Simplifying the Four-Square

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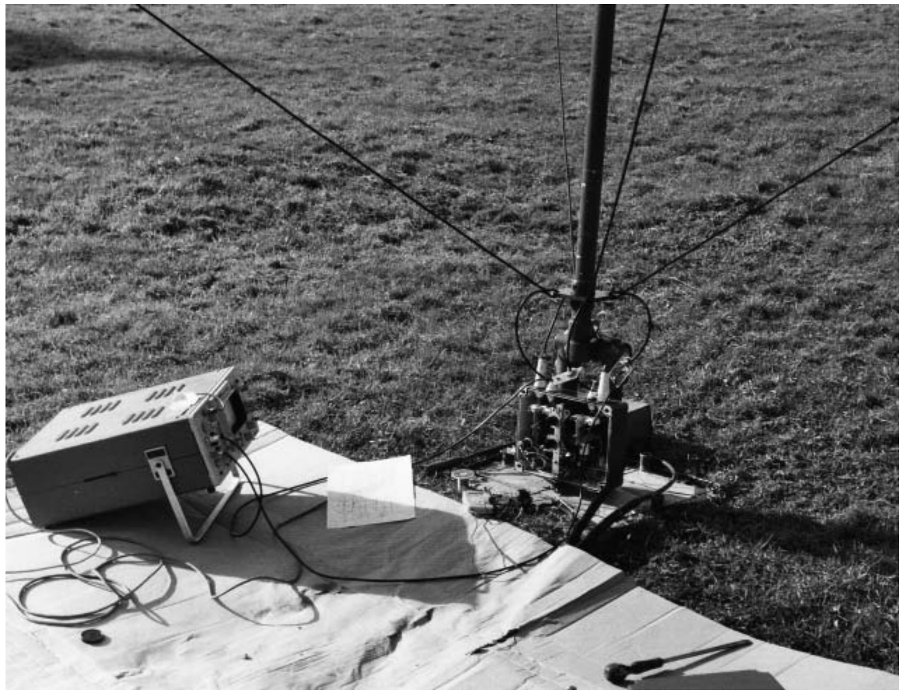
The four-element square antenna array of quarter-wave vertical elements with quadrature current drive — or "four-square" — has become very popular among low-band DXers. For many of us, however, its site area requirements have been a negative factor in its adoption. More compact versions generally require more complex drive circuitry, such as that in Figure 2a, and this can also be a disincentive.

Have you been put off building a four-square array by the multiple towers, elaborate ground system, complex feed circuits and finicky adjustment procedure? Here's an alternative that works as well as the real thing but only needs one tower, a single radial ground system, no phasing lines and no L networks, and it tunes easily.



The base of the antenna, showing the method of terminating the wire elements on the guyed scaffold tower. Current transformers are fitted for tuning.

Construction

Photo 1 (right) shows one of the four elements that are deployed every 90° around a single quarterwave-tall support. Element shape and size is chosen to simultaneously minimize horizontally polarized radiation, provide suitable spacing between points of maximum current and present a 50 Ω feed point impedance[1]. Ideally the support should be insulated to reduce the possibility of pattern distortion by current induced by the radiators, but there are ways to make grounded towers transparent at the array's working frequency[1, 2]. I use three 6-meter steel scaffold poles to support my 80 meter array. The elements are made of inexpensive steel-core satellite coaxial cable because this has minimum stretch and provides a large effective diameter to minimize loss with light weight. At the mast base the wires terminate on a piece of insulating-sheet material and connect — inner and outer conductors together — via feed-through insulators at the control box.

A ground system of buried radials, as many and as long as you can fit onto the site, radiates from the array's center. The element wires are pulled away with 2 mm Nylon twine to posts, trees or buildings. You can change the shape of the elements if necessary to reduce the pulling radius, but it will degrade the radiation pattern. That takes care of the construction details. Now, the theory.

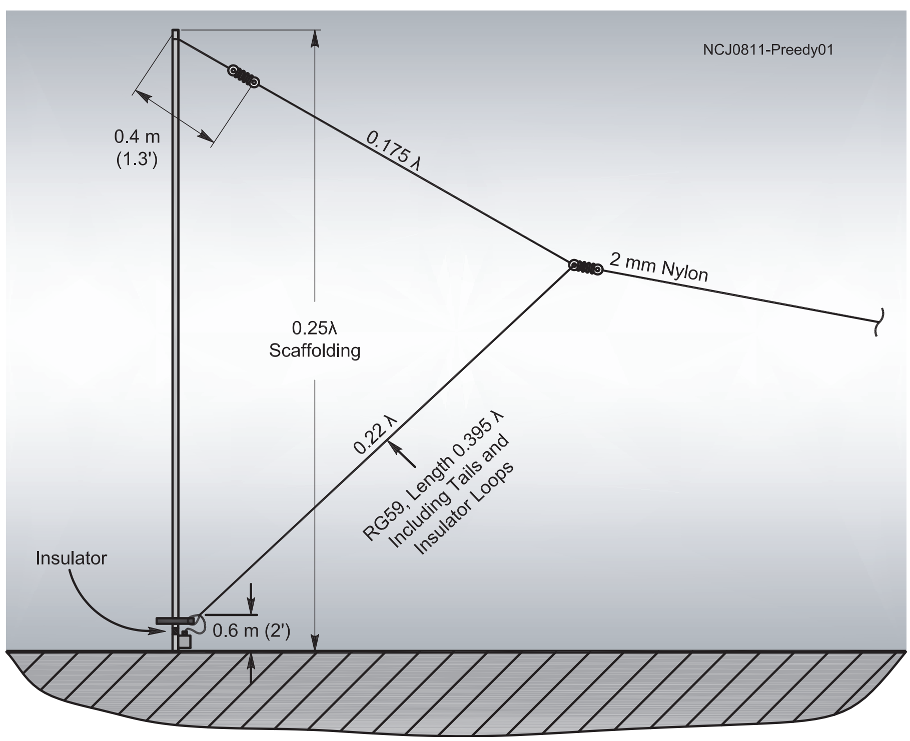


Figure 1 — Construction of the elements for the parasitic four-square array.

How it Works

The elements are effectively 0.4 λ when the dielectric loading by the cable sheath is considered. The points of

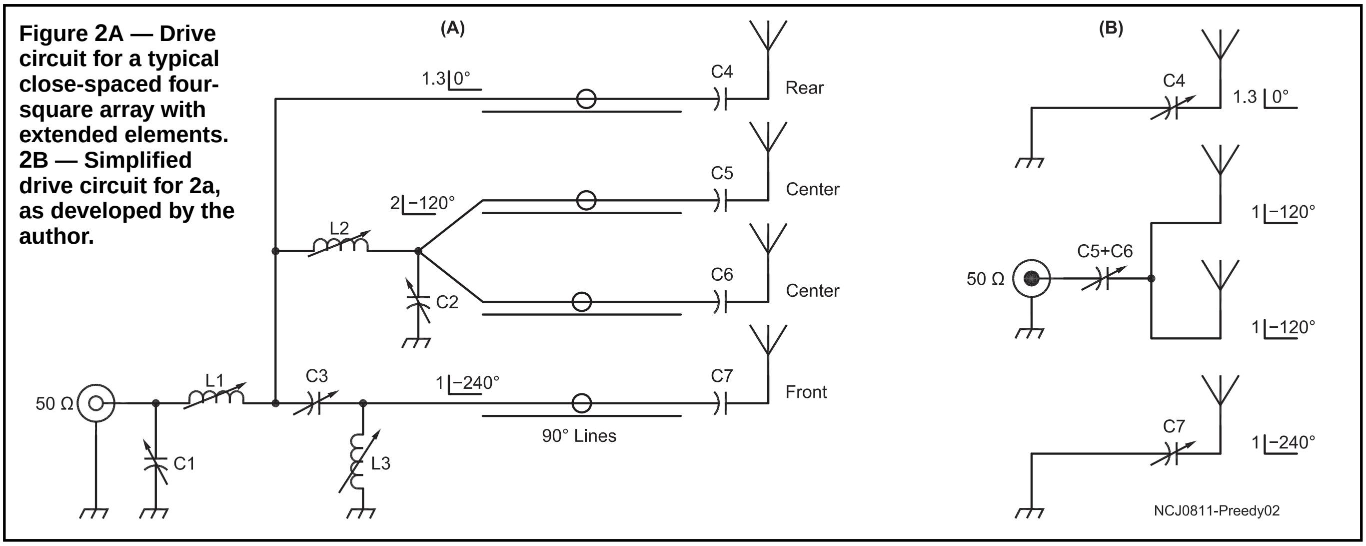


Figure 2A — Drive circuit for a typical close-spaced four-square array with extended elements. 2B — Simplified drive circuit for 2a, as developed by the author.

maximum current on each element are 0.25 λ from the top, which makes their effective spacing about 0.15 λ. If we drive this array as a conventional close-spaced four-square it requires relative currents of 1.3 A at 0°, two of 1 A at -120° and 1 A at -240° for the rear, center and front elements, respectively. Because all these currents return to a common ground point, the Earth connection loss is only that due to their vector sum of 0.8 A at -230°. Consequently the ground system is less important from a loss standpoint than for a conventional four-square with individual ground returns. Conventional all-driven-element operation requires a feed system like that in Figure 2. Here L_1/C_1 handle input matching for the feeder. L_2/C_2 and L_3/C_3 are dual-purpose networks that determine phase delay and voltage ratio.

The 90° coaxial phasing lines are used to convert the voltages at their input ends into corresponding currents in the elements. In this case, because the elements are longer than 0.25 λ, we also need to match them with series capacitors C_4 to C_7 of equal value in order to keep the VSWR low on the phasing lines.

We do not have to do it this way!

Simplifying the Feed System

If we don't drive the front and rear elements, we have a parasitic array. By adjusting the matching capacitors in this configuration, we can control the current amplitude and phase. In fact we can find values that will give the optimum amplitudes that we could have calculated for all-driven-element operation. Because this array is relatively close spaced the

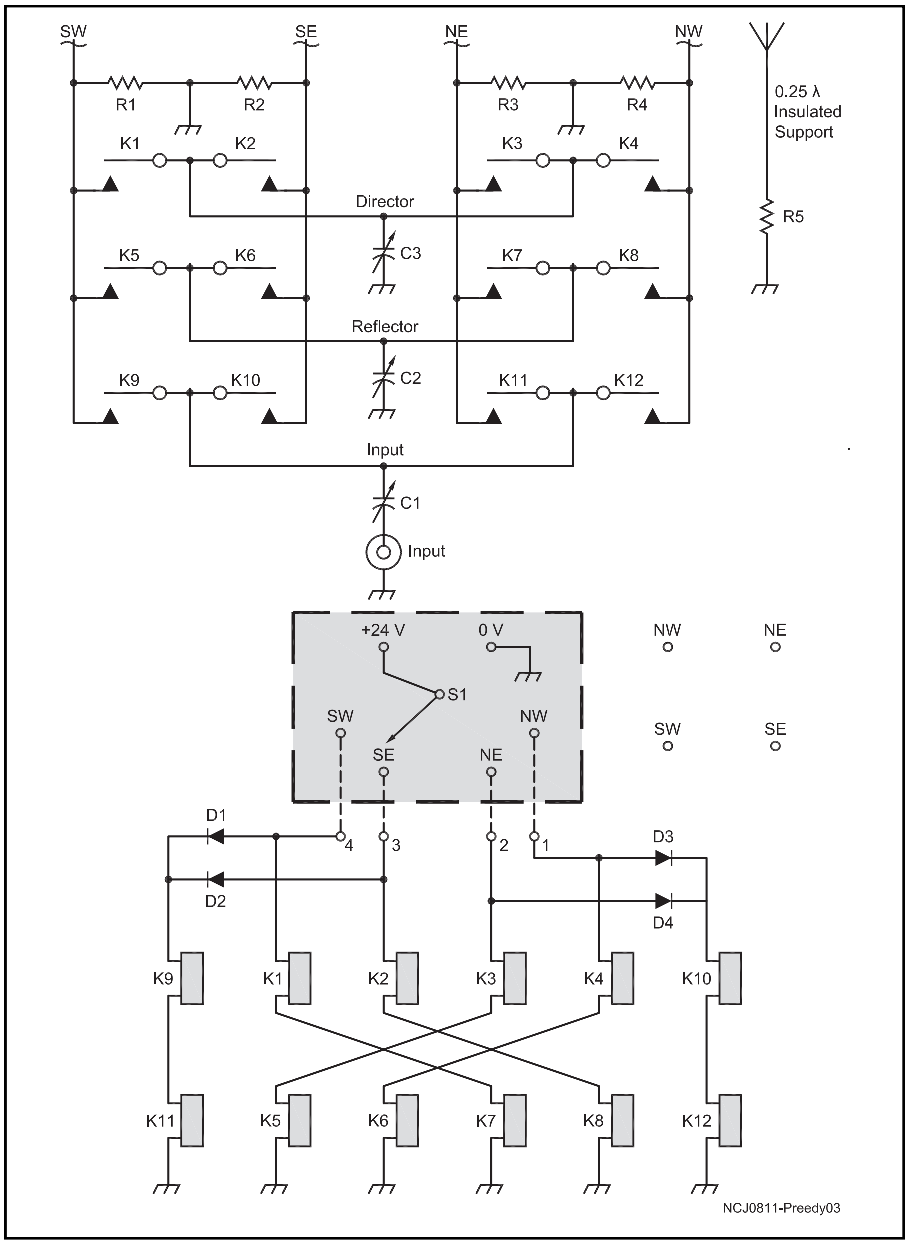


Figure 3 — Direction control and tuning circuit for the G3LNP four-square.

optimum phase angles for the currents in the elements tend to correspond with the optimum amplitudes. This can be confirmed by computer modeling, which shows no difference in the radiation pattern for either the all driven-element configuration or the parasitic configuration. The drive circuit now simplifies to that in Figure 2B. All we have to add are the direction-switching relays.

Direction Switching

Unless operating very low power (QRP), voltages at the ends of the wires are high and beyond the capability of conventional relays to handle. Vacuum relays with changeover contacts might simplify the circuit, but I found their self capacitance led to unwanted coupling between elements. This resulted in poor directivity. High-voltage dry-reed relays designed for electro-medical applications are the only type I have found to be suitable. These represent the primary expense in constructing this antenna. High-value resistors are added to discharge static electricity from the elements and from the tower if it is insulated. Figure 3 shows the switching and drive circuit, which is built in an ABS weatherproof box as in Figure 4. Construction objectives are to keep the wiring length as nearly constant as possible for each direction and to minimize stray capacitive coupling between elements.

Setting to Work

To tune the array you must be able to measure the current amplitude in any pair of adjacent elements at their feed point. I use 20 turn current transformers, a dual-trace 'scope and a fraction of a watt of RF input. Low-impedance devices such as automotive lamps or RF ammeters should also work. Confirm that all relays are working correctly. Set the director

Table 1 — Component List

C_1: Variable 150 pF 2.5 kV (for 1.5 kW), fitted with a ⅜ inch shaft insulating bushing or otherwise insulated (Double capacitor values for 160 meters, and halve them for 40 meters.)

C_2, C_3: Variable 80 pF 2.5 kV (double capacitor values for 160 meters, and halve them for 40 meters)

R_1—R_5: each comprised of three 220 kΩ 2W in series

K_1—K_{12}: Reed relay, 10 kV, 3 A with 12 V coil (Meder Electronics H12-1A69 for surface mounting or HM12-1A69-150 for direct PC mounting or Cynergy3 type DBT71210S for PCB mounting)

Wire for elements: Steel core 6 mm coaxial cable, RG-59 or similar

S_1: 4-position, single pole, 1 A

D_1—D_4: 1N4002

Element insulators: Ribbed plastic type. Eight required, attached using cable ties

Lower insulator: Fabricated from 6 mm glass laminate or Plexiglass to suit tower

Feed-through insulators (4) for ABS control box: Glass or porcelain type with waterproof bushing and a minimum 30 mm leakage path

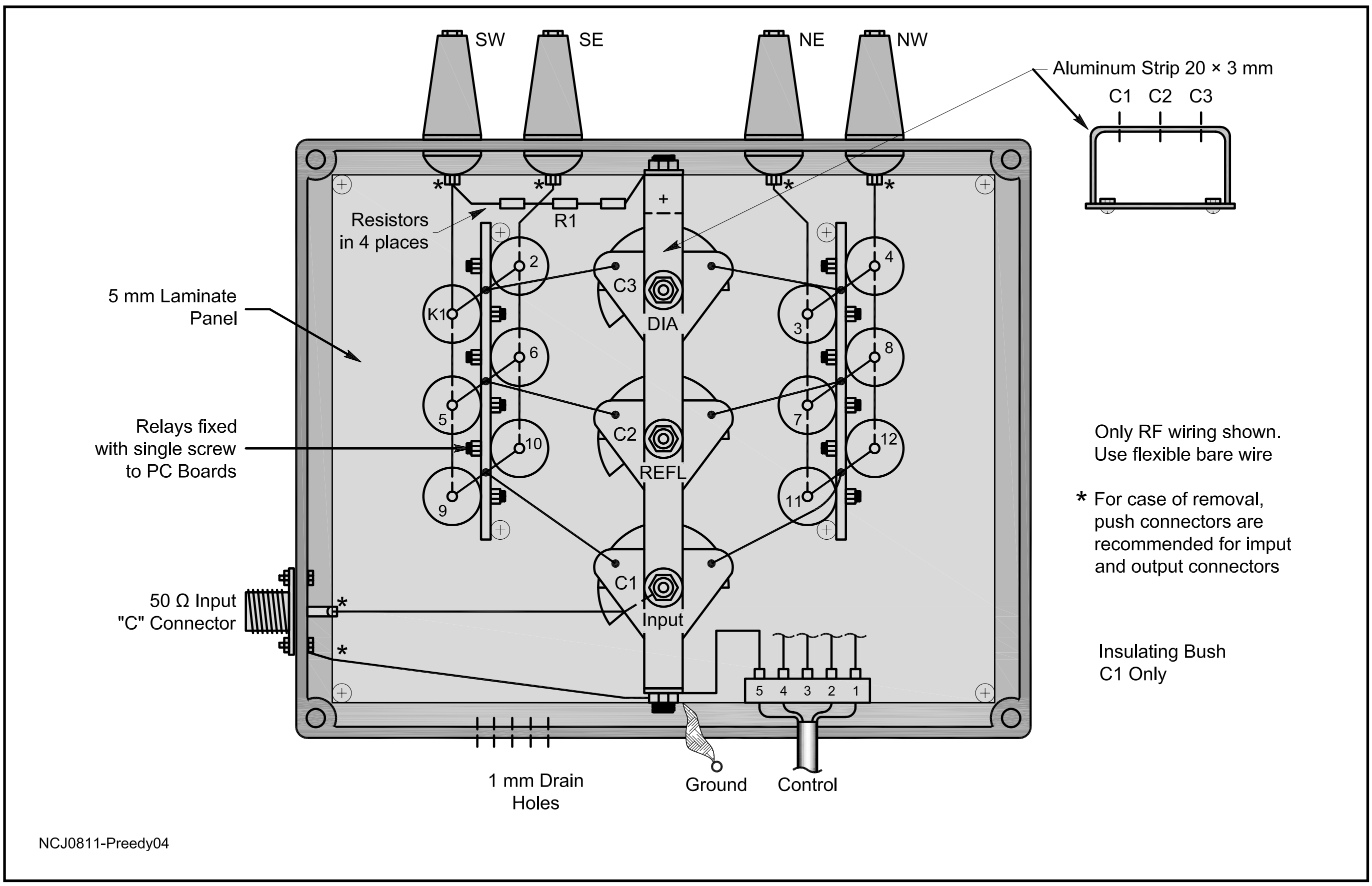


Figure 4 — Construction detail for the circuit in Figure 3.

capacitor to minimum and the reflector and input capacitors to maximum. Apply low power and reduce the rear element (reflector) tuning capacitance for 1.3 times the current or brightness as the driven element wire. Reverse the array and increase the front element (director) capacitance for the same current as in the driven element wire. If using lamps, you will need to experiment with a variable dc supply in order to know what 30 percent additional current looks like.

Repeat these adjustments because they interact. Then adjust the input capacitor for minimum VSWR. You may be able to improve on these settings by a front-to-back test with the assistance of a local station, but it is unlikely that you will get any more gain. Figure 5 shows measured F/B results for my 80 meter array after such adjustments. Figure 6 shows a computer-generated vertical radiation pattern at 30° elevation for the 80 meter array, while Figure 7 shows the horizontal pattern.

Notes

[1] Preedy,G3LNP. "Single-Support Directional Wires." *RadCom*, Aug/Sep 1997.

[2] Devoldere, ON4UN. *Low-Band DXing* (4th ed), p 11-35, ARRL.

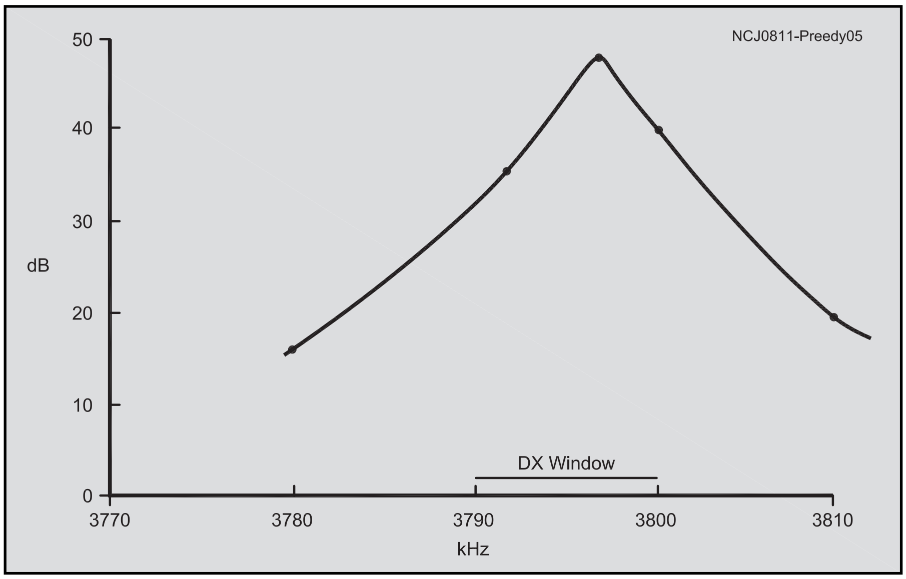


Figure 5 — Measured front-to-back directivity for the G3LNP array.

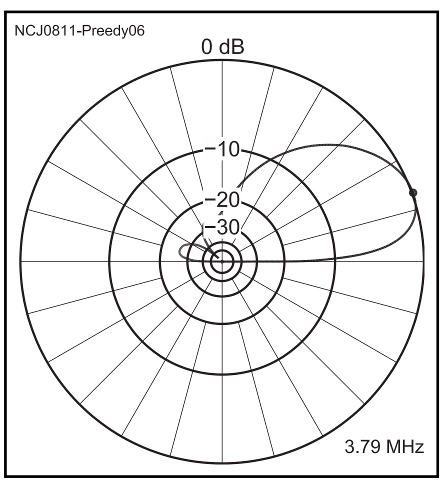


Figure 6 — An *EZNEC* plot of the vertical radiation pattern at 30° elevation with the antenna adjusted as a parasitic array on 3.79 MHz.

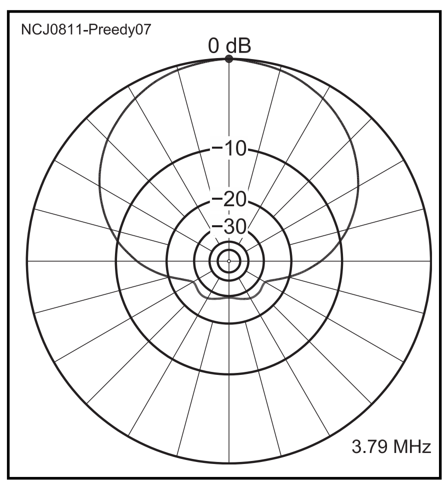


Figure 7 — An *EZNEC* plot of the horizontal radiation pattern at 3.79 MHz.