ZS1ZC

Silver Spider

Multiband HF Antenna

Design and Construction Guide

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INTRODUCTION

Since the availability of advanced antenna simulation software there has been an upsurge in the range and novelty of HF antennas on the market. Software kernels like NEC and NEC2 have led to the customisation of software packages like EZ-NEC and Arrie Voors' 4NEC2 – this has allowed a new approach of highly iterative design to be within reach of the radio amateur.

The basic design problem facing radio amateurs in HF beam design is in achieving high performance (gain, front-to-back ratio, with a reasonable power match) over multiple bands spanning a 2:1 frequency range - while reducing antenna size, weight and wind loading.

The "traditional" approach to satisfying these requirements was the triband yagi, utilizing wavetraps in each element to adjust its electrical length – the Hy-Gain TH3 being a classic example. While this provided a solution to the matching problem over many bands, it did not optimise the antenna in terms of element spacing since one common (and therefore compromise) spacing had to be used for all bands. In addition, wavetraps can be lossy, and two of the three bands of a tribander would suffer from the basic inefficiency of a loaded antenna (i.e. reduced aperture).

A more modern approach has been the SteppIR yagi, in which the physical lengths of the driven and parasitic elements of a yagi are adjusted mechanically with stepper motors, allowing optimum frequency adjustment of the antenna – but again, only one set of element spacings is used.

The interleaved yagi overcomes these issues by overlaying multiple monoband yagis in such a way that takes into account any interaction between them, thereby ensuring not only correct element length but also optimum spacing for each band. Unfortunately, with conventional yagis, separate feedpoints have to be used, which requires either multiple transmission lines or a remote switching system at the antenna.

What antenna simulation allows is the possibility of optimising multiple yagis with a common feedpoint, which is a method used by many antenna manufacturers today. Two particularly good quality solutions are OptiBeam and Spiderbeam. But whereas OptiBeam have designed a range of all-metal antennas that are heavy and exhibit high wind loading, the Spiderbeam design is a low-wind resistance wirebeam suspended on a framework of fibreglass spreaders.

The Spiderbeam is an exceptionally good antenna that can handle high power over either three or five bands, and is also light-weight. It is basically three (or five) interleaved monoband yagis, each with optimally spaced parasitic elements, and it does not use wavetraps. The compromise is that the parasitic elements are not parallel to the driven elements, which naturally causes some loss of performance. However, simulations show that gain is within a decibel or so of a classic three-element yagi – this is a very acceptable trade-off in favour of light weight, ease of assembly and reduced wind loading.

As a company, Spiderbeam is unusual in that they encourage amateurs to copy and home-brew their innovative design. In fact, they provide a comprehensive assembly instruction manual on their website at http://www.spiderbeam.com/documents/index.php?coID=28, with translations into many languages.

DESIGN HISTORY

After consideration of many multiband beam designs, I opted for the Spiderbeam because it offered a compromise that suited me – monoband yagis, low weight and wind loading.

What makes the Silver Spider unique? You'll notice that Spiderbeam use insulating fibreglass spreaders in a symmetrical cross formation, lashed together, to provide tie-points for the various wire elements. When I decided to build my own Spiderbeam, I investigated fibreglass suppliers in Cape Town, but their tubes were either too expensive or the wrong size. So I made two observations:

1. The booms of most symmetrical antennas like yagis are invariably metal, and the parasitic elements are often mounted directly on them. How can this be? It's because the centre points of the parasitic elements are at low impedance, and therefore a direct connection between them has no effect on performance. So the front-to-back spreader boom could be replaced by a similar sized (and cheaper!) aluminium tube.

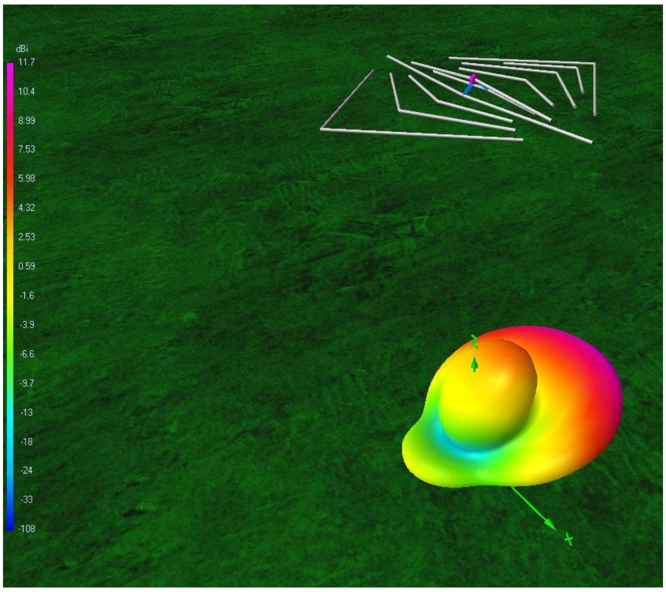
2. The 20m driven element (DE) of the classic Spiderbeam is almost as long as the left-to-right spreader. This means that the 20m DE could be replaced by an aluminium tube like the boom. I ran simulations on 4NEC2 and found that using a 30mm tube required a slightly shorter element, but the solution worked. In other words, the end of the 20m DE would serve the same purpose as the end of the spreaders for holding the shorter, higher-frequency wire elements in place.

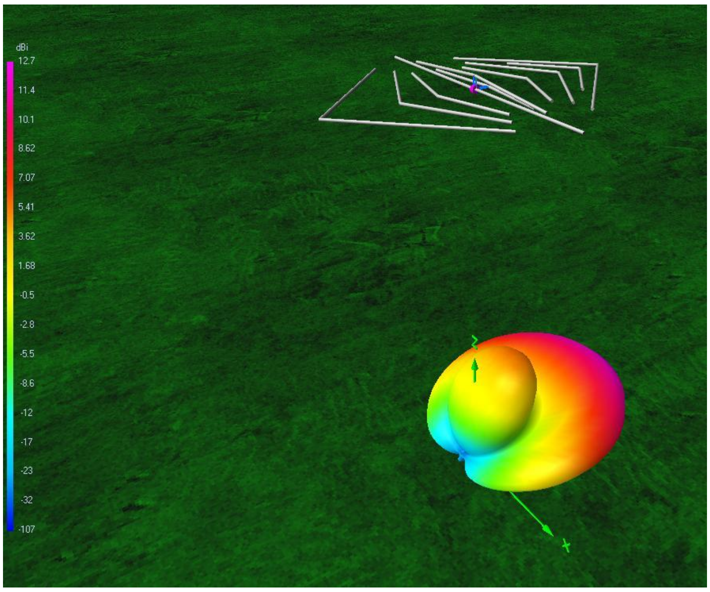
How did it perform? Well, the left-hand picture below is a simulation of the original "classic" Spiderbeam (dimensions based on their literature), and the right-hand one is the Silver Spider (so-called because the "spreaders" are now metal). The radiation patterns are very similar, but the 20m performance of the Silver Spider shows improved front-to-back ratio (not by much in practice). The situation is reversed on other bands, yet the gain remains within a dB or so of the original.

These simulations were based on an antenna at 15m above ground, where a real-life ground was simulated.

I designed and built the Silver Spider for 20m, 15m and 10m, but in principle it can be extended to cover the intervening WARC bands too. I've found this antenna to be very effective in actual use, providing significant gain over my inverted vee as expected. It also seems to have quite deep front-to-side nulls which is a useful feature.

<u>20 Metre Band</u>:

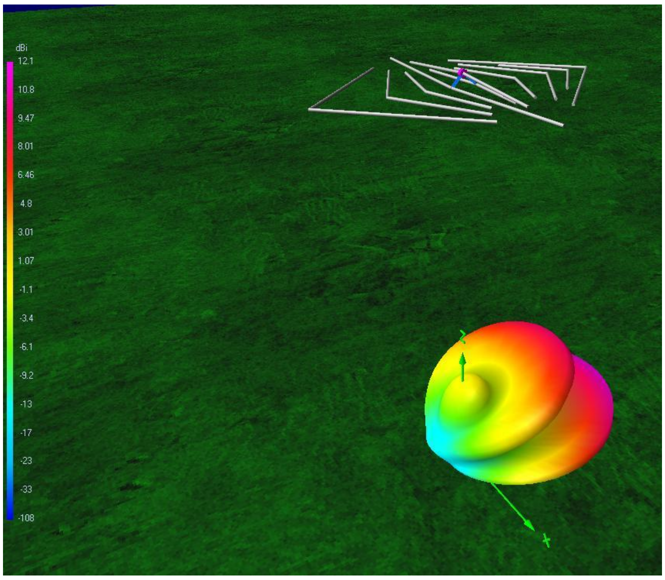


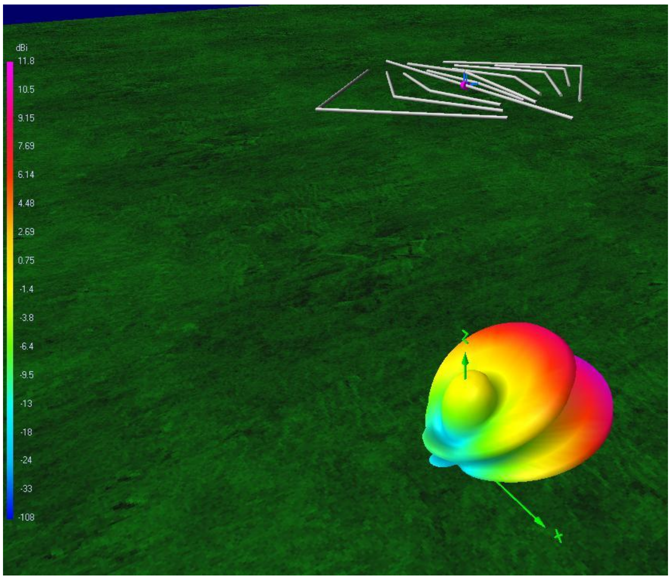


Spiderbeam gain: 11.7dBi Silver Spider gain: 12.7dBi

The improved front-to-back ratio is apparent in the Silver Spider, on the right.

15 Metre Band:

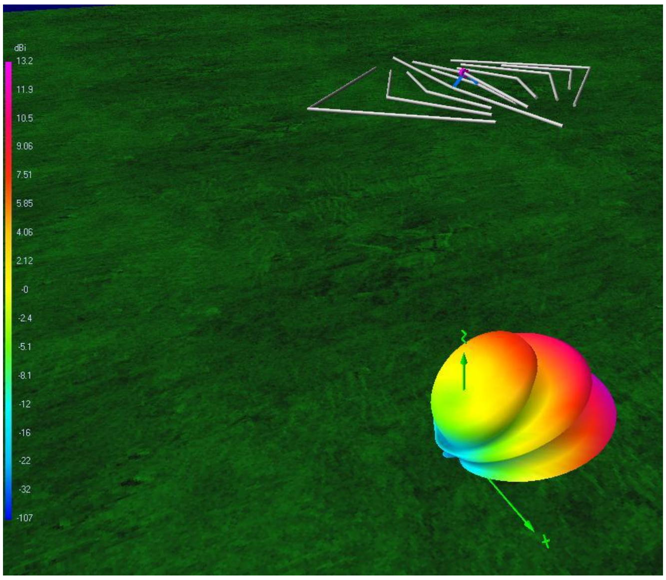


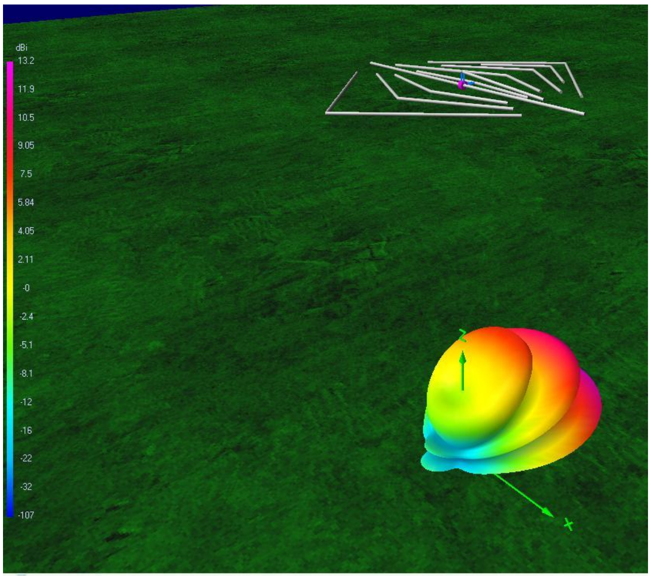


Spiderbeam gain: 12.1dBi Silver Spider gain: 11.8dBi

The F/B performance is slightly reduced in the Silver Spider and the gain is down by a negligible 0.3dB.

10 Metre Band:



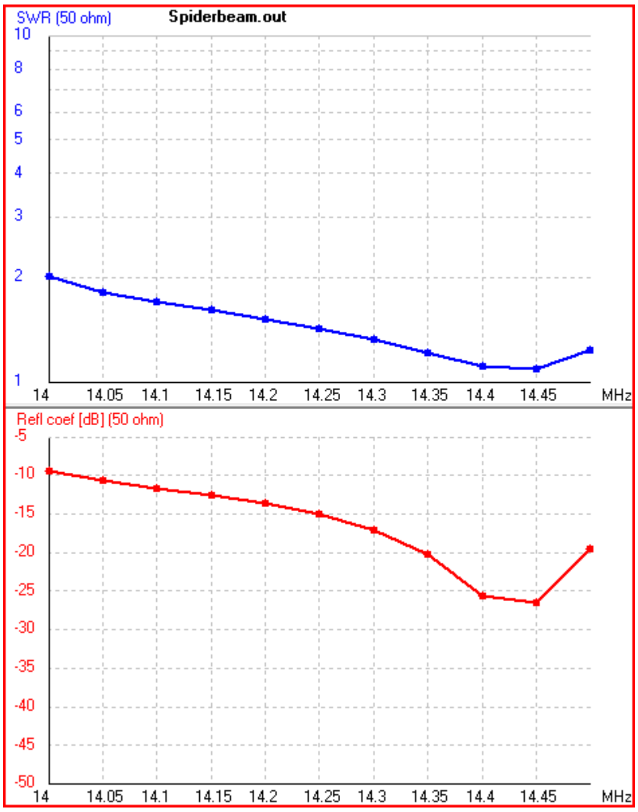


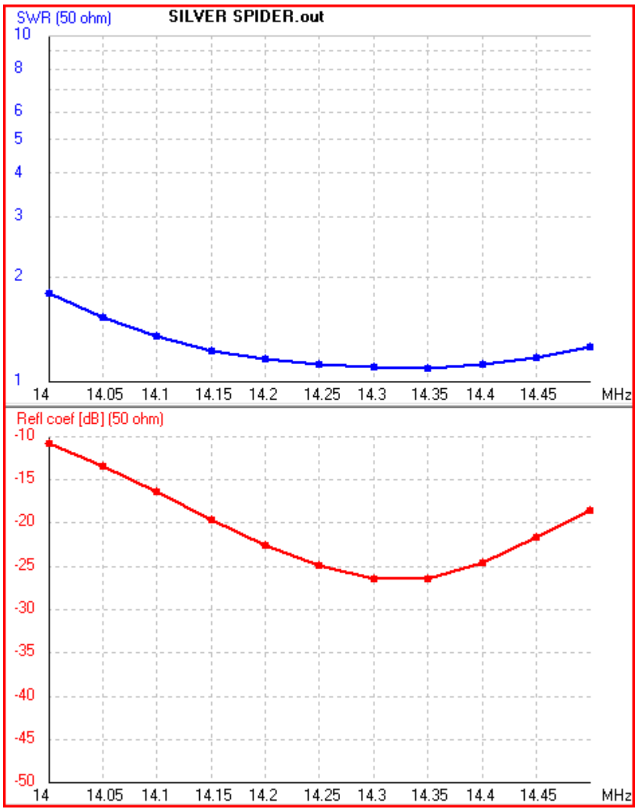
Spiderbeam gain: 13.2dBi Silver Spider gain: 13.2dBi

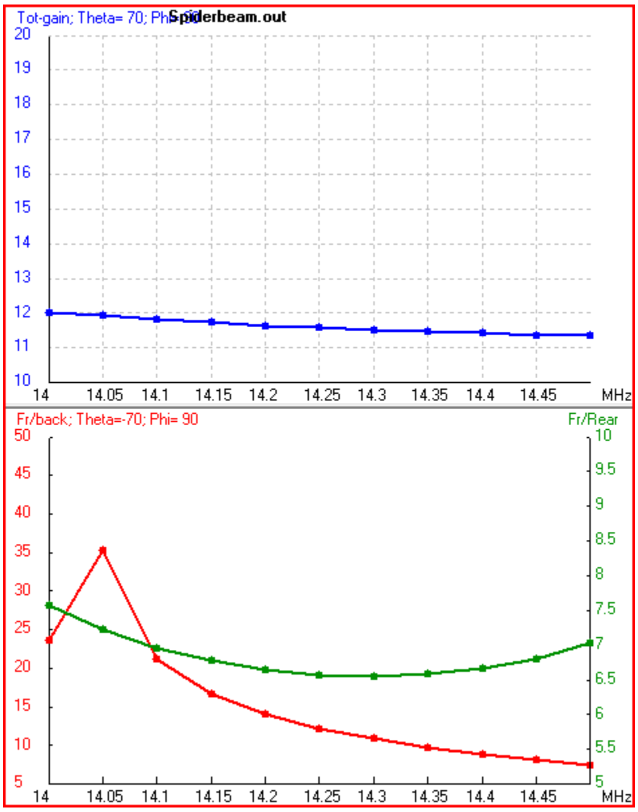
The F/B performance is slightly reduced in the Silver Spider but the gain is equal to that of the Spiderbeam.

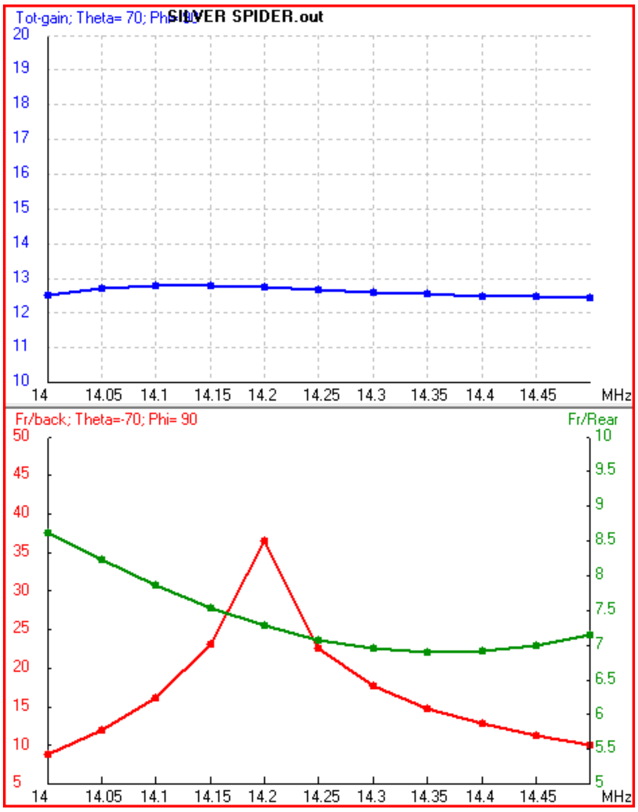
The 3-D gain plots above are at spot frequencies, so here are the SWR and gain graphs over each band.

<u>20 Metre Band</u>:



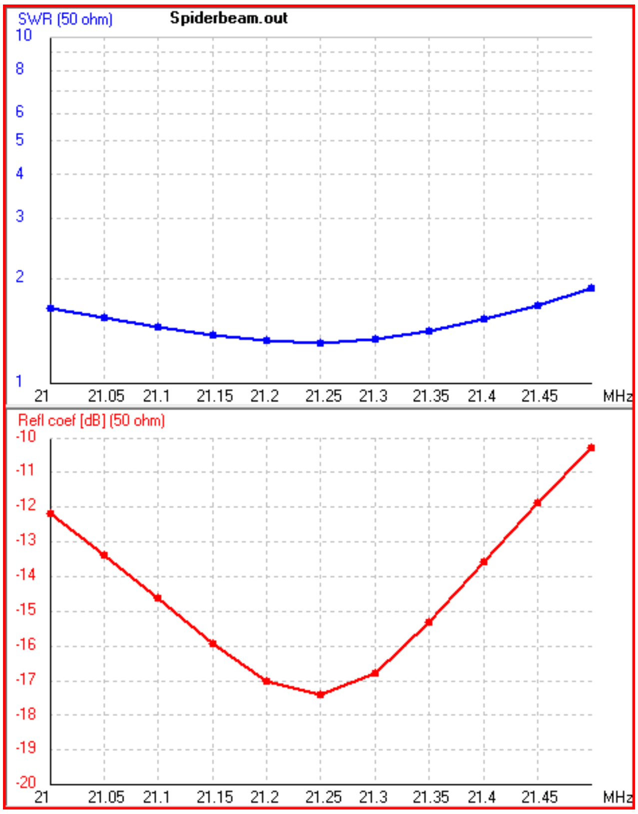


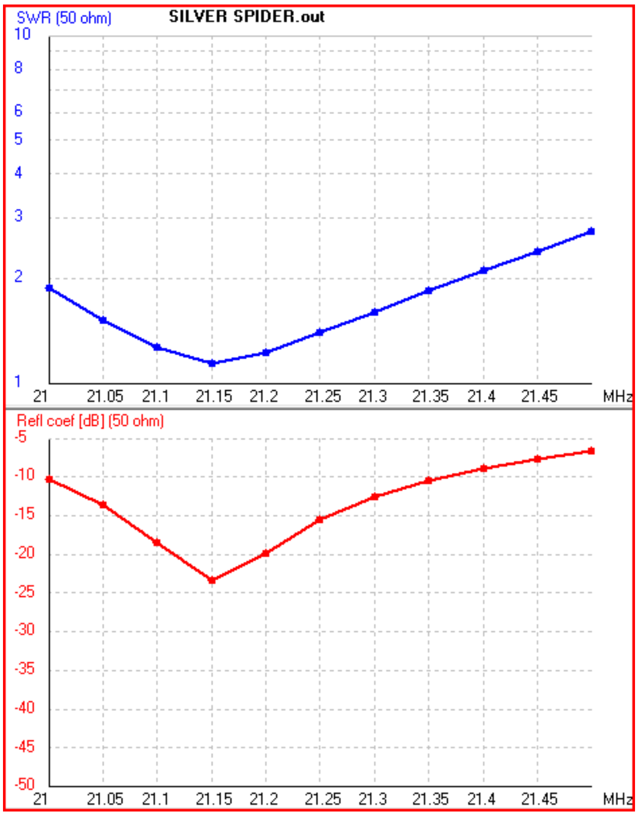


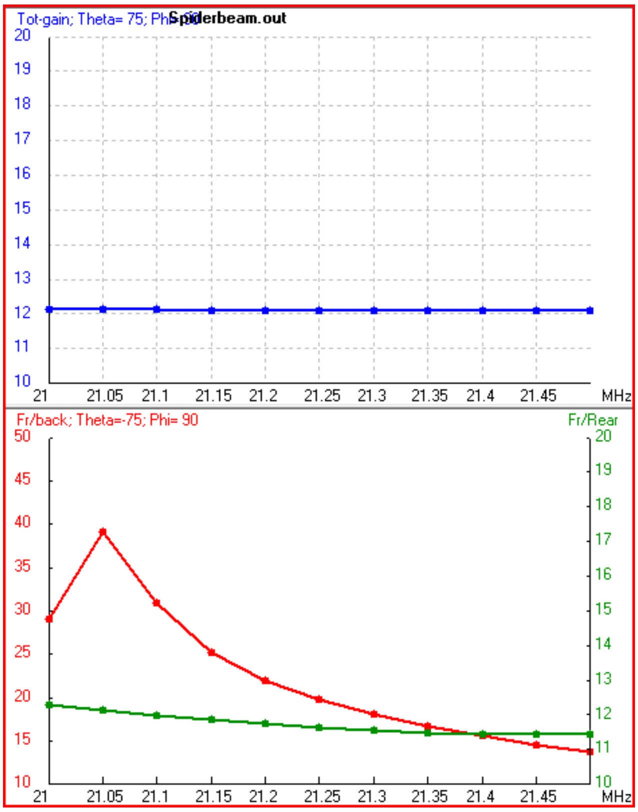


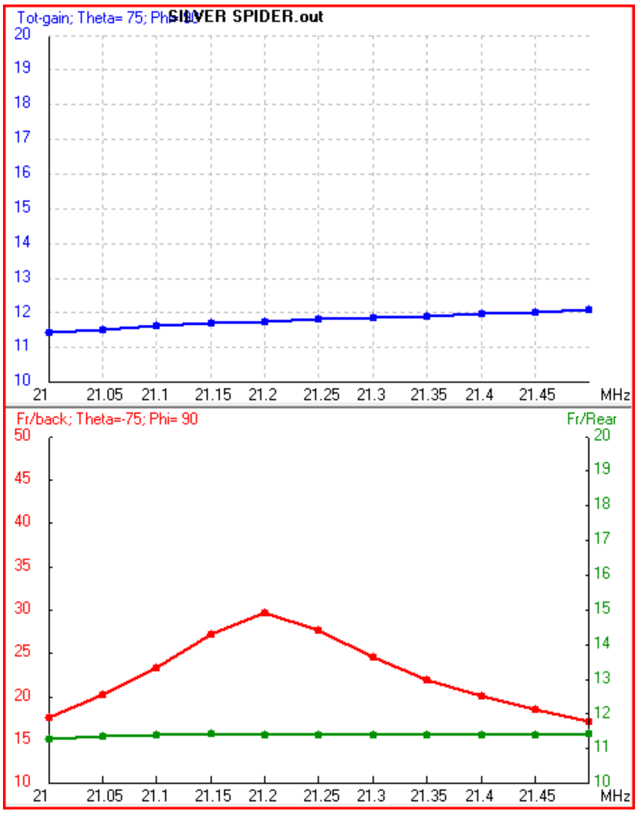
At 20m the Silver Spider has quite uniform gain and good bandwidth. F/B performance equals the Spiderbeam.

<u>15m Band</u>:



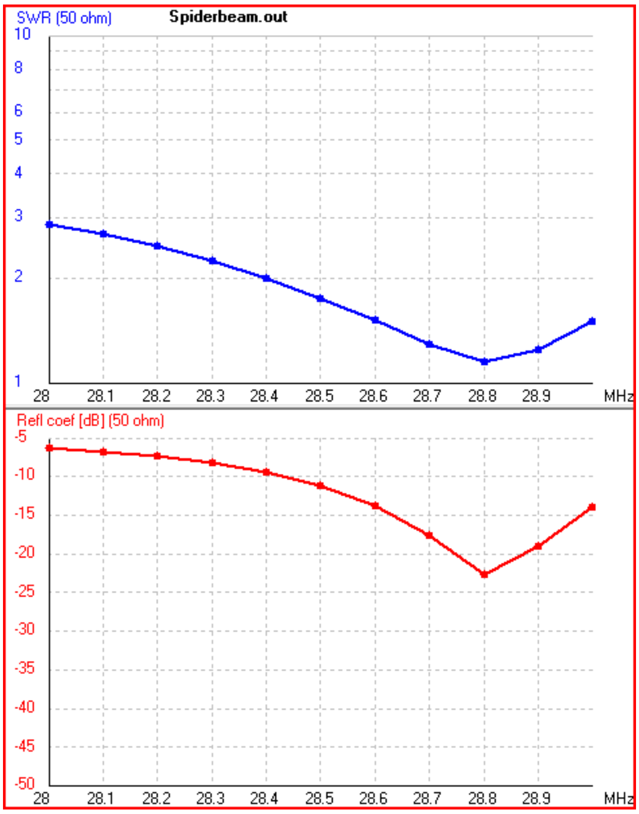


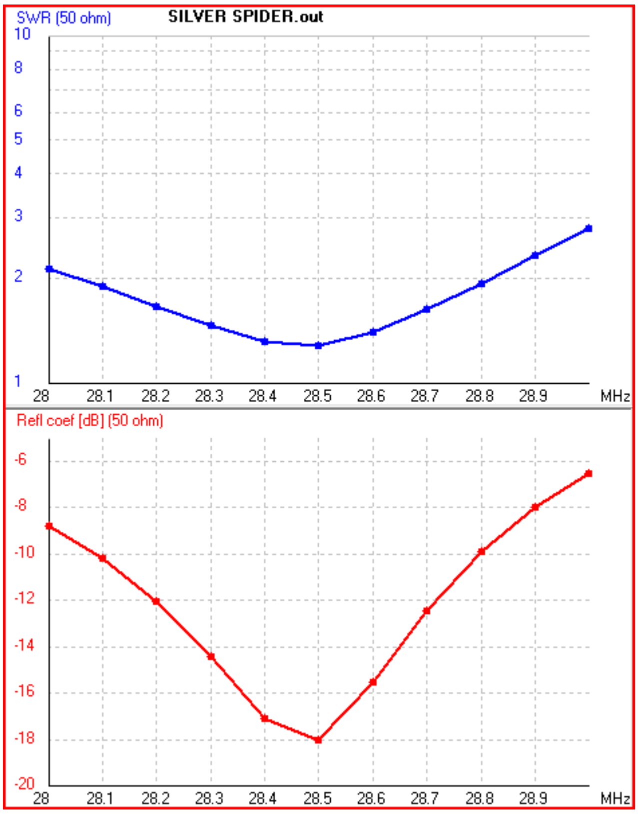


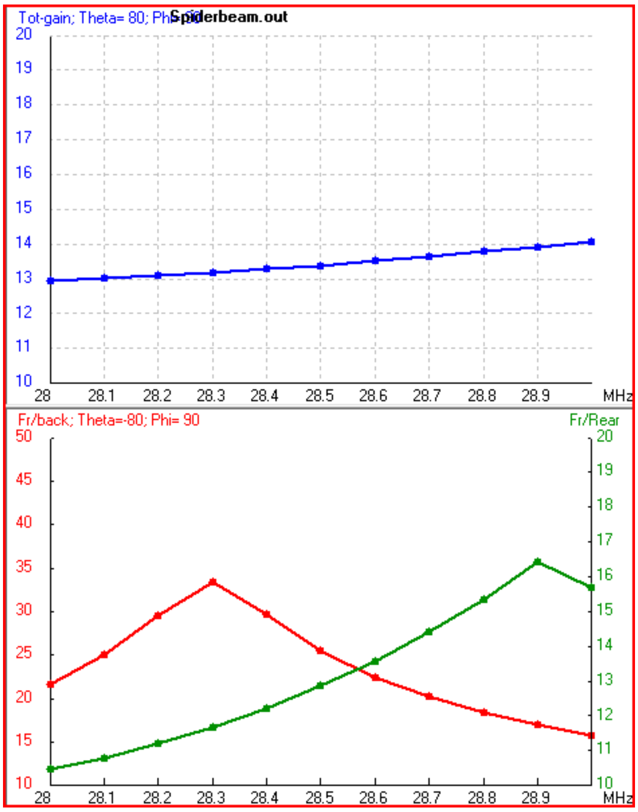


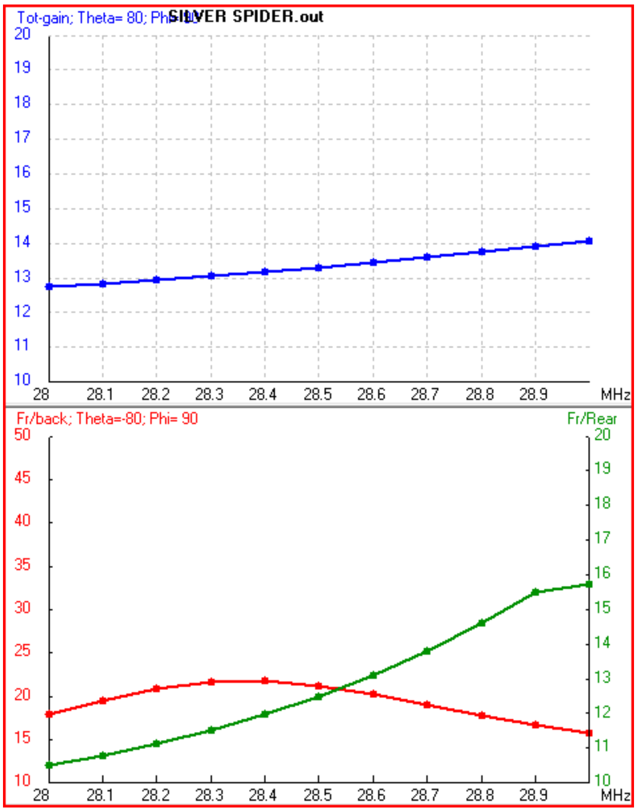
At 15m, bandwidth is still adequate, and gain still uniform to within 0.5dB. F/B is largely the same.

<u>10m Band</u>:





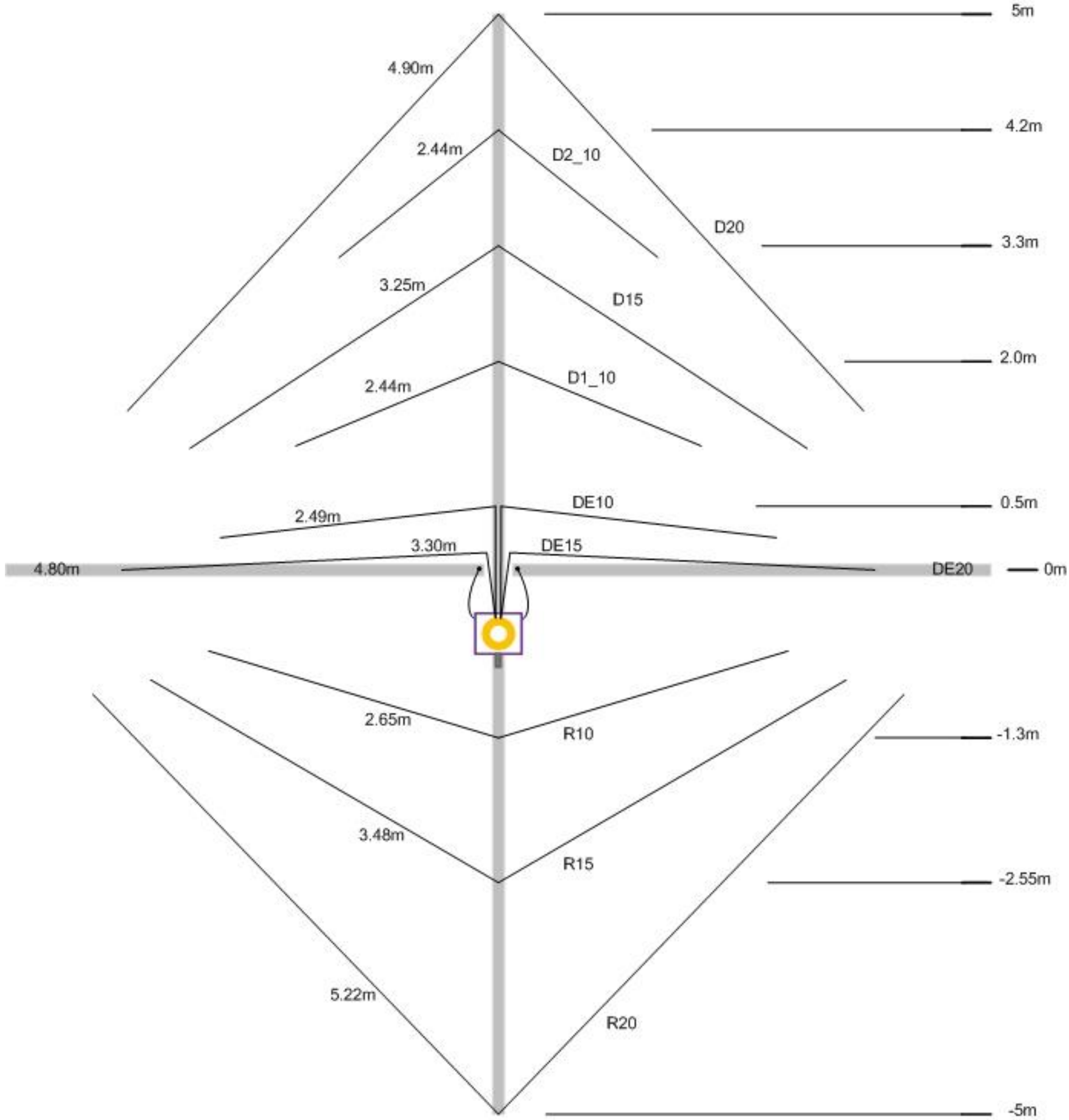




At 10m, gain over the 1MHz span varies by little over 1dB. The 2:1 SWR bandwidth is 700kHz, which allows safe use over the full 28MHz band – the antenna can be optimised for either the SSB or CW band segments by adjusting the driven element lengths slightly. F/B ratio is still at least 3 S-points.

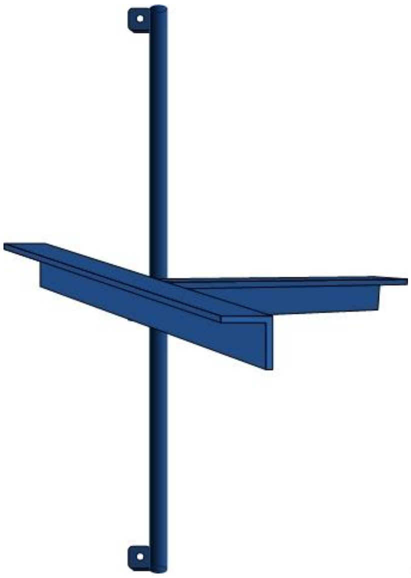
<u>ZS1ZC “Silver Spider” Dimensions: Mounting Points and Element Lengths</u>

<u>Notes</u>:
1. The basic mechanical frame of the Silver Spider is almost identical to the original Spiderbeam, except that 30mm aluminium is used instead of fibreglass.
2. All wire elements are fixed at their ends to the end of the 20m driven element (DE20) via fishing braid (not shown).
3. DE15 is mounted directly above DE20 with its feedpoint 40cm above the centre of DE20.
4. All elements are 1mm galvanised wire, except the 20m driven element (DE20) which is 30mm diameter aluminium tube.
5. On the prototype Silver Spider, the centre of each wire element is fixed to the boom through plastic tie-wraps mounted on hoseclips. The antenna should function just the same if the element centres are directly connected to the boom.
6. The driven elements DE15 and DE10 are each fed directly from the balun at the 20m element DE20 using RG58 coax, 40cm and 50cm, respectively (cut to cover the mounting separation distance).
7. The balun is identical to the balun described in the Spiderbeam construction guide.
8. All element lengths shown here are one side only, and must be doubled for all wire elements except for DE15 and DE10 (which are dipoles so each length refers to one half of the dipole).
9. The 20m driven element DE20 seems shorter than it should be (4.8m each side) because it is much thicker than the wire elements – this does not affect performance.



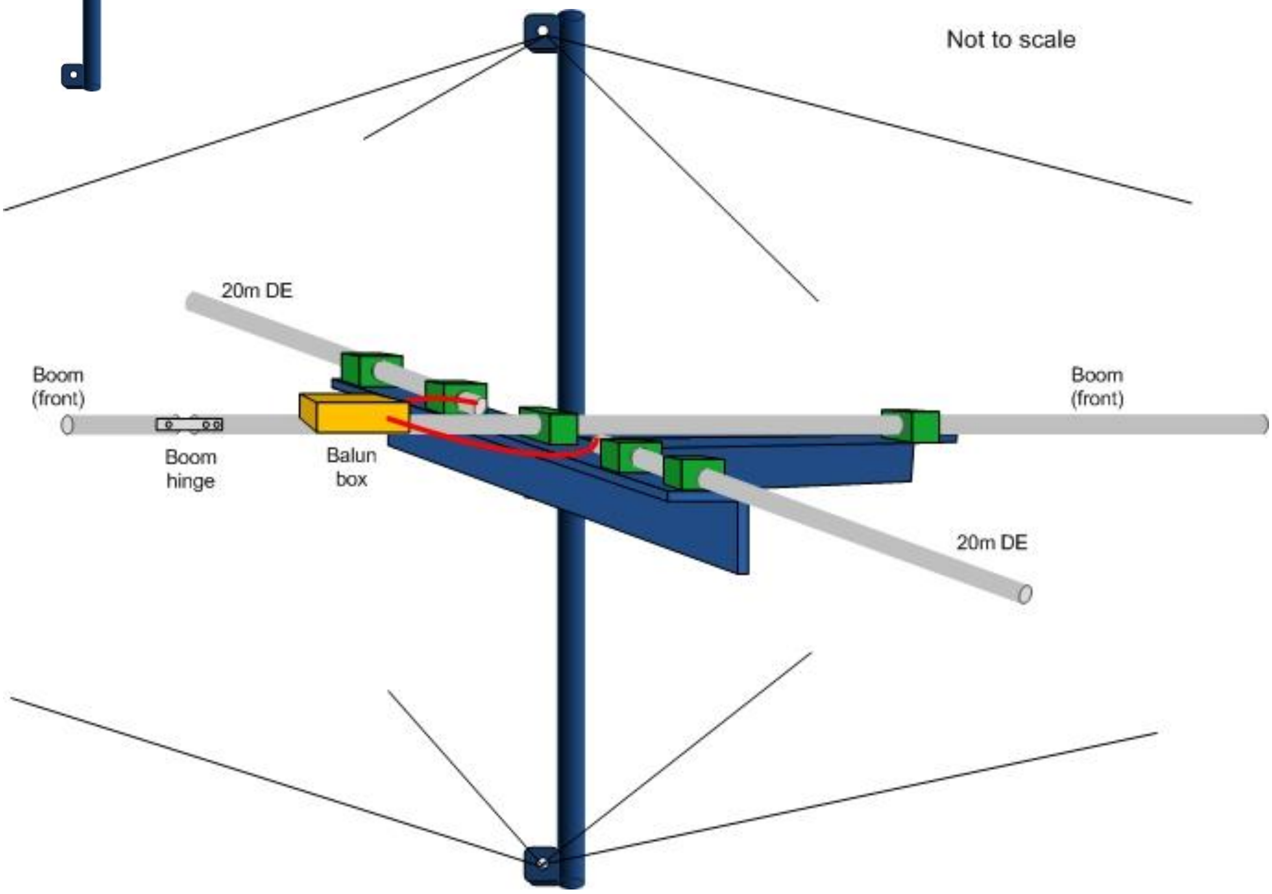
BUILDING IT

The important thing is that construction of the Silver Spider is performed similarly to the Spiderbeam in terms of the placement of guy lines for tethering of the main structure; however, the centre mounting has to be modified to hold a pair of insulated 20m driven elements in place, and the relative lengths and positions of the wire elements change.



This is a schematic of the central bracket of the Silver Spider. It comprises two 40mm steel angles welded together at right angles, with a 1m long vertical steel support tube welded into the corner where the angles meet. The support tube has a mounting lug welded at each end to act as tension points for the fishing braid that holds the antenna boom and 20m DE horizontal.

The detailed schematic shows how it all comes together. The boom is made up of a 6m length of 30mm aluminium tube that passes along the forward bracket such that 5m of it is in front and 1m is behind the 20m DE, which has each of its elements held onto the rear bracket with green pipe clamps. The rear pipe clamp of the boom sits between the two driven elements, and the front pipe clamp is on the forward bracket. The 1m

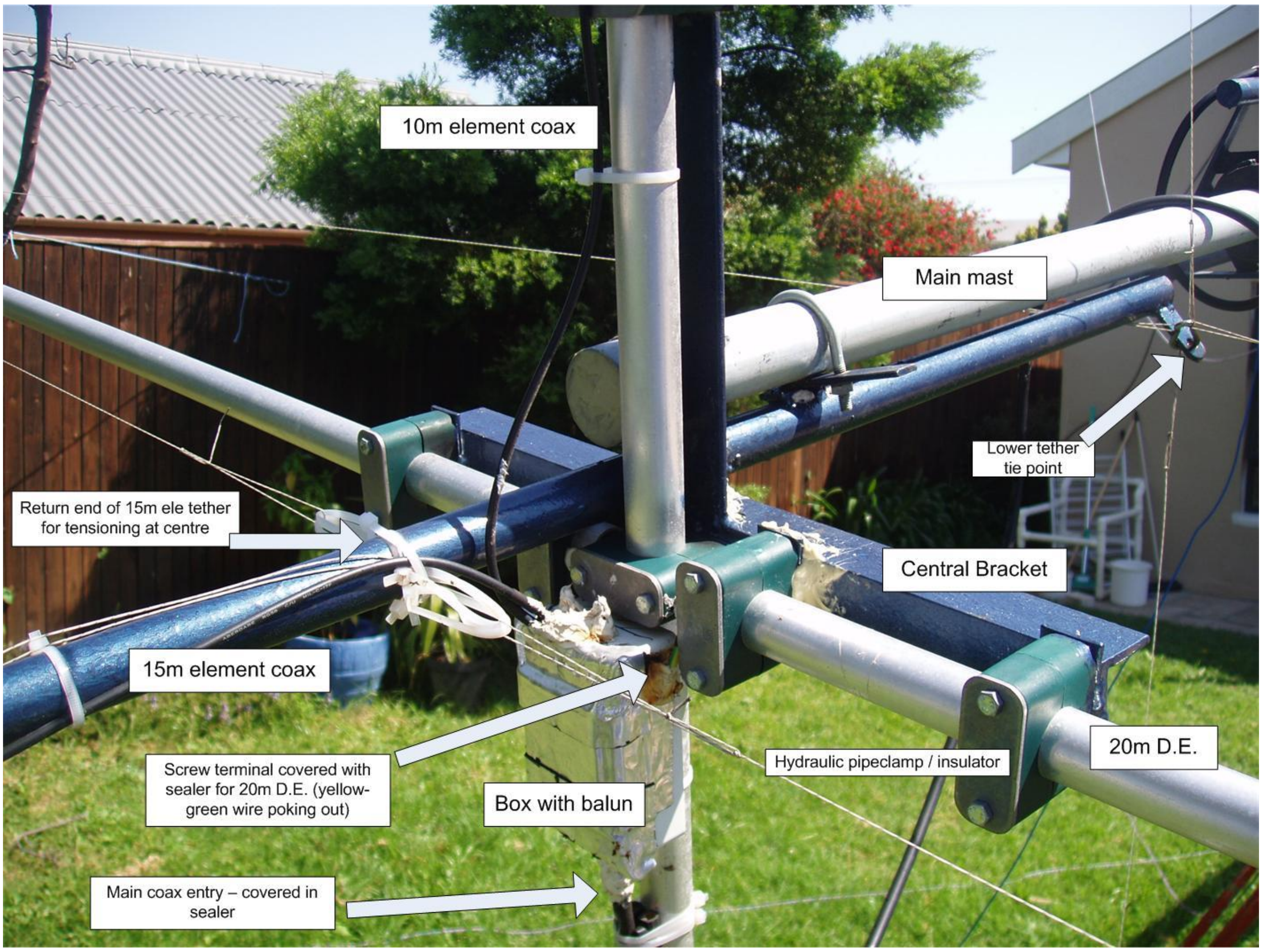


length of boom at the rear is extended by a further 4m length with a joint in it made up of a bolt and some aluminium angle extrusion – this is how the antenna gets brought down on a cantilever tower, since the back section of the boom gets folded “upwards” of the antenna.

The fishing braid support lines have been shown for the 20m DE and the boom – the lower set might not be necessary, but I included them to ensure stability in high winds.

Note that this is simply the arrangement I chose since I had access to a welding machine. Any mechanically sound bracket will suffice as long as it is stable and allows for insulation of the 20m DE.

The photo below is taken of the antenna in the tower-down position, so the vantage point is from above the antenna, to the right of the boom. You can see the balun box behind the 20m DE, wrapped in aluminium flashing to protect it from the weather.



You can see how the mounting bracket, painted in blue, gets mounted to the galvanised rotator mast with U-bolts. The main U-bolt is not visible here, it's located at the end of the galvanised mast bolted through the "vertical" portion of the blue T. The lower U-bolt holds onto a lug welded onto the blue pipe of the antenna bracket.

The base of each pipe clamp is welded to the bracket that supports it (the white substance is excess silicone sealant used to protect a rough weld!); the pipe clamp is then assembled on top of it.

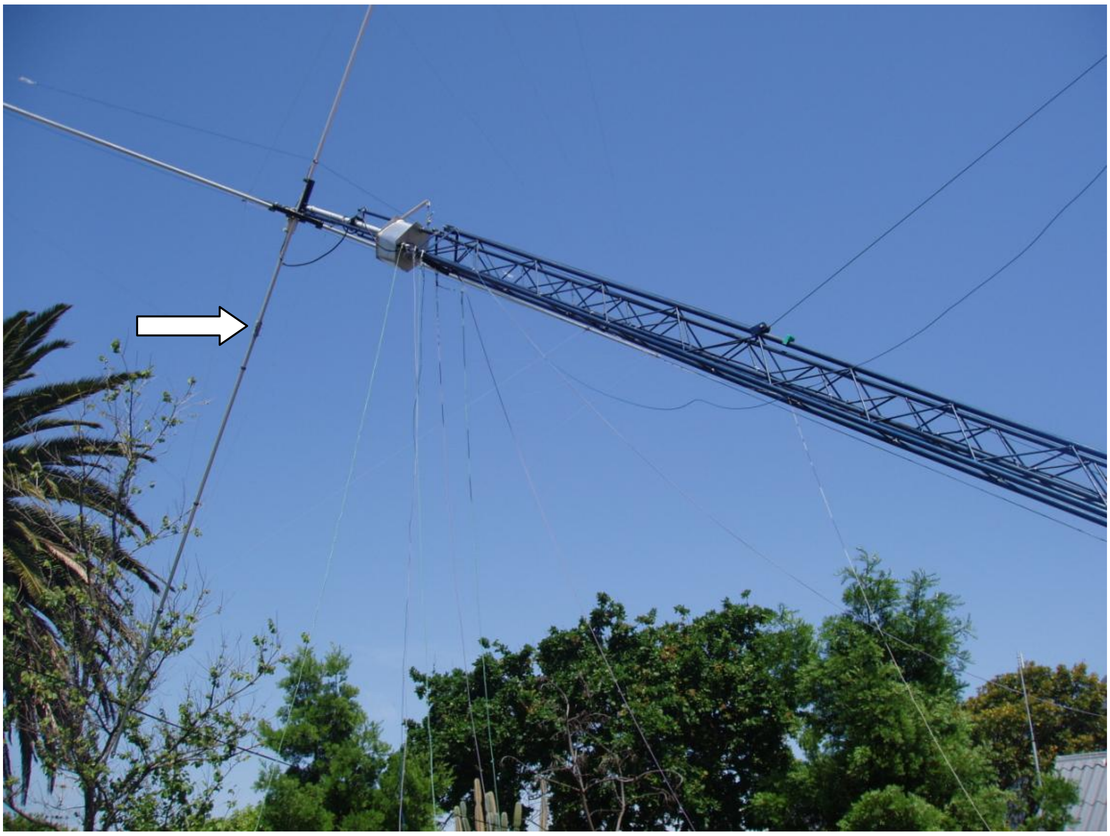
The support lug at each end of the blue support tube takes a snap hook to which each length of fishing braid support line gets tied. On the right hand side of the photo you can see how the fishing braid gets tensioned on this fixing point.

The electrical connections from the balun box to the 20m DE is simply heavy insulated copper cable for each side, emanating straight from the inside of the box via sealed holes. The 10m and 15m connection points are bolts in the forward side of the box, and short lengths of RG58 are connected to them with small connector lugs. These lengths of coax go straight to the 10m and 15m DE wires at their respective positions. You will need to make a secure connection there; I simply used a (messy) combination of terminal blocks, cable ties and silicone sealer, and I'm sure a better method is possible. Also, coaxial cable is not really the correct solution here since it is not a balanced transmission line – but I figured that the lengths are too short to degrade performance.

The next photo was taken after repainting the tower and antenna (now silver), with the tower in the lowered position. The view is therefore from "below" the antenna. Here you can see how the upper U-bolt holds the bracket to the mast.

You can also see a method for managing the coaxial cable. I use LMR-400, which is quite an inflexible cable that does not handle repeated bending well. Rotating an antenna with this coax will cause fatigue and failure. The solution is to wind a few turns around the mast so that as the antenna turns, the bend is distributed through a length of the cable rather than stressing it at one point.

Bringing the Silver Spider down is easy on a cantilever tower. This is where the hinge in the rear boom section comes into play… as the tower is lowered and the end of the boom nears the ground, the lower fishing braid support line is disconnected from the boom, and the rear boom section is then moved away from the tower.



This photo shows how the boom gets folded away.

CONCLUSION

So, in summary – when constructing a Silver Spider, you need to:

1. design and build a bracket of your own to support the front and rear boom and the 20m driven element (DE), all of which are made from 30mm diameter aluminium tubing.
2. Add support lines of fishing braid or Kevlar to hold the aluminium tubes in a horizontal position.
3. Follow the Spiderbeam instructions for mounting the guy lines.
4. Build the balun as per the Spiderbeam instructions.
5. Cut and position the wire elements as shown in this Silver Spider Construction Guide

In my prototype I used 1mm galvanized wire. There are better antenna wires available such as the Wireman CQ-532 Silky Stranded Copperweld that Spiderbeam use – this is definitely the better alternative, but I have not prototyped using this wire. However, my simulations assumed 1mm copper and should therefore be accurate – in fact I have not had to make any alterations to accommodate the galvanized wire I used.

As a last note, I found it easiest to do the construction with the blue mounting bracket mounted on a spike driven into the lawn of my back garden. This meant that I could get the tensions exactly right to make the elements hang horizontally with no droop, which makes for a very attractive antenna.

Good luck in your construction and enjoy your DXing!