This new antenna configuration offers 10 dB of gain and 20+ dB of front-to-back ratio over a dipole at 40 feet. It uses no loading coils, yet is small with dimensions given for 75, 80, and 160 meters.

The Box Antenna

A New High-Gain, Two-Element, Vertical Parasitic Array For The Low Bands

BY TIMOTHY P. HULICK*, PH.D., W9QQ

In March of 1995 the solution for a two element parasitic vertical array (radiator and reflector) for 75 meters was derived using the Antenna Optimizer software available from K6STI. The computer solution showed that without ground loss the gain over a dipole at a height of 40 feet was 10 dB!

When the antenna was constructed in the same month, a careful ground loss measurement was made with only the radiator in place and was found to be 10 ohms. The measured feedpoint resistance without any matching section was 22 ohms, while the lossless model indicated that it should be 12 ohms. It was decided that 10 ohms of ground loss was acceptable from a practical point of view, still providing 6 dB of gain over the dipole at a height of 40 feet. A full description of the antenna was presented in the December 1995 issue of *QST* on pp. 38–41.

After more than a year of use, the conclusion is that the antenna is indeed a pile-up buster, getting answers on the second or third call on rare occasions. The rule has been that the first call gets the answer. In spite of this performance, I've always felt that there was still room for improvement, since after all, loading coils were used and they tend to be lossy no matter what. Ground loss is one thing that may be overcome by using more and more radials. Coils or inductors, however, are just mediocre at best, and if possible should not be used in an antenna where there is a practical way to eliminate them.

In the first vertical parasitic array a self-imposed height limit for the antenna was set at 30 feet. This is about half of the required height for a quarter-wave vertical antenna. The logical way to substitute for height is with a center loading inductor, even though the inductors (one for each element) represented about 1.4 dB of loss compared to the impractical full-length antenna. This loss has been overcome by a new design only five feet higher than the original version.

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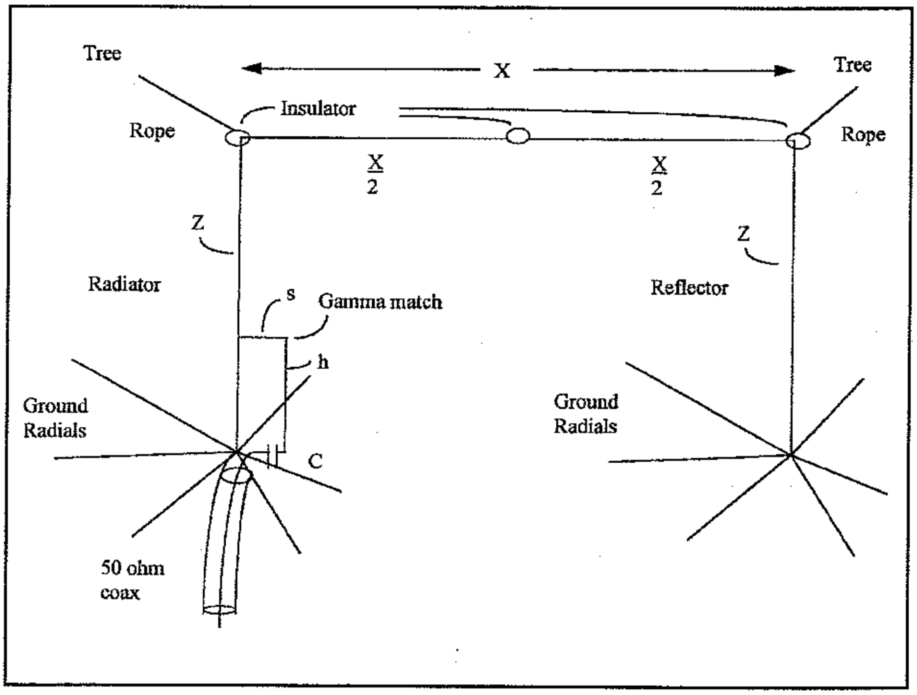

Fig. 1– The box antenna is shown here in general terms. The actual dimensions are presented in Table I.

Because the material to be presented is the result of an evolutionary process, reading the article in the December 1995 issue of *QST* is strongly suggested. It serves as background and should be understood first.

An Abridged Review

Before fully describing the new antenna, your review of the article from the December issue of *QST* should lead to most of the following ten observations about the two-element vertical parasitic array:

1. With 10 ohms of measured ground loss, gain over a dipole at 40 feet is 6 dB at a radiation angle of 5 degrees. This is a very respectable number and served as the inspiration for writing the December *QST* article.

2. The front-to-back ratio is only one or two dB at the same radiation angle.

3. The height of both elements is slightly under 30 feet. To be no more than 30 feet was a design goal.

4. Element spacing is 48 feet.

5. The fed element is the radiator, while the parasitic element is the reflector. Although not brought out in the article,

Center Frequency	X	Z	s	h	C	ATC Part Number
1810	128.0	70.0	2.0	14.0	750	100E751JCA2500X
3525	67.4	35.0	2.0	6.5	390	100E391JCA2500X
3600	64.8	35.0	2.0	6.5	390	100E391JCA2500X
3795	58.0	35.0	2.0	6.5	330	100E331JCA2500X

Note: The chip capacitor, C, made by American Technical Ceramics may be obtained in single quantities from: M. Lader Co., 1495 Alan Wood Road, Conshohocken, PA 19428 (phone 610-825-3177 from 9–12 and 1–5 Eastern Time; ask for Chris Zielke).

Table I– The physical dimensions of the box antenna are given as a function of three choices of center operating frequencies in the 80/75 meter band and one in the 160 meter band. Units are kHz, feet, and pF. The dimensions are to be used in fig. 1.

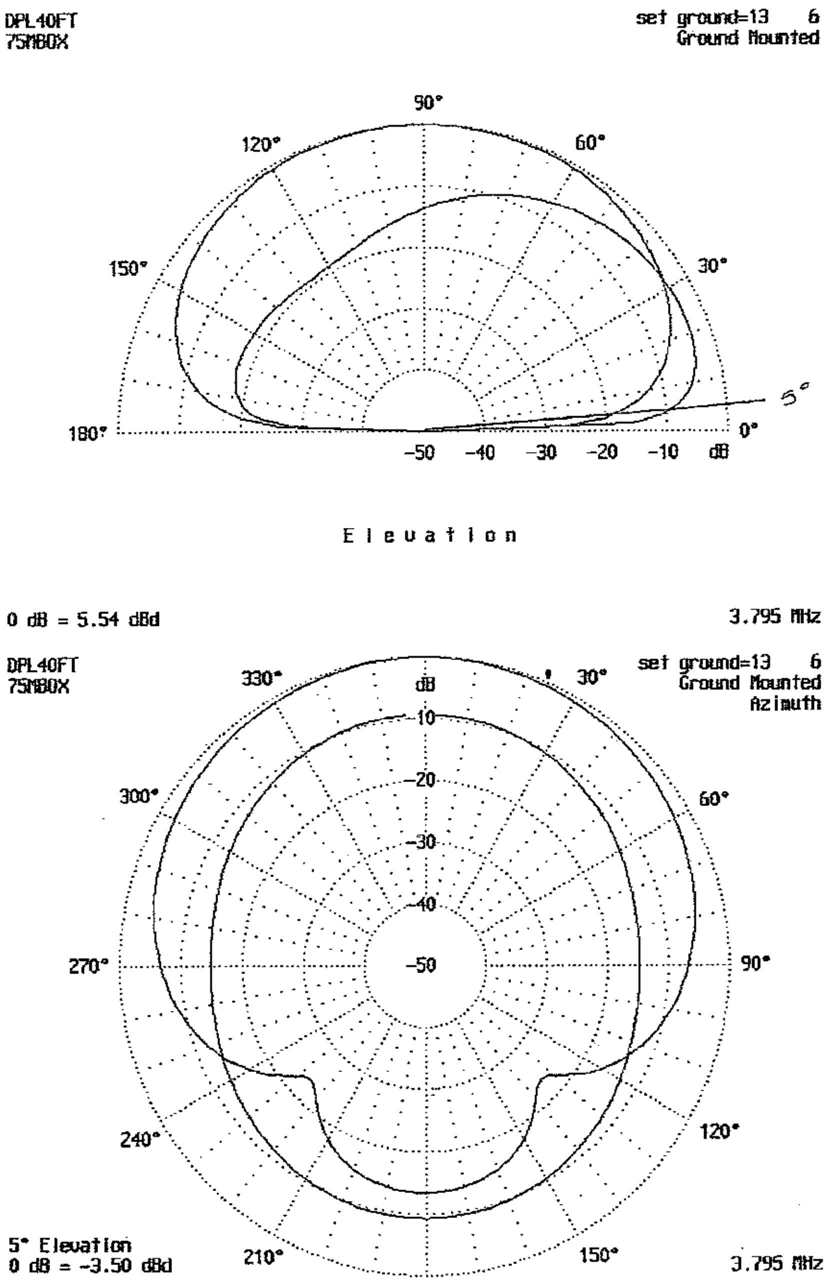

Fig. 2– In the vertical plot at 3795 kHz for a radiation angle of 5 degrees, the gain is seen to be just under 10 dB compared to a dipole at a height of 40 feet. This performance includes the actual ground loss of 10 ohms in the box antenna ground system. The azimuthal plot at the bottom shows deep nulls at the "port and starboard quarters." The front-to-back ratio at a radiation angle of 5 degrees is more than 13 dB at 3795 kHz. The new box antenna has gain over the dipole for 132 degrees of azimuth.

Freq. in kHz	VSWR	Gain over Dipole (dB)	F/B (dB)	Gain over ver. array (dB)
3500	3.73	6.38	1.18	-
3525	3.47	6.61	1.45	-
3550	3.23	6.88	1.79	-
3600	2.77	7.53	2.74	-
3650	2.31	8.18	4.12	-
3700	1.85	8.77	6.13	-
3725	1.65	8.98	7.47	-
3750	1.45	9.14	9.13	-
3760	1.38	9.18	9.88	-
3770	1.32	9.28	10.76	-
3780	1.26	9.29	11.73	VSWR>1.5
3790	1.20	9.29	12.78	3.66
3795	1.18	9.29	13.37	3.65
3800	1.16	9.27	13.91	3.69
3805	1.13	9.26	14.59	3.78
3810	1.11	9.25	15.30	VSWR>1.5
3820	1.08	9.21	16.93	-
3830	1.05	9.16	18.82	-
3840	1.03	9.10	21.29	-
3850	1.04	9.04	24.47	-
3900	1.13	8.61	22.04	-
3950	1.14	8.16	14.55	-
4000	1.09	7.75	11.18	-

Table II– Comparing the gain of the new box antenna optimized at 3795 kHz with the dipole at 40 feet and the two-element vertical array presented in the December 1995 issue of QST.

changing the design so that the parasitic element is a director provides performance insignificantly better than the radiator alone. Therefore, it was never considered as an alternative, but many readers have asked the question.

6. The 1.5:1 VSWR bandwidth of the antenna is from 3785 to 3800 kHz—only 15 kHz.

7. The antenna is easy and inexpensive to build on a city lot with trees.

8. Two loading inductors are used, resulting in 1.4 dB of loss compared to the theoretical (not constructed) unloaded quarter-wavelength version.

9. The gamma match is used with a series 330 pF chip capacitor.

10. Feedback from fellow 75 meter DXers indicated that obtaining the 330 pF chip capacitor used in the gamma match was nearly impossible. This problem has been fixed and it is now readily available (see footnote in Table I). Read on!

Although the original antenna is great in the pile-ups, items 6 and 8 are negatives and are very important areas that require improvement. Item 2 may also be considered a negative, but this depends on expected use of the antenna. If working Europe is your primary objective and you still want the ability to work the VKs and ZLs off of the back, then front-to-back ratio should be small. On the other hand, if QRM off the back prevents you from easily working in the direction of gain, then more front to back is needed.

The New Box Antenna

When first observing the shape of the newly evolved antenna, the term *box* immediately came to mind. There are still two elements, and the parasitic element is a reflector (a director provides almost no desirable effect). The geometry of the new configuration is shown in fig. 1. It

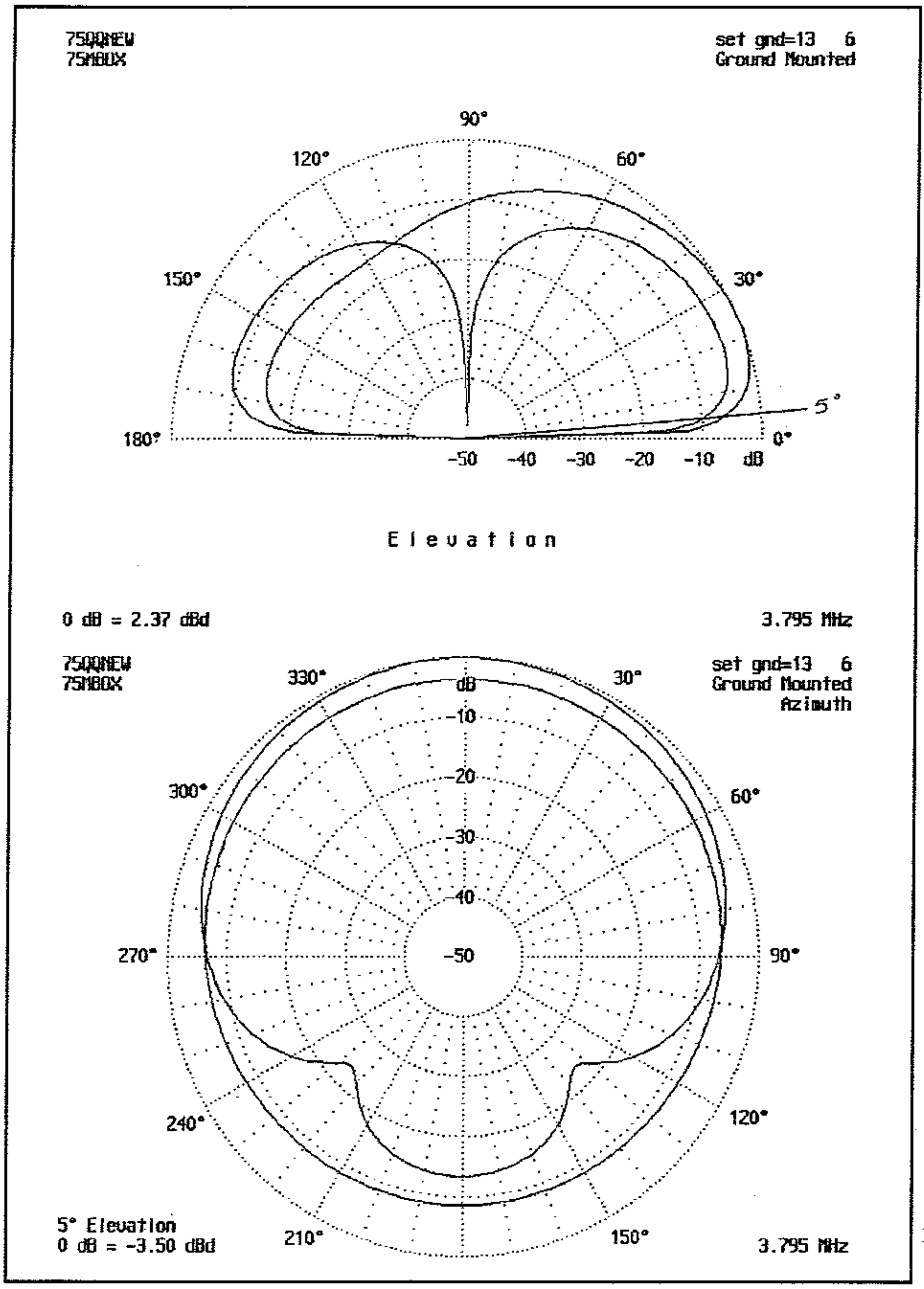

Fig. 3– The gain and front-to-back ratio of the box antenna on 3795 kHz are compared to the original design presented in the December 1995 issue of QST *beginning on page 38. Gain is more than 3.6 dB higher for the box antenna at a 5 degree radiation angle, while the front-to-back ratio is improved by more than 5 dB at this frequency. Deep nulls occur with the box antenna at 134 and 226 degrees relative to the direction of maximum gain. The new box antenna has gain over the original parasitic array for nearly 180 degrees of azimuth.*

should be studied with the dimensional values given in Table I for useful operating center frequencies of 3795, 3600, 3525, and 1810 kHz.

The first thing you will observe about the box antenna is that it appears to consist of a pair of inverted Ls with the ends of the horizontal sections coming together, but not connecting. Examination of the overall length of the vertical and horizontal sections indicates that this is true, since each is about a quarter wavelength long. However, the positions of the horizontal sections are crucial to the antenna's gain and front-to-back ratio. In the inverted L, the intended use of the horizontal section is for top loading; it really doesn't contribute much to the radiation pattern of the antenna, although some front-to-back ratio is realized.

In the box antenna the orientation of the horizontal sections greatly contributes to the radiation pattern, gain, and front-to-back ratio. With the two horizontal sec-

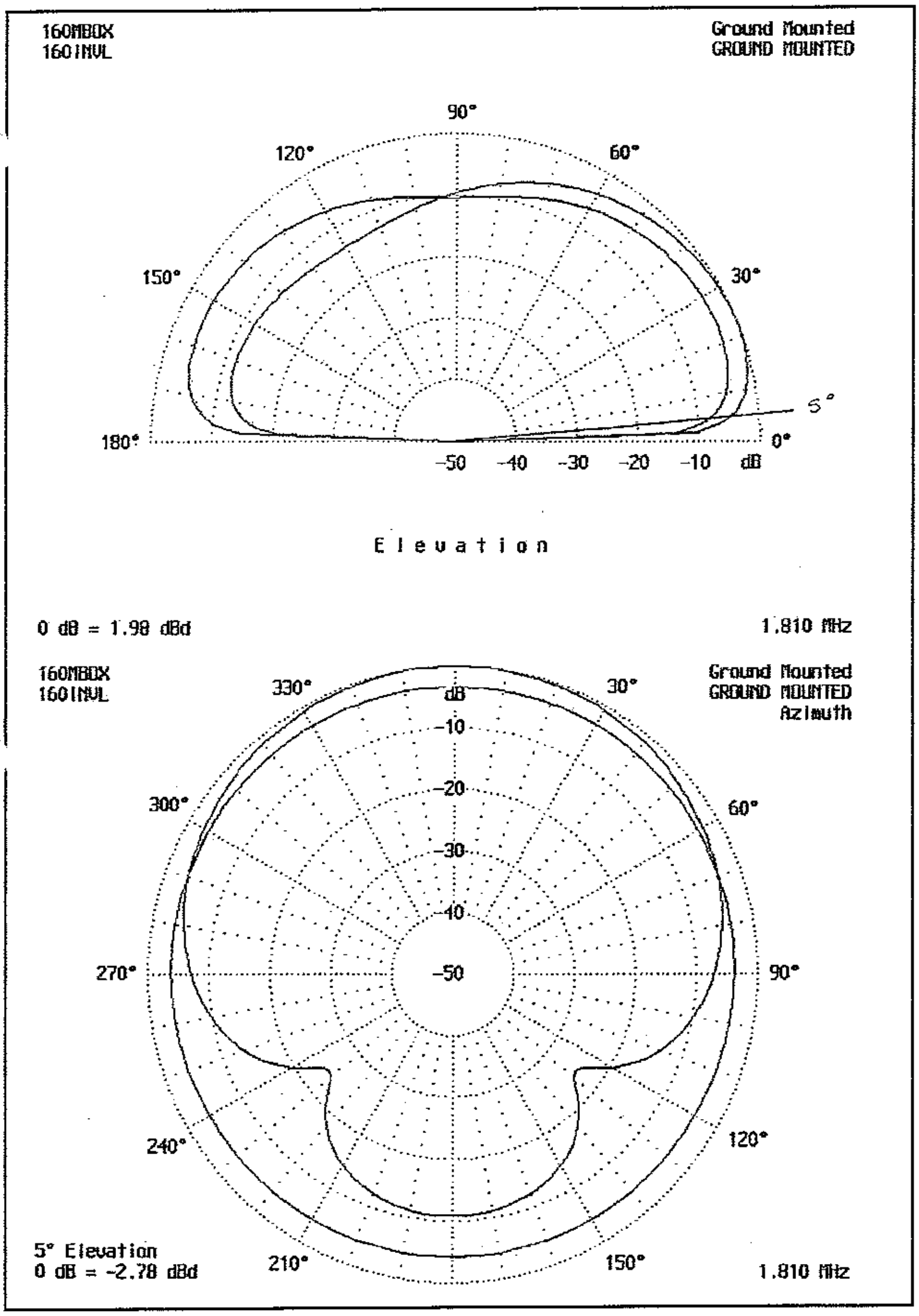

Fig. 4– Even on 160 meters the box antenna shows more than 3 dB gain on 1810 kHz compared to the inverted L antenna at a radiation angle of 5 degrees. The front-to-back ratio of the box antenna is more than 11 dB at this frequency, while the inverted L with no help shows a front-to-back ratio of nearly 5 dB due to the orientation of the horizontal loading section. The new box antenna has gain over the inverted L for about 140 degrees of azimuth.

tions pointed toward each other, gain and front-to-back ratio are optimized, but not on the same frequency. Also, the antenna is easier to construct than two inverted Ls oriented identically. Construction requires only two high supports, and from the ground appears to be continuous as one piece—up, over, and back down.

Notice also that the height of the antenna and the dimensions of the gamma match remain the same from a center frequency of 3525 to 3795 kHz. However, spacing of the vertical elements consequently changes the dimension X. The value of capacitor, C, is 390 pF at 3525 and 3600 kHz, and is 330 pF at 3795 kHz. On 160 the value of C is 750 pF. Although the original height restriction of 30 feet on 75/80 is violated here, it is felt that 35 feet is not impossible and is worth the sacrifice. It turns out to be absolutely necessary, since the performance of the antenna collapses rather quickly if any attempt is made to make it shorter. Do not try to trade off vertical height here for additional horizontal length. It just doesn't work!

Comparisons

Before any comparisons are made to reference antennas, it must be understood that 10 ohms of resistance is used in the computer modeling at the ground end of each vertical section. This simulates ground loss of the radial system and real earth at my QTH. A ground conductivity of 6 millisiemens per meter and a dielectric constant of 13 are used for computer modeling. This is the loss measured with 20 #18 insulated copper wires as long as 60 feet and as short as 20 feet (complemented by 500 feet of old RG-11/U cut up into various lengths) out to 60 feet under each element. Also, the tables represent computer results with the simulated 10 ohms of ground loss in all cases.

Table II shows the performance of the box antenna compared to the reference dipole at a height of 40 feet. It indicates the useful 1.5:1 VSWR bandwidth to stretch between about 3730 kHz and 4000 kHz.

The design center frequency is 3795 kHz. Gain throughout most of this spectrum is on the order of 9 dB. Gain compared to the two-element vertical parasitic array presented in the *QST* article is more than 3.5 dB even though that antenna is only useful over a 15 kHz bandwidth where the VSWR is less than or equal to 1.5:1. The original antenna has very little front-to-back ratio, while the new box antenna has a very respectable front-to-back ratio of up to more than 24 dB at 3850 kHz.

The new box antenna was also designed for a center frequency of 3600 kHz. The results are shown in Table III.

The same comparisons as made in Table II may be made with gain peaking at 9.31 dB at 3600 kHz and the front-to-back ratio peaking at nearly 27 dB at 3700 kHz. Useful 1.5:1 VSWR bandwidth is 3530 to 3950 kHz. Gain over the original version with the loading inductors is slightly more than 2 dB, whereas the original is useful over a much narrower bandwidth.

The new box antenna centered at 3525 kHz has results given in Table IV. Most of the 80/75 meter band is usable with a 1.5:1 VSWR bandwidth from 3500 to about 3870 kHz. Gain over a dipole peaks at 9.31 dB at 3525 kHz ,and the front-to-back ratio peaks at more than 23 dB at 3600 kHz. It also has about 1.5 dB more gain than the original antenna.

For 160 meters, comparison is made to the popular inverted L antenna, since it is felt that this is a more realistic competitor. Ten ohms of ground loss is also assumed even though this measurement was made at 3795 kHz. The presumption is made that the same number and wire size radials are used as at 3795 kHz, but they are twice as long. Unlike 80/75 meters, where

Freq. in kHz	VSWR	Gain over Dipole (dB)	F/B (dB)	Gain over ver. array (dB)
3500	1.83	8.75	5.34	-
3510	1.71	8.86	5.76	-
3520	1.59	8.96	6.24	-
3525	1.54	9.00	6.48	-
3530	1.49	9.01	6.75	-
3540	1.39	9.08	7.29	-
3550	1.30	9.19	7.88	-
3600	1.06	9.31	11.84	-
3650	1.30	9.08	19.36	-
3700	1.41	8.63	26.92	-
3725	1.41	8.37	19.82	-
3750	1.39	8.12	15.97	-
3760	1.37	8.02	14.86	-
3770	1.35	7.97	13.86	-
3780	1.33	7.86	13.00	-
3790	1.31	7.78	12.26	VSWR>1.5
3795	1.30	7.73	11.92	2.09
3800	1.28	7.69	11.65	2.11
3805	1.27	7.65	11.32	2.17
3810	1.26	7.60	11.04	2.18
3820	1.24	7.51	10.50	VSWR>1.5
3830	1.22	7.43	10.01	-
3840	1.21	7.35	9.55	-
3850	1.20	7.27	9.15	-
3900	1.27	6.92	7.48	-
3950	1.51	6.63	6.37	-
4000	1.87	6.38	5.56	-

Table III– Comparing the gain of the new box antenna optimized at 3600 kHz with the dipole at 40 feet and the two-element vertical array presented in the December 1995 issue of QST.

the dipole is more popular, the inverted L seems to be the antenna of choice. The presentation given in Table V shows that the box antenna provides more than 3 dB of gain from 1800 to 1850 kHz as compared to the inverted L. This is not too surprising, since the box antenna is two inverted Ls with the ends of the horizontal sections meeting but not touching. Front-to-back peaks out at more than 28 dB at 1850 kHz.

Gain plots are shown in fig. 2 with the box antenna compared to the dipole at a height of 40 feet on 3795 kHz. They confirm the performance listed in Table II for a radiation angle of 5 degrees. Notice the rather deep nulls at the starboard and port quarters of the azimuth plot. This may or may not be desirable.

Fig. 3 is a plot of performance of the box antenna compared to the loaded two-element, vertical parasitic array presented in the December issue of *QST*.

The vertical plot shows the deep null

Freq. in kHz	VSWR	Gain over Dipole (dB)	F/B (dB)	Gain over ver. array (dB)
3500	1.15	9.27	8.79	-
3510	1.10	9.30	9.51	-
3520	1.06	9.31	10.37	-
3525	1.06	9.31	10.78	-
3530	1.07	9.31	11.27	-
3540	1.10	9.20	12.28	-
3550	1.14	8.97	13.45	-
3600	1.30	8.94	23.32	-
3650	1.34	8.42	21.69	-
3700	1.26	7.89	13.97	-
3750	1.15	7.41	10.49	VSWR>1.5
3790	1.13	7.13	8.71	1.50
3795	1.14	7.10	8.53	1.46
3800	1.16	7.06	8.38	1.48
3810	1.19	6.99	8.04	1.57
3820	1.22	6.91	7.73	VSWR>1.5
3850	1.36	6.73	6.95	-
3900	1.67	6.45	5.88	-
3950	2.08	6.21	5.14	-
4000	2.61	6.01	4.58	-

Table IV– Comparing the gain of the new box antenna optimized at 3525 kHz with the dipole at 40 feet and the two-element vertical array presented in the December 1995 issue of QST.

straight up and off the vertical end of the antenna, while the box antenna does not, due to the active horizontal sections of the box. The azimuth plot with the radiation angle at 5 degrees shows gain over the loaded vertical for 3795 kHz to be in agreement with thet figure in the last column in Table II.

Fig. 4 compares the box antenna with the inverted L antenna on 160 meters. The azimuth plot is for a radiation angle of 5 degrees. Deep nulls are also apparent at the starboard and port quarters.

Construction

Building this antenna for any of the center frequencies presented is as easy as or easier than putting up a dipole or inverted L. In addition to the usual wire, etc, all that is needed are two suitable skyhooks; if they are useful for other antenna types, then they certainly are useful for the box. No. 12 bare copper antenna wire is used for the antenna and gamma match. In fact, the gamma match is constructed in precisely the same manner as described in my article in the December issue of *QST*.

The two corner insulators and the center insulator in the horizontal run are ordinary glass or porcelain wire antenna insulators. All lengths should be measured carefully and not approximated by pacing on the ground. The corner insulators must be connected to the wire so that ithe wire cannot slip, but maintains the same vertical and horizontal lengths even when the wind blows.

A system of pulleys and counterweights must be used to allow the trees to sway even in mild wind. The weights will go up and down, but your antenna will not. The ends of both vertical runs connect to ground at the convergence point of each set of ground radials. Generally, clamped or otherwise unsoldered connections do not hold up to the weather, so it is imperative that all radials are soldered together at the point of connection to the vertical sections. Run the radials on top of the ground—i.e., do not bury them. Do not strip the coax cable radials, so that the copper braid remains like new for best conduction. Only the braid serves as the radial. The center conductor is not used, but may be soldered to the braid at the convergence point.

Conclusions

Although four frequency versions of the same antenna have been presented, only one actually has been built. Since the original antenna was constructed for 3795 kHz, this was the frequency of choice for the box antenna. Unfortunately, both cannot be in position at the same time, so a completely objective comparison was not possible. Also, since the original antenna worked so well, a good comparison is fur-

Freq. in kHz	VSWR	Gain over inverted L (dB)	F/B (dB)
1800	1.37	3.52	9.55
1805	1.29	3.54	10.49
1810	1.22	3.56	11.48
1815	1.16	3.54	12.67
1820	1.11	3.52	14.05
1825	1.08	3.48	15.54
1830	1.08	3.44	17.41
1835	1.10	3.36	19.65
1840	1.13	3.29	22.48
1845	1.15	3.20	26.05
1850	1.18	3.06	28.69
1900	1.21	2.11	11.85
1950	1.09	1.38	7.47
2000	1.52	0.84	5.35

Table V–Comparing the gain of the new box antenna optimized at 1810 kHz with the inverted L reference antenna.

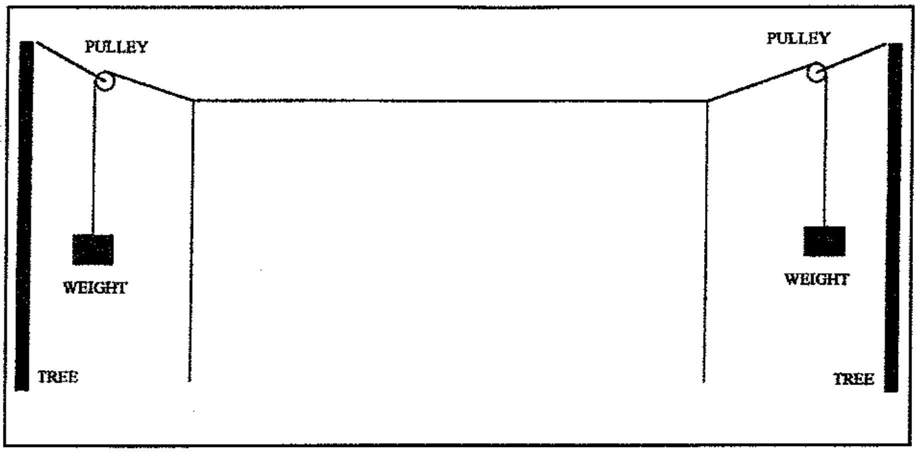

Fig. 5– The box antenna may be held in place between two trees shown here as simple poles. The ground ends of the vertical runs must be securely anchored to the ground by means of a heavy weight, screw-anchor, or ground rod of some type. The weights should be no heavier than that necessary to allow the antenna to retain its box shape without pulling on the ground anchors any more than necessary. Use proper rope size to fit the pulleys so that it cannot jump the wheel and get caught between the wheel and the wheel pin.

ther confounded. Stateside stations off the back of the antenna are definitely weaker on average, and the much wider projected 1.5:1 VSWR bandwidth is also evident as predicted. No tuning of the gamma match is needed, nor did the chip capacitor need to be changed to a different value than that predicted by modeling. The 160 meter version has not been built, but there is no reason to think that it will not work as predicted. That will be a summertime exercise before the next 160 meter DX season.

The Challenge

With the new box antenna exhibiting nearly 10 dB of gain and 25 dB or so of front-to-back ratio over a dipole on 80/75 meters even with 10 ohms of ground loss, and the 160 meter version showing 3+ dB of gain and 25 dB of front-to-back ratio over the inverted L, the next big step is to figure out how to rotate them! ■

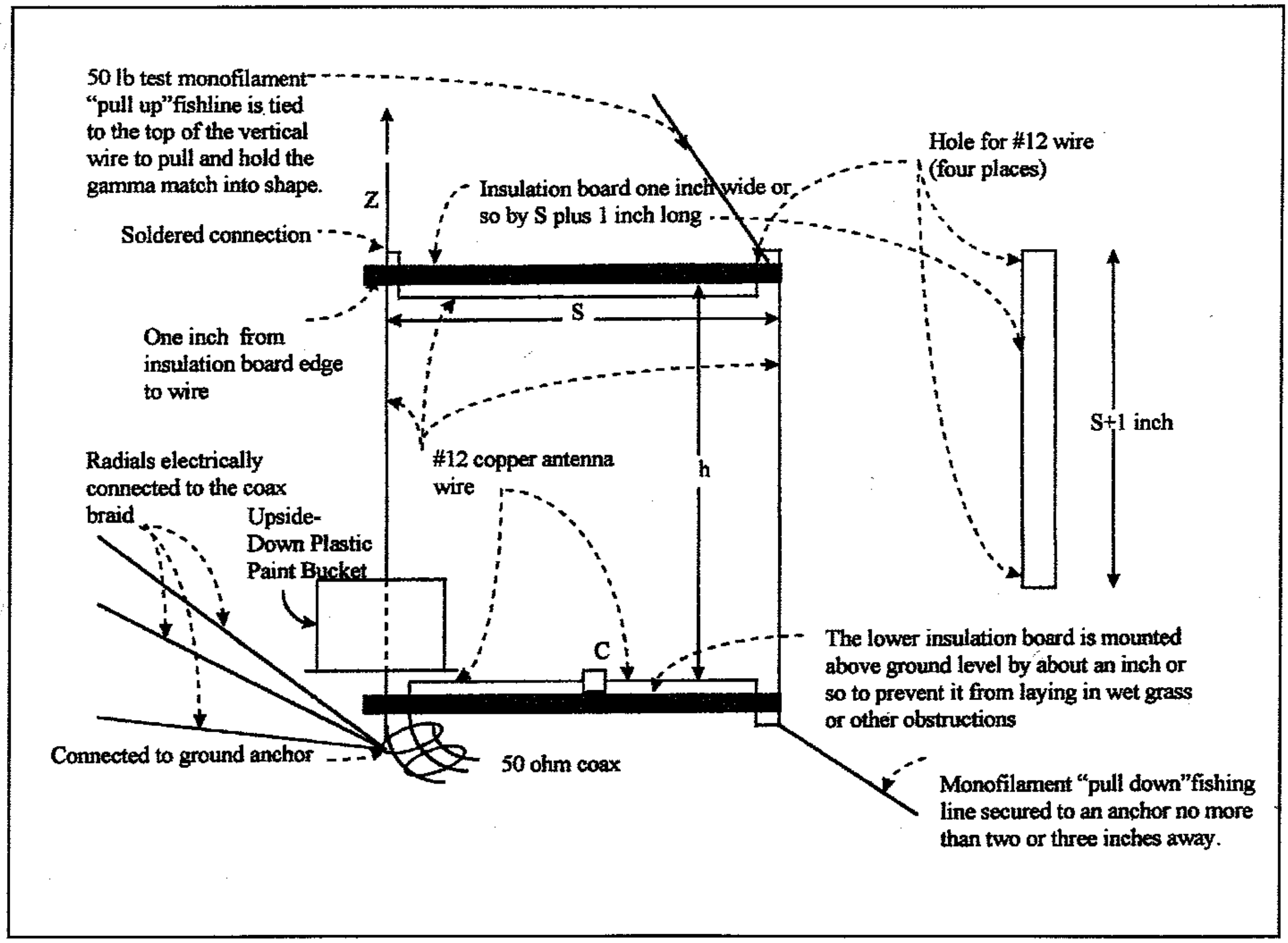

Fig. 6– An exaggerated view of the gamma match. Wire actually runs on the surface of the insulation board. The insulation board may be PVC, plate plastic, or any other rigid insulating material that will maintain horizontal runs of the gamma match horizontal. The holes near the ends of the insulation board allow the wire to weave through and catch on the hole edges, preventing it from slipping away from the rectangular geometry. The thickness of the board is assumed to be thin compared to dimension h. C is soldered to the wires at its ends, weather sealed with silicone rubber and double taped.