cm dish with feed based on LNB feedhorn	29.5	
G3LYP	PW dish with penny feed	29.5	After adjustment
G3LYP	Horn	19.8	20 dB commercial
			design
G8LSD	80cm prime focus with penny feed	34.5	
G3JMB	60cm prime focus with penny feed	27.5	
G3JMB	60cm prime focus with dipole and reflector	27.5	
G3JMB	PW dish with penny feed	29.0	
G3NYK	Horn	21.5	Commercial horn with large aperture
G3NYK	Elliptical Horn with Fresnel lens	19.5	Commercial
G3NYK	Small horn	15.8	Commercial
G4DDK	Andrew 60cm prime focus with shepherd crook and horn feed	33.1	The popular commercial surplus dish
G4DDK	RSGB '20dBi' horn from the Microwave manual	20.0	Calculates at 19.9dB at 10368MHz
G4ZXO	42cm dish with dipole and reflector feed	30.0	
G7JTT	Channelmaster minidish with tubular horn feed	30.3	One of the popular digital Sky dishes. About 42cm wide
G8GTZ	Grundig Sky minidish with G3PHO/W2IMU feed	30.3 !	Also one of the popular digital Sky dishes. About 42cm wide
G7JTT	16 slot (8 each side) waveguide	12.3	Typical beacon antenna
G3XGK	Horn	19.0	Commercial
G3XGK	25 inch prime focus with penny feed	32.0	Home brew fibreglass design

Lessons learnt

What lessons were learnt from the 10GHz range at Adastral Park?

The most important was to have a go. We have all assumed for some time that you just can't do accurate antenna gain measurements on an amateur test range. This assumption has persisted too long. Let's hope it's been put to bed once and for all.

There is great satisfaction is seeing the gain of your precious dish/horn/WHY confirmed by measurement. I would guess that many of the onlookers started thinking about trying that dual mode horn after all. It might just make it possible to work that extra path that doesn't quite go now.

Even small dishes such as the Sky minidish give very acceptable gain when correctly fed. Just the job for that mast head system where there isn't quite room for a 90cm dish on the short and already overloaded stub mast.