No. 40: More Frequently Asked Questions

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The frequently asked questions that we shall examine in this session related to beam antennas, most of which are varieties of Yagis. On ten meters, we find a variety of beam construction methods and a variety of matching systems. So our questions tend to relate to these two topics.

1. *Which is better: elements that attach directly to the boom or elements that are insulated from the boom?*

Like many frequently asked questions, this one contains an ambiguity, since the question does not refine the idea of being better into some specific set of concerns.

a. With respect to performance, when the element lengths are suitably adjusted, there is no difference in gain, front-to-back ratio, pattern shape, or feedpoint impedance between a beam with elements directly connected to the metal tube forming the boom and a beam with the elements insulated from the boom.

However, the element lengths required for a given set of performance figures will not be the same for the two methods of construction. Elements that are fully insulated and spaced by a non-conductive plate away from the boom will be the shortest. Elements attached to metal plates that are U-bolted to the boom tend to be the longest, since the plate acts as a short, fat portion of the element.

These rules of thumb apply to elements that otherwise have the same lengths of tubing forming the element's decreasing diameter away from the element center. As we saw in a recent column, these "tapered-diameter-schedule" elements tend to be longer already than elements having a constant diameter. In both cases, the degree of length change from an ideal insulated uniform-diameter element is a complex affair to calculate, and Yagi design software is the best way to redesign one system of construction to another.

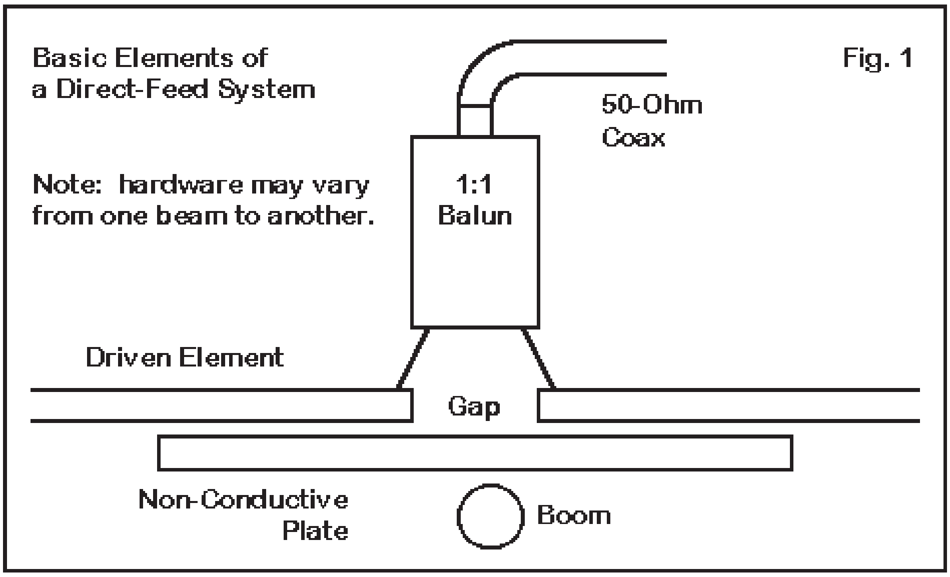
For any beam with more than 2 elements, trying to field adjust the elements to the required lengths often leads to frustrating exercises in sliding tubing and to relatively poor results. The final suggestion, then, is that the backyard builder should use the exact techniques specified in a design being copied unless the builder has considerable experience in redesigning Yagis.

b. The Yagi with element connected directly to the boom has a slight advantage in terms of noise and discharge of static build-up on the elements. The boom is connected to the mast and the mast to a grounded tower. Therefore, when the elements are connected to the boom, static charges bleed off the elements as the wind and other weather phenomena create them.

Insulated elements can build considerable static charges over time. We can discharge them by connecting a high-value resistor (about 5,000 Ohms or more) or an RF choke (100 microHenries or so) between the element center and the boom.

2. *What does it mean to say that a certain Yagi design uses "direct feed?"*

Although many Yagi designs in current use have feedpoint impedance running from 20 to 30 Ohms, it is possible to design a high performance Yagi that shows a feedpoint impedance of 50 Ohms. In this case, we do not need a matching network, since the feedpoint impedance is the same as the characteristic impedance of the most common coaxial cables.



However, we do have some constraints when using a direct feed driven element, as shown in **Fig. 1**. Regardless of the construction methods used for the other elements, the driven element must be insulated from the boom. The driven element must be split at the center to create a gap similar to what we find in a common wire dipole. The size of the gap is not critical at 10 meters and might range from 1/4" to 1".

We connect the inner conductor of the coax to one side of the element, and the braid to the other side. Hence: direct feed.

Since the coax is an unbalanced line and the Yagi driver is balanced, we can encounter radiation currents on the outside of the braid. To suppress these currents and maintain a good pattern with no radiation from the feedline, a 1:1 balun is a useful device to insert between the element terminals and the coax line. Bead-type balun chokes are the lightest and work well in this application. We can often use coils of the coax feedline to perform the choking function. Recommended coil sizes appear in The ARRL Antenna Book.

Some Yagi designs using direct 50-Ohm feed have broader operating bandwidths than Yagis with lower feedpoint impedances. As well, the feedpoint losses are often less. Every connection represents a small loss, since the connection of one part to another will not have precisely zero Ohm resistance. When we lower the feedpoint impedance of the antenna, these resistive losses will be a higher percentage of the total impedance (the sum of the natural radiation resistance and the loss resistance) than when the radiation resistance is higher. As well, direct-feed systems usually have fewer connections than low impedance systems with matching networks.

3. *Which is best as a matching system for a Yagi: a gamma, a Tee, or a beta match?*

Once more we have an ambiguous question, the simplest answer to which is this: it all depends. . . The first consideration is whether a matching system is needed. If the Yagi has a feedpoint impedance well below 50 Ohms--say in the 20-30 Ohm range, then you will need a matching system. There are many fine Yagi designs with feedpoint impedances in this range, so understanding a little more about matching systems is wise.

a. If you are determined to use a direct connection between the driven element and the boom, then you will need to use either a gamma or a Tee match. (There is also a more complex form of the gamma called the Omega match, but we can bypass it in these brief notes.)

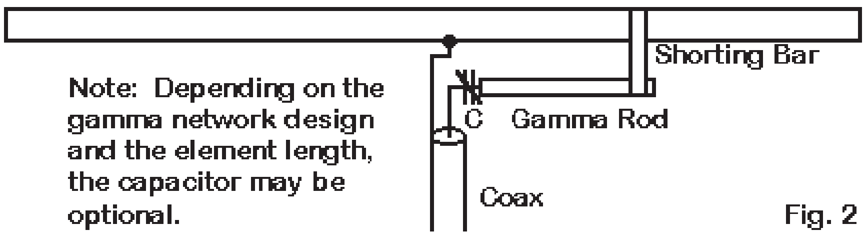


Fig. 2

Elements of the Gamma Match

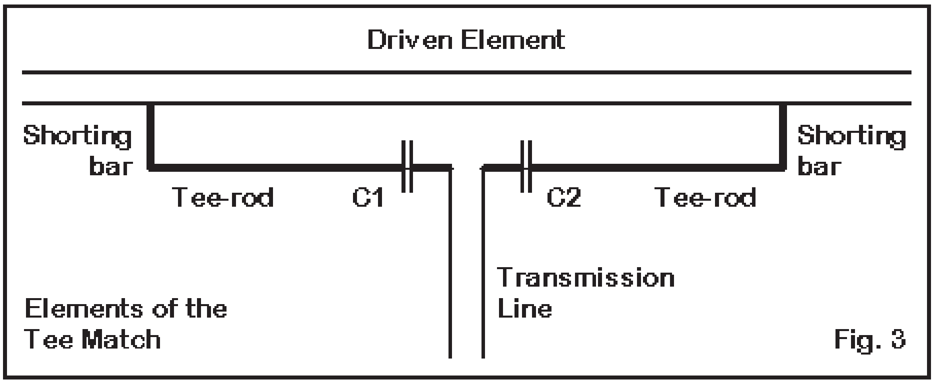
The most commonly used matching network for home-built Yagis is the gamma. As **Fig. 2** shows, it consists of a line in parallel with part of the element and connected to the element. We add a series capacitor between the coax center conductor and the gamma line. By adjusting the line diameter, spacing from the element, length, and the capacitor value, we can arrive at a good match.

The number of element playing a role in the gamma match system makes hand calculation of the dimensions very tedious. There are computer programs that can put you in the ball park and ease the adjustment. The first step is to reduce the length of the driven element to make is capacitively reactive, which often allows us to omit the capacitor.

As a starting point, make the gama rod or line about 1/3 to 1/2 the diameter of the driven element itself. Then the line can be about 0.04 to 0.05 wavelength long and spaced (center-to-center) about 0.007 wavelength from the element. The capacitor should be about 7 pF per meter (about 70 pF at 10 meters) for a resonant driven element with an impedance of about 25 Ohms.

If you use the capacitor, alternatively adjust the length of the gamma rod to the shorting bar to the main element and the capacitor until you obtain the best match. Replace the variable capacitor with a fixed capacitor. If you omit the capacitor, adjust the length of the gamma rod to the shorting bar and the length of the element until you get a perfect match.

b. The gamma match can produce some distortion in the beam pattern, since it is an unbalanced system. The distortion has shown up more at VHF and UHF than at HF, but 10 meters is just on the cusp of the VHF region. Therefore, some beam builders prefer to us a Tee match. As **Fig. 3** shows, the Tee looks like a double gamma and still permits a direct connection between the element and the boom.



Elements of the Tee Match

Fig. 3

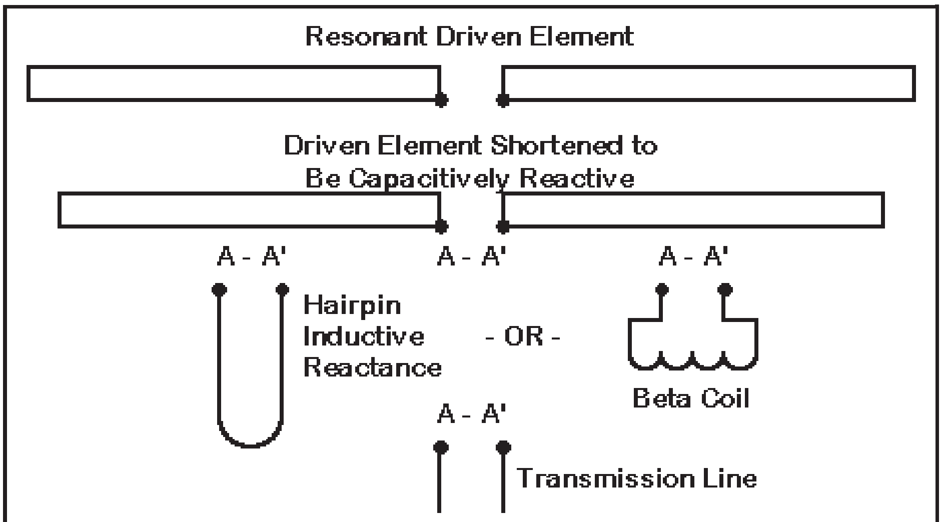
Tee match calculations are not just simple adjustments of gamma calculations. One Yagi optimizing program (YO by K6STI) has a Tee-match calculating module, and it allows you to either use the series capacitors or to omit them--although the Tee rods will be different for each case.

Some builders use the Tee match not only to obtain a good match but also to raise the feedpoint impedance to 200 Ohms. Then they place a 4:1 balun at the feedpoint to arrive at the coax 50-Ohm impedance.

As a balanced matching system, the Tee match avoids potential pattern distortions. However, it is the most complex of our matching systems and requires considerable patience to adjust.

c. The simplest balanced matching system is the beta match. We have taken a long look at the beta match in past episodes of this column. Essentially, we shall form an L-network to transform a low antenna impedance to the higher coax cable impedance.

The L-network requires a series capacitor on the low impedance or antenna side. We form this by shortening the element from its resonant length, thereby making it capacitively reactive. Then we add a shunt or parallel inductive reactance across the terminals--effectively on the coax side of the network.



Elements of the Beta Match

Fig. 4

As shown in **Fig. 4**, we can use either of two ways to obtain the required shunt inductive reactance. One method is to make a length of parallel transmission line with a short at the far end. A shorted transmission line less than 1/4 wavelength provides inductive reactance. The amount depends on the wire spacing and diameter, as well as the line length. This is the so-called "hairpin" matching device.

The other method uses a coil--wound to provide the inductance that has the required inductive reactance. Either method will do the job. The coil has slightly higher losses than the shorted transmission line hairpin, but provides a slightly wider operating bandwidth. The short at the end of the hairpin can float or you may ground it to the boom--there should be no difference in performance either way.

L-network calculations abound. One convenient program for calculating a beta match while evaluating your antenna design is YW, a program accompanying The ARRL Antenna Book.

The beta match does require that the driven element be insulated from the boom and have a center gap for the connections.

3. *What is the best way to make adjustments to my Yagi and its matching system?*

Only a few hardy folks who love working at heights enjoy adjusting a Yagi at the top of a tower. To make the initial adjustments on a Yagi, we can work closer to the ground, using a step ladder at most.

Mount the Yagi pointing straight up. The reflector should be about 5' to 10' off the ground at 10 meters for best results on the widest variety of designs. You can jury-rig an assembly to support the beam while you do your work. Just be sure to move yourself and your ladder well out of the way when making measurements to test your adjustment work. Indeed, the test site should be as much in the open as your situation permits.

Adjustments made by this system should hold if the antenna is a half-wavelength or higher in its final position. The higher the front-to-back ratio of the beam, the better the system will work, since a high front-to-back ratio minimizes interactions with the ground. This adjustment system does not give 100% assurance that you will not have to make further adjustments when you get the beam mounted at its operating height, but it should handle 90% or more of the cases and the work.

Hopefully, these brief answers to frequently asked questions will get you started toward better antenna building. As I have noted on several occasions, if you plan to roll your own antennas--whatever the type--or if you simply want to understand antennas better, make sure that you have a copy of *The ARRL Antenna Book* on your shelf--or better, on your work bench opened to a relevant section.