A Broadband Hexbeam

Steve Hunt, G3TXQ

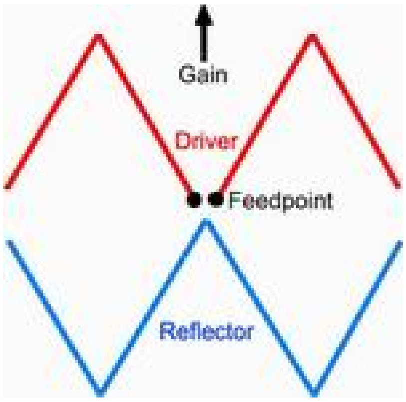
Introduction

I like the Hexbeam. Anyone who wants an HF antenna that can be multi-banded, exhibits useful gain and directivity, is lightweight, has a small turning radius, and which lends itself readily to "Do It Yourself" construction, should put it high on their list of options. I also admit to being strangely drawn to its unusual shape, which seems to attract less adverse interest from the XYL and our neighbours - an important consideration in today's sensitive environment! But it's not a "magic" antenna: other designs beat it for gain, front-to-back ratio, and, crucially, performance bandwidth.

This article describes a programme of modelling and experimental work that I undertook to evaluate ways of extending the Hexbeam's bandwidth without compromising its elegant hexagonal structure. The work has resulted in a new antenna design that trades a modest increase in size for a very significant bandwidth enhancement. I believe it is a useful addition to that family of wire beams which includes the VK2ABQ, the Moxon, the X beam, and of course the traditional Hexbeam

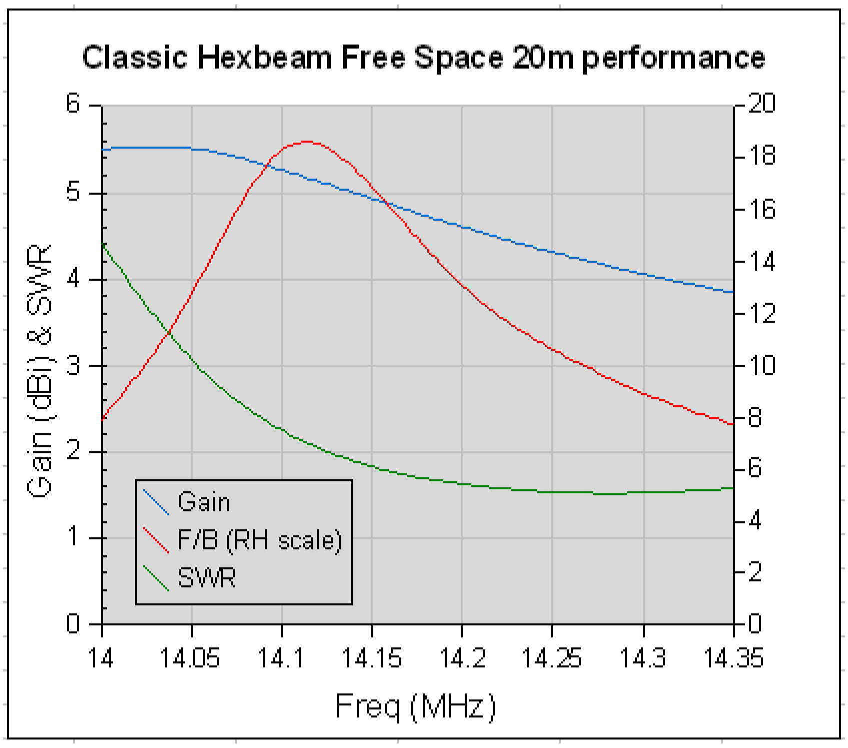
The Classic Hexbeam

The defining feature of the Classic Hexbeam is its shape. To conserve space the driven element and the reflector are bent into "W" shapes. The result is a 2-element parasitic beam with a turning radius about one-half that of the corresponding full-sized Yagi. The classic implementation of the Hexbeam is a lightweight support structure of six bowed fibreglass spreaders, onto which the wires for the 5 HF bands (20m thru 10m) are stacked vertically.



A consequence of bending the driven element and reflector into the W shape is to increase their Q. I measure a value of about 30 for a 10m Hexbeam reflector, compared to 10 for the equivalent linear element. The result is a relatively narrow performance bandwidth.

Here's the typical modelled Free Space performance of a 20m Hexbeam constructed from #16 copper wire:



We see that the forward gain drops by a couple of dB across the band - a result typical of many 2-element parasitic beams. The F/B peaks at 18.3dB but falls quite sharply either side of the maximum, particularly on the low-frequency side. The SWR reaches a satisfactory 1.53:1, but it exceeds 2:1 at the F/B peak, and it rises rapidly at lower frequencies. A consequence of this SWR characteristic is that constructors who are tempted to tune the beam for minimum SWR are invariably disappointed by the F/B performance.

Of course, if we use a series matching section, or shorten the driven element and employ a beta match, we can make the SWR minimum coincide with the peak F/B; but both of these techniques rule out the use of a single feedline on a multi-band array, which is one of the most popular features of the classic Hexbeam implementation.

If we define "useful performance" as F/B>10, SWR<2:1 and forward gain>2dBd, the Hexbeam's performance bandwidth is a very low 150 kHz, or 1% of centre frequency. So, in an attempt to extend the bandwidth I investigated ways of lowering the Q of the W-shaped elements.

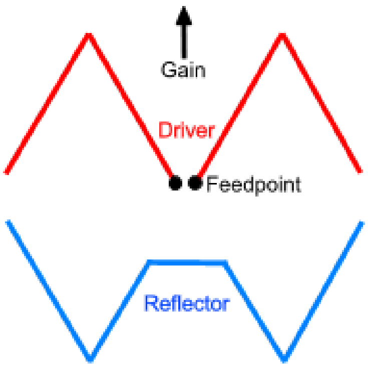
Low Q Reflector Experiments

Traditionally, dipole elements have been made low-Q by building them out of "fatter" materials, or by connecting in parallel a number of elements with slightly staggered lengths. A quick look at the constructional and tuning issues convinced me that "fatter" was the better approach. Modelling the beam indicates that the performance bandwidth is relatively independent of driver Q, so I built and evaluated a number of 10-m monoband Hexbeams with reflectors fabricated from:

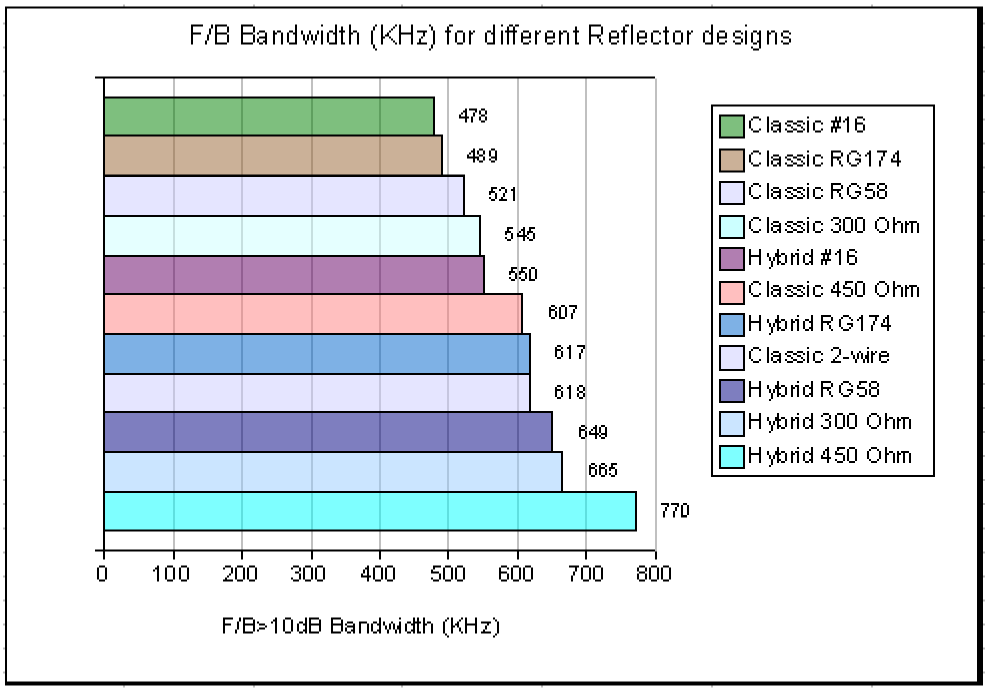
- RG147 coaxial cable
- RG58 coaxial cable
- 300 Ohm "window"
- 450 Ohm "ladder line"
- A "cage" of 2 wires, joined at the half-reflector ends, but separated by several inches at the mid-point spreader attachments.

The last option was particularly effective, but its tuning was very sensitive to the vertical and horizontal spacing values achieved at the spreader attachment points. It was judged to be a design that would be difficult to prescribe for novice constructors, who may not have the appropriate test gear or skill to tune the reflector in-situ.

On his website L.B. Cebik has a page entitled “A Tale of 4 Beams: The X, the Hex, the Square, and the Rect” where he presents the performance of a modified Hexbeam. This antenna has a slightly altered shape: the acute angles formed at the centre of the hexagon by the driver and reflector wires are avoided, with a resulting improvement in bandwidth. For ease of reference we will call this shape “Hybrid” to distinguish it from the “Classic” W shape



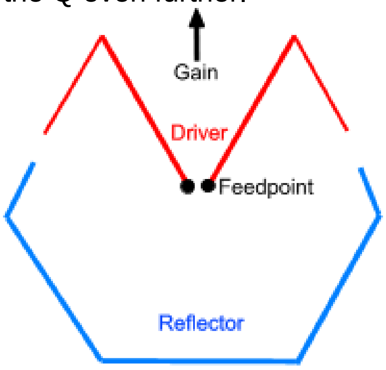
I constructed and evaluated a 10m beam using the Hybrid geometry for the reflector. It showed promise, so I next combined it with the various “fatter” wire options. In all, a total of 11 combinations of wire type and Classic/Hybrid shape were built and tested. The measured F/B>10dB bandwidths are presented below:



There are no surprises here: the fatter the wire the better the bandwidth, and the Hybrid shape outperforms the Classic shape for each wire type. Some of the arrangements are more practical than others: the 2-wire Classic combination delivers good performance, but its tuning is quite unpredictable; the Hybrid shape using 450 Ohm window does best of all, but construction is more difficult with this type of wire.

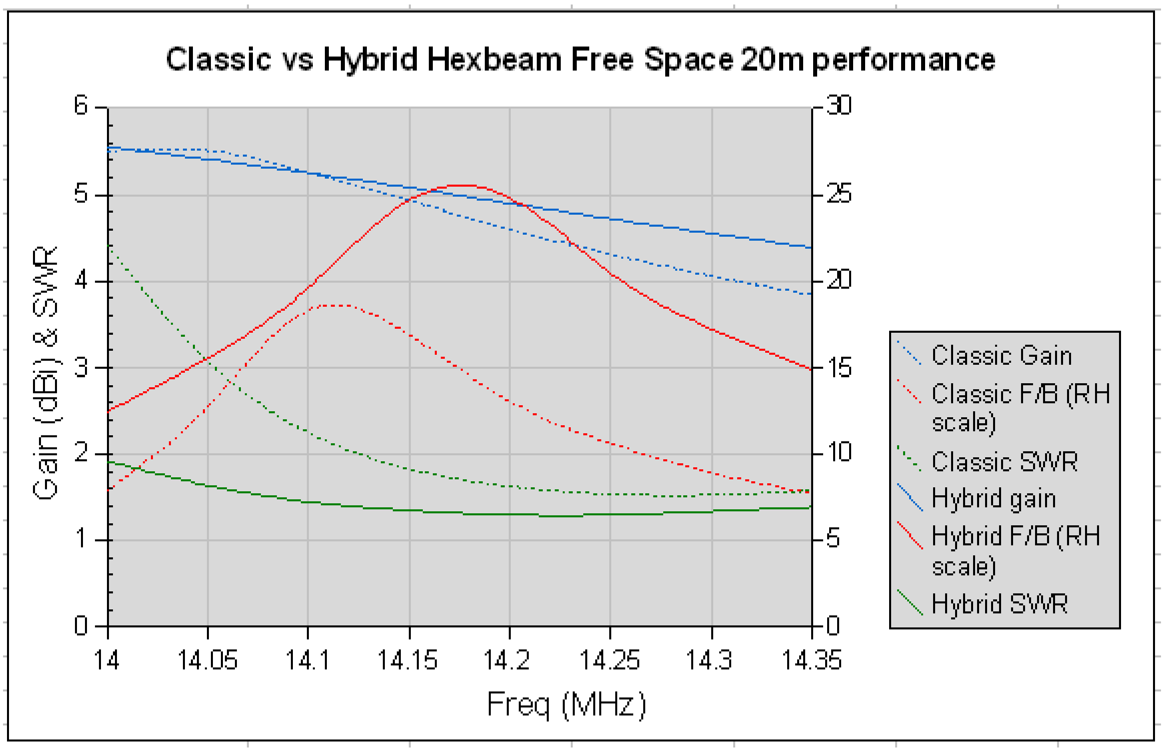
A New Broadband Hexbeam

At this point, a little schoolboy math showed that if the entire reflector was constrained to the perimeter of the support structure there would be only a small increase - about 15% - in turning radius compared to a Classic Hexbeam. And we might expect that avoiding any "indent" at the centre of the reflector should lower the Q even further.



Modelling showed that the reflector Q would be as low as 17 (Rrad about 44 Ohms) even when built with #16 wire, and that this would translate to a F/B performance better than 10 dB across all of the 20m, 17m, 15m and 12m bands, and at least 1MHz of the 10m band. This performance potential emerges from a beam with a turning radius of 130". Better still, by keeping the Classic shape for the driven element we avoid a further increase in size, and the natural feedpoint impedance of the beam becomes a good match to 50 Ohms.

A comparison between the Classic and Hybrid's performance shows that the new design is superior in all respects:



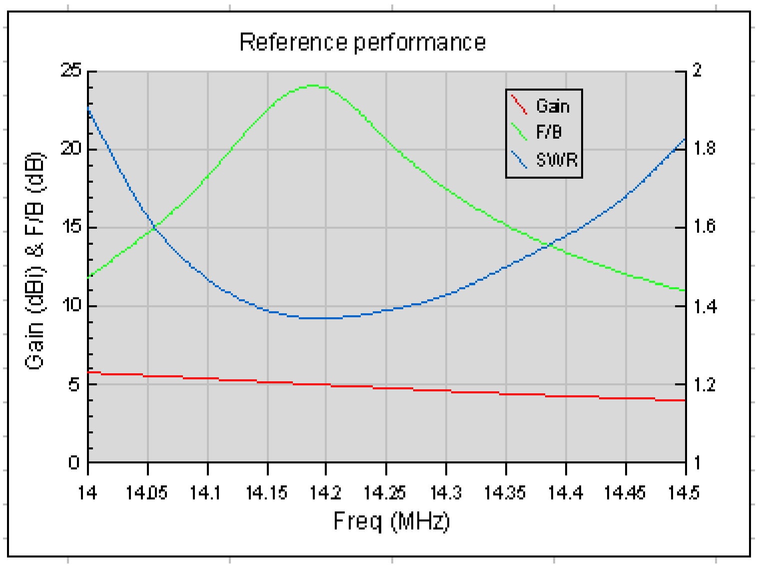
Critical Dimensions

In this section we will look at how the key antenna dimensions affect particular performance parameters. The conclusions will be very similar to those for the Classic Hexbeam:

- Reflector dimensions determine the tuning of the antenna
- Driver dimensions largely determine the feedpoint impedance of the antenna
- End spacing mostly affects the peak F/B performance

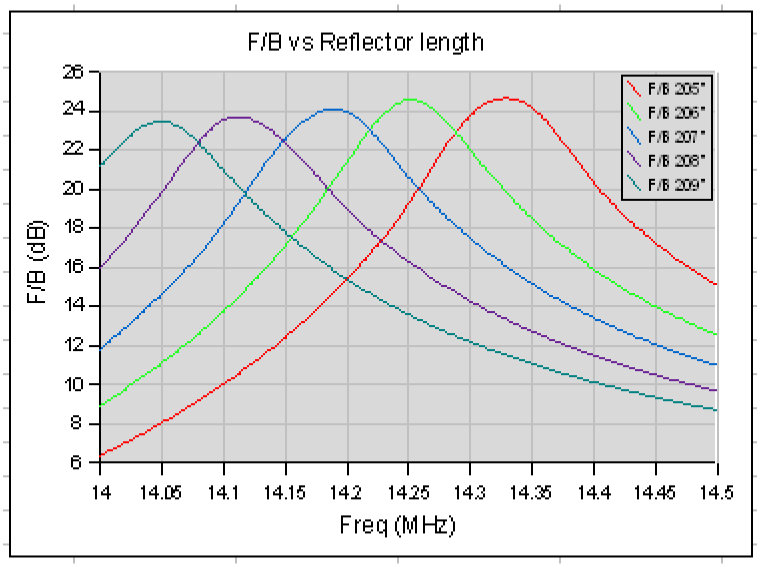
.... however, we shall find a surprising result when we look at wire gauge.

A number of modelling experiments were carried out using a "reference" 20-m beam whose performance across the band from 14 MHz to 14.5 MHz is shown below. Its dimensions were as follows: Driver = 219", Reflector = 207", and End Spacing = 24".



Critical Dimensions - Reflector

The length of the reflector on the reference model was changed from 205" to 209" in 1" steps; at each stage the forward gain, SWR, and F/B performance were noted across the band. The SWR changed some as a result of the Reflector / Driver ratio changing, but the critical dependency was the antenna tuning, which is illustrated below:

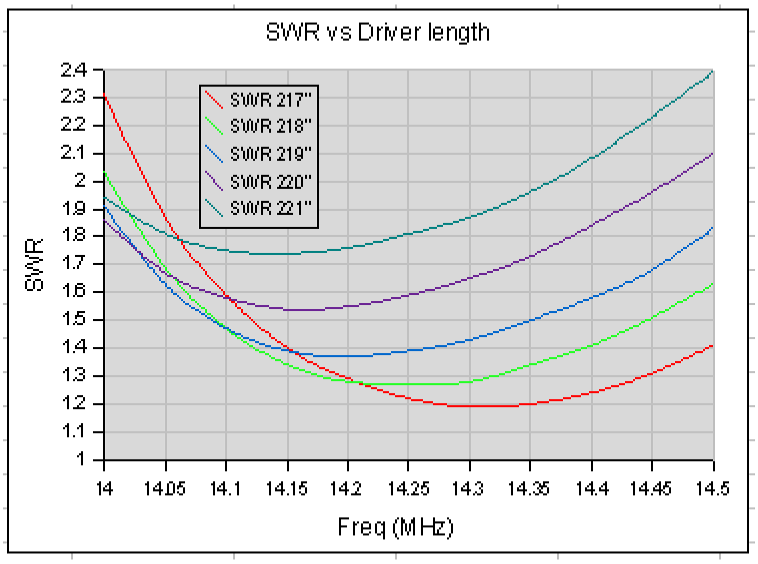


We see that for each 1" increase in Reflector length the frequency of peak F/B drops by about 70KHz, indicating that the beam tuning is linearly dependent on reflector length. A more detailed analysis of the results shows that peak F/B on the reference model occurs at 14.184 MHz, about 100 KHz (0.7%) above the self-resonant frequency of the reflector

(14.088 MHz); in contrast the peak F/B on the Classic Hexbeam occurs much closer to its reflector resonance.

Critical Dimensions - Driver

Next, the length of the driven element on the reference model was changed from 217" to 221" in 1" steps. The length had little effect on forward gain or F/B tuning; however it had a major effect on the feedpoint impedance as seen below:



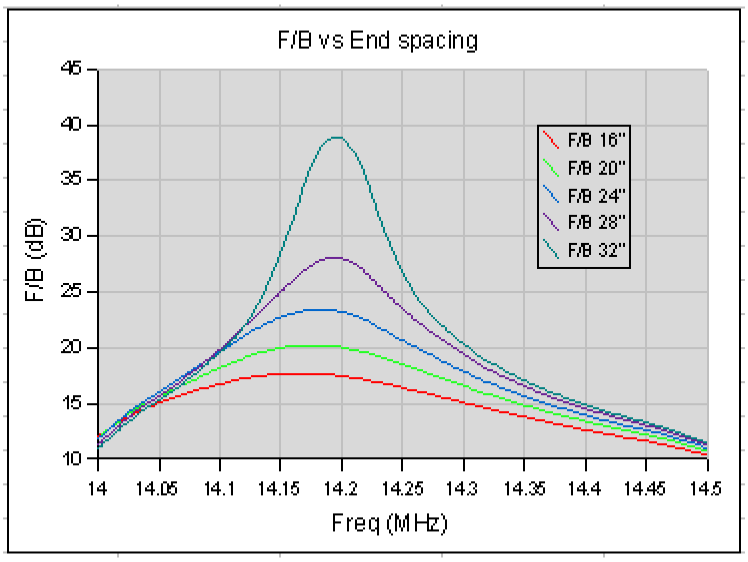
The shortest driven element value (217") produced the lowest SWR; however, bearing in mind that the F/B performance is centred within the band, and that forward gain peaks below the bottom band edge, the shortest value may not be the best choice operationally. The 219" driven element might be a better choice: it produces an SWR curve that is better centred, and its minimum SWR is not unacceptably worse at 1.37:1 vs. 1.19:1.

At first sight it may seem strange that this parasitic beam has a driven element that is significantly longer than its reflector. The differing shapes of the elements explain this apparent anomaly. A detailed analysis of the modelling results shows that the 219" driven element is self-resonant at about 14.330 MHz, a value that is 242 KHz **above** the 207" reflector's resonance! What matters here is not the relative lengths, but the relative resonant frequencies.

We conclude that making the driven element self-resonant about 1.7% higher than the reflector resonance produces a reasonable match to 50 Ohms across the operating band. It's no coincidence that this is the same Reflector/Driver ratio often used on the Classic Hexbeam; but in the case of that antenna, because Driver and Reflector are the same shape, the ratio translates directly to wire lengths.

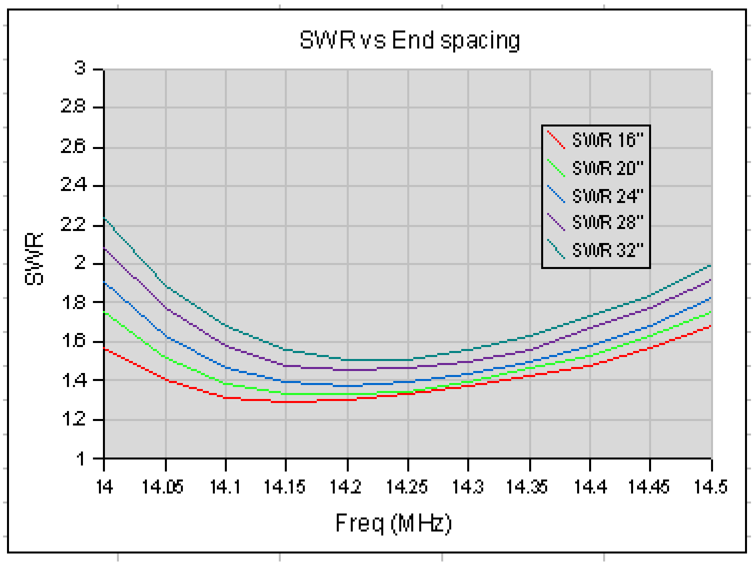
Critical Dimensions - End Spacing

The size of the End Spacing on the Reference model was changed from 16" to 32" in 4" steps. It had little effect on antenna tuning. It had some effect on forward gain and a slightly greater effect on SWR, but the major impact was on the peak value of F/B as shown below:



Looking at this chart we might be tempted to opt for a large End Spacing in pursuit of the highest peak F/B performance. However:

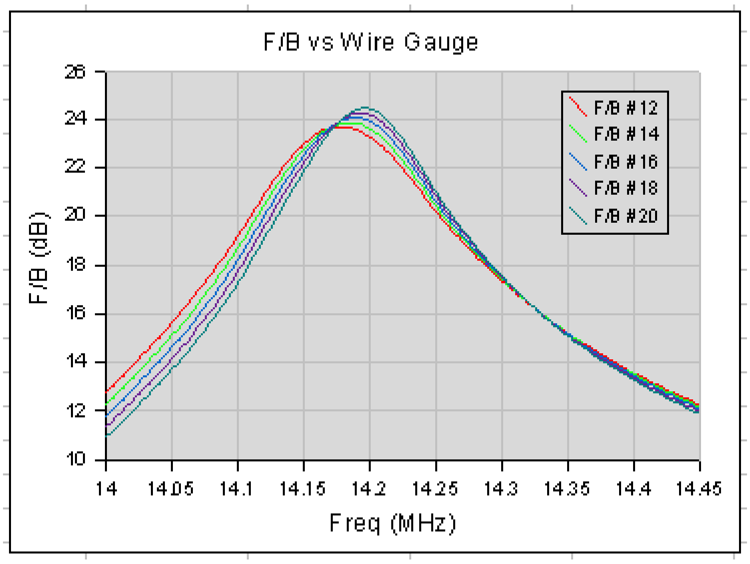
- The F/B performance is little better at the band edges with the larger spacing
- Detailed analysis of the azimuth patterns shows that the high F/B numbers are somewhat illusory. They result from deep, narrow, "notches" in a cardioidal pattern, which may not be particularly useful in day-to-day operation.
- The bigger we make the spacing, the bigger the turning radius
- The SWR suffers, as shown in the chart below



The cardioidal pattern with its narrow "notch" begins to develop with End Spacing values between 24" and 28". So if we opt for a more "modest" spacing, like 24", we shall lose little practical F/B performance and will keep the SWR below 2:1 across the band.

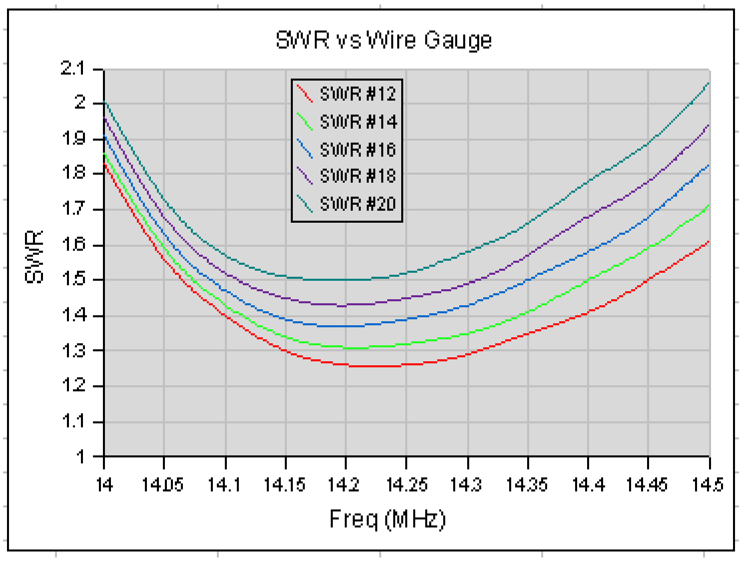
Critical Dimensions - Wire Gauge

The wire gauge on the reference model was changed from #12 to #20 in 4 steps. The effect of F/B performance is shown below:



Interestingly, the antenna tuning is largely independent of wire gauge. This may seem strange: usually, employing thicker wire tunes an antenna lower in frequency. But in the case of the W-shaped elements of the Classic Hexbeam the opposite turns out to be the case - thicker wire tunes the element higher in frequency - and certain shapes, intermediate between the Classic Hexbeam and a linear dipole, exhibit almost no dependence on wire size. Fortuitously the Broadband Hexbeam reflector is in this category, which means that wire gauge correction factors do not have to be applied to published reflector dimensions.

The chart below shows how the SWR varies as wire gauge is changed:



The thicker wire tunes the driven element slightly higher in frequency and with it the minimum SWR; but any "skew" at the band edges - which became a problem when we shortened the driven element - is more than offset by the significantly lower SWR overall.

A 5-Band Prototype

Armed with this knowledge I modelled a 5-band version of the new design which is fed at the 20-m (top) position, and on which the various driven elements are interconnected with 50-Ohm coax. Monoband dimensions always needed adjusting when elements are brought together in a multi-band array of this type: each reflector tends to be de-tuned lower in frequency because of the proximity of the other reflector wires; and the array impedance becomes a complex combination of the parallel connection of the driven elements and their interconnecting cables.

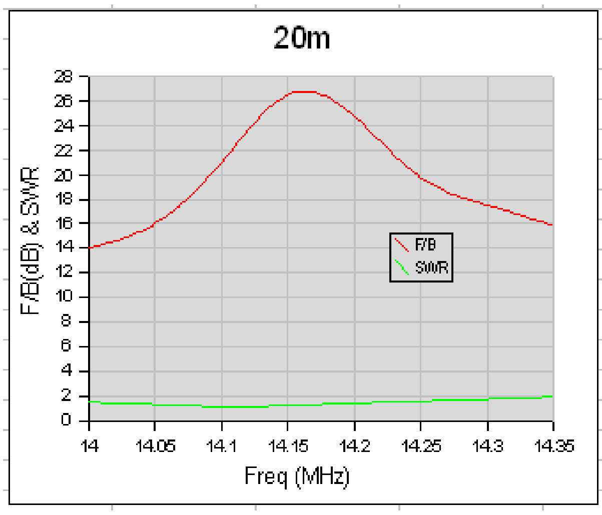
I spent some time optimising dimensions on the model and then constructed a 5-band prototype, which was checked for F/B and SWR performance at a test height of 20ft. I have no facilities for measuring forward gain accurately.

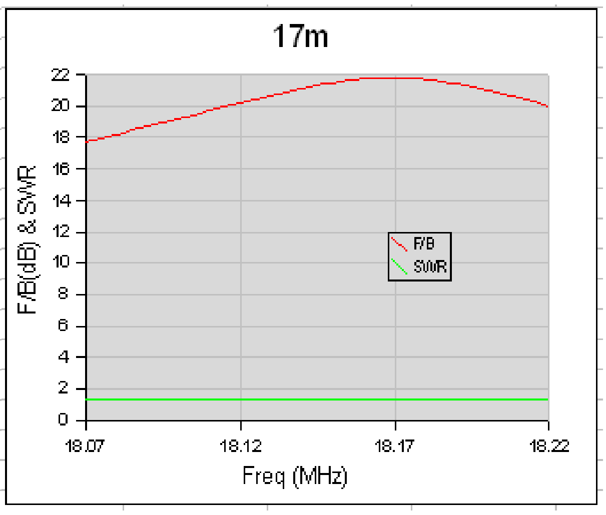
Results for the 20m, 17m and 15m bands were as expected from the modelling. However, the shallow "dish" of the typical multi-band Hexbeam support structure places the 12m and 10m wires very close to one another. As a result, the tuning on these bands becomes very inter-dependent and beam performance suffers. This proved to be the case with the new design, and I spent some considerable time finding a set of 10m and 12m wire dimensions that would give an acceptable compromise performance.

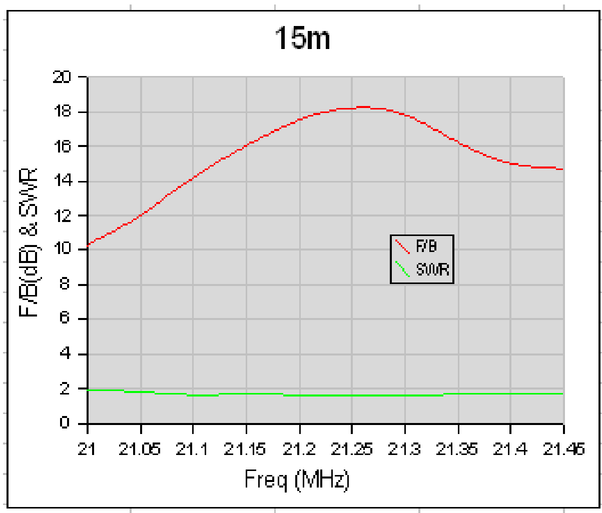
The final dimensions were:

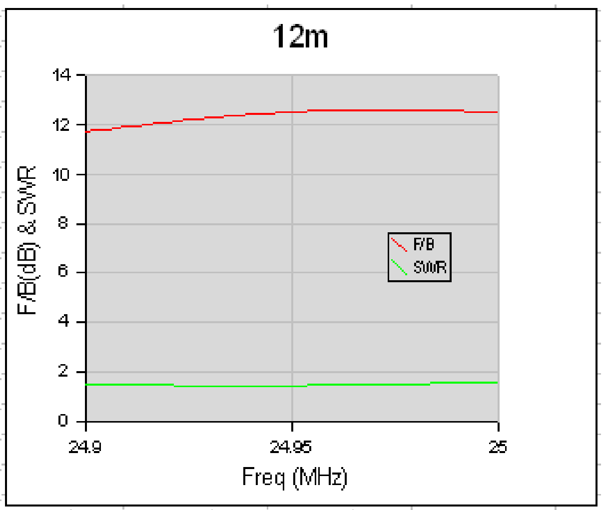
	20m	17m	15m	12m	10m
Half Driver	218"	169.5"	144.5"	121.7"	106.8"
Half Reflector	206"	160.5"	137.2"	116"	102.2"
End spacing	24"	18.5"	16"	13.5"	12"
Vertical spacing from 10m wires	38"	15"	9"	5"	0"

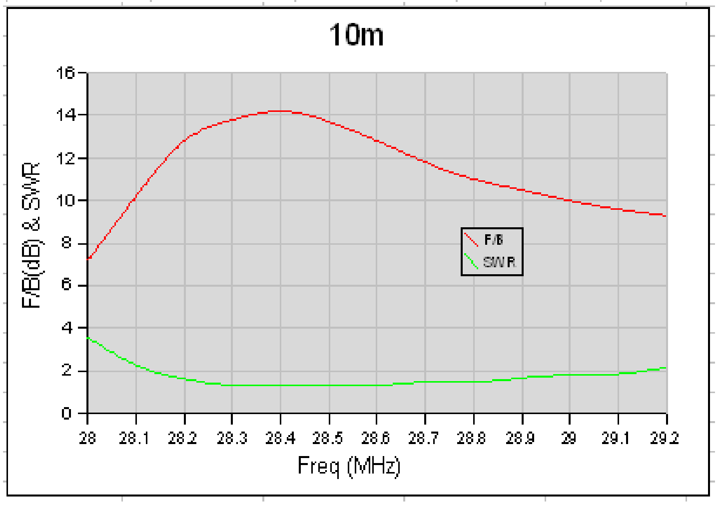
Finally, we present the measured performance of this design with the base plate at a height just less than 20 ft. At this height, ground reflections cause the 10-m and 12-m peak F/B figures to be suppressed compared to the Free Space values, and the 20-m and 17-m figures to be enhanced. Clearly, the wire dimensions may need some further slight adjustment to optimise the tuning once the antenna has been evaluated at more representative heights.











If you'd like to know more about the Hexbeam, take a look at my web site: http://www.karinya.net/g3txq/hexbeam/ There is also a very active Yahoo Hexbeam discussion group at: http://groups.yahoo.com/group/hex-beam/.

Any readers wishing to build a Hexbeam should look at K4KIO's site: http://www.leoshoemaker.com/hexbeambyk4kio/general.html, which contains an excellent step-by-step constructional guide to the Classic design. Most of the techniques described there are applicable to the broadband design - just be careful to use the wire dimensions quoted in this article and remember that you will need to use longer spreaders. In due course K4KIO is planning to document construction of the broadband version, so keep an eye on his site.

To hijack a well-known saying: “There are lies, damned lies, statistics, and antenna specifications”. The Broadband Hexbeam will not outperform a full-size 2-element Yagi; but if you’re searching for a low-cost, lightweight antenna with useful directivity across 20m thru 12m plus a good slice of 10m, which exhibits moderate SWR values, and which has a turning radius under 11 ft, this new design is worth a look. **-30**

Steve Hunt, G3TXQ

BRIEF BIOGRAPHY OF AUTHOR

Steve Hunt, G3TXQ, has been a radio Amateur since 1963 when he got "hooked" on the hobby building crystal radios as a schoolboy.

Steve graduated from Birmingham University at UK with a Master's Degree in "Information & Systems Engineering" and spent a career in radio design with the British Broadcasting Corporation, the UK Ministry of Defence, and the UK Foreign & Commonwealth Office.

Steve is now retired and lives in Northamptonshire with his wife Betsy. His radio interests are experimenting with antennas and designing QRP equipment.

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