Reflector Impedance Control within Yagi Antennas (1)

- uncalculated Software Model Error Corrections & Best Practice Feed Point preparation

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Last time I presented some of the capabilities of the UA9TC bent reflector Yagi and in this article, I would like to describe the benefits and potential pitfalls of using bent reflectors to control impedance within Yagi antennas. I will also look at the corrections required and how often they are omitted when translating the software model into a real-world antenna. Firstly, I will look at ‘best practice’ as far as the dipole and feed points are concerned, to ensure that model replication can be achieved as accurately as possible. To some, this section may seem somewhat controversial.

As discussed previously, the use and arrangement of unconventionally shaped elements within a Yagi can alter the impedance within the design, so that a 50 Ω feed point impedance can be achieved without having to use matching devices, which are typically only added in the real world, and not modelled by the software, so any associated losses and reduction in performance are not shown. Modelling matching devices ensures that any associated loss is included in the model predictions (this is not often considered in performance predictions after the software design is complete) and also that any degradation of performance caused by the physical structure of the matching arrangement does not adversely affect the completed antenna. This is easier said than done as most software packages used by hams to model antennas are not accurate when modelling anything other than simple wires. However, the associated losses and degradation in performance due to any matching device remain within the built antenna.

The loss that matching arrangements can cause was highlighted to me while conducting experiments in the Waters and Stanton service department recently. Our engineers were testing a radio that was being offered for part exchange, it was an older radio but had a built in ATU. While checking the operation of the ATU, I measured the output power with and without the ATU into a dummy load. The results were surprising, 10 to 20 W were lost when the ATU was placed in line, depending on the band selected.

Expecting this to be largely due to the age of the radio (a Kenwood TS-450), I tested some newer, current radios and established that 10 W of loss from 100 W input was indeed typical. Now, while an internal transceiver Auto ATU will be much more complex and with potentially higher loss than a simple antenna matching unit placed at a feed point, it does highlight how much power can be lost within matching units and why ideally no form of matching is needed or used.

In recent times, bent element matching has become far more commonplace with antennas such as the DG7YGN GTV, my LFA2, the UA9TC bent reflector types and my own UA9TC inspired OP-DES. However, the OP-DES employs a bent driven element rather than bending the parasitic elements for impedance control whereas the UA9TC and LFA2 configurations bend the reflector. This means that the complete antenna with any and all matching can be modelled accurately provided a number of precautions are taken during and after the software model design phase. We will take a look later at the capabilities of bending reflectors to affect impedance but before so doing, I would like to highlight why I believe the re-shaping of the driven element to effect an impedance change is a more viable and reproducible method.

Shortfall of NEC and MININEC

One of the shortfalls of the most commonly used antenna modelling packages within ham radio is the assumption of a perfect, ‘tail-less’ connection between the coax and the antenna itself, so what does this mean? NEC and MININEC both assume that the coax stops where the driven element starts and there is no tail connection between them. This means that when an antenna built from a software model using either of the above mentioned calculation engines, the driven element will need to be shorter than the model suggests when built, in order to account for the tails that will indeed exist between the coax and the feed point of a real antenna.

Photo 1: An open feed-point example, the feed should be as close to a 'T' shape as possible

RF does not wait until it arrives at the dipole itself to radiate. The radiating element begins at the point where the feed cable is no longer coaxial and this includes any tail sections. It is for this reason that a driven element will always need to be shorter than the model, assuming that the antenna is built correctly and any correction factors have been appropriately applied. This highlights the fact that tail length should be reduced to an absolute minimum and should be more 'T' shaped rather than 'Y' shaped at the feed point in order to follow the software model as closely as possible. The higher the frequency, the more relevant this rule becomes. So how about those instances where an antenna is built and the antenna is ''perfect'' without any adjustment at all? This is usually a result of a combination of different factors or errors which give the appearance that everything is well and exactly how it was expected to be. However, if the results are studied closely, it is likely that the built antenna does not follow the model exactly and some of the results described below will have been achieved by accident.

SWR not quite as low but antenna broader in bandwidth than the model predicts

Often this is dismissed as a by-product of coaxial cable loss and may well be partly true. However, there are several other reasons why this effect may occur. The first is that all the parasitic elements are slightly shorter than they need to be. Not that the model was incorrect, but more likely that above-boom element holders were used, having a single bolt through the boom and element, electrically connecting them together. Or it could be that the elements are fully insulated from the boom, but are too close to the boom to ignore its effect. In either case, a boom correction will need to be applied, so giving an additional length to each element.

For example, an insulator with a single bolt through the element and boom is used on a 6 m Yagi. Even with a 20 mm diameter boom, a small amount of correction is needed to the model. If the driven element were made shorter as I am suggesting, the resulting impedance curve would be very similar to that of the model but moved higher in frequency. Without the dipole adjustment, the driven element would be oversized due to the tails between the coax and dipole and would therefore move the SWR minimum and apparent bandwidth lower in frequency, even though the dip in SWR is not quite as low as the model would suggest.

Figures 1 and 2 show this effect graphically. Fig. 1 shows the modelling of a relatively narrow band 144 MHz Yagi. A narrow band type is chosen in order to best show the effect when tails are not accounted for in a model.

Fig. 2 shows what happens where the dipole is too long as a result of 'real world' tails between the coax and the antenna. The antenna bandwidth for a VSWR of 1.5:1 has an increased by 100 kHz, from 700 to 800 kHz, with a less pronounced minimum in the centre. The centre frequency has also shifted down from 144.120 MHz (1.01:1) to 143.975 MHz (1.12:1). This broader bandwidth may be desirable, but consider that you are moving away from your software model and the performance you expect, as particularly on a narrow-band model such as this, two important performance parameters, gain and Front to Back ratio (F/B) will change quickly.

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