

Three-Element Yagi Models: Standards of Comparison

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I have had numerous requests for models of the 3-element Yagis that I use regularly as a standard of comparison for other models. To make the models more readily available for use or improvement, I have placed them at the end of this note. They are in the form of EZNEC antenna descriptions and contain all the information needed to create AO, NEC-Wires, NEC-Win, NEC4WIN, ELNEC, and EZNEC models. In fact, the antenna geometries are quite simple, consisting of 3 wires of 21 segments each. (Reduce the segments to 20 per element for versions of MININEC.) The original source of the models is a 20-meter Yagi included in an earlier version of AO and modified to simplify construction as a model.

The antennas have not been modeled to build. A real Yagi would likely use elements of tapered diameter sections. The models use a constant diameter for each band: 0.5" for 10 meters; 0.75" for 15 meters; and 1.0" for 20 meters. In fact, all three antennas are essentially the same antenna, frequency scaled and then tweaked a bit to use standard size element diameters.

Each model has a center design frequency, but the performance center (in this case, maximum front-to-back ratio) has been moved to provide close to band-edge to band-edge 2:1 SWR bandwidth relative to a feedpoint impedance of 25 ohms. The premise is that a well-designed beta match would only require shortening of the driven element to supply the needed capacitive reactance, while a gamma match would require driven element lengthening. In both cases, beam performance would be altered hardly at all.

The beams have been modeled in free space. Performance and matching hold up well at heights from 1 wavelength upward. Adjustments would be necessary for some lower heights.

The following tables show the modeled performance of the beams on each band in free space. Note that performance is very good for the boom lengths involved. However, one might well tweak slightly better performance from the beams with further optimization--better, but not too much better, unless one is aiming for either gain or front-to-back ratio without regard for other parameters. These models strove for a balance of gain, front-to-back ratio, and operating bandwidth as examples of what a decent 3-element Yagi might achieve. Figures are seriously exact from NEC-4 models.

Antenna: 3-element 20 meter Yagi: 1.0" diameter al. elements; boom = 22.544'

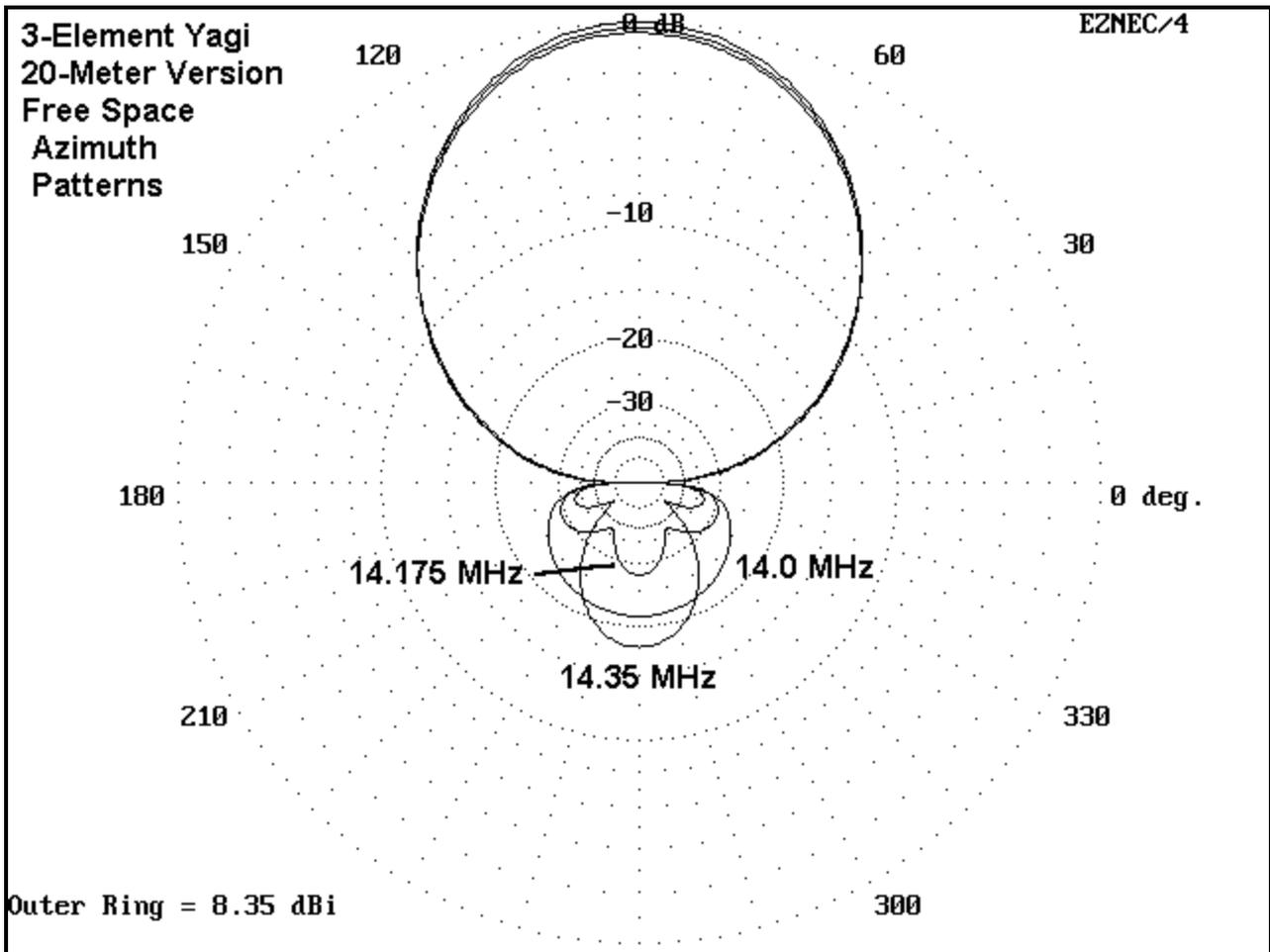
Frequency	Gain (dBi)	F-B (dB)	Feed (R+/-jX)	SWR (25 ohms)
14.0	7.94	20.81	27.04 - 13.25	1.665
14.1	8.03	27.30	26.50 - 6.35	1.288
14.2	8.14	25.68	25.38 + 0.93	1.041
14.3	8.27	19.82	23.81 + 8.78	1.439
14.35	8.35	17.69	22.90 + 12.96	1.723

Antenna: 3-element 15 meter Yagi: 0.75" diameter al. elements; boom = 15.074'

Frequency	Gain (dBi)	F-B (dB)	Feed (R+/-jX)	SWR (25 ohms)
21.0	8.01	24.58	26.17 - 9.15	1.432
21.1	8.08	28.57	25.60 - 4.49	1.196
21.2	8.16	26.72	24.80 + 0.37	1.017
21.3	8.25	21.84	23.80 + 5.48	1.258
21.4	8.34	18.57	22.65 + 10.88	1.590
21.45	8.39	17.24	22.04 + 13.70	1.802

Antenna: 3-element 10 meter Yagi: 0.50" diameter al. elements; boom = 11.212'

Frequency	Gain (dBi)	F-B (dB)	Feed (R+/-jX)	SWR (25 ohms)
28.0	7.87	17.35	27.04 - 18.07	1.985
28.1	7.91	19.64	27.09 - 14.74	1.758
28.2	7.95	22.42	26.98 - 11.37	1.554
28.3	8.00	25.76	26.70 - 7.94	1.368
28.4	8.05	28.44	26.27 - 4.43	1.197
28.5	8.11	27.15	25.70 - 0.80	1.043
28.6	8.17	23.87	25.02 + 2.95	1.125
28.7	8.23	20.99	24.23 + 6.86	1.323
28.8	8.30	18.65	23.36 + 10.94	1.574
28.9	8.37	16.71	22.43 + 15.19	1.896
29.0	8.44	15.06	21.45 + 19.63	2.309



The figure shows the free space azimuth pattern for the 20 meter model, which differs by little from

the models for the other bands. Note that for each model, the highest front-to-back ratio is in the lower half of the operating band, while the gain climbs beyond the upper limit of the operating band defined by the 2:1 SWR ratio. The antennas can each be retuned for resonance at a higher gain, but at the expense of a lower front-to-back ratio and a lower feedpoint impedance. Further performance improvements might also be garnered through the use of a longer boom.

Remember, however, that these are not antennas to be built. Significant adjustments to element lengths and even some slight revisions of spacing might be required with typical Yagi building materials. Those tapered-diameter element sections would complicate these models, which are only standards for comparison.

Using the Standards

Modeling standards have a number of proper uses, so long as we remember that they do not define the limits of performance in any category.

1. Experimental Platforms: the models are useful as models for a number of initial experiments in modeling. For example, we can get a fair idea of stacking performance for antennas of similar gain from a set of these models. Likewise, we can obtain initial ideas about antenna interaction as we place pairs of these antennas at various horizontal spacings and directional orientations. How the gain, front-to-back and feedpoint impedance vary from the baseline values can give direction to the most productive modeling we can do with more complex and slower running of models of actual antennas in their class.

2. Comparison with Experimental Designs: Antennas come in more sizes and shapes than pills in a pharmacy, and new shapes are emerging with great regularity (although most are spin-offs of rather ancient basic designs). Evaluating whether a new shape is worth building is a matter of judging whether the improvements to be made are likely to be worth the effort involved. Since a 3-element Yagi is a fairly standard amateur antenna, comparing the modeled performance of the new antenna against the modeled performance of the standard can aid one in the evaluation. The models need to be transferred to the proposed height over the proper type ground for the new antenna to make the comparison tighter, and both azimuth and elevation patterns require study. Additionally, if terrain modeling software is available, it should also be brought into play.

3. Comparison with Models of Real Antennas: Antennas we see in magazines may or may not have performance figures associated with them. Even where performance figures are given, their source and reliability may sometimes be open to question. Modeling these real antennas and comparing them to the standards can clarify source claims and provide a common setting for various other comparisons. However, these comparisons are meaningful only if due account is taken of the real antenna type. 2-element Yagis should not be expected to have the performance of 3-element Yagis. Likewise, 3-element trap beams should not be expected to be the equal of 3-element optimized monobanders. Within the limits of each type, appropriate accurate models of real antennas within a common modeling framework can take much of the guesswork out of comparisons.

There are other uses for standards, but these are enough to provide the start toward their proper use. And if you get the urge to modify, improve, and actually build one of these antennas, so much the better. But be sure you do some investigation into good Yagi construction techniques (in other words, read Leeson's fine book, *Physical Design of Yagi Antennas*) before investing in a batch of aluminum tubing.

EZNEC/4 ver. A2.11

3 el Yagi 1" elements 06-22-1997 08:49:34

Frequency = 14.175 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : ft) Conn. --- End 2 (x,y,z : ft) Dia(in)
Segs

1	-17.280, 0.000, 70.000	17.280, 0.000, 70.000	1.00E+00	21
2	-16.500, 10.455, 70.000	16.500, 10.455, 70.000	1.00E+00	21
3	-15.525, 22.544, 70.000	15.525, 22.544, 70.000	1.00E+00	21

----- SOURCES -----

Source Wire Wire #/Pct From End 1 Ampl.(V, A) Phase(Deg.) Type
Seg. Actual (Specified)

1	11	2 / 50.00 (2 / 50.00)	1.000	0.000	V
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No loads specified

No transmission lines specified

Ground type is Free Space

----- EZNEC/4 ver. A2.11

3 el Yagi 3/4" el 06-22-1997 08:49:51

Frequency = 21.2 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : ft) Conn. --- End 2 (x,y,z : ft) Dia(in)
Segs

1	-11.554, 0.000, 0.000	11.554, 0.000, 0.000	7.50E-01	21
2	-11.032, 6.991, 0.000	11.032, 6.991, 0.000	7.50E-01	21
3	-10.381, 15.074, 0.000	10.381, 15.074, 0.000	7.50E-01	21

----- SOURCES -----

Source Wire Wire #/Pct From End 1 Ampl.(V, A) Phase(Deg.) Type
Seg. Actual (Specified)

1	11	2 / 50.00 (2 / 50.00)	1.000	0.000	V
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No loads specified

No transmission lines specified

Ground type is Free Space

EZNEC/4 ver. A2.11

3 el Yagi 1/2" al elements 06-22-1997 08:53:38

Frequency = 28.5 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : ft) Conn. --- End 2 (x,y,z : ft) Dia(in)
Segs

1	-8.595, 0.000, 0.000	8.595, 0.000, 0.000	5.00E-01	21
2	-8.207, 5.200, 0.000	8.207, 5.200, 0.000	5.00E-01	21
3	-7.722, 11.212, 0.000	7.722, 11.212, 0.000	5.00E-01	21

----- SOURCES -----

Source	Wire	Wire #/Pct From End 1	Ampl.(V, A)	Phase(Deg.)	Type
	Seg.	Actual (Specified)			

1	11	2 / 50.00 (2 / 50.00)	1.000	0.000	V
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No loads specified

No transmission lines specified

Ground type is Free Space
