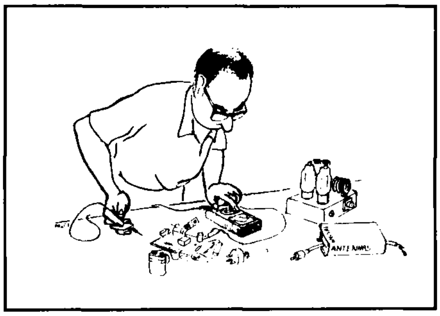


Bill Orr, W6SAI

THE GAMMA MATCH: AN UPDATE

When the 88 to 108-MHz FM broadcast band was authorized shortly after World War II, a VHF transmitting antenna using an off-center feed system was introduced. Adapted for Amateur use, the system was termed the "gamma match" and was featured in *QST*, September 1949. The builder, H. Washburn, W3MTE, remarked that the device worked well, permitting him to achieve an SWR value as low as 1.75:1. His arrangement is shown in **Figure 1**.

Several other antenna experimenters and I worked with the W3MTE gamma match. We soon determined that to lower the SWR appreciably below 2:1 a variable capacitor had to be placed in series with the gamma rod (see **Figure 2**).

Little information was available on optimum rod-to-antenna spacing, rod length, or rod diameter. It was strictly a cut-and-try situation. Some Amateurs had good luck with the device; others couldn't get it to work. The gamma match soon got the reputation as a tricky device that was hard to adjust. In time, it became apparent that the gamma rod had to be small in diameter compared with the driven element, and that the spacing of the gamma rod to the element had to be quite large compared with rod diameter, in order to make the system work properly.

Some attempts were made to analyze the gamma match using transmission line equations. But it wasn't until Harold Tolles, W7ITB, analyzed the device[1] that a computer program was derived that would predict gamma dimensions accurately for a particular antenna.[2]

The gamma match program

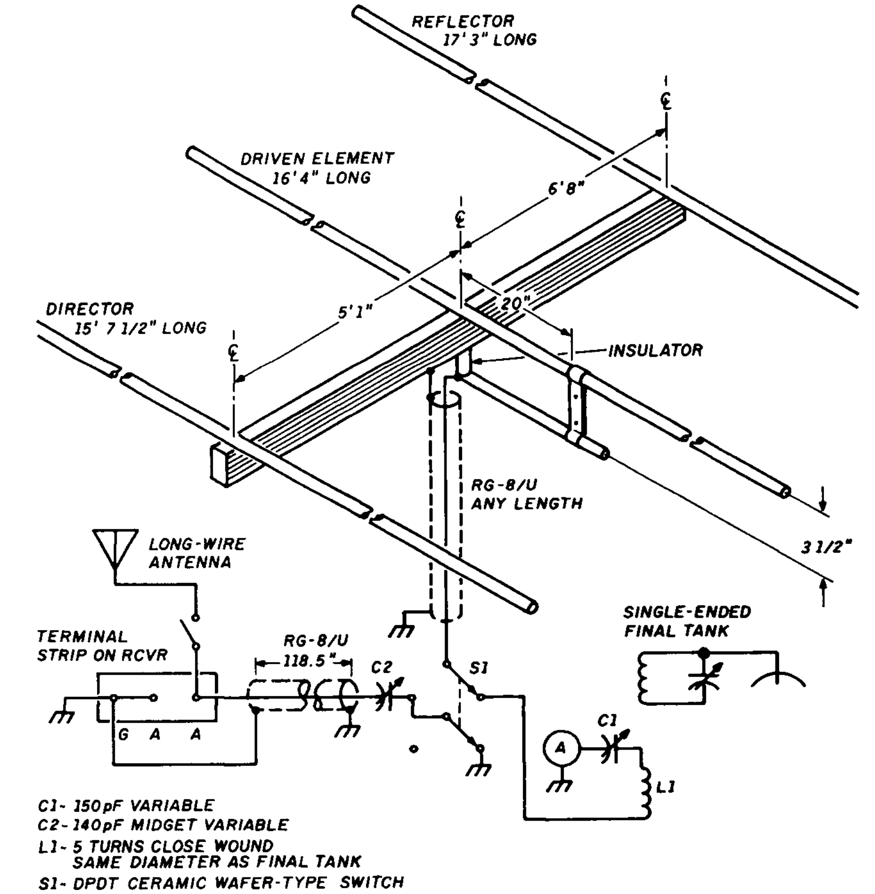
The gamma program, written in BASIC by Richard Nelson, WBØIKN, is based upon W7ITB's analysis and designed for the Apple II+. It can be modified to work equally well with many microcomputers.[3]

I put the program to use designing a gamma match for a three-element, 10-meter Yagi. I took beam dimensions from my *Beam Antenna Handbook*.[4] Design frequency was 28.5 MHz. I planned to use a 1-inch diameter element, a 1/4-inch diameter gamma rod, 3-inch center-to-center spacing, and a 100-pF series capacitor (refer to **Figure 3**). Feedpoint impedance was estimated to be 18 ohms and I wanted to match to a 50-ohm line. When I plugged these values into the computer program, it indicated a gamma rod length of 22 inches and a series capacitance of 180 pF.

These results immediately rang an alarm bell. Our experiments had indicated that the series gamma capacitor should be about six times the operating frequency in meters and the gamma rod

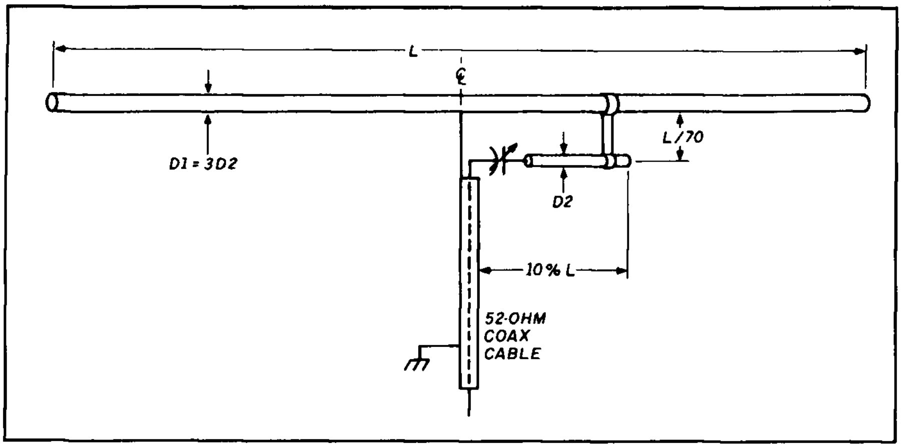
FIGURE 1

Dimensions of the gamma match beam at W3MTE.



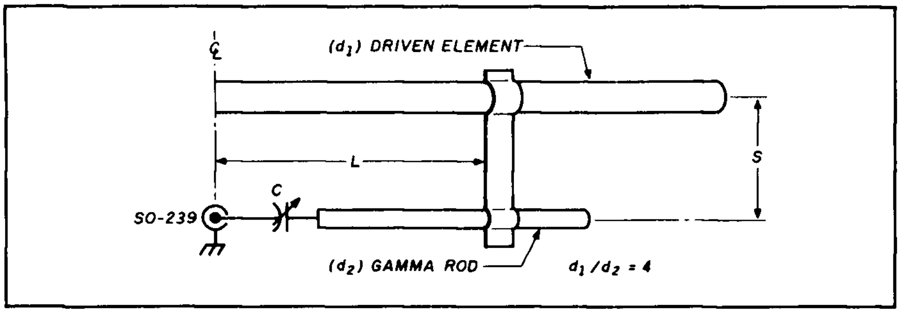
The early gamma match described by W3MTE (*QST*, September 1948).

FIGURE 2



Early *Radio Handbook* shows series gamma capacitor and approximate dimensions for gamma match.

FIGURE 3



W6SAI's 10-meter gamma match. Diameter d_1 = one inch, d_2 = 1/4 inch. Center-to-center spacing = 3 inches.

should be about 0.04 wavelength long. For the 10-meter band, this works out to a capacitor of 60 pF and a rod length of about 16 inches. To back up my assumption, I found a commercially produced 10-meter beam with substantially the same dimensions as my design, using a 19-inch gamma rod and a 45-pF capacitor. Not too close, but a lot closer than the answer ground out by the computer program!

Obviously, there was some factor I hadn't taken into account that influenced gamma dimensions. There was more to the gamma match than met the eye!

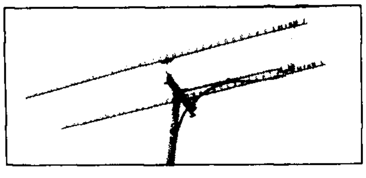
Gamma match computation

I found the answer to the puzzle in a short remark (almost an afterthought) in the text of the W7ITB computer program article.[1] Harold worked out gamma dimensions for a sample antenna and then mentioned that if the drive point impedance of the antenna had capacitive reactance, the value of the gamma capacitor would decrease, as would the length of the gamma rod. Armed with this morsel of information, I read the WB∅IKN computer program again. At the end of the article the author mentioned that a smaller gamma capacitor may be used if radiator reactance is made capacitive (negative) by reducing its overall length.

Aha! Here was the missing clue. With a given value of drive point resistance, and a given gamma to driven element spacing, what would happen to the rod length and series capacitance values when different amounts of negative reactance were introduced into the driven element?

Varying the driven element reactance

For a given frequency, an antenna element may exhibit either positive or negative reactance at its drive point when the antenna is simply made longer or shorter than the resonant length. Shortening the element produces negative reactance; that's what I was interested in! I reran the WB∅IKN program, plugging in various



values of negative reactance from j=0 to j=−50 (see **Figure 4**).

The plot shows that the series capacitance value peaks at the element resonant frequency (j=0) and decreases in value either side of resonance. The length of the gamma rod, however, follows a different curve. It exhibits the shortest length when the antenna exhibits negative reactance (−j15).

A practical gamma match system (one that can be built cheaply and adjusted easily) calls for the shortest gamma rod and the least amount of capacitance. It's no fun to hang from the top of a tower and try to adjust a gamma rod whose shorting bar isn't quite within reach!

You can build a small gamma capacitor inexpensively with a coaxial gamma rod that has the inner conductor serving as one capacitance element as shown in **Figure 5**.

In my case, a 22-inch adjustable gamma rod would work over a range of antenna reactance from j0 to −j50. However, as the antenna element approached resonance, the value of the gamma capacitance rose sharply, and the coaxial rod length didn't provide sufficient capacitance. From the plot, it was obvious that the designer of the manufactured antenna had cut his driven element shorter than resonance to provide a negative value of reactance (about −j30 ohms) in order to have reasonable gamma dimensions.

Gamma rod spacing

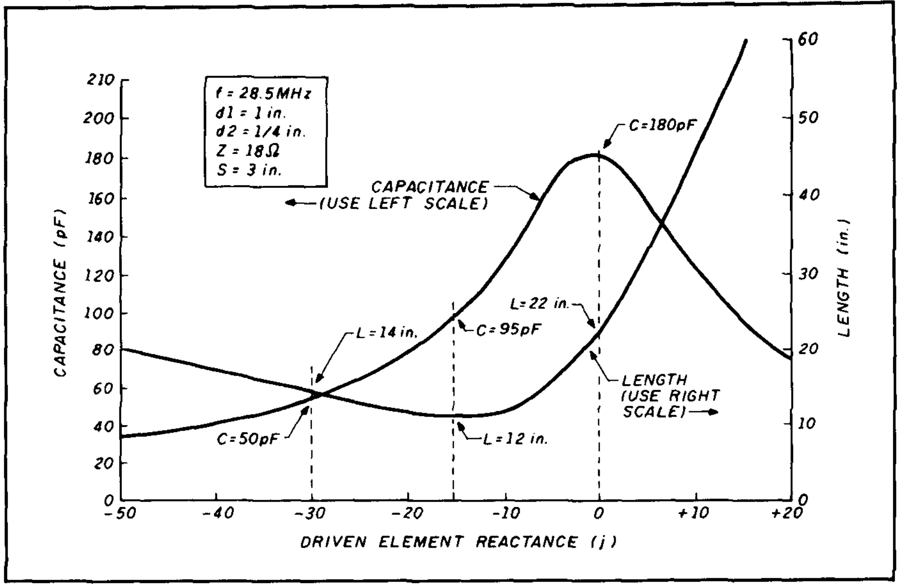
My next question was: what is the effect on gamma dimensions when element-to-rod spacing is varied? I used the computer program for the 10-meter beam element diameters; the results are summarized in **Table 1**. Rod length compared with spacing is given for four values of antenna reactance: j=0 (resonance), j=−15, j=−30 and j=−50 ohms.

Larger values of element-to-gamma spacing require a shorter rod length, but greater gamma capacitance. The shortest rod length is achieved when the driven element has a reactive value between −j15 and −j30, with an element-to-gamma spacing of 3 to 4 inches.

Gamma capacitance increases with element-to-gamma spacing, and decreases as the driven element exhibits greater values of negative reactance. Practical (small) values of capacitance are reached in the reactive region between −j30 and −j50.

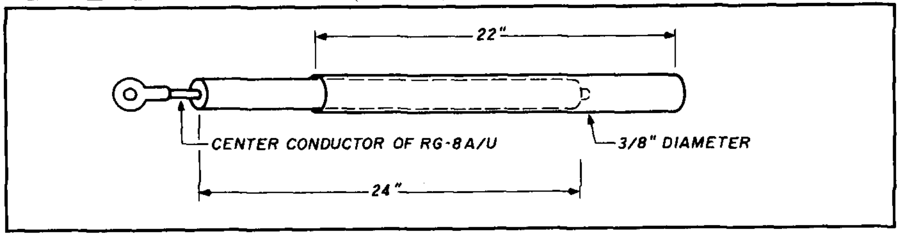
Because shortening the driven element has minimal effect on beam performance, it would be helpful to choose a length providing a negative reactance of 30 to 50 ohms.

FIGURE 4



Graph for determining design lengths of the gamma match.

FIGURE 5



Coaxial gamma-rod capacitor for 10-meter beam. Maximum capacitance is about 55 pF.

TABLE 1

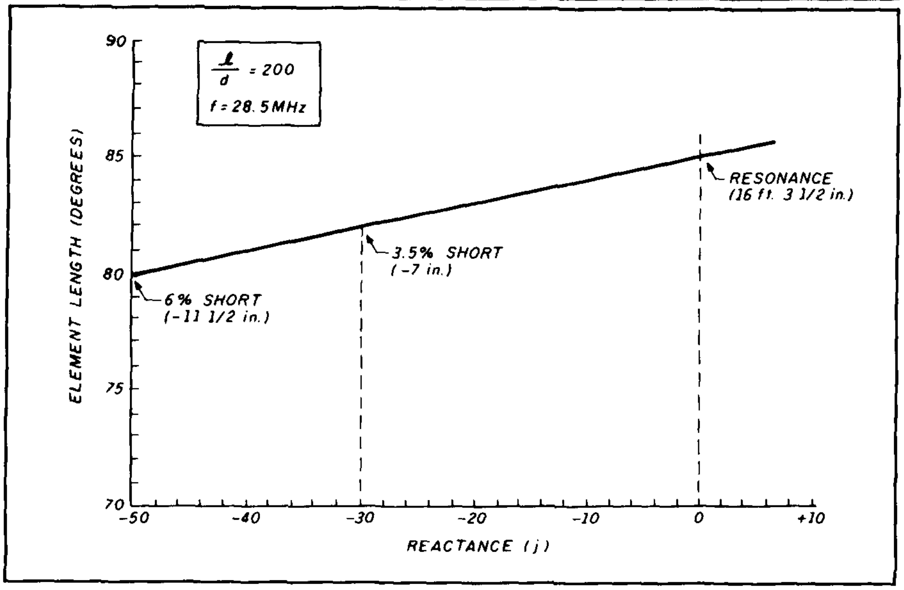
Various gamma and series capacitance values for different length driven elements.

j	Spacing inches	Rod Length inches	Capacitance pF
j0	1	39	83
	2	25	145
	3	23	180
	4	22	212
−j15	1	33.5	57
	2	15	80
	3	12	95
	4	11	105
−j30	1	36	24
	2	18	31
	3	13	52
	4	12	58
−j50	1	36	22
	2	22	31
	3	20.5	32
	4	17	35

Element shortening

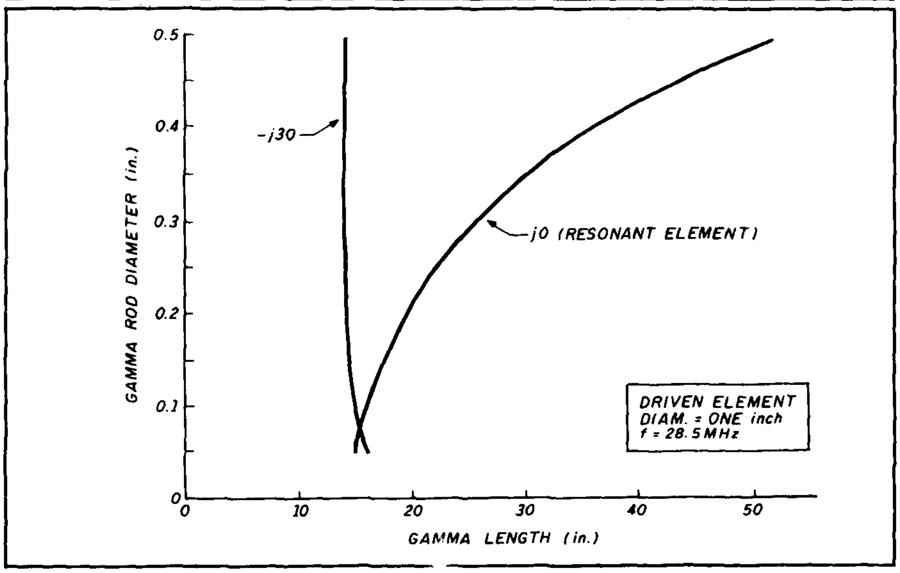
How much physical shortening is

FIGURE 6



Tip-to-tip shortening required for various values of driven element reactance for 1-inch diameter element.

FIGURE 7



The length of the gamma rod with a shorter than resonant driven element (−j30) is nearly independent of gamma rod diameter.

required to provide a reactance of −30 to −50 ohms? It depends upon the ratio of element length to diameter. Such ratios have been computed and measured,[5] and a simplified plot for a length-to-diameter ratio of 200 is shown in **Figure 6**. This corresponds to a 1-inch diameter element at 28.5 MHz. To achieve a reactance value of −j30, you must shorten the driven element about 7 inches (tip to tip). For a reactance of −j50, you'll need a shortening of 11.5 inches.

Drive point impedance and element length

What happens to the 18-ohm figure if the driven element has a drive point value of 18 ohms at resonance and is shortened to provide a negative reactance? It decreases in value. The reduction depends upon the amount of shortening and the element diameter, as discussed previously. Assuming that the new resistance value is 15 ohms at a reactance value of −j50, a computer run shows that gamma rod length increases by an inch, and that the series capacitance decreases by 3 pF from the values determined for a feedpoint value of 18 ohms. This indicates that the actual feedpoint resistance isn't critical, and that the feedpoint values given in the literature for multi-element Yagi beams hold well for use in the gamma computer program.

Gamma rod diameter

The computer program provides interesting information about gamma rod diameters (see **Figures 7** and **8**). The curves show the importance of having a shorter than resonant driven element. With the −j30 element length, gamma rod length changes less than 2 inches as the rod diameter is varied from 0.05 to 0.5 inches. The gamma capacitor, given the same rod diameters, varies from 36 to 65 pF. When the driven element is resonant, the values of rod length and series capacitance vary largely. This gives further proof that adjustment of driven element length is of paramount importance in making the gamma match work.

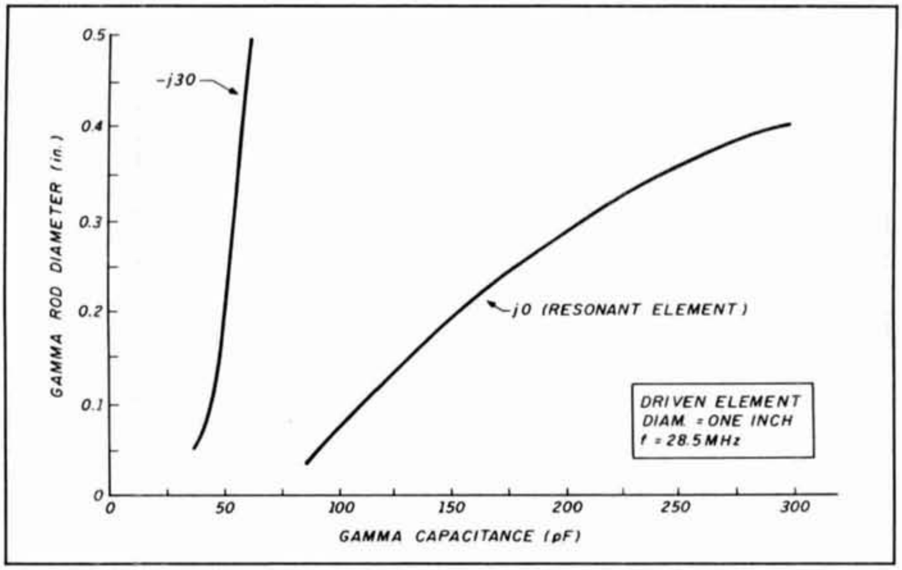
Frequency scaling

If all the dimensions of a 28.5-MHz beam and gamma match system are doubled, the computed results will be identical at half the frequency — or 14.25 MHz. This scaling isn't practical for my 10-meter beam; it would result in a 20-meter driven element diameter of 2 inches. I prefer a diameter of about 1.25 inches, all else being equal. I would probably also build a tapered element. The gamma match computer program doesn't consider this element, but there are programs that compute an equivalent element length for a tapered element.[6] This equivalent element can then be used with the gamma program once its length is readjusted to provide a reactive termination. Someday the Yagi computer program will be modified for frequency scaling. It will also accommodate the gamma match, as well as other matching systems requiring adjustment of the driven element length.

Is there pattern distortion with the gamma match?

The gamma match feeds only half the driven element. What happens to voltages and currents in the other half? Does the unbalanced feed system upset the beam pattern? Tests run by

FIGURE 8



Gamma capacitance is nearly independent of gamma length when shorter than resonant driven element (−j30) is used.

Katashi Nose, KH6IJ, show that voltage at the driven element tips of a 20-meter Yagi isn't equal when a gamma match is used.[7] Even so, the azimuth pattern seemed balanced. Nose concluded that the voltage imbalance wasn't important.

Later tests run by Bob Sutherland, W6PO, a VHF "moonbounce" enthusiast, on a large array of 220-MHz gamma-fed Yagis showed that the array's pattern was normal with no noticeable "squint" or distortion that could be attributed to the gamma matches.

Gamma match summary

The gamma match provides a mechanically simple and easily adjusted network for matching a Yagi to a coaxial transmission line, provided the driven element of the array is somewhat shorter than the resonant length. This point has often been overlooked or not emphasized in the literature, leading to puzzling results.

For the best mechanical arrangement, make the capacitor part of the gamma rod, as shown in **Figure 5**. As they say in the world of computers, the gamma match is "user friendly." Information provided in this article, along with the gamma computer program, should make life easier for those contemplating using this interesting match system.

Electric stove RFI! (What next?)

My friend Wyn Wagener, W6VQD, called me the other evening to give me the latest news on the continuing RFI battle. He was concerned about the new electric ranges.

Old-style electric stoves have a multiple circuit heating element. The circuits are selected by a rotary switch that cuts the heating coils in and out, depending upon the cooking heat required. The newer electric ranges have dispensed with this common sense idea in favor of modern gimmicks and the results are questionable, to say the least.

The new brand of electric range has only one coil in the heating element and the circuit is cycled on and off by a continuously variable heat control, instead of a multicontact switch. The control mechanism consists of a small rheostat in series with a low wattage heating element and bimetallic strip heat sensor. As you advance the control, the heater warms up and the strip cycles on and off. The strip controls the main heating element which, in turn, cycles on and off. Wyn discovered that some ovens created copious RFI during the cycling process, which can run in a sequence of 3 to 20-second on/off bursts.

Before he bought a new range for his home, Wyn took a portable receiver to the appliance store and monitored several ovens. Although there seem to