Playing with Matches
Part 2 – Some Examples

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Abstract.
Applying some of the concepts from part 1, a couple of examples on matching to a Yagi are looked at in more detail.

A Quick Recap.
In part one of this series we had a brief look at some of the theory behind matching the antenna to the transmission line. (Ref 1.) We saw that the antenna reactance plays an important part in any match and a number of equations and tools were identified to assist us with design and analysis.

An Example - the VK3VT Two Metre Fox Hunt Beam.

As the old cookbook says when wanting to cook a rabbit, step one catch your rabbit. In our case here what this means is, we need to select the basic design we are going to use. For this example we are looking for a beam to use when on a Two-Metre Foxhunt, so the attributes we are looking for are:

- Relatively small (say three elements)
- Clean pattern with a single main lobe
- Good front to back at usual frequency (144.250Mhz)
- Well balanced ie. lobe centred on forward direction.

Rather than start from scratch on all these things the simplest thing to do is to see what is already being used. In the case here, certainly locally in Victoria, the most common design used is the Greg Williams VK3VT yagi. This is a well-proven design that has been used by many people over a number of years. The significant details for this antenna as published by Greg (Ref 2.) are as shown in Table 1. Note. The elements are mounted through and in contact with the boom, which is square section of side 12mm. All are made of aluminium.

Element	Length (M)	Spacing (M)	Diameter (M)
Reflector	1.029	0.0	0.005
Driven element	0.981	0.311	0.005
Director	0.930	0.622	0.005

Table 1 VK3VT 2M Foxhunt beam.

This beam also has the advantage for the purposes here that little has been published on matching to it, so hopefully the resultant match will be of interest to a number of people.

The next step is to find the input impedance that we need to match to, and this is where in the past many people have come unstuck. Because it is not particularly simple to measure this item many of the available matching cookbooks forget about it and use some sort of average figure. The assumption being, that differences can be compensated for by using a variable capacitor, or adjusting an arm length. At best, if your antenna is close to this average value, this approach will, with some adjustment, give you a workable match. The amount and size of adjustments required will however increase as your antenna becomes less like the average. At worst, as seen in part one, in some cases a match just will not be possible using the basic parameters derived using the wrong values of impedance. The frustration and self-doubt of having built an antenna, and then spending several hours climbing up and down a mast fruitlessly adjusting gamma arm lengths and capacitor values with no sign of a good VSWR, has I’m sure has put many Amateurs of antenna building for life. This is particularly disappointing as in most cases there is probably nothing wrong with the basic antenna, it is just that its actual value of input impedance is sufficiently different from the average, and a perhaps slightly different diameter of matching arm, could have produced a much better result.

It is possible for an Amateur to measure the input impedance of an antenna without being rich or lucky enough to have access to a HP vector impedance meter but it does require a bit of an effort so that is not the method used here. Instead thanks to the advent of powerful personal computers and sophisticated mathematical models it is now possible to calculate, amongst other things, what input impedance you can expect from your antenna. This is how the impedances mentioned in part one were obtained.

There are a large number of different packages or programs available to the Amateur these days to do this, most are based or at least referenced to a particular model called NEC2. Which one you use is a matter of individual preference, but for the example here I will use my own package called Yagicad which is freely available at the URL in Reference 3.

Entering the dimensions etc. from Table 1 into Yagicad we get the following results:

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YAGI COMPUTER AIDED DESIGN PROGRAM  VERSION 5.0  VK3DIP 1991/2003


     FILE: C:\YC5\vk3vt.yag        LAST SAVED: 01-15-2004
     TITLE: VK3VT FOX HUNT YAGI     SOURCE: VK3VT Web Site
     COMMENTS: Example for "Playing with Matches part 2"
     PRINTED 01-15-2004    18:48:36


   ELEMENT NO.         LENGTH         SPACING         DIAMETER
        1              1.029           0.0            0.005
        2              0.981           0.311          0.005
        3              0.93            0.622          0.005

     NOTE ALL DIMENSIONS IN METERS, WITH SPACES MEASURED FROM THE REFLECTOR
     BOOM DIAM   0.014 (M)    Element lengths displayed using NBS correction factor
     BOOM DIAM   0.0142 (M)     CORRECTION FACTOR   0.25

     FREQUENCY = 144.25( MHz)

     INPUT IMPEDANCE = 22.64 J -9.16 OHMS
     FORWARD GAIN = 5.8 dBd
     FRONT-TO-BACK RATIO = 43.7 dB


     Calculated using the Nec 2 with  21 segs.
     Calculated Eff: 99.1 %
     Using Aluminium (3.82E7) Elements
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You would note that the boom diameter is shown as 14.2mm, this is the equivalent diameter in a round boom to the 12mm square one used by Greg. I also used the NBS boom correction factor as this allows for elements mounted through the boom.

It is always worth while to try and verify the model and in this case if we use it to produce a pattern plot and a frequency swept plot we get the results shown in Figure 1. and 2. respectively.

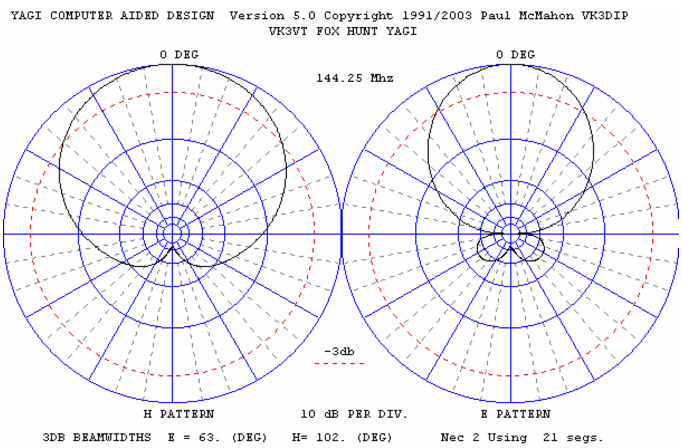


Figure 1. Polar Pattern Plot of a model of the VK3VT foxhunt beam.

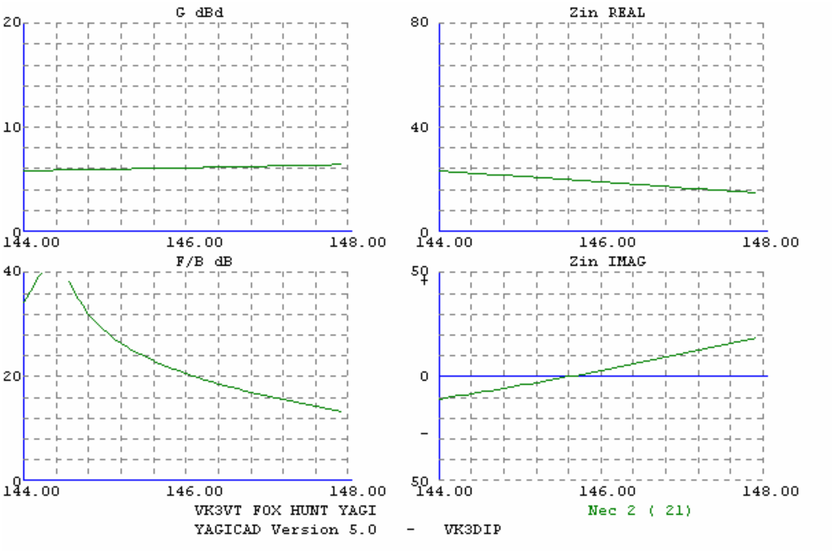


Figure 2. The swept frequency response of the model of the VK3VT Beam.

From these we can see that this model does show all of the attributes we identified above, in particular the swept response shows the front to back more or less peaking at the 144.25MHz foxhunt frequency. If these things are correct then it suggests, though not guarantees, that the other items such as the impedance will also be close.

So we have an impedance of about 22.64 –J9.16 what is next?

Next we need to decide what sort of match we will use. In Greg's original article he mentioned using a Tee match, but didn't give many details other than a diameter and spacing of the arms, and the fact that he never managed to get the VSWR very low.

If we use Greg's figures for a Tee match (arm diam 0.005mm and spacing 14mm), and the impedance above, in the spreadsheet mentioned in part one, we obtain the following graph (Figure 3.)

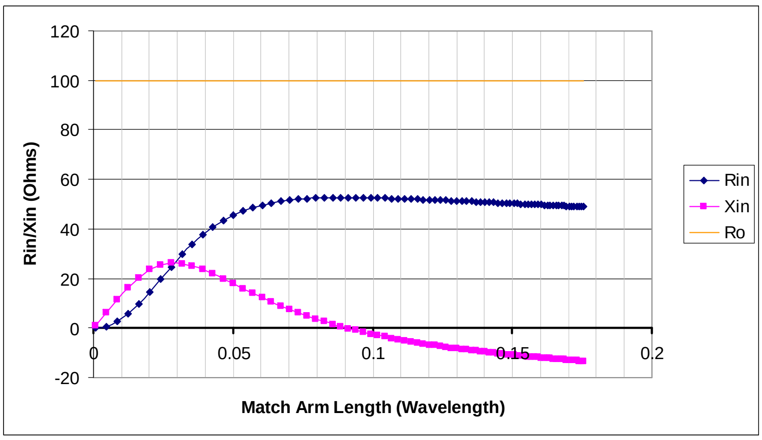


Figure 3. Graph of effect of varying arm length on a Tee (or Gamma) match on a VK3VT beam.

Note that the R curve never rises above about 55 Ohms. While this would be fine if we were looking for a Gamma match to 50 ohms, in this case where we want a good balance Greg was using a Tee with a four to one coax balun ie. the value he needed would be 100 Ohms. Remember from part one that a Gamma is the same as half a Tee but the impedance is halved. In this case to reach the 200 Ohms level of the output of the coax balun each arm would need to reach 100 Ohms. In this case we can see that irrespective of what length of arm was used or if there was a series capacitor or not, you could never do better than about a 2:1 VSWR. Now we can see why Greg had trouble with the VSWR.

To make a Tee match, with or without C, work with this antenna as it stands you would need to lower the diameter of the arm to about 1mm and increase the spacing to about 15mm. At this point an arm length of about 0.24m would give a reasonable VSWR. Figure 4. As calculated by Yagicad illustrates this.

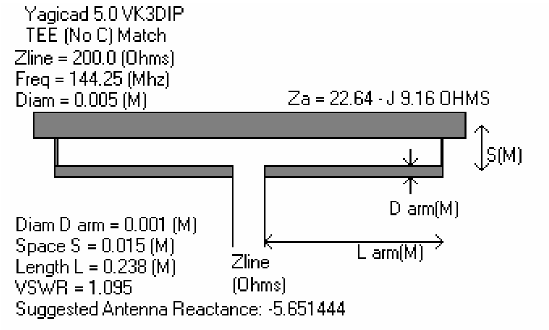


Figure 4. Yagicad Tee match on unchanged VK3VT beam.

In practice however it probably wouldn't be a good idea to build this match as the 1mm diameter arm would not be very robust, and definitely wouldn't survive the usual foxhunters equipment packing techniques.

A much better solution is found by slightly shortening the original driven element length to increase the magnitude of the negative or capacitive reactance. This also shows the benefit of the mathematical/computer model as this scenario can be explored without having to actually spend time and aluminium physically building anything.

To achieve a good match using Gregs original arm diameter and spacing we can see from a program like Yagicad that we need to increase the magnitude of the capacitive reactance to about –24 Ohms. The Model indicates that this can be done very simply by decreasing the driven element length from 0.981 to 0.962 Metres ie. approximately one centimetre is removed off each end of the driven element. At this point an arm length of about 133mm should produce a good VSWR. This is seen in Figure 5.

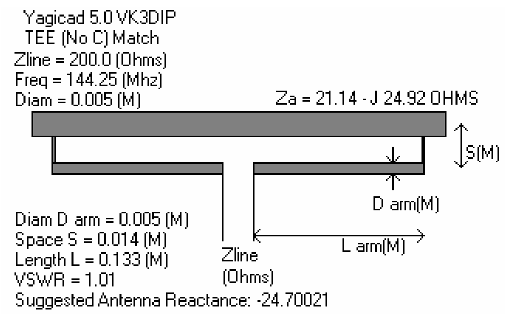


Figure 5. Slightly shortening the driven element makes for a simpler, better match.

It is of course a very good idea to verify with the model that this change in dimensions has not adversely effected the good pattern and front-to-back ratio of the beam. Recalculating with this new driven element length shows virtually no change to the pattern with a 0.01dB increase in forward gain and a 0.2dB decrease in Front-to-back. In practice you probably couldn't tell the difference other than by measuring the VSWR at 144.25 MHz where it should be much better. So if you have already built one of these antennas, with the same size boom and elements, and want a better VSWR get out the hacksaw and take just under a centimetre off each end of the driven element, and then you should be able to shorten the tee arms to obtain a good VSWR at least at 144.25MHz.

Conclusions and Summary
From the above we can conclude a number of things:

Absolute resonance of the driven element in most cases makes it harder to match, not easier.
Having the driven element being a bit short (Capacitive) is a common strategy.
Numerical Models make matching much easier.
You do not have to always use complex matching, the simpler the better.

Next time we will look at the practicalities of building some of these designs and in particular at the question of balanced and unbalanced transmission lines.

73 Paul McMahon
VK3DIP

YAGI COMPUTER AIDED DESIGN PROGRAM VERSION 5.0 VK3DIP 1991/2003

FILE: C:\local\article\vk3vt.yag LAST SAVED: 01-15-2004
TITLE: VK3VT FOX HUNT YAGI SOURCE: VK3VT Web Site
COMMENTS: Example for "Playing with Matches part 2"
PRINTED 02-05-2004 17:11:58

ELEMENT NO.	LENGTH	SPACING	DIAMETER
1	1.028	0.0	0.007
2	0.954	0.311	0.007
3	0.919	0.622	0.007

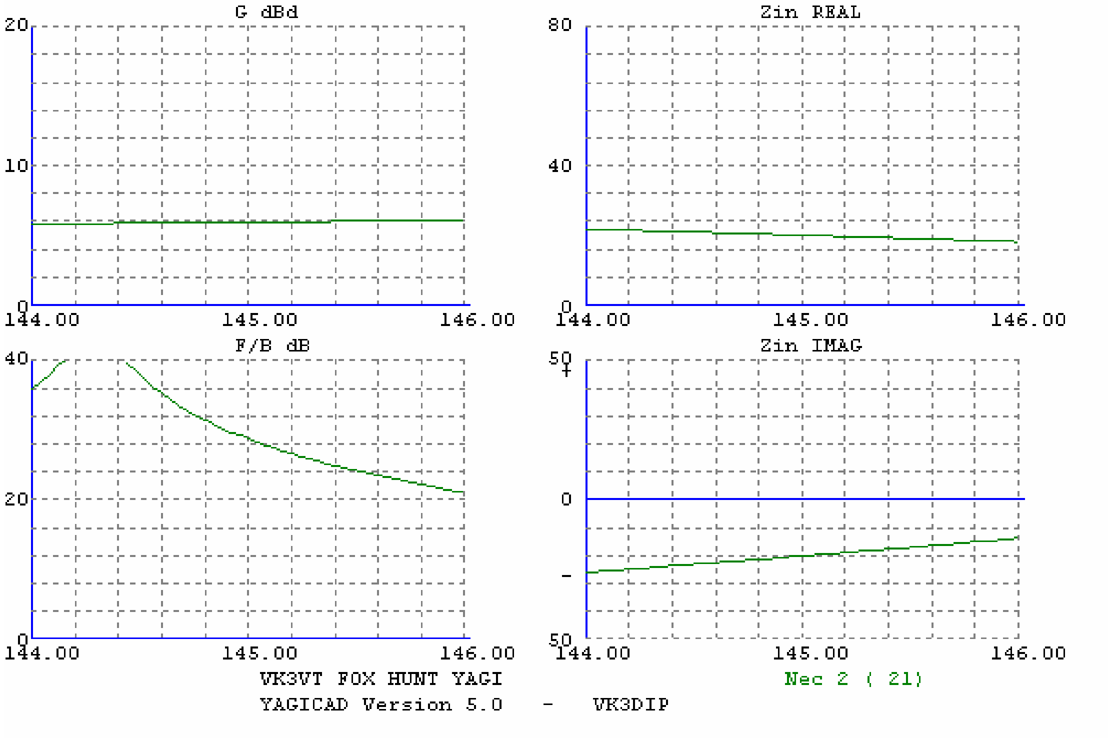
NOTE ALL DIMENSIONS IN METERS, WITH SPACES MEASURED FROM THE REFLECTOR
BOOM DIAM 0.014 (M) Element lengths displayed using NBS correction factor
BOOM DIAM 0.0142 (M) CORRECTION FACTOR 0.25

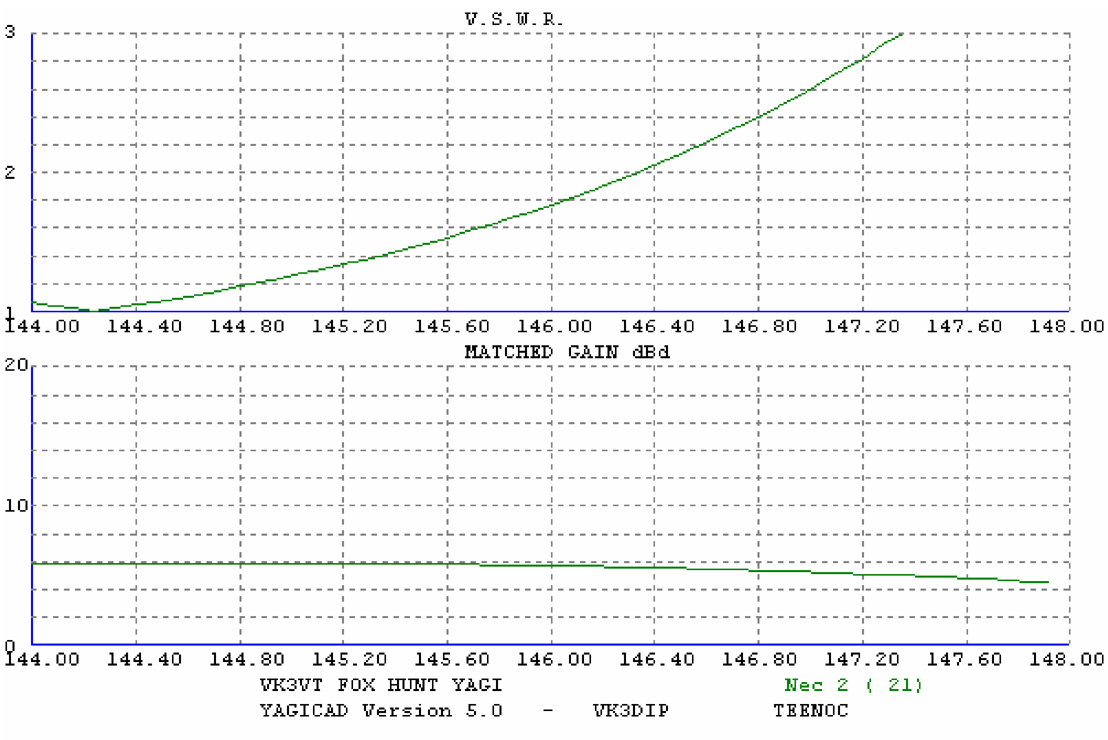
FREQUENCY = 144.25(MHz)

INPUT IMPEDANCE = 21.37 J -24.65 OHMS
FORWARD GAIN = 5.8 dBd
FRONT-TO-BACK RATIO = 43.0 dB

Calculated using the Nec 2 with 21 segs.
Calculated Eff: 99.4 %
Using Aluminium (3.82E7) Elements

TEE MATCH PARAMETERS (No C)
ARM DIAMETER (M) 0.007 SPACING (M) 0.0139
ARM LENGTH (M) 0.166
MATCHING IMPEDANCE 200


G dBd
20
10
0
144.00
145.00
146.00
Zin REAL
80
40
0
144.00
145.00
146.00
F/B dB
40
20
0
144.00
145.00
146.00
Zin IMAG
50
+
0
-
50
144.00
145.00
146.00
VK3VT FOX HUNT YAGI
Nec 2 (21)
YAGICAD Version 5.0 - VK3DIP


V.S.W.R.
3
2
1
144.00 144.40 144.80 145.20 145.60 146.00 146.40 146.80 147.20 147.60 148.00
MATCHED GAIN dBd
20
10
0
144.00 144.40 144.80 145.20 145.60 146.00 146.40 146.80 147.20 147.60 148.00
VK3VT FOX HUNT YAGI
Nec 2 (21)
YAGICAD Version 5.0 - VK3DIP
TEENOC