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The Gamma Match—An Overview

The gamma match is used to transform a Yagi antenna's feedpoint impedance to match that of coaxial cable. How does it do that?

A survey of amateur monoband Yagi antennas will show that one of the most popular matching techniques used to create a 50 Ω unbalanced feed point impedance is the gamma match. Named after its shape, which is similar to that of the capital Greek letter gamma (Γ), the gamma match is a mechanically simple and electrically robust design. It works well with "plumber's delight" center grounded antenna designs constructed of metal tubing. Furthermore, its adjustment is straightforward.

Although not called "gamma match" at its introduction, the design was first described in a July 1937 paper, "The Shunt-Excited Antenna" in *The Proceedings of the Institute of Radio Engineers*[1] *(IRE)*. The application was primarily for AM broadcast antennas and other point-to-point communications links that operated at MF using electrically short towers or vertical antennas and these are still used by commercial broadcasters.

The gamma match made its amateur debut in a September 1949 *QST* article, entitled "The "Gamma" Match" by H. H. Washburn, W3MTE.[2] In that article, the author describes his attempts to use a T-match on a 10-meter Yagi without success, then his subsequent creative leap to the gamma configuration. (It's not known whether or not he was aware of the earlier *IRE* paper.) He closes his article with "... it's so very simple to build and adjust!" Thus was launched one of the most common matching design techniques ever to be used on amateur antennas.

Why is Matching Required?

To understand why the gamma match works, it is necessary to first examine the circumstances under which it can be used. While the driven element of a Yagi antenna is much like a dipole, there are several crucial differences. The impedance at the center of a resonant dipole one-half wavelength above ground is approximately 70 Ω.[3] Yagi antenna elements (and those of parasitic arrays in general), while similar in length to the dipole, are quite another story.

The Yagi has several elements spaced closely to each other. They interact in such a way as to concentrate the radiated energy in a single direction along the antenna axis. This interaction causes the element impedances to be radically different from that of an isolated dipole. The driven element of a Yagi, designed for optimum gain, often has a resistive component impedance of 10 to 30 Ω (typically around 20 Ω), with some reactance. The resulting antenna and transmission line standing wave ratio (SWR) would be 2.5:1 if we attempted to connect that 50 Ω cable directly to the antenna's 20 Ω feed impedance.

Some method of transforming the low, reactive impedance of the Yagi's driven element to match the 50 Ω characteristic impedance of coaxial cable must be used. There are several techniques available. Along with the *gamma*, the T, *omega* and *hairpin* matches are also described in *The ARRL Antenna Book*.[4] Only the gamma match, however, supports unbalanced coaxial connections without a balanced to unbalanced (balun) transformer.

Half-a-T

Before coaxial cable came to be commonly used as a transmission line, most amateur antennas, including Yagis, were fed with open-wire, balanced, feed lines. The Delta and T configurations, shown in Figure 1, were used to match low impedances to these 300 to 600 Ω transmission lines. These matching configu-

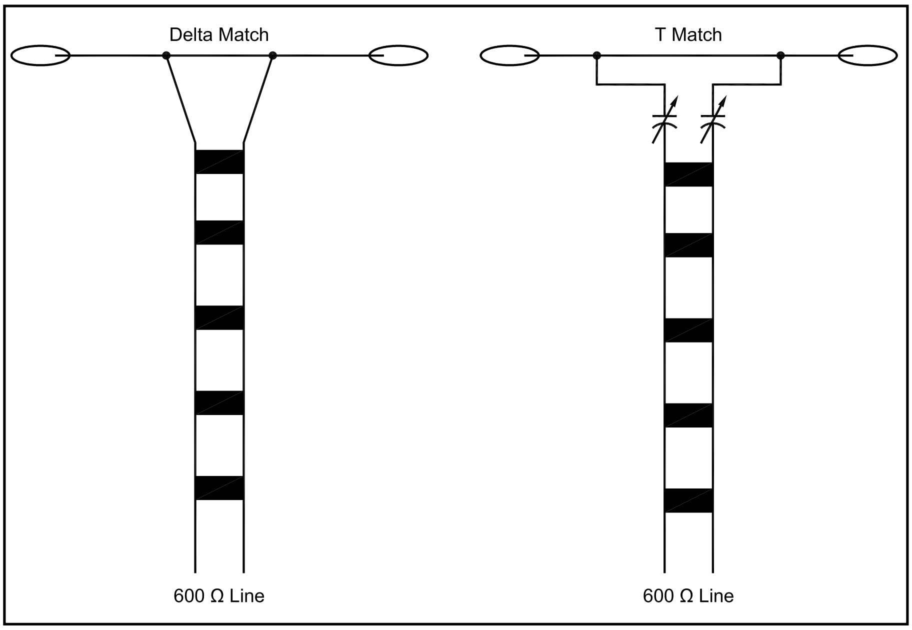

Figure 1—The Delta and T matches.

[1]Notes appear on page 38.

rations work because the impedance along the wire antenna or driven element increases steadily toward the ends of the element or wire and the matching connections step up the feed point impedance. (A folded dipole is a good example of an antenna with a built-in matching network.) These antennas all have balanced feed points. Our feed line, being coaxial cable and having concentric conductors, is an unbalanced transmission line with its shield at ground potential. This balanced-unbalanced connection often led to significant line radiation and, in fact, was observed by Washburn, in his 1949 *QST* article.[5]

There is a clue to solving the unbalanced feed line problem. While the current is a maximum at the center of the element and zero at the ends, the voltage is just the opposite: a maximum at the ends and a minimum in the center. This is shown in Figure 2. If the voltage is minimum (actually zero) at the center, then the element center (the boom mounting junction) and the unbalanced coaxial cable shield can be attached directly, without unbalancing the element. That is just what Washburn did; he removed half of the T and connected the coax shield to the voltage minimum at the center of the element, as shown in Figure 3.

Impedance Transformation

There's more to the gamma match than that simple explanation. There are two recognized "methods of understanding" for explaining this matching technique. The model most frequently referenced was described by D. J. Healey, W3PG, in *QST*[6] and later, by H. F. Tolles, W7ITB.[7] Here, the gamma match is treated as a parallel element that steps up the impedance of the shunted section (like a folded dipole). In addition, the shorting bar at the rod end creates a short parallel-conductor transmission line that presents an inductive reactance at the gamma feed point, shunting the stepped-up antenna impedance. A series capacitor is then used to cancel out the remaining inductive reactance in the matching arm.

Using this model, the element to be matched is required to be slightly *shorter* than resonance so that it presents a small capacitive reactance along with its resistive component (around 20 Ω). Why? Because the stepped-up antenna impedance, shunted by the transmission line's inductance, approaches $(50 + j0)\ \Omega$ much more closely with the capacitive component present. If the antenna is resonant (purely resistive), it is much more difficult to achieve a 50 Ω resistive impedance at the feed point. [Because then the inductive reactance introduced by the shunt can't be canceled by the driven element's reactance.—*Ed.*]

More recently, a different method was presented in the May/June 1999 issue of *QEX* by G4JNH.[8] The author treats the gamma match as an equivalent network, consisting of a single-turn inductor with some radiation resistance formed by the gamma rod and the driven element. The input capacitor then forms the series arm of an L-network that performs the impedance step-up. This method also gives useful solutions for the situation in which the driven element is actually resonant. The author claims that the results are more representative of empirically observed values.

How to Design a Gamma Match

There is no single solution to any particular gamma match design. There is a large set of values for gamma rod diameter, spacing, length, and series capacitance that will provide for a 1:1 SWR. The trick is to find a convenient and reproducible set of element diameters, spacings and lengths.

Designing the mechanics of the gamma match begins with determining the characteristics of the antenna element to be matched. Its diameter and feed point impedance (in complex R ±*j*X form) must be known. An antenna modeling program or a set of antenna tables can be used to

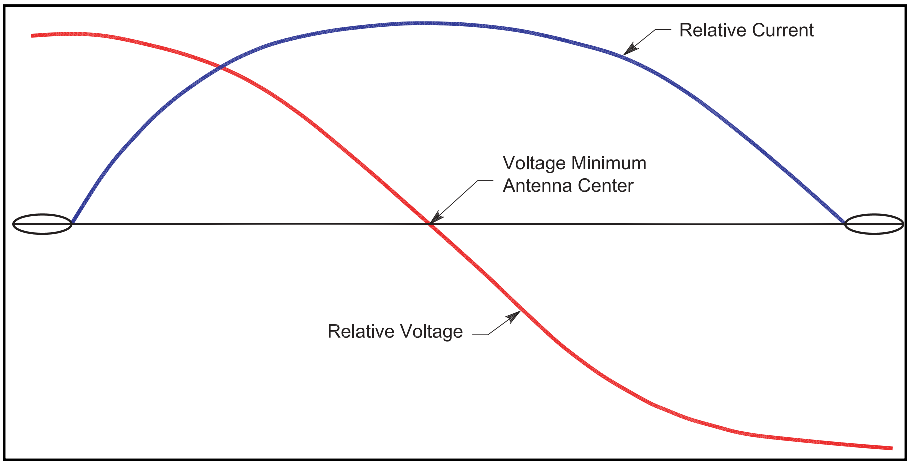

Figure 2—Voltage and current distribution on a ½ wave dipole antenna.

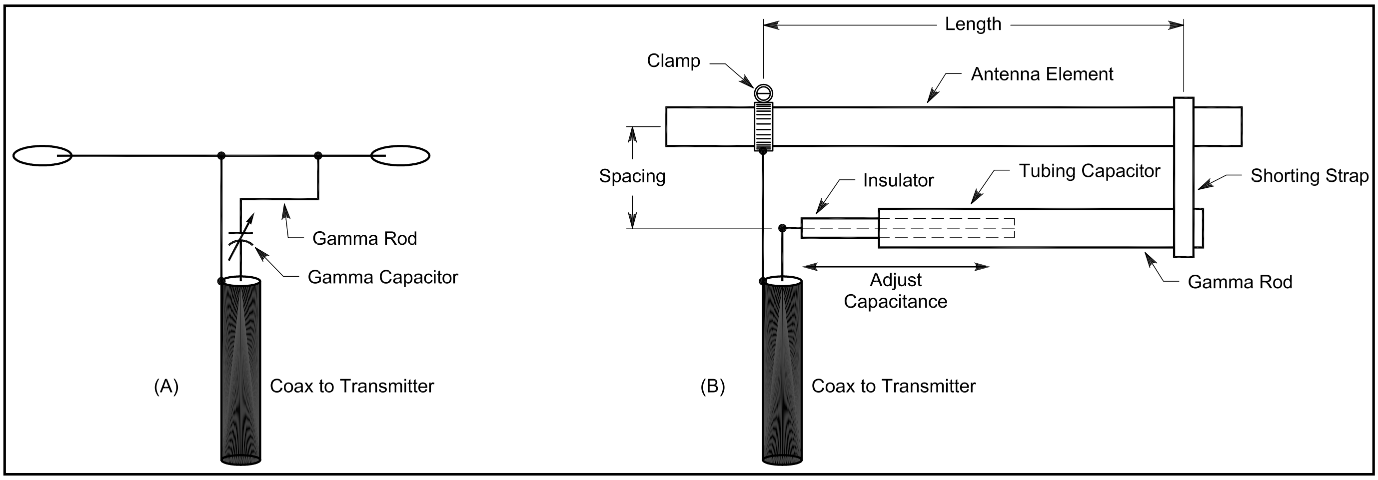

Figure 3—The gamma match. Its electrical schematic is shown in (A). The physical equivalent is shown in (B). The Gamma capacitor is adjusted by sliding more or less wire into the rod.

obtain these values.[9]

The diameter and spacing for the gamma rod are then selected. A length for the rod and a value of capacitance are then calculated. Assuming a computer program is used, multiple combinations of tubing and/or spacing can be used to obtain convenient element lengths and standard values for series capacitances. Tables (such as Figure 4) are useful, if their assumed characteristics are close to those of the actual element being matched.

Designers should avoid configurations where the gamma rod spacing becomes very short (less than 0.025 wavelength) because of losses in the gamma rod and the shorting bar due to the high circulating RF current. If a suitable configuration cannot be arrived at, it may be an indication that the element lengths need to be adjusted further or that a different matching technique needs to be used.

Applications of the Gamma Match

The most common application of the gamma match is the monoband Yagi antenna. Matching a single element on multiple bands, while not impossible, is mechanically unwieldy, and the interactions between the adjustments can make tuning very difficult. The monoband antenna match is a "set and forget" configuration, and the gamma match also obviates the need for a balun transformer.

Another use of the gamma match is to match a feed line to an electrically short tower, commonly known as a "shunt-fed" system. The tower, fed against a good ground screen or radial system, acts very much like a shortened dipole element, with a feed point impedance of less than 50 Ω and with a feed point having significant capacitive reactance. This is a particularly useful matching technique on the 160 and 80 meter amateur bands.

If the tower is quite short electrically, the resulting gamma match design will probably require that the gamma rod be very long—sometimes nearly the length of the tower itself. In such cases, the match bandwidth may be very narrow. Experimentation with the spacing and rod diameter is often required to achieve acceptable bandwidth along with a decent SWR.

Additional antennas that can make use of the gamma match include electrically short antennas, such as loops and verticals. Any antenna with a feed point impedance of less than 50 Ω, and which must be fed with an unbalanced transmission line, is a candidate for application of the gamma match.

Drawbacks of the Gamma Match

Weaknesses of the design include:

- Adjustment—with two interacting parameters to control (length and capacitance) the adjustments can be time-consuming, although they are straightforward.
- Mechanical complexity—making a reliable connection between the coax, the capacitor, the rod and the driven element can be troublesome. Designs that use sliding tubes and insulators for the tuning capacitor and stainless steel hardware have largely solved this problem.
- Unbalanced drive—mostly a problem at VHF and above, the asymmetric drive configuration can result in a distorted current distribution in the antenna, degrading its performance.
- Losses—for the short rod length, high RF currents flow in the matching components, requiring the maintenance of solid, low-loss connections.

Alternatives to the Gamma Match

A matching configuration that has grown in popularity is the *beta* or *hairpin* match. This balanced configuration can transform similar low impedances to 50 Ω, and it is somewhat easier to adjust. The drawback to this configuration is the requirement that the driven antenna element be split and insulated from ground, thus complicating the mechanical design and the element to boom mounting. Further, a balun transformer is required in order to connect the unbalanced transmission line to the balanced matched load.

Computer Programs

The modern antenna designer has the hard part of gamma match design, the mathematics, taken care of by software. There are a number of programs that will calculate the gamma match design, but all are not equally accurate. Rarely do these programs state the algorithm formulated by the program.[10] Here are three widely used programs:

- *GAMMA*—a BASIC program included with *The ARRL Antenna Book*.[11]
- *Low Band Software*—a package of antenna design modules including a gamma match optimizer.[12]
- *YagiMax* by K4VX—a Yagi design package that includes the MATCH module, which designs several different match configurations.[13]

All of these packages require that the designer know the characteristics of the antenna element to be matched. For this purpose, several antenna-modeling programs are available. A favorite is *EZNEC* by W7EL.[14]

Construction and Adjustment

Once the numbers have been crunched, and one has a set of specifications for tubing lengths, separations and capacitors, building the physical assembly is the next step. Originally, the gamma capacitance was supplied by a discrete variable capacitor.[15] The discrete capacitor approach is still viable, but it requires a protective enclosure to keep moisture out. A more robust and weatherproof implementation is the creation of the capacitor from the gamma rod itself! This technique was illustrated in a July 1999 *QST* article by AA1DO on 10-meter antenna construction.[16] G4JNH also described a method for calculating the necessary tubing and wire lengths in his gamma match modeling article.[17]

How is the gamma match adjusted? If you have a commercial antenna, it is likely that the manufacturer has specified exact matching lengths and assembly steps, so, by all means, follow them! If you are "rolling your own," however, you'll have no such guidelines. Here is a summary of the process for tuning a gamma-matched Yagi, written by the venerable Katashi Nose, KH6IJ (SK), in the March 1958 issue of *QST*.[18]

You'll need an SWR meter or analyzer. The latter, such as an Autek Research RF1 or an MFJ-259 or equivalent, is much easier to use. If you use an SWR meter or bridge, you'll also need a low-power RF signal source to excite the antenna. [The advantages of the analyzer, as compared to the meter or bridge, are portability; a built-in signal source; the safety of very low-power measurements and continuous indication; without the necessity of calibration. It usually cannot be used as an "in-line" device, however.—*Ed*.] The meter or analyzer should be installed at the antenna so you can easily see the effect on SWR as you make adjustments.

Replace the gamma shorting bar with a temporary strap made from a pair of large clips joined back-to-back with wire or a piece of coax braid. This will allow you to make the adjustments quickly. The actual shorting strap used should then only require minor adjustments, if at all.

Place the antenna on a support in the clear, such as a roof or short mast. For larger antennas, orient the antenna vertically, with the reflector closest to ground. In other words, point it straight up. That will minimize ground effects that could require that the antenna be retuned when it's placed in its final position.

Set the gamma capacitor to the design value (half that value will do if you don't have an exact setting) and excite the antenna.

Adjust the gamma rod length by sliding the shorting strap back and forth in small increments until you find the point of lowest SWR. The antenna should not be

Gamma-Match Element Data for a Yagi with a Radiation Resistance of 25 Ohms

Rod		Step	−20 ohms		−15 ohms		−10 ohms		−5 ohms		0 ohms		+5 ohms	
d	*S*	*up Rat.*	*L*	*C*	*L*	*C*	*L*	*C*	*L*	*C*	*L*	*C*	*L*	*C*
0.50	5.0	5.28	118	350	123	502	138	614	171	734	231	396	317	734
	4.0	5.42	131	342	135	488	151	592	184	700	255	376	331	700
	3.0	5.65	152	332	155	468	172	562	207	656	267	349	351	654
	2.5	5.83	169	324	172	452	189	540	224	634	285	332	369	624
0.38	5.0	5.87	119	322	121	450	133	536	158	618	203	328	269	618
	4.0	6.08	132	314	133	434	145	514	171	588	216	311	281	584
	3.0	6.43	153	302	154	412	165	482	192	548	238	288	302	558
	2.5	6.71	170	292	169	396	188	462	208	520	255	273	319	520
0.25	5.0	6.75	120	290	119	394	128	458	147	516	181	270	230	516
	4.0	7.07	133	282	131	374	140	430	158	482	192	251	239	482
	3.0	7.62	154	268	151	356	160	408	179	452	213	236	262	452
	2.5	8.06	172	258	167	340	175	398	195	428	230	223	278	428

Design parameters: D = 1.0; Z_{ant} = 25 ohms; Z_{cable} = 50 ohms. The element diameter is normalized as 1. Values are shown for a design frequency of 7.1 MHz. L is the length of the gamma rod in cm, C is the value of the series capacitor in pF. The length of the gamma rod can be converted to inches by dividing the values shown by 2.54.

Figure 4—A typical table of gamma match design values. From J. Devoldere, ON4UN, *Low-Band DXing,* 3rd Edition (Newington: ARRL, 1999), Table 13-10, p 13-54.

touched during the measurements. Depending on the excitation frequency and the size of the antenna, you may need to move away from the antenna to obtain an accurate reading. If you do move away and the SWR changes significantly, you are too close.

It is unlikely that the shorting strap adjustment alone will suffice. Once a minimum reading is found, adjust the gamma capacitor to further minimize the SWR. Then repeat these steps until you are satisfied that the SWR is indeed as low as possible. The adjustments should result in a clear minimum, without either the strap or capacitor being at extremes of adjustment. If you do run out of range, adjust the element length slightly; not more than 1 or 2 percent, or change the rod spacing slightly and then repeat the measurements.

The antenna can then be mounted in its final position. If you then choose to further adjust element lengths for gain or front-to-back ratio, you will likely have to readjust the gamma match, as element spacings and lengths strongly affect the antenna's driven element impedance.

Troubleshooting

If you are unsuccessful in adjusting the gamma match, check the following:

Be sure all of your instrumentation is okay—check the SWR meter or analyzer, connecting cables, and all connectors and adapters. Be sure that a nearby transmitter isn't causing the SWR meter to indicate an erroneous reading.

Radiator length—Yagi driven elements should be at resonance or just a few percent below their resonant length.

Loose connections or lossy materials—While fine at HF, PVC insulation at UHF is a very lossy material and these losses will mask the matching adjustment effects. The gamma rod connecting strap must be electrically sound, as high RF currents abound at this joint.

Poor connections in telescoping antenna joints—this can be a problem with used antennas that have been exposed to the weather for some time. Check each joint with an ohmmeter to be sure they're making good contact. [This is not easy to do with ohmmeter probes on oxidized aluminum. Make sure the oxide layer is punctured by the probes.—*Ed.*]

Summary

The gamma match has been a fixture on the amateur antenna scene for more than half a century. It effectively solves one of the most common antenna design problems—the matching of coaxial transmission lines to the low driven-element impedance of parasitic arrays, like the Yagi. Its behavior is well understood and good information abounds on its construction and maintenance. Whether you are adjusting a gamma match on a commercial antenna or you decide to "homebrew" your own, it is hoped that you are now more knowledgeable about the history of this matching technique and how its "magic" is performed.

Notes

[1] J. F. Morrison and P.H. Smith, "The Shunt-Excited Antenna," *Proceedings of the Institute of Radio Engineers*, Vol 25, No 6, Jun 1937, pp 673-696.

[2] H. H. Washburn, W3MTE, "The "Gamma" Match," *QST*, Sep 1949, pp 20-21, 102.

[3] R. D. Straw, N6BV, Ed., *The Antenna Book,* 19th Edition (Newington: ARRL, 2000), pp 3-2, 18-5, 18-6, 26-9, 26-10.

[4] See Note 3.

[5] See Note 2.

[6] D. J. Healey, W3PG, "An Examination of the Gamma Match," *QST*, Apr 1969, pp 11-15, 57.

[7] H. F. Tolles, W7ITB, "How to Design Gamma Matching Networks," *Ham Radio*, May 1973, pp 46-55.

[8] R. Barker, G4JNH, "A New Look at the Gamma Match," *QEX*, May/Jun 1999, pp 23-31.

[9] J. Devoldere, ON4UN, *Low-Band DXing,* 3rd Edition (Newington: ARRL, 1999), pp 13-53 to 13-55.

[10] An algorithm, as used in software programming, is a procedure or formula for solving a recurrent problem. The algorithm of a BASIC program can usually be deduced from its code… if one has access to it.—*Ed.*

[11] See Note 3.

[12] ON4UN's Low Band Software is available from J. Devoldere, ON4UN, Poelstraat 215, B9820 Merelbeke, Belgium or from G. Oliva, K2UO, 5 Windsor Dr, Eatontown, NJ 07724.

[13] *YagiMax* software is available from L. Gordon, K4VX, at **k4vx@arrl.net**.

[14] *EZNEC* software is available from R. Lewallen, W7EL, PO Box 6658, Beaverton OR 97007 or **www.eznec.com**.

[15] W. I. Orr, W6SAI, *Beam Antenna Handbook,* 4th Edition (Wilton, CT: Radio Publications, Inc) pp 55-56, 113-115.

[16] A. Alvareztorres, AA1DO, "Two On Ten," *QST*, Apr 1999, pp 67-69.

[17] See Note 8.

[18] K. Nose, KH6IJ, "Adjustment of Gamma Matched Parasitic Beams," *QST*, Mar 1958, pp 44-46.

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