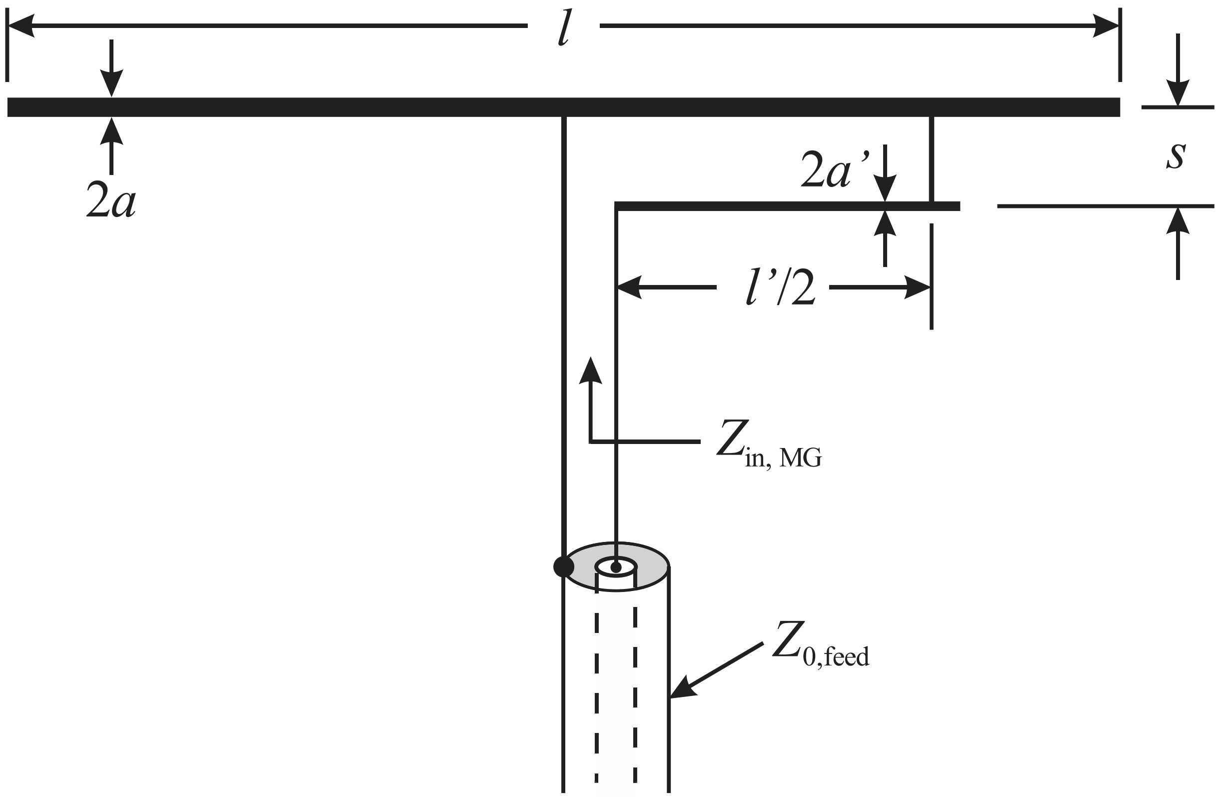
Matching Techniques for Driving Yagi-Uda Antennas: Modified Gamma-Match

[Sections 9.5, 9.6, & 9.8 of *Antenna Theory, Analysis and Design* (4e) by Balanis)]

Modified Gamma-Match:



- The modified Gamma-Match (Γ-Match) also allows dipoles or the driven element of Yagi-Uda antennas to be fed by coaxial transmission lines (unbalanced). Again, the shield of the coaxial line is connected to the center of the driven element (the axis of symmetry) or the metallic boom by "pigtailing" the shield braid. The center conductor is connected to the modified Γ-Match.
- Note the modified Γ-Match simply omits the series capacitor of the Γ-Match. This can make matching more difficult, requiring more adjustments of element lengths. However, eliminating the capacitor saves on component costs and simplifies the structure design.

- The modified Γ-Match is simply the T-Match split down the middle. The analysis follows that of the T-Match.
- The input impedance of the modified Γ-Match $Z_{\text{in,MG}}$ is half that of the T-Match Z_{in}. Conversely, the input admittance of the modified Γ-Match $Y_{\text{in,MG}}$ is twice that of the T-Match Y_{in}. Or, the input impedance/admittance of the modified Γ-Match is that of the Γ-Match without the reactance/susceptance of the series capacitor.

$$Y_{\text{in,MG}} = 2Y_{\text{in}} = Y_t + \frac{2Y_a}{(1+\alpha)^2}$$

and

$$Z_{\text{in,MG}} = \frac{Z_{\text{in}}}{2} = \frac{(1+\alpha)^2 Z_a Z_t}{(1+\alpha)^2 Z_a + 2Z_t}.$$

where Z_a is the input impedance of the antenna mode of the driven element, α is the current divisor factor, and Z_t is the input impedance of the transmission line mode of the modified Γ-Match.

Design Process:

- We desire to match a given Yagi-Uda antenna to a transmission line characteristic impedance $Z_{0,\text{feed}}$. Typically, a specification in terms of the VSWR is given.

1) Select a driven element length l_2 so that $l_1 < l_2 < l_3$ as well as a', s, and $l'/2$ (usually $l'/2 < l_2/4 < \lambda/4$). These values may be changed later.

2) Calculate the characteristic impedance of the transmission line mode of the modified Γ-Match –

$$Z_0 = \frac{\eta}{2\pi}\cosh^{-1}\left(\frac{s^2 - a^2 - a'^2}{2aa'}\right)$$

where $\eta = \sqrt{\mu/\varepsilon_{\text{eff}}}$ is the intrinsic impedance of the material wherein the modified Γ-Match exists.

3) Calculate the transmission line mode input impedance –

$$Z_t = jZ_0 \tan\left(kl'/2\right) \text{ where } k = \beta = 2\pi/\lambda.$$

4) Calculate the parameters u, v, and α –

$$u = \frac{a}{a'},\quad v = \frac{s}{a'},\quad \text{and}\quad \alpha = \frac{\cosh^{-1}\left(\frac{v^2 - u^2 + 1}{2v}\right)}{\cosh^{-1}\left(\frac{v^2 + u^2 - 1}{2vu}\right)} \qquad \begin{array}{l} \alpha > 1 \text{ when } a > a' \\ \alpha = 1 \text{ when } a = a'. \\ \alpha < 1 \text{ when } a < a' \end{array}$$

5) Calculate the equivalent radius of the modified Γ-Match section –

$$a_e \approx a' e^{\frac{u^2 \ln u + 2u \ln v}{(1+u)^2}}.$$

6) Find input impedance of antenna mode Z_a (i.e., use NEC-2) of the driven element as part of the overall Yagi-Uda antenna. Remember to modify the driven element to have an equivalent radius of a_e over the length $l'/2$ corresponding to the position of the modified Γ-Match and radius a for the remainder. [Notes: Put feed on either the first or second (more realistic) segment of the a_e part. If Z_a has an inductive reactance (i.e., $X_a > 0$), may need to **shorten l_2** to make Z_a have a capacitive reactance (i.e., $X_a < 0$).]

7) Find overall input admittance $Y_{\text{in,MG}}$ and impedance $Z_{\text{in,MG}}$ –

$$Y_{\text{in,MG}} = Y_t + \frac{2Y_a}{(1+\alpha)^2}$$

and

$$Z_{\text{in,MG}} = \frac{(1+\alpha)^2 Z_a Z_t}{(1+\alpha)^2 Z_a + 2Z_t}.$$

8) Determine if $Z_{\text{in,MG}}$ meets your specification. If so, stop design process. If not, back to step 1) and adjust l_2, $l'/2$, s, l_1, l_3, & a' can be varied (try in that order), and repeat steps 2) - 8).
   - Remember, the magnitude of the input impedance $|Z_{\text{in,MG}}|$ is greatly affected by α (i.e., when α increases, $|Z_{\text{in,MG}}|$ increases, and vice versa). In turn, α is inversely related to s (i.e., if s decreases, α increases, and vice versa).
   - Try changing $l'/2$ *toward* the length suggested by –

$$l'/2 = \frac{1}{k}\tan^{-1}\left[\frac{1}{Z_0 \,\text{Im}\left(\dfrac{2Y_a}{(1+\alpha)^2}\right)}\right]$$

     to better offset the antenna mode reactance.
   - See http://montoya.sdsmt.edu/ee483_583/notes/matching_tips.pdf for further tips.