A Revision to Section 3.81. of Low Band DXing

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3.8.1. The Gamma match

In the past, Gamma-match systems have often been described in an over-simplifying way. A number of homebuilders must have gone half-crazy trying, for example, to match one of W2PV's 3-element Yagis with a Gamma match. The reason in that case is the low radiation resistance in that design, coupled with the fact that the driven-element lengths were rather long as published, giving a significant inductive reactance. The driven element of the 3-element 20-meter W2PV Yagi example has a radiation resistance of only 13 Ω and an inductive reactance of + 18 Ω at the design frequency for the published radiator dimensions of 0.489661 λ (Ref 957). Yagis with low radiation resistance and a positive reactance sometimes cannot be matched with an acceptable Gamma (or an Omega) match. It may be necessary to shorten the driven element to introduce a capacitive reactance in the feed-point impedance.

Yagis with a relatively high radiation resistance, say 25 Ω, or with some amount of capacitive reactance, typically –10 Ω, can easily be matched with a whole range of Gammamatch element combinations. The same is largely true for inductive reactance but the required gamma rod length may then become too long.

Fig 13-56 shows the electrical equivalent of the gamma match. Zg is the element impedance to be matched. The gamma match must match the element impedance to the feedline impedance, usually 50Ω. The step-up ratio of a Gamma match depends on the dimensions of the physical elements (element diameter, Gamma-rod diameter and spacing) making up the matching section. **Fig 13-57** shows the step-up ratio as a function of the driven-element diameter, the gamma rod diameter and spacing between the two.

The calculation of both the step-up value and gamma rod inductive reactance involves a fair bit of complex mathematics, but software tools have been made available from different sources to solve the Gamma-match problem. The YAGI DESIGN software addresses the problem in one of its modules (MATCHING SYSTEMS), as does *YW* (Yagi for Windows, supplied with late editions of *The ARRL Antenna Book*).

To illustrate the matching problems evoked above, I have listed the gamma-match element variables in **Table 13-10** for a Yagi with R_{rad} = 25 Ω, and in **Table 13-11** for a Yagi with R_{rad} = 7.5 Ω.

Table 13-10 shows that a Yagi with a radiation resistance of 25 Ω can easily be matched with a wide range of Gammamatch parameters, while the exact length of the driven element is not at all critical. It is clear that short elements (negative reactance) require a shorter Gamma rod and a slightly smaller value of Gamma capacitor.

Table 13-11 tells the story of a high-Q Yagi with a radiation resistance of 7.5 Ω, on the low side of some radiation resistances but relevant for some Yagis. If such a Yagi has a "long" driven element, sometimes a match cannot be achieved with these parameters, though it may be possible with a larger step-up ratio. It may be impossible to match with a Gamma match in some cases without reducing the length of the driven element and/or increasing the step-up value.

How much shortening is needed (in terms of driven element length) can be derived from **Fig 13-58**. Table 13-11 shows that an impedance of $7.5 - j\ 5$ Ω can be easily matched with step-up ratios ranging from 5 to 8:1. 1.

Several Yagis have been built and matched with Gamma systems, calculated as explained above. When the reactance of the driven element at the design frequency was exactly known, the computed rod length was always right on. In some cases the series capacitor value turned out to be smaller than calculated. This is caused by the stray inductance of the wire connecting the end of the gamma rod with the plastic box containing the gamma capacitor, and the wire between the series capacitor and the coaxial feed line connector. The inductance of such a wire is not at all negligible, especially on the higher frequencies. With a pure coaxial construction, this should not occur.

A coaxial gamma rod is made of two concentric tubes, where the inner tube is covered with a dielectric material, such as heat-shrink tubing. The length of the inner tube, as well as the material's dielectric and thickness, determine the capacitance of this coaxial capacitor. Make sure to properly seal both ends of the coaxial gamma rod to prevent moisture penetration.

Feeding a symmetric element with an asymmetric feed system has a slight impact on the radiation pattern of the Yagi. The forward pattern is skewed slightly toward the side where the gamma match is attached, but only a few degrees, which is of no practical concern. The more elements the Yagi has, the less the effect is noticeable.

The voltage across the series capacitor is quite small even with high power, but the current rating must be sufficient to carry the current in the feed line without warming up. For a power of 1500 W, the current through the series capacitor is 5.5 A (in a 50-Ω system) The voltage will vary between 200 and 400 V in most cases. This means that moderate-spacing air-variable capacitors can be used, although it is advisable to over-rate the capacitors, since slight corrosion of the capacitor plates normally caused by the humidity in the enclosure will derate the voltage handling of the capacitor.

Fig 13-56—Layout and electrical equivalent of the Gamma match where SU is the step-up ratio and X_R is the inductive reactance from the gamma rod transmission line.

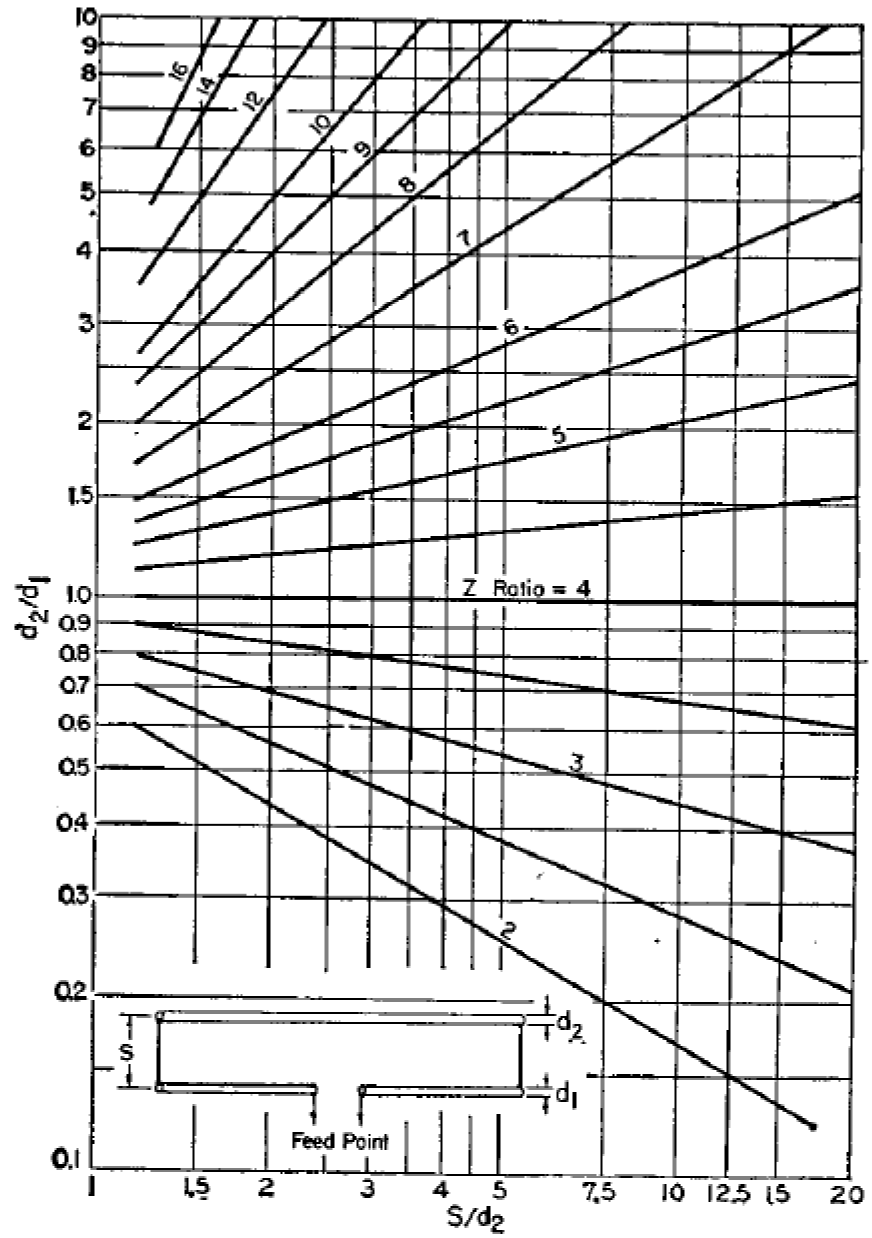

Fig 13-57—Step-up ratio for the Gamma and Omega matches as a function of element diameter (d2), rod diameter (d1) and spacing (S). (After The ARRL Antenna Book.)

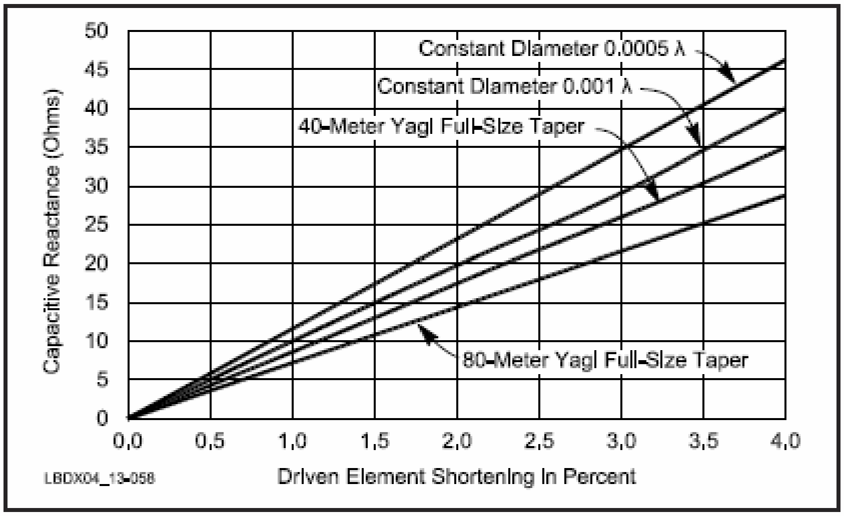

Fig 13-58— Capacitive reactance obtained by various percentages of driven-element shortening. The 40-meter full-size taper is the taper described in Table 13-1. The 80-meter taper is that for a gigantic Yagi using latticed-tower elements, varying from 42 cm at the boom down to 5 cm at the tips.

Rod		Step	-20 Ω		-15 Ω		-10 Ω		-5 Ω		0 Ω		5 Ω	
d	S	up Rat.	L	C	L	C	L	C	L	C	L	C	L	C
0.5	5	5.28	171	246	169	279	173	312	186	339	211	350	248	339
	4	5.42	189	242	186	274	190	306	205	332	231	343	269	332
	3	5.65	218	235	214	266	219	297	234	322	262	332	303	322
	2.5	5.83	242	231	237	260	242	291	257	315	287	324	330	315
0.375	5	5.87	172	230	169	259	172	289	183	313	205	322	238	313
	4	6.08	190	225	186	253	189	282	201	305	224	314	259	305
	3	6.43	219	217	214	244	217	271	229	293	254	301	291	293
	2.5	6.71	243	211	237	238	239	264	252	284	278	292	316	284
0.25	5	6.75	173	211	169	237	170	263	180	283	199	291	228	283
	4	7.07	191	205	186	230	187	254	197	274	217	281	248	274
	3	7.62	221	196	215	219	215	243	225	261	246	268	278	261
	2.5	8.06	245	189	237	212	237	234	247	251	269	258	302	251

Table 13-10 Gamma-Match Element Data for a Yagi with a Radiation Resistance of 25 Ω

Design parameters: D = 1.0; Z_{ant} = 25 Ω; Z_{cable} = 50 Ω. 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.

Table 13-11 Gamma-Match Element Data for a Yagi with a Radiation Resistance of 7.5 Ω

Rod		Step	-10 Ω		-5 Ω		-2.5 Ω		0 Ω		2.5 Ω		5 Ω	
d	S	up Rat.	L	C	L	C	L	C	L	C	L	C	L	C
0.5	5	5.28	95	409	115	1180	-	-	-	-	-	-	-	-
	4	5.42	106	400	124	1073	-	-	-	-	-	-	-	-
	3	5.65	123	385	140	948	-	-	-	-	-	-	-	-
	2.5	5.83	137	375	153	874	-	-	-	-	-	-	-	-
0.375	5	5.87	96	373	107	860	-	-	-	-	-	-	-	-
	4	6.08	107	362	116	796	237	3895	-	-	-	-	-	-
	3	6.43	125	346	131	716	213	1681	-	-	-	-	-	-
	2.5	6.71	139	335	144	666	215	1306	810	5792	1026	1306	1041	666
0.25	5	6.75	98	333	101	659	151	1268	605	4003	969	1268	1011	659
	4	7.07	109	321	110	614	155	1059	386	1812	741	1059	876	614
	3	7.62	127	304	126	556	166	864	318	1188	576	864	743	556
	2.5	8.06	142	292	138	519	175	765	303	981	518	765	684	519

Design parameters: D = 1.0; Z_{ant} = 7.5 Ω; Z_{cable} = 50 Ω. The element diameter is normalized as 1. Values are shown for a design frequency of 7.1 MHz. C is expressed in pF; L in cm (divide by 2.54 to obtain inches). Note there is a whole range where no match can be obtained. If sufficient negative reactance is provided in the driven-element impedance (with element shortening) there will be no problem in matching Yagis even with a low radiation resistance with sufficient step up ratio.