The Double Cross Vertical Antenna

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Antennas have been part of my business for years and I have placed my designs at large stations in a number of countries. (Money is no object with the big commercial arrays.) Even though I design antennas for a living, I still like to play with them at home. Part of the fun of antenna construction is producing a high quality, efficient antenna that is truly low in cost.

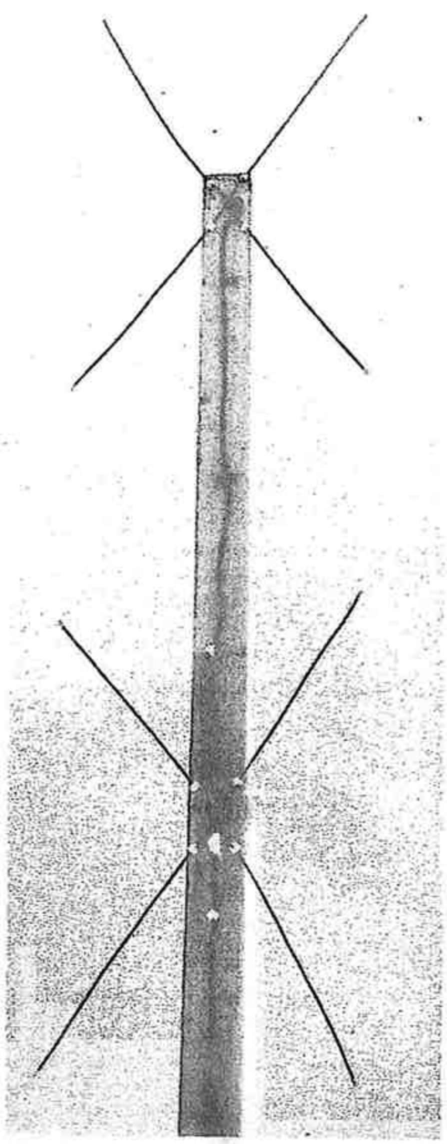
One snowy Alaskan afternoon I was inspired to design a home-brew antenna project. Simplicity was the primary consideration. It had to be something I could build with just a couple of coax connectors, a few coat hangers and my trusty soldering iron. It also had to be theoretically feasible and efficient. Despite my best intentions, my antennas have a tendency to grow like rabbits. Within a short period of time my living room was filled with paper and wire!

The Double Cross Design

Where would antenna designers be without computers? After a bit of work at my keyboard I soon developed the "X" antenna. As I examined the design I noticed a unique property of the "X": It could be mounted on a metal pole with almost no interaction. (The vertical center line between elements was also a null line.) Stacking the antenna seemed natural, and after looking at the result (see Fig 1) the name "Double Cross" seemed natural too!

This antenna is a variation on a vertical dipole. Imagine two V-shaped wires, one opening upward and one downward. Now imagine that both V wires are connected to a coax cable at their apexes. The coax shield is soldered to one V and the coax center wire to the other V.

By adjusting the angle of the V to 70°, the antenna can be made to resonate at the desired frequency and that angle will give the best bandwidth. The angle does not have to be extremely precise. Angles from about 60 to 110 degrees do little to change the feed impedance. (The impedance remains about 30 to 35 Ω over these angles.) The mid-line between the V wires is a null line. This permits the support pole and coax feeder harness to be mounted in the center line area with no problems.



The 2-meter experimental version of the Double Cross antenna made with no. 10 wire, coax, silicone glue and a 2 × 4 board.

The angle of the V apex is set easily by adjusting the tip-to-tip spacing of the V elements. On paper and in actual practice it seems to be reasonably noncritical. For example, a tip-to-tip error of ±5% seems to make little difference in the operation of the antenna.

It also occurred to me that grounding the topmost elements on the antenna would offer lightning protection for the receiver. Turning the top dipole upside down and mounting the hot element of the next lower dipole *upward* also seemed to be a neat symmetrical method to balance the antenna currents. Feeding the dipoles 180° out of phase is all that is required for both protection and balance. This can be easily accomplished by adjusting the length of the feed harness (see Fig 2).

Old hams told me that using two wires in a V would not give a circular pattern because it was not balanced. This "old ham's tale" is simply not true; the pattern of the Double Cross is only 0.5 dB out of round. For the sake of a little irregularity there isn't a compelling reason to increase the complexity by adding more wires. To prove that more complex designs were not necessary, I constructed a three-dimensional version of the antenna and found it was indeed very difficult to handle. After a thorough examination of the calculations and construction of the flat "X" antenna, I proved that a two-dimensional design was entirely sufficient.

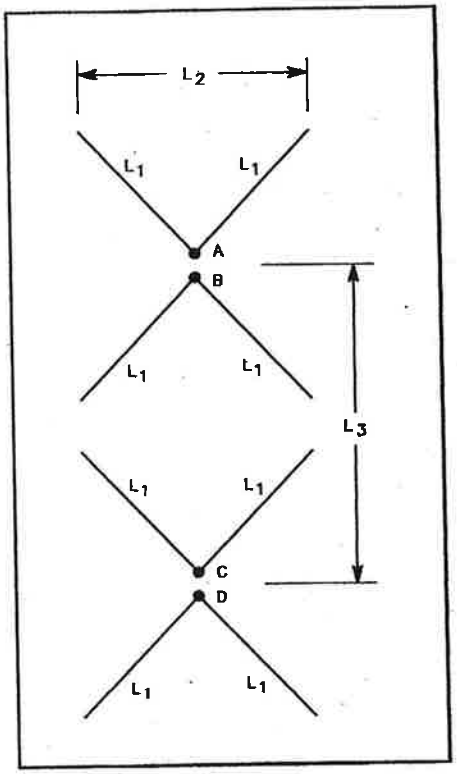


Fig 1—Double Cross antenna design.

Table 1
Double Cross Antenna Lengths for Amateur Bands

All dimensions are in feet. "Bandwidth" shows the lower and upper 2:1-SWR frequencies, MHz.

Band	Freq.	L1 Element	L2 Tip-tip	L3 Spacing	L4 Coax 1	L5 Coax 2	L6 Diam.	Bandwidth
160	1.90	111.05	127.38	323.68	256.36	85.45	3.04	1.7—2.1
80	3.70	57.03	65.41	166.22	131.64	43.88	1.56	3.3—4.1
75	3.90	54.10	62.06	157.69	124.89	41.63	1.48	3.5—4.3
40	7.15	29.51	33.85	86.01	68.12	22.71	0.81	6.4—7.9
30	10.13	20.84	23.90	60.74	48.11	16.04	0.57	9.1—11.1
20	14.18	14.89	17.07	43.39	34.36	11.45	0.41	12.8—15.6
17	18.11	11.65	13.36	33.96	26.90	8.97	0.32	16.3—19.9
15	21.23	9.94	11.40	28.98	22.95	7.65	0.27	19.1—23.3
12	24.93	8.46	9.71	24.67	19.54	6.51	0.23	22.4—27.4
10	28.50	7.40	8.49	21.58	17.09	5.70	0.20	25.7—31.4
6	50.10	4.21	4.83	12.28	9.72	3.24	0.12	45.1—55.1
2	146.00	1.45	1.66	4.21	3.34	1.11	0.04	131.4—160.6

Table 2
Double Cross Antenna Lengths for Various SWL Bands

All dimensions are in feet. "Bandwidth" shows the lower and upper 2:1-SWR frequencies, MHz

Band	Freq.	L1 Element	L2 Tip-tip	L3 Spacing	L4 Coax 1	L5 Coax 2	L6 Diam.	Bandwidth
1	1.00	211.00	242.02	615.00	487.08	162.36	5.77	0.9—1.1
2	1.20	175.83	201.68	512.50	405.90	135.30	4.81	1.1—1.3
3	1.44	146.53	168.07	427.08	338.25	112.75	4.01	1.3—1.6
4	1.73	121.97	139.89	355.49	281.55	93.85	3.34	1.6—1.9
5	2.07	101.93	116.92	297.10	235.30	78.43	2.79	1.9—2.3
6	2.49	84.74	97.20	246.99	195.61	65.20	2.32	2.2—2.7
7	2.99	70.57	80.94	205.69	162.90	54.30	1.93	2.7—3.3
8	3.58	58.94	67.60	171.79	136.06	45.35	1.61	3.2—3.9
9	4.30	49.07	56.28	143.02	113.27	37.76	1.34	3.9—4.7
10	5.16	40.89	46.90	119.19	94.40	31.47	1.12	4.6—5.7
11	6.19	34.09	39.10	99.35	78.69	26.23	0.93	5.6—6.8
12	7.43	28.40	32.57	82.77	65.56	21.85	0.78	6.7—8.2
13	8.92	23.65	27.13	68.95	54.61	18.20	0.65	8.0—9.8
14	10.70	19.72	22.62	57.48	45.52	15.17	0.54	9.6—11.8
15	12.84	16.43	18.85	47.90	37.93	12.64	0.45	11.6—14.1
16	15.41	13.69	15.71	39.91	31.61	10.54	0.37	13.9—17.0
17	18.49	11.41	13.09	33.26	26.34	8.78	0.31	16.6—20.3
18	22.19	9.51	10.91	27.72	21.95	7.32	0.26	20.0—24.4
19	26.62	7.93	9.09	23.10	18.30	6.10	0.22	24.0—29.3
20	31.95	6.60	7.57	19.25	15.25	5.08	0.18	28.8—35.1

After I built the first coat-hanger "X" antenna I also discovered that the measured bandwidth was better than expected. The element diameter was increased to ½ inch on the 2-meter theoretical model and this allowed the antenna to cover more than the full band.

Table 1 provides element lengths, tip-to-tip spacings, element diameters and phasing-line information for most ham bands. Table 2 offers the same information for 1 to 30 MHz in arbitrarily numbered bands. Incidentally, using wire for the elements is quite acceptable even though tubing is indicated. For ham operation a sufficient bandwidth can be obtained by using thin wire elements.

A single stacked "X" dipole could be strung between two trees for low-frequency operation. Attempting the Double Cross stacking arrangement on 80 or 160 meters would be unreasonable, but a single unstacked "X" would perform as an excellent wide-band vertical on these bands.

It may be a good idea to employ a matching transformer between the 50-Ω coax and the antenna. Such an RF transformer can be made by using a high quality, high frequency powdered core with a cross section of at least ½ by ¼ inch for 150 watts. For the HF bands the 50-Ω primary should be 10 turns and the 30-Ω secondary should be 8 turns. I prefer to use 18 gauge wire with Teflon insulation, wrapping the first winding and then interlacing the second. I also like to tie down the ends with fishing line and coat the transformer with a heavy layer of clear silicone glue. A properly constructed transformer should last up to 50 years—if it doesn't take a direct lightning strike!

Design Calculations

A simple four-function calculator can be used to calculate the antenna dimensions.

1) The lengths of each leg of the V elements (L1):

$$L1 = \frac{64.2 \text{ meters}}{f_{MHz}} = \frac{211 \text{ feet}}{f_{MHz}}$$

2) The tip-to-tip distance (L2) of the open end of the V element gives a 70° apex angle:

L2 = 1.147 × L1 (results in either feet or meters, according to the original L1 values)

3) The separation of two "X" elements is ⅝ λ or L3:

$$L3 = \frac{187.0 \text{ meters}}{f_{MHz}} = \frac{615 \text{ feet}}{f_{MHz}}$$

4) L4 represents the length of the 50-Ω solid polyethylene dielectric coax (velocity factor 0.66) from the **upper** dipole to the summing junction where upper and lower dipoles are connected:

$$L4 = \frac{224.4 \text{ meters} \times 0.66}{f_{MHz}} = \frac{738 \text{ feet} \times 0.66}{f_{MHz}}$$

5) L5 represents the length of 50-Ω solid polyethylene dielectric coax from the **lower** dipole to the summing junction mentioned above, *and* the length of the two parallel 70-Ω coaxial cables used for impedance matching:

$$L5 = \frac{75 \text{ meters} \times 0.66}{f_{MHz}} = \frac{246 \text{ feet} \times 0.66}{f_{MHz}}$$

6) L6 represents the diameter of the V legs required for the indicated bandwidth. However, ordinary wire also works well for practical ham antennas:

$$L6 = \frac{1.759 \text{ meters}}{f_{MHz}} = \frac{69.2 \text{ in.}}{f_{MHz}} = \frac{5.77 \text{ ft}}{f_{MHz}}$$

Double Cross Construction

Construction of the first "X" antenna was accomplished with coat-hanger wire soldered to a coax connector. The coax line was connected and the free end was pulled through a ½-inch support pipe for testing. The results were excellent. The SWR was low and the bandwidth was exactly as calculated.

The next step was construction of a stacked 2-meter Double Cross antenna with a complete coaxial feed harness. This was done using no. 10 Copperweld wire salvaged from an open-wire telephone system. It was screwed to a 2 × 4 board and glued in place with silicone adhesive. There is no question that this was a minimum cost antenna! Once again, everything worked fine and the SWR was 1.1:1 over the entire 2-meter band.

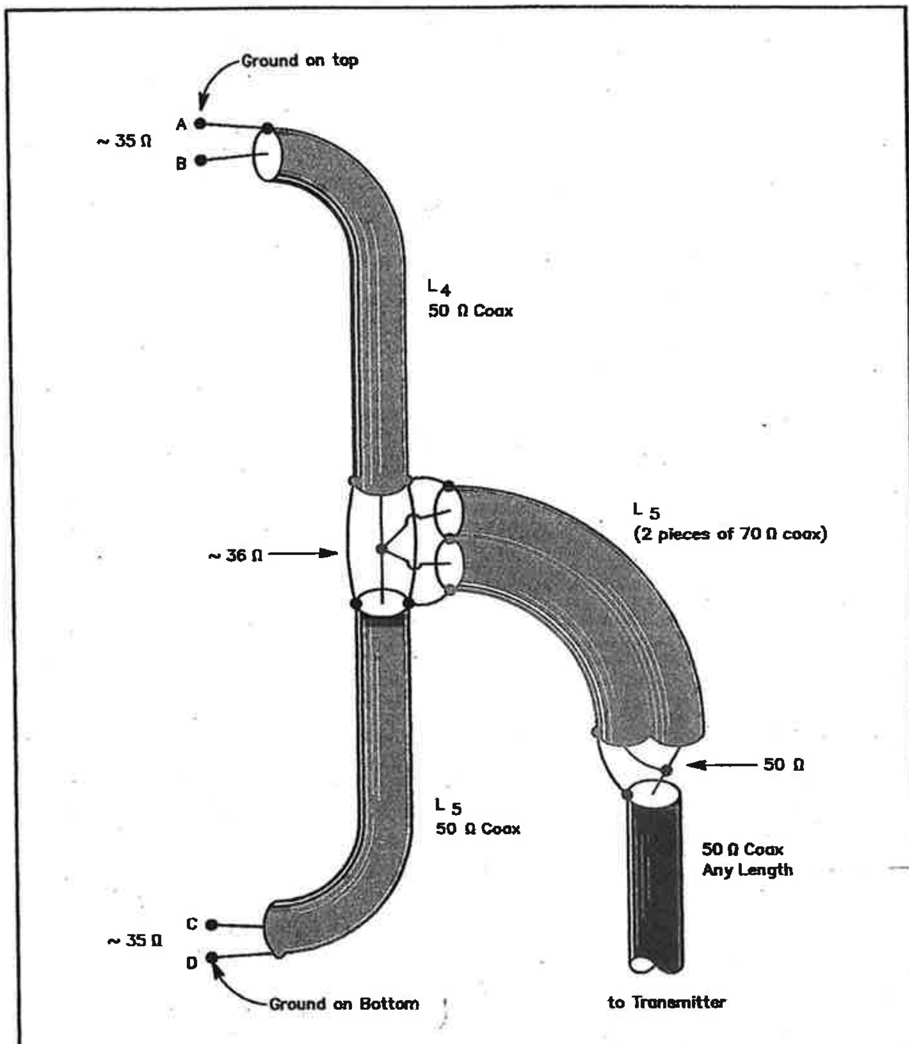


Fig 2—Double Cross coax harness.

The stacking harness shown in Fig 2 is designed for a 180° phase reversal. The shield of the ¾-λ section of 50-Ω coax goes to the top V. This is length L4. The shield of the ¼-λ 50-Ω coax section goes to the bottom V. This is length L5.

The two 50-Ω phasing lines are soldered together at a common point. The impedance at this point becomes about 36 Ω because there are two 50-Ω lines in parallel.

Matching is easy with a "Q" section, a ¼-λ series matching section made from 42-Ω coax. Two pieces of solid polyethylene coax are cut to length L5 and soldered in parallel (shield to shield and center to center) to make the "Q" section. I used two pieces of 70-Ω coax and achieved an excellent match, but it is possible to substitute one length of 95-Ω coax if you need to improve the match further. Examples of 95-Ω coax are RG-180B or RG-195A. Alternatively, it is possible to build short pieces of 42-Ω coax from brass hobby tubing. The inner conductor needs to be 0.217 inch or about 7/32 inch, and the outer conductor's inner diameter should be 0.5 inch. However, I recommend starting with two parallel 70-Ω coax cables first.

All harness connections should be kept short. I prefer to connect all center conductors first. Make one last check against Fig 2 to be sure that everything is correctly connected. Then smooth the joints and wrap them tightly with Teflon plumber's tape. Now connect the shields, taking care not to melt the polyethylene insulation. A wet cloth will quickly cool the joint after soldering. Let it cool for several minutes because the polyethylene core cools much more slowly than copper. The joint can then be dried and coated with silicone glue to make it waterproof. If you insist on a neater appearance, slide some shrink tubing over the joint before the silicone hardens and shrink it. Wipe off the extra silicone for a first-class job.

The final step is to use a VOM and make a resistance check of the antenna with the coax in place. The path from the center conductor of the coax to the shield should exhibit an infinite resistance (open circuit). The path from the center conductor to the two inside V elements should show a short. The resistance from the coaxial shield to the outside V elements should also indicate a short.

Route all coax straight down the middle line of the antenna. Secure it in place so that wind, ice and time will not change its location.

These Double Cross stacked dipoles have given me the extra low-angle gain necessary for improved 2-meter coverage. I keep thinking about how well a long dipole stack would perform on the UHF bands and how nicely a 20-meter Double Cross could work—if I could only get two tall trees to grow in my muskeg swamp!