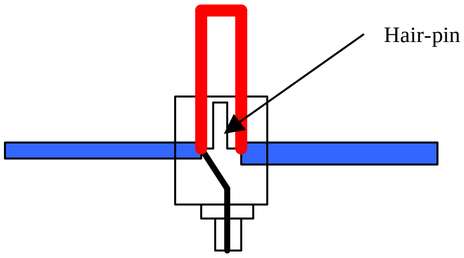
Matching of 432Mhz Yagi by PA0PLY

Introduction

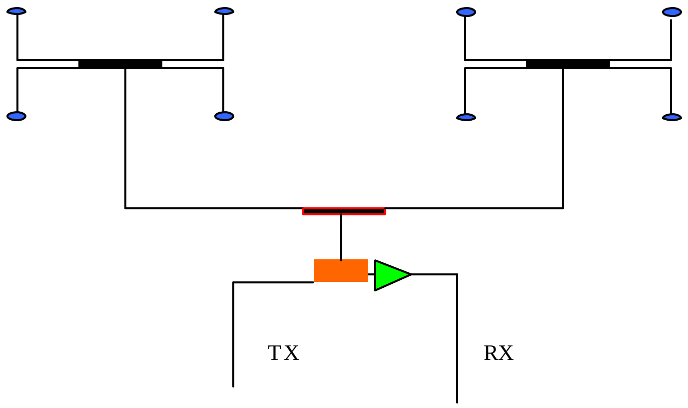
Several years ago, starting EME communication, I decided to use relatively short antenna's for this purpose. Based on a DL6WU design, I modified the length to become shorter then 3 meters.
Using YO- software the final typical parameters were as follows:

Length:	2.98m (4.2 Lambda)
Gain:	14.36 dBd
F/B ratio:	36.7 dB
Impedance:	10.8 – j45.2
VSWR:	1.04

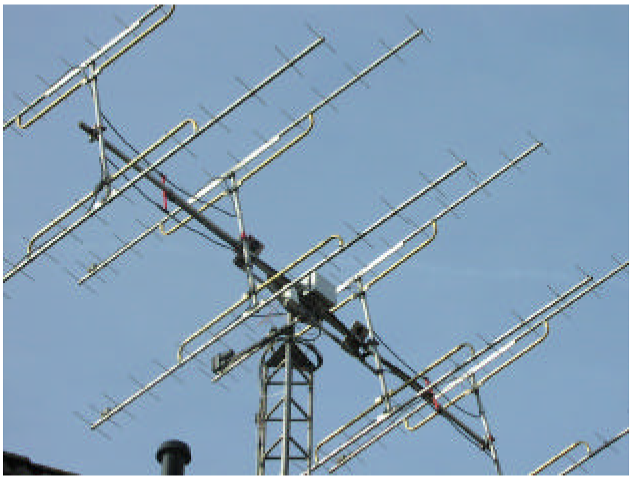
To prepare a good match for the feeder, a hairpin construction was suggested in combination with a 1:4 Balun.



After some mechanical difficulties, a group of 8 antenna's was completed. The antenna configuration is shown below.



These antenna's were used successfully over a period of more then 4 years. Unfortunately the performance of the array decreased slowly over some time. Further investigation on this problem was barely needed. Although the VSWR became better and better, my signals became weaker and weaker, while fewer stations were heard.

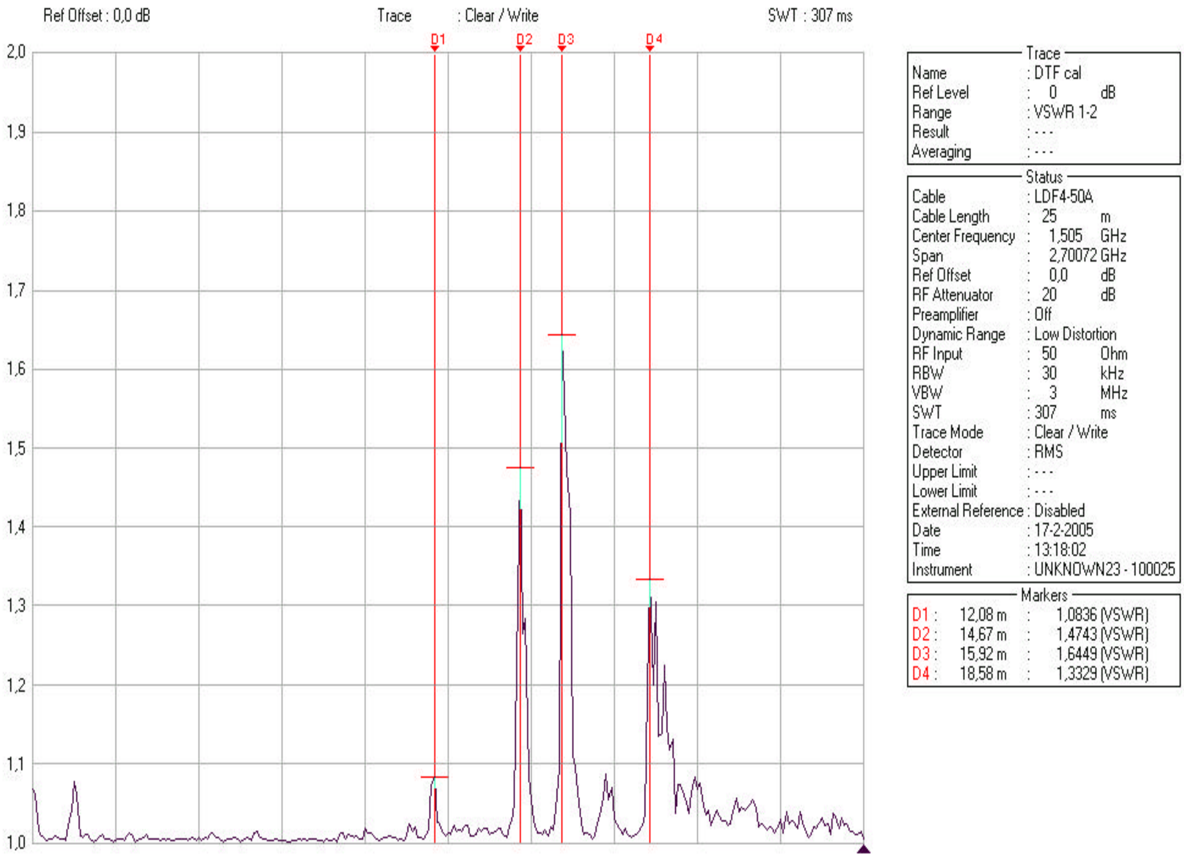


Time-domain measurement

Using a time-domain spectrum analyzer, FSH-3 of R&S, we found possible area's of problems.
The graph below shows four points, D1-4, with higher VSWR values.

Marker	Description
D1	Bird coupler – mast mounted
D2	2-way splitter
D3	4-way splitters
D4	Antenna's

Without further dismantling the entire antenna array, it is virtually impossible to check each section / antenna individually.
From history I knew the feeder matching was a potential problem area, so was the construction of the 4-way splitters.
Markerpoint D4 indicated a VSWR of 1.3, while D3 shows 1.6. Since these points are the result of a combination of various items, I suspect serious problems here. Based on this I decided to replace both the splitters as well as the feeder systems for all antenna's.



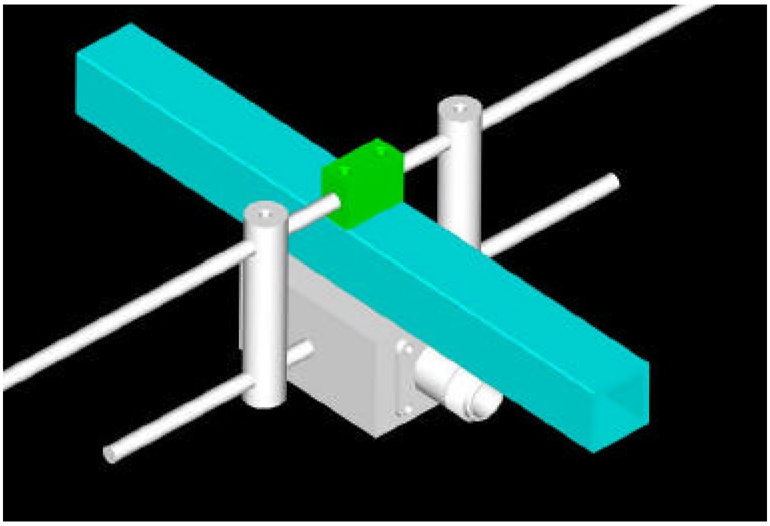
Plot from FSH-3 time domain analyser

Feeder matching

The choice of a hairpin matching circuit allows an easy method for matching a wide range of impedances. However there are several negative issues on this type of matching as well. A hairpin mach uses a small inductive short between the two legs of the dipole.
Due to this induction, the actual length of the dipole elements will have to be shorter to create a good match. The shorter elements are not an optimal transformer to the further elements of the antenna and thus a loss of energy will appear here. The hairpin between the dipole also absorbs energy which is another point of RF loss. Furthermore the impedance at the feedpoint is very low and matching became very critical. Talking to expert antenna designers, the low impedance should have been avoided to ensure an easier matching. Changing the first director position with respect to the feeder point was suggested to meet an 50 Ohm impedance (F9FT method).
Since I constructed all my antenna's already this was not felt as a good solution for my problem. Changing element positions I felt concerned on the impact of it to the antenna diagram and other performances. Discussing my problem with various other hams, I was attended to the double T-matching method as an easy fix for all!

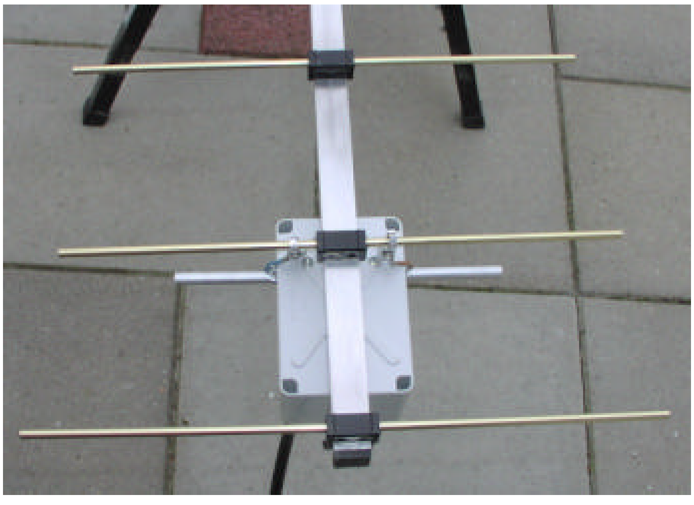
Double T-matching

This method was used for example in the M2 (former KLM) yagi designs. The low impedance is transformed to a much higher impedance. Since very low currents flow in this circuit minimal losses will occur. The feeder element is designed for maximum length, which ensures maximum transformation of the RF energy into the antenna.



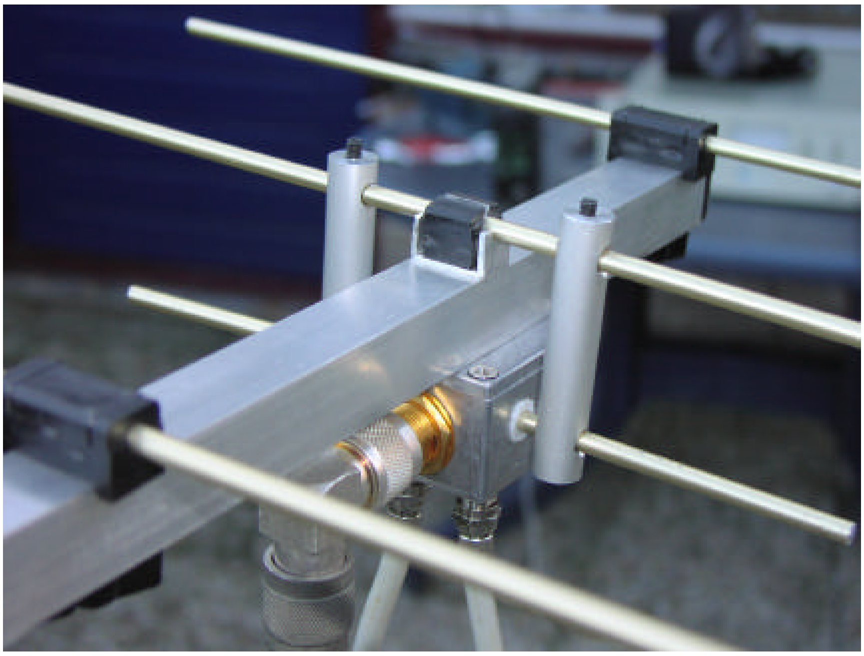
Principle of double T match

Although talked to many hams, it turned out very little information could be found for the use of this matching on 432Mhz. I decided to construct another yagi, similar to my EME antenna's to run some testing for matching. Based on the details of a double T-match for a 50Mhz antenna with almost same low feeder impedance, a first attempt for matching was made. The length of the feeder was cut on a length which is visually in between the length of the first director and the reflector element lengths.

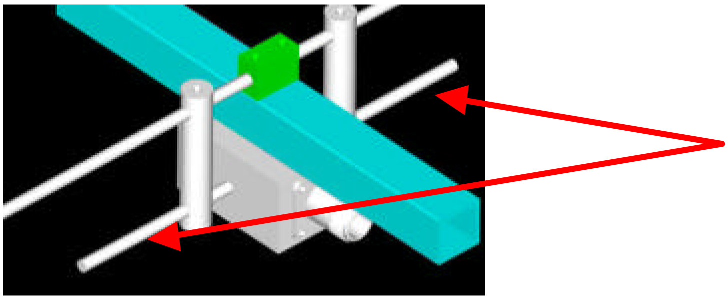


The feeder was prepared using the same type of elements used on the entire antenna. Material is aluminum diameter 5mm with isolated mounting. The parallel elements were prepared from Alu tubing diameter 8mm and mounted into a box together with a 1:4 Balun.
First tests showed the mounting box was to large as the shortcuts couldn't move furthermore to the boom center.
Scaling the distances found on the 50MHz yagi its matching point should be found 2-3cm from the boom center. For this reason a new smaller mounting box was prepared allowing close to the boom adjustments. Also the parallel elements were replace by 5mm Alu parts. Besides this problem, with the new configuration asymmetrical positions of the shortcuts were found, while a good matching point still was not achieved.

The asymmetry was caused by the fact that the feeder center was isolated from the boom, allowing the zero point floating. After preparing a fix for this problem, adjustments now were symmetrical.



Some experiments were conducted with the length of the Balun. This seems relatively non critical, even the impedance of the piece of coaxial cable is not relevant.
Using small pieces of aluminum foil, wrapped around elements an easy adjustment could be done to see what happens without cutting elements definitively.
It turned out that the length of the parallel elements do heavily influence the total performance. Finally I had to cut 30mm of each parallel element to find a good matching. (Forward 75W // Return < 0.1W).



Important for capacitive coupling into feeder

In its final configuration the antenna shows VSWR influences from the environment. Even touching or approaching the very first director could be found into changes of the VSWR. With the hairpin construction I never noted such an effect.
To me it seems all elements now affects the total performance of the antenna.
Having found a good matching now, the last concern was the possible impact to the antenna diagram.

Antenna diagram

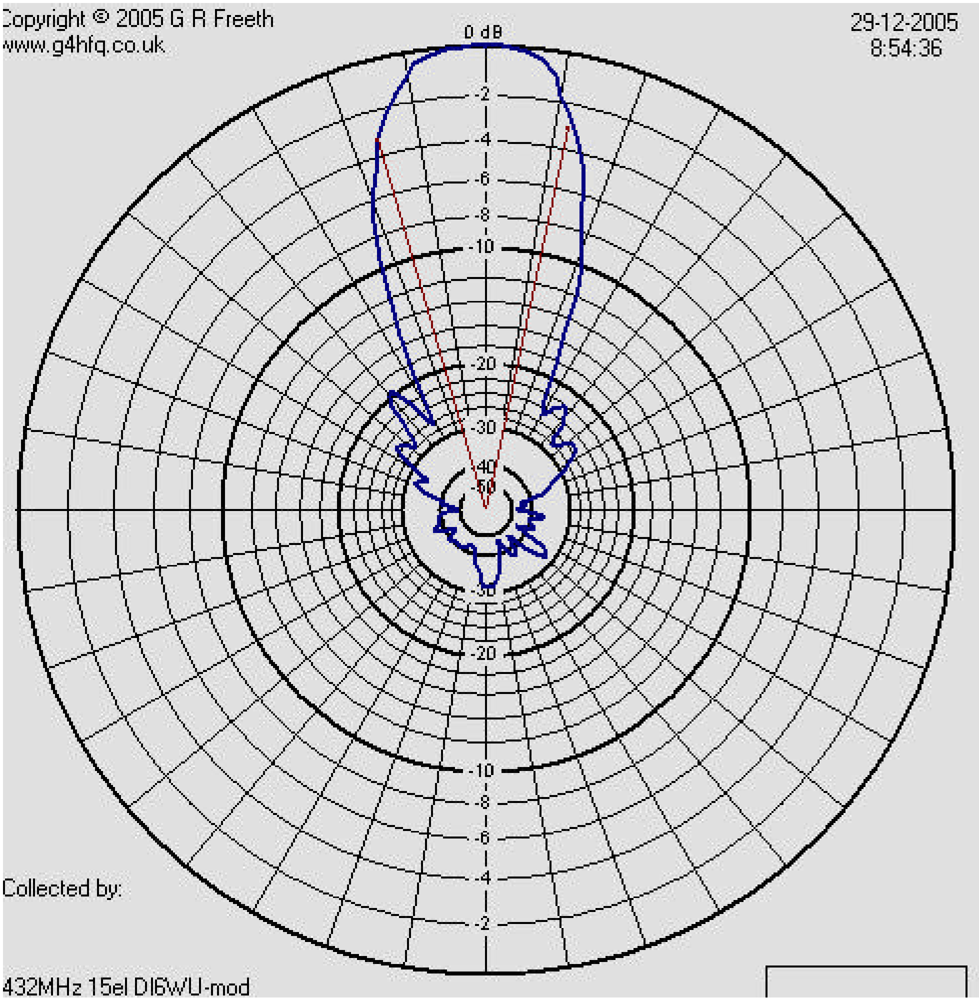
In order to check out the antenna diagram, I was able to test the antenna in an full anechoic EMC test chamber.

The antenna was mounted about 2.5m above the absorber floor on an antenna rotor system, while a reference antenna was located about 4m away from this position. A spectrum analyzer in zero-span mode, connected to a plotter was calibrated in dB steps.

For gain estimation a dipole replaced the test antenna and it's value was noted on the plot.

With the help of POLAR PLOT freeware the figures found were converted into an antenna plot diagram.

The resulting diagram and gain compares to the values found in the YO software. The antenna diagram shows a clean diagram free from large sidelobes and a good front to back ratio, which all is essential for EME operation.

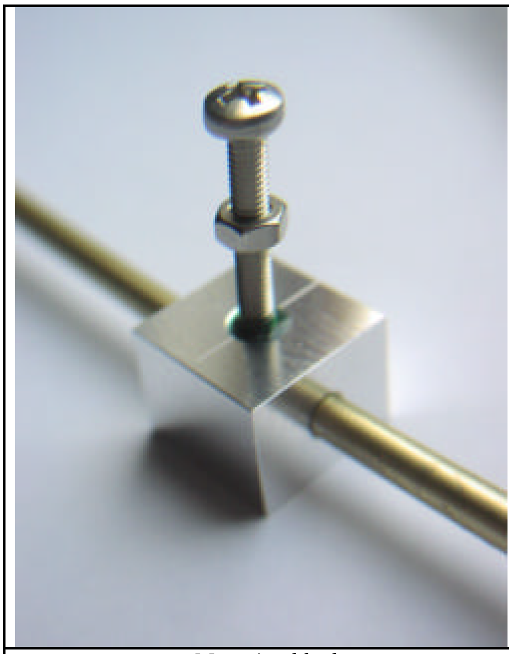


At 130 degrees a larger sidelobe was shown, which could not be explained immediately. It was generated by the antenna, as we run another test with a different set-up in the EMC room to ensure chamber effects are avoided. So far it is assumed this lobe could be caused by the fact that the directors of the antenna are not all properly centered on the boom. Recently I found that the isolating mounting supports were not always in the center of the elements. Unfortunately I had no possibility to proof this statement by redoing the measurements. Since this sidelobe is at a -30dB level compared to the mainlobe we should not take further notice.

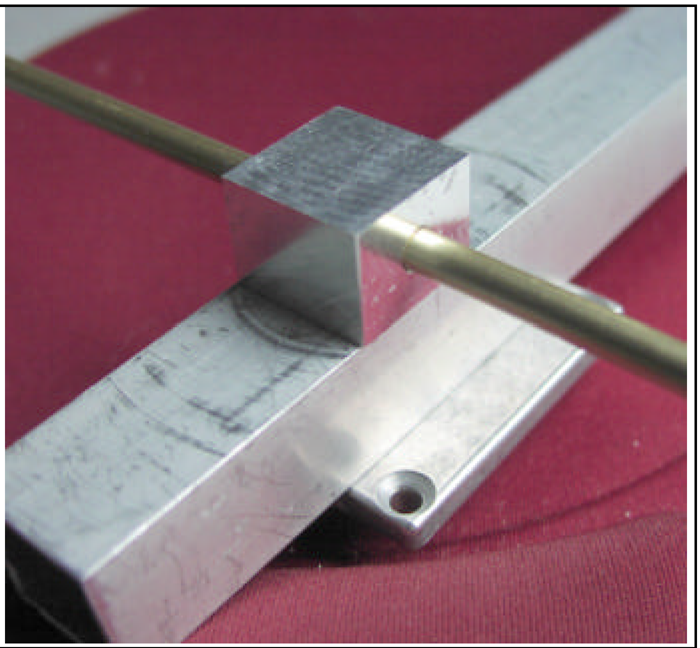
Final construction

Based on above experiments a construction is prepared to replace the existing feeders of all 8 EME antenna's.

Instead of the isolation mounting block a conducting aluminum mounting is prepared to ensure good boom contact for the feeder. The M4 screw ensures fixation of the feeder, while it also serves as an mounting for the connector box on the other side of the boom.

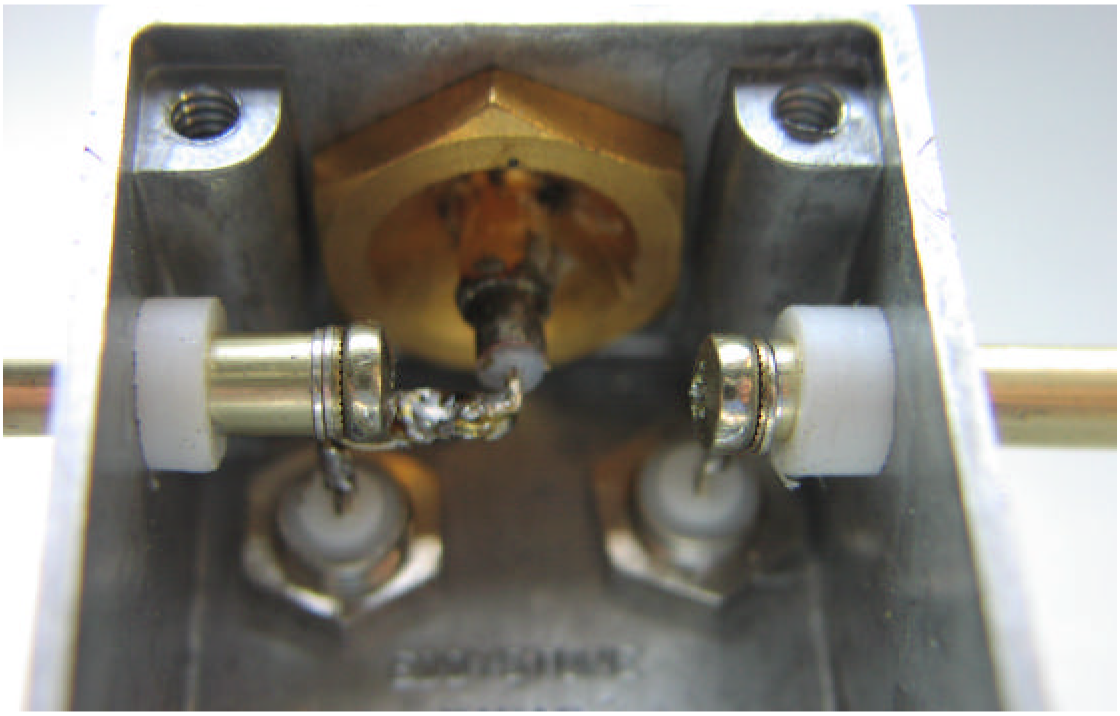


Mounting block



Completed assembly including cover of box

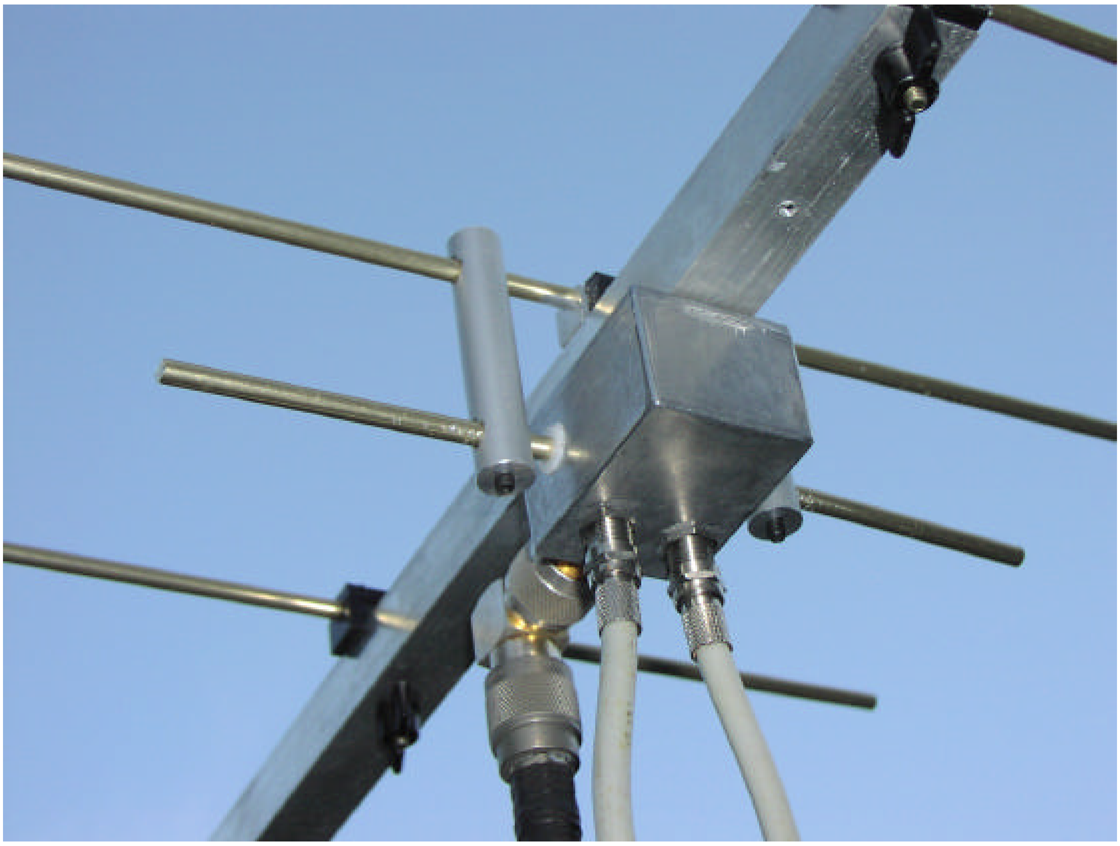
Teflon spacers are used to guide the dipole elements trough the box. The Balun is prepared from 75Ohm satellite TV coaxial cable fitted with F- connectors. The center pin of those connectors act as a mounting support for the dipole elements.



Final notes

During my experiments following useful notes were made:

1. Feeding type doesn't influence the antenna pattern
2. Balun coaxial is not critical in impedance
3. Wrapping household foil is an ideal method to find effects of element lengths
4. Double T-match is a very loss less and effective matching method
5. Be aware of capacitive coupling effects on 432Mhz.



Final version with double T-match

Thanks to

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