Array Solutions
Four Square Array Manual and User's Guide

Array Solutions Four Square Array Pattern Steering System

Congratulations!

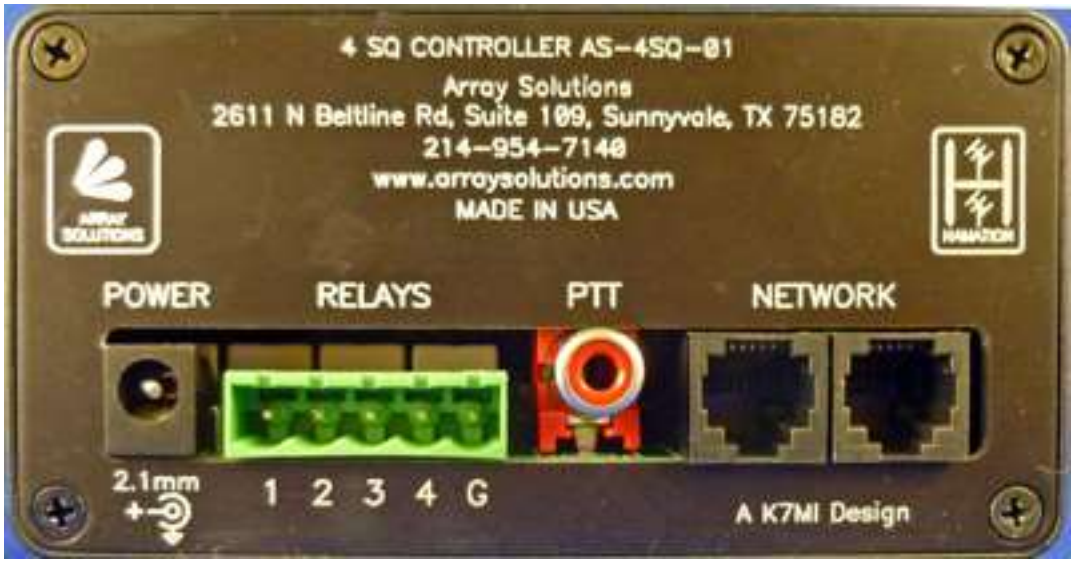
You have selected one of the finest phased array steering systems made. We have under-rated the power capability of this system to assure the user high reliability under heavy use such as in a 48 hour radio contest. Please contact us if you have any questions about the product.
The Array Solutions Four Square Array system has two components: a relay box that will be mounted midway between the four verticals and a control box that is connected with a 5-wire control cable inside the operating room. With this system you will be able to beam in 4 directions and also take advantage of the OMNI mode for domestic use to listen in all directions at once.

The system is available in standard quadrature feed and an optimized feed version and you can purchase the optimization kit at any time to add to your controller.

Wiring the system:

A 5 wire connector is supplied with the controller switch. Table 1 shows the 5 wires to the corresponding 5 wire terminals in the relay box and the control switch connector. You may use our DC power supplies which are regulated linear supplies, or use one of your choice. A 2.1mm DC coaxial connector pigtail is included for connecting to your DC supply. We recommend a 1000 mA or more power supply current rating.

You will need a cable with 5 conductors. Small gauge wires are fine and will fit inside the boxes better than large rotor cable. For runs of less than 500 feet (152.40 m), #18 (1.02 mm Ø or 0.82 mm^2) or larger gauge stranded wires will be adequate. The relays draw only 120 mA at 12 V DC. Try to use a supply that has a 13.8 V+ DC output or more for very long runs.



Wire the control switch connector to the relay box per the following Table 1.

Control Switch Connector	Relay Box Terminal strip
1	1
2	2
3	3
4	4
G	Gnd - Ground

Table 1

Suggestion: use a connector on a short piece of cable so you may disconnect the control unit from the control cable when not in use, or when a thunderstorm arrives. We also recommend the use of a surge protector at the station end for the control cable and RF cables, such as our AS-8-SP control line protector and our AS-303U coaxial cable surge protector. A little money spent now can save valuable radios and other gear later. We also have MOV protection inside the relay box.

Plug both the control line and power supply connectors into the back of the control box box.

Hot Switch Protection – to activate the hot switching safety feature, just plug an RCA PTT line from your transceiver into the RCA jack in the back of the controller. When PTT is asserted (GND) no relays will switch if a control pushbutton is accidentally pushed.

NETWORK – is for the ShackLan network and will allow control over the network for instance for a remote station or for networking with other Hamation controllers.
See http://hamation.com/ for more information.

Relay Box

Route the control cable through the rubber grommet hole in the relay box tray. Use the supplied Ty-wrap™ as a strain relief. The relay box terminal strip is marked to indicate the connection to terminals. See the above **Table 1** for the proper connections. The relays are bypassed with MOVs, capacitors, and diodes for RF and lightning suppression. See **Fig. 2** which is a picture of the relay phasing controller.

Figure 2 description

Input - RF connector is for the 50 ohm feedline

Antenna Ports 1-4 these are the output connectors to the 4 antennas. Each one should have a ¼ wavelength 70 - 75 ohm feedline connected to it. We use ¼ wavelengths to take advantage of the current forcing properties of this length of line. This will also give the Hybrid coupler impedance close to 50 ohms for most antenna arrays. The antenna ports are marked as directions that the antennas would normally be attached to the controller. NE, SE, NW, SW.

Dummy Load – A 50 ohm dummy load rated at 100 W minimum continuous duty should be plugged into the RF connector labeled “Dummy Load” on the Relay controller box.

Water proofing the connections is always a good idea even though the lip of the cover will protect the connectors from direct rainfall.

Setting up the system

The **AS-4Square** is pretty much plug and play and special instruments should not be necessary to set it up and get it operational in the normal quadrature feed situation.

Place the controller relay box in the geometric center of the array. Use the U-bolt mounting bracket provided to mount the box onto a ground rod, pipe, or tower leg. Feed each vertical with ¼ wavelength of 70 ohm feedline. The galvanized U - bolt can accept a water pipe driven into the ground as the mounting post. It has a 1.5 inch (38 mm) inside diameter. Mount it on the edge of the cover as shown on the picture below and tighten the U-bolt against the pipe with the connectors facing down. For added lightning protection you can drive in a ground rod and ground the relay box to the ground rod as well.

Set up your verticals into a square spaced ¼ WL apart from each other; we will define the square as follows. The antenna ports are marked from 1 to 4 with four directions to be set up as follows and cabled to the controller in the center.

NW **NE**
● 2 **● 3**

● 1 **● 4**
SW **SE**

The above diagram indicates verticals (●), Antenna number (1-4), and Directions

Antenna Feed lines- Build your 4 antenna feed lines from RG-11 or other 75 ohm coax and make them ¼ wave-length long. You will need to use "foam" coax with a velocity factor greater than 0.80 to reach all 4 antennas. If you have raised radials you will need to use ¾ wave-length lines.

Attach the antenna feed lines to the correct ports silkscreened on the relay box per the above diagram. Also attach your dummy load (100 W or more) to the Dummy Load port of the relay box.

PTT – there is a PTT input in the back of the controller to inhibit hot switching the relays.

Switching the directions of the array's pattern is done with the push buttons on the controller control switch. The no power and default position is to the North East. On this direction the system is not supplying any voltage to the array.

OMNI Mode- The middle pushbutton is the OMNI directional position. In this position you will need to tune the LC network for an SWR of 1:1 at your desired frequency. Tune it by adjusting the inductor tap and by adding some of the supplied capacitors in this network. The network has enough inductance to adjust it for the band you have selected and for the common types of antennas used for a four square array.

A Word about VSWR and Matching

The Hybrid coupler is very forgiving and the SWR you see driving your array providing you have tuned all your antennas correctly and identically should be nearly 1:1 or less then 1.3:1 over the band for normal ¼ wavelength verticals.

If you have an oscilloscope or phase meter you can observe the phasing of the controller at the antenna ports with the probes connected to the SO239 Antenna connectors. You can solder a short wire into each of the four connectors on the PCB side to make test points. Using the optional optimizing kit you can adjust the waveforms to further enhance the system. **But, as it is, the system should show very good directivity without the optimization kit.**

Optimization Kit

We have added the positions in the PCB to accommodate the shunt capacitors and inductor to optimize the directivity of the quadrature-fed Four Square controller. By using the "Two shunt compensation design system" by W1MK, you can predict the values necessary to optimize your array. For instance an 80 m four square would use about 300 pF of capacitance and 6 µH of shunt inductance.

Since we have carefully designed the Hybrid inductance, it should be pretty close to optimum, it is probably more useful to place in some C in the circuit at position C13.

Watch your SWR over the whole band as well as the Power into the dump load. Make a chart to help you see the differences over the frequency range your interested in. You should add one capacitor at a time from our kit or from capacitors you have, by soldering them in, and then measure the SWR and plot it on your chart. Also monitor the power in the dump load with a wattmeter and it also should improve as you plot it vs frequency. Use the following chart for both L and C values.

A more exact way to adjust the C and L values is to use an oscilloscope to fine tune the phase and magnitude of the 4 antennas.

The values may vary a bit, so using an oscilloscope to observe magnitude and phase is a common way to adjust. We have designed the hybrid quadrature toroid device to incorporate the proper amount of inductance for standard 4 Square arrays. So you may find that you do not need the supplied inductor at all. But it is worth putting into the circuit and checking if there is a reduction in SWR, and or power into the dummy load. You may have to vary the inductance of the inductor by removing turns to optimize this effect.

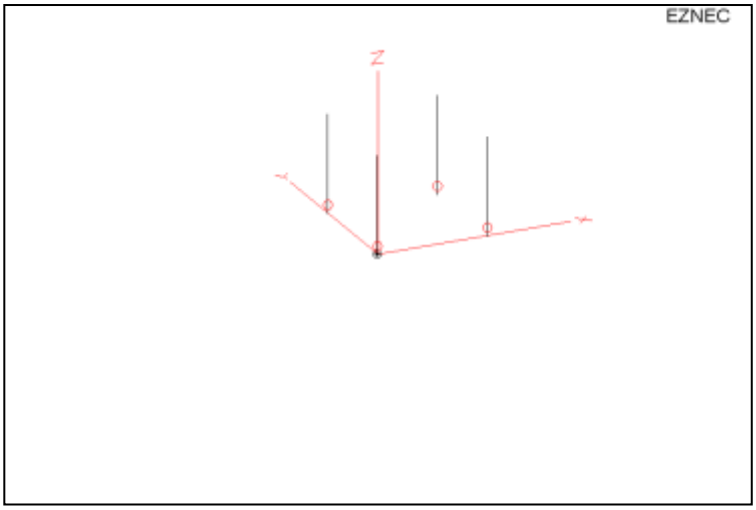
Band	C to add	L to add
160	33-600 pF	1-12 µH 12 µH supplied
80	33-300 pF	1-6 µH
40	110-220 pF	1-3 µH

Relay Logic by Direction

Relay	NE	SE	SW	NW	Omni
K1	0	1	0	1	0
K2	0	1	0	1	0
K3	0	0	1	1	0
K4	0	0	0	0	1

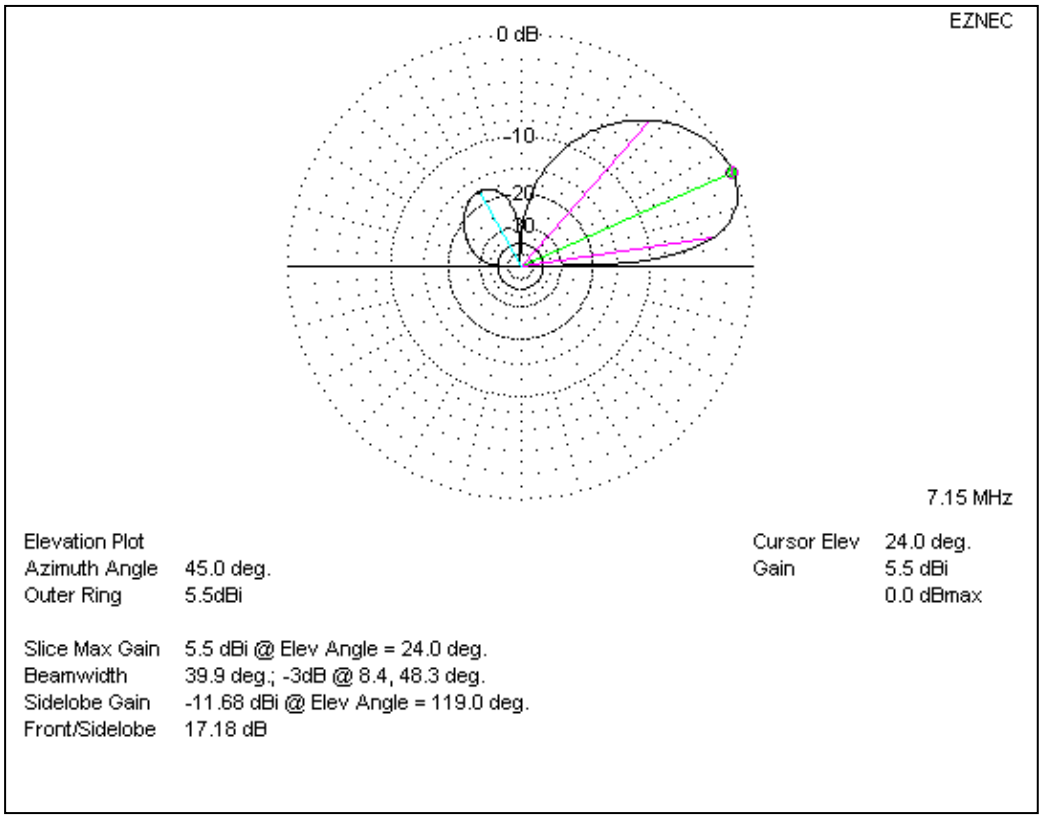
Theory of operation:

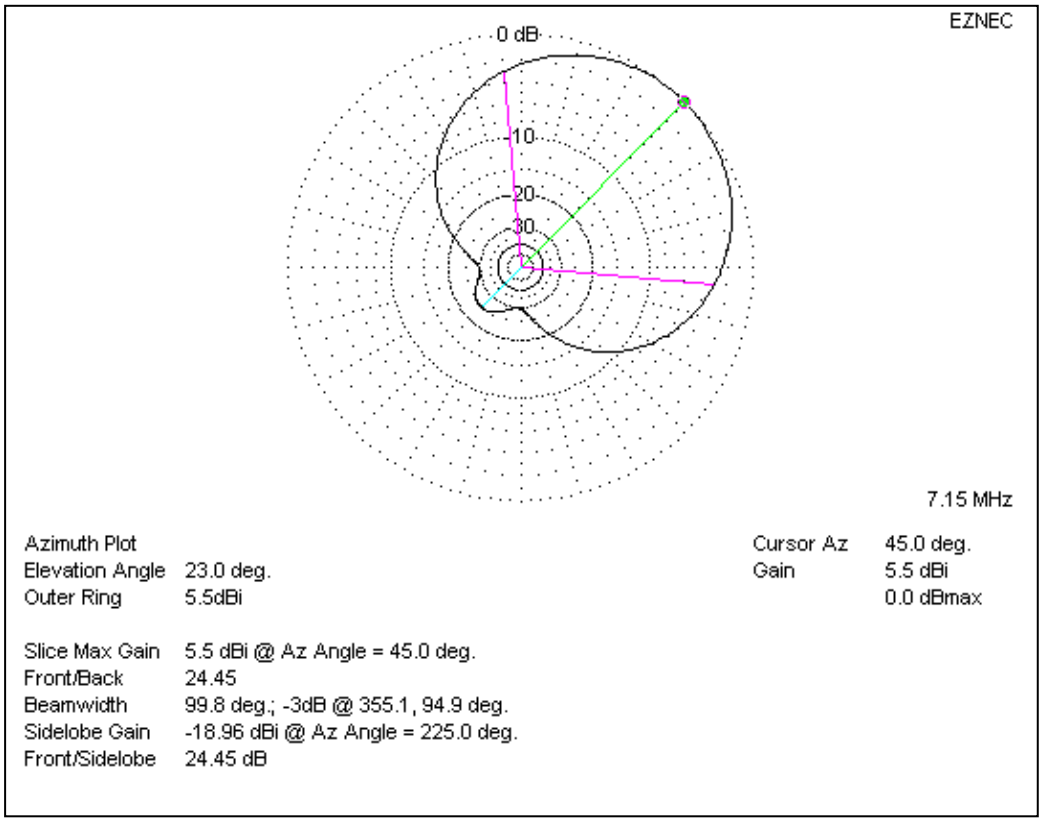
The system consists of four verticals in a square with sides 1/4 Wavelength long.



The Array Solutions controller will power all 4 of these verticals in such a way as to accomplish a quadrature feed to each antenna, with the proper current magnitudes. The “rear” element in our diagram above is the one on the closest to us on the axis. It is powered with 1A of current at +90 degrees, the next two elements are crossways in the box are powered with 1A of current at 0 degrees in phase, and finally the element furthest away is powered with 1A of current at -90 degrees of lagging current. The direction of gain is through the diagonal of the box towards the -90 degree lagging element. The array will have a forward gain of 5.5 dB over a single vertical.

Note the following diagrams are normalized to 5.5 dB of gain over a single same type vertical. Do not confuse 5.5 dBi with real gain, which can be more with tall verticals and good ground conditions. This is to display the gain over same type vertical ignore the dBi notation and consider it as dB reference over single vertical.

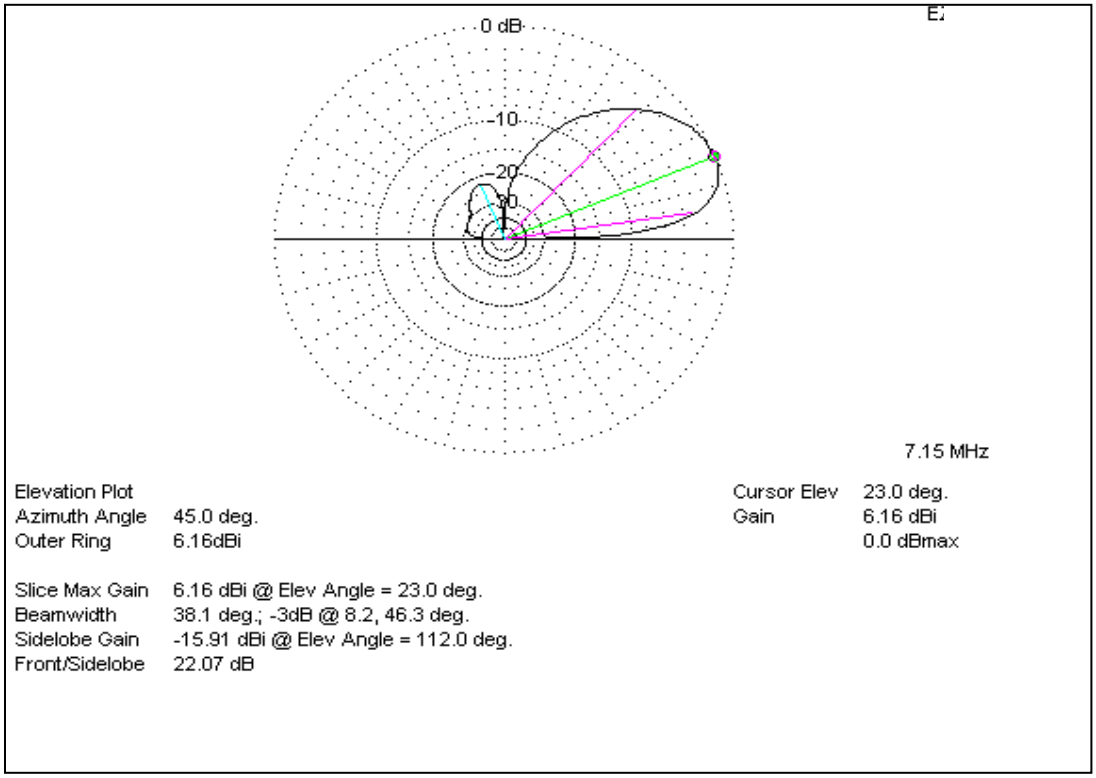

EZNEC
0 dB
-10
-20
-30
7.15 MHz
Elevation Plot
Azimuth Angle 45.0 deg.
Outer Ring 5.5dBi
Slice Max Gain 5.5 dBi @ Elev Angle = 24.0 deg.
Beamwidth 39.9 deg.; -3dB @ 8.4, 48.3 deg.
Sidelobe Gain -11.68 dBi @ Elev Angle = 119.0 deg.
Front/Sidelobe 17.18 dB
Cursor Elev 24.0 deg.
Gain 5.5 dBi
0.0 dBmax


EZNEC
0 dB
-10
-20
-30
7.15 MHz
Azimuth Plot
Elevation Angle 23.0 deg.
Outer Ring 5.5dBi
Slice Max Gain 5.5 dBi @ Az Angle = 45.0 deg.
Front/Back 24.45
Beamwidth 99.8 deg.; -3dB @ 355.1, 94.9 deg.
Sidelobe Gain -18.96 dBi @ Az Angle = 225.0 deg.
Front/Sidelobe 24.45 dB
Cursor Az 45.0 deg.
Gain 5.5 dBi
0.0 dBmax

Optimized Phasing Option Pattern

The above plots show the gain of this array over a single vertical of the same construction.
The plots have been normalized to demonstrate the 5.5 dB of gain achievable over a single element. The take off angle in this system with this average ground quality is 23 degrees. But with an excellent ground radial systems and better ground conditions it is possible to lower the angle a few degrees.

Here is what this pattern looks like using the same system, same ground and the new optimized delays. Remember that this is normalized to show gain over a single same type vertical.



We have increased the gain by 0.66 dB and the front to back radio by 6 dB or more!
This can be easily achieved with your controller by adding the optimization kit and adjusting the L and C shunt reactance using an oscilloscope. Again, the ON4UN's "Low Band DXing" 5th edition is the reference on this technique.

Specifications

Construction	Corrosion resistant Aluminum metal box, painted and silkscreened
Power	3+ kW CW / 6+ kW PEP
VSWR	Less than 1.3:1 over the band of operation
Gain	5.5 dB over single vertical 6.16 dB optimized see theory
Directions	4 directions with an additional Omni-directional feature
Electronic phasing	Optimized Hybrid Coupler. An LC network for OMNI mode
Phasing Options	Quadrature and Optimization Kit
Capacitors in networks	Temperature stable high current RF capacitors – NPO
Weight and size	15 lb. ~11" x 7.5" x 3.625" relay box, 2" x 4" x 5" controller box

Thank you for purchasing this high quality phasing system.

Please visit our website at www.arraysolutions.com