DX Engineering 4-Square Receive Antenna Review & Realignment

Caribbean Contesting Consortium (PJ2T)

Jeff Maass K8ND

The Background and the Plan

In 2005, K9SG and K8ND purchased and donated a DX Engineering ("DXE") 4-Square receiving antenna system to CCC/PJ2T. The various pieces were carried or shipped to the island during 2006, and it was first placed into use in the 2006 CQWW CW Contest.

When the system was designed for use at the PJ2T station, the preferred direction of the four selectable nodes was determined based on population centers not covered by the two permanent Beverages at the PJ2T station. The map at Figure 1 shows the selected directions in red on an azimuthal projection map centered on PJ2T. The plan was based on the "True Bearings" to the desired area, and the diagram was also marked with calculated "Magnetic Bearings" to compensate for magnetic declination at the site, to aid in on-site installation. Note that the Europe Beverage is marked as 40-degrees (true): subsequent measurements show that it is, in fact, aimed at 56-degrees (true)).

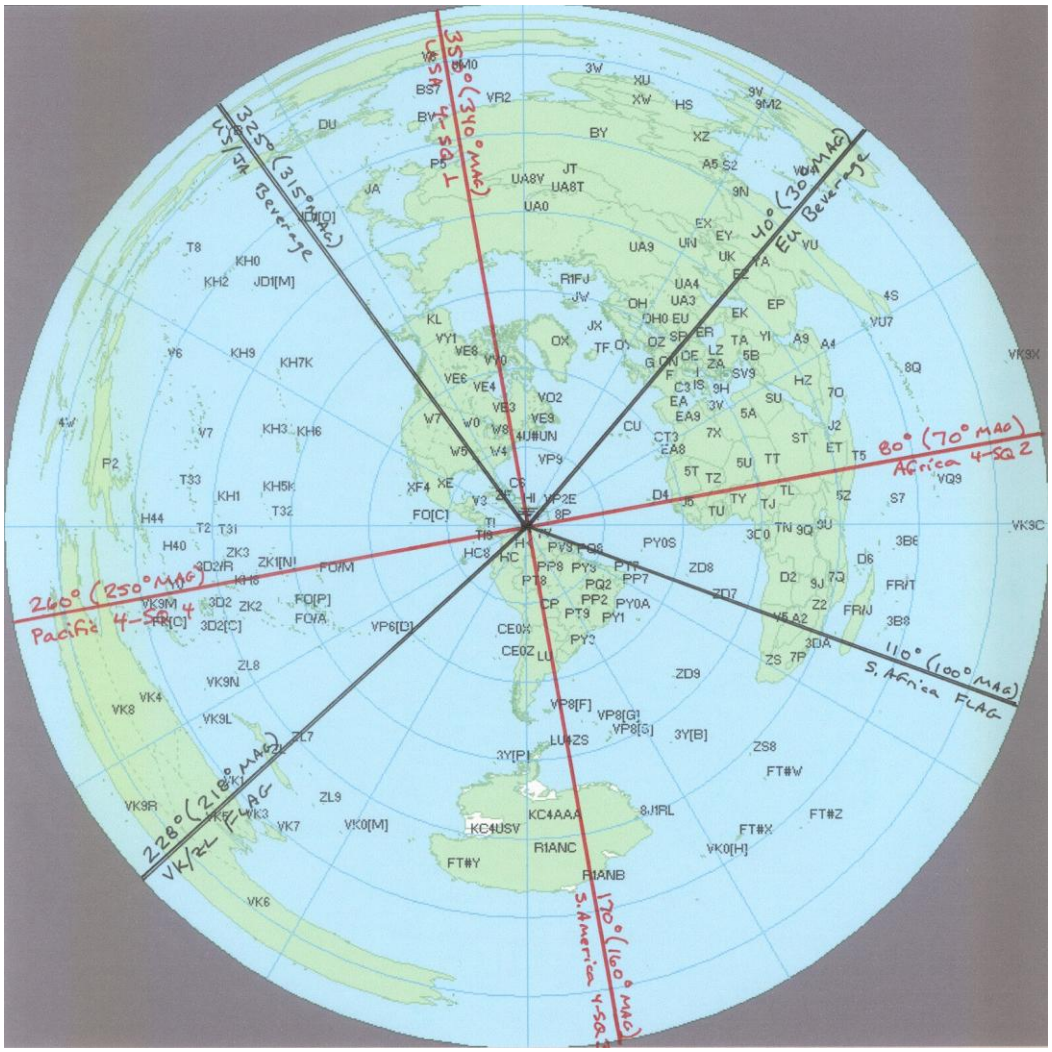


Figure 1: Receiving Antennas Plan, 2006 CQWW CW

DX Engineering 4-Square Receive Antenna Review & Realignment

Caribbean Contesting Consortium (PJ2T)

Jeff Maass K8ND

The bearings chosen were 350-degrees (#1), 80-degrees (#2), 170-degrees (#3) and 260-degrees (#4).

The bearings were chosen primarily for the North-South alignment. The PJ2T US/JA Beverage works *very* well, but points at 325-degrees (true), a bearing that crosses the Florida and the central USA (AL, MO, NE, MT) and through VE7.

Most contesters in the US, however, are within 150 miles of the US East Coast. The #1 lobe for the PJ2T 4-Square is aimed at 350-degrees (true), which places the center of the lobe through W2 (NY) and W3 (MD/PA) and into VE3. The lobe provides enhanced coverage of the US East Coast, W4 and Eastern Canada. A Good Thing.

The reciprocal bearing (#3) is at 170-degrees (true), which passes through the center of South America. Also A Good Thing.

That leaves the #2 and #4 bearings. Providentially, the #4 lobe falls at 260-degrees. This passes across Central America, the island-filled Southern Pacific, and into Australia, providing some coverage for VK and ZL, although too far North to be optimal.

The #2 bearing falls at 80-degrees (true). This bearing provides a lobe which will cover the islands of the Eastern Caribbean, the northern coast of South America, and through central Africa.

In 2006, the plan was to configure the new DXE 4-square system as described above, supplementing the existing US/JA and Europe Beverages. Two Flag antennas were used to fill in the perceived remaining holes in the coverage, to South Africa and the population centers of VK (VK1, VK2, VK3, & VK7) and ZL. These Flag antennas are also shown on the map above.

This plan promised to provide considerable improvement in the lowband receive capabilities of the PJ2T station, and receiving capability is the key to performance for the lowbands.

The Siting

The 4-square system needs to be installed on flat terrain and far enough away from the transmit antennas to prevent damage to the element preamplifiers. The DXE 4-square manual provides the following table:

Band	Unity (0 dB) Gain	3 dB Gain (2x)	6 dB Gain (4x)
160m (1.8 MHz)	273 ft	410 ft	550 ft
80m (3.5 MHz)	140 ft	210 ft	280 ft
40m (7.0 MHz)	70 ft	105 ft	140 ft

Because the specific conditions at Signal Point require the installation of the DXE 4-square to be performed “Field Day style” for each contest, the area selected needed to be accessible and likely to remain accessible as the overgrowth comes and goes with time.

DX Engineering 4-Square Receive Antenna Review & Realignment

Caribbean Contesting Consortium (PJ2T)

Jeff Maass K8ND

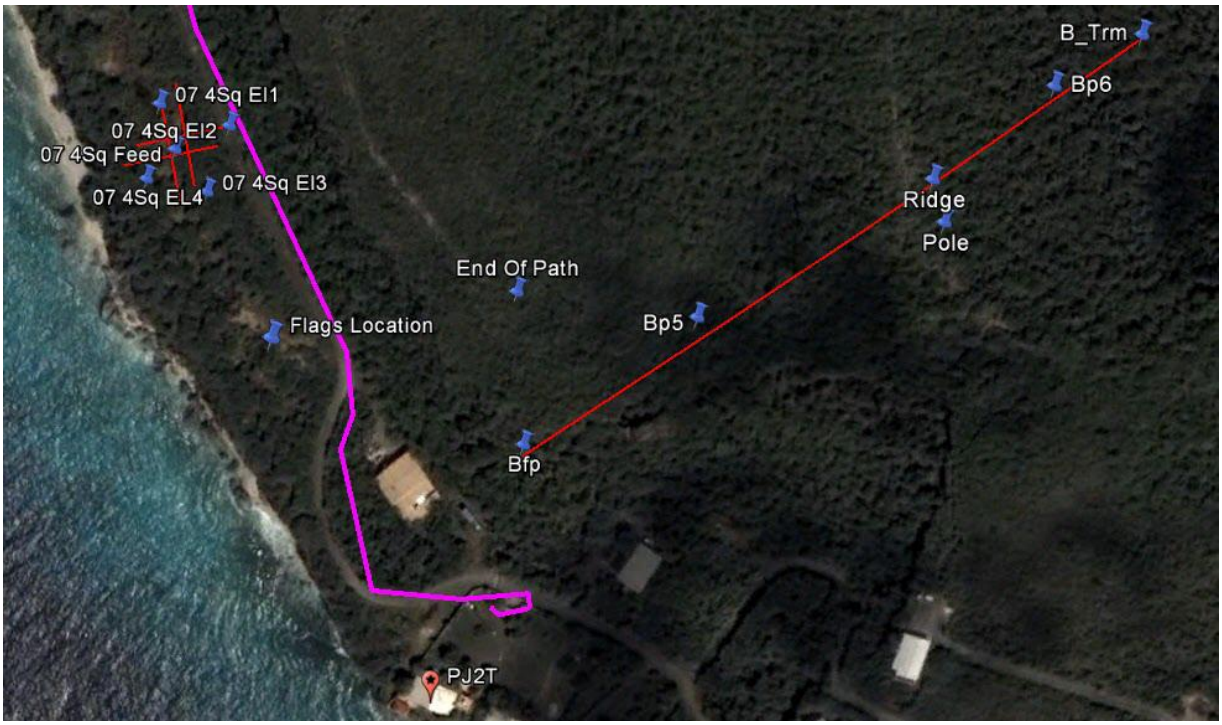
The width of the 4-square array must also fit between the road and the cliff that drops down to the sea.

The dimensions of the DXE 4-Square can be sized to provide optimal performance on one band (160, 80, or 40) or a “best compromise” size for two or three bands. The table below (from the RFS-1P DXE 4-Square manual) shows the recommendations. Optimal for a band is approximately a quarter-wave on a side.

Band	Freq - MHz	Optimal Side Length in Ft.
160	1.83	135
80	3.60	70
40	7.10	35
160, 80	1.83, 3.60	98
80, 40	3.60, 7.10	50
160, 80, 40	1.83, 3.60, 7.10	70

Initially, the plan was to size the array to the 160-meter optimal dimension – 135-feet on a side. However, after measurements of the only practical site, the 98-foot-on-a-side size (optimal size for 160 and 80 meters) was determined to be the largest that would fit in the available location for the 4-square in “the flats” West of PJ2T.

The Google Earth image below, with an overview of the PJ2T site with locations marked by GPS, includes the site selected for the 4-square array at the upper left, meeting the requirements described above. The nearest element is 675-feet from the transmit antenna. (Note the location of the Europe Beverage, marked by GPS measurements, pointed at 56-degrees (true).



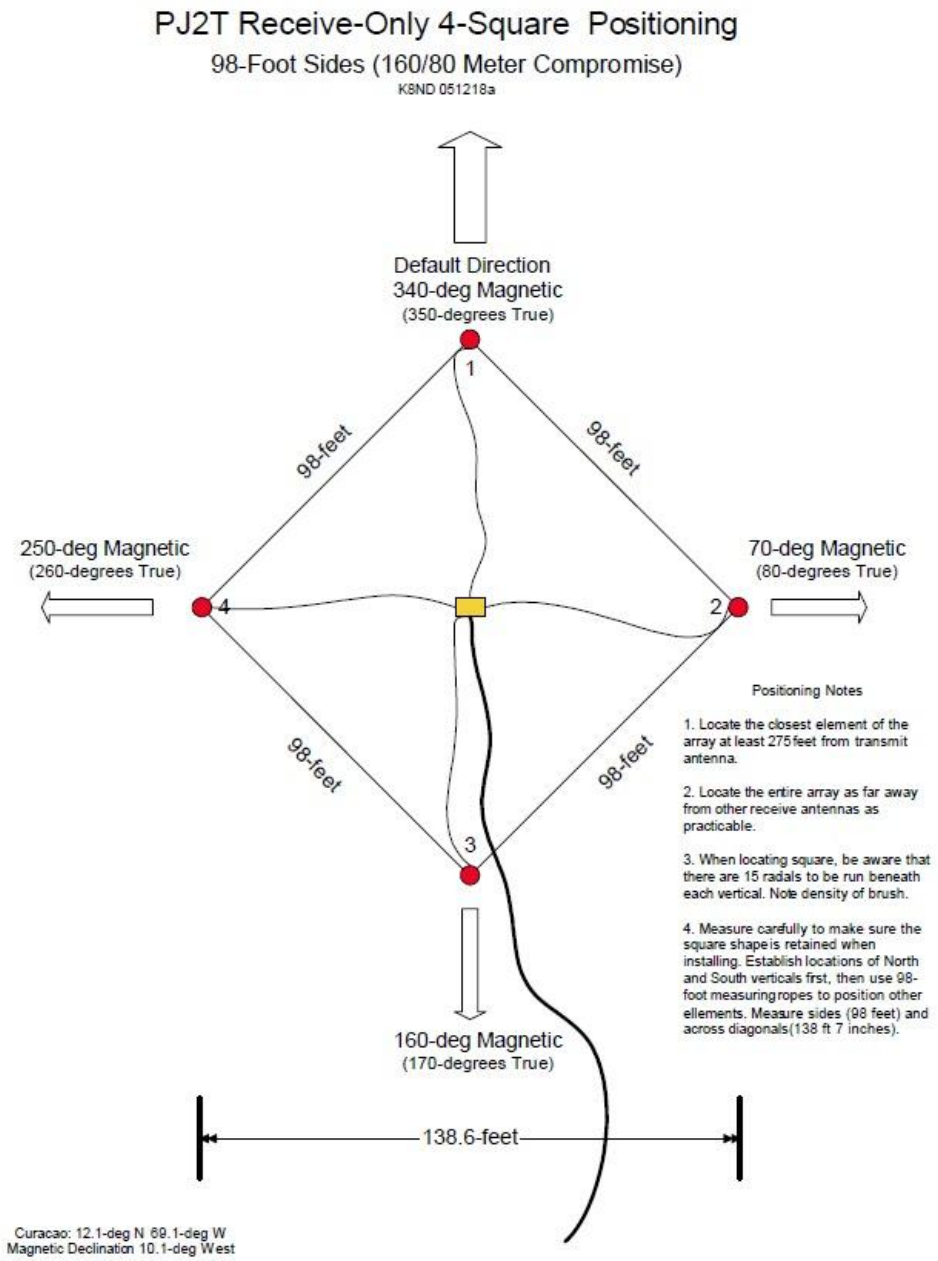
DX Engineering 4-Square Receive Antenna Review & Realignment

Caribbean Contesting Consortium (PJ2T)

Jeff Maass K8ND

Installation

A diagram was assembled to aid in the installation at the site. That diagram is shown in the image below. Note that the spacing of the elements and direction of alignment are noted, including both “True Bearing” and calculated “Magnetic Bearing”. It was from this diagram that the 4-square system was installed in November 2006, and the element locations marked with piles of rocks for later reference and use. Later, holes were drilled and lengths of rebar were mounted at the element locations to provide mounting points for the element whips, and radials spread.



DX Engineering 4-Square Receive Antenna Review & Realignment

Caribbean Contesting Consortium (PJ2T)

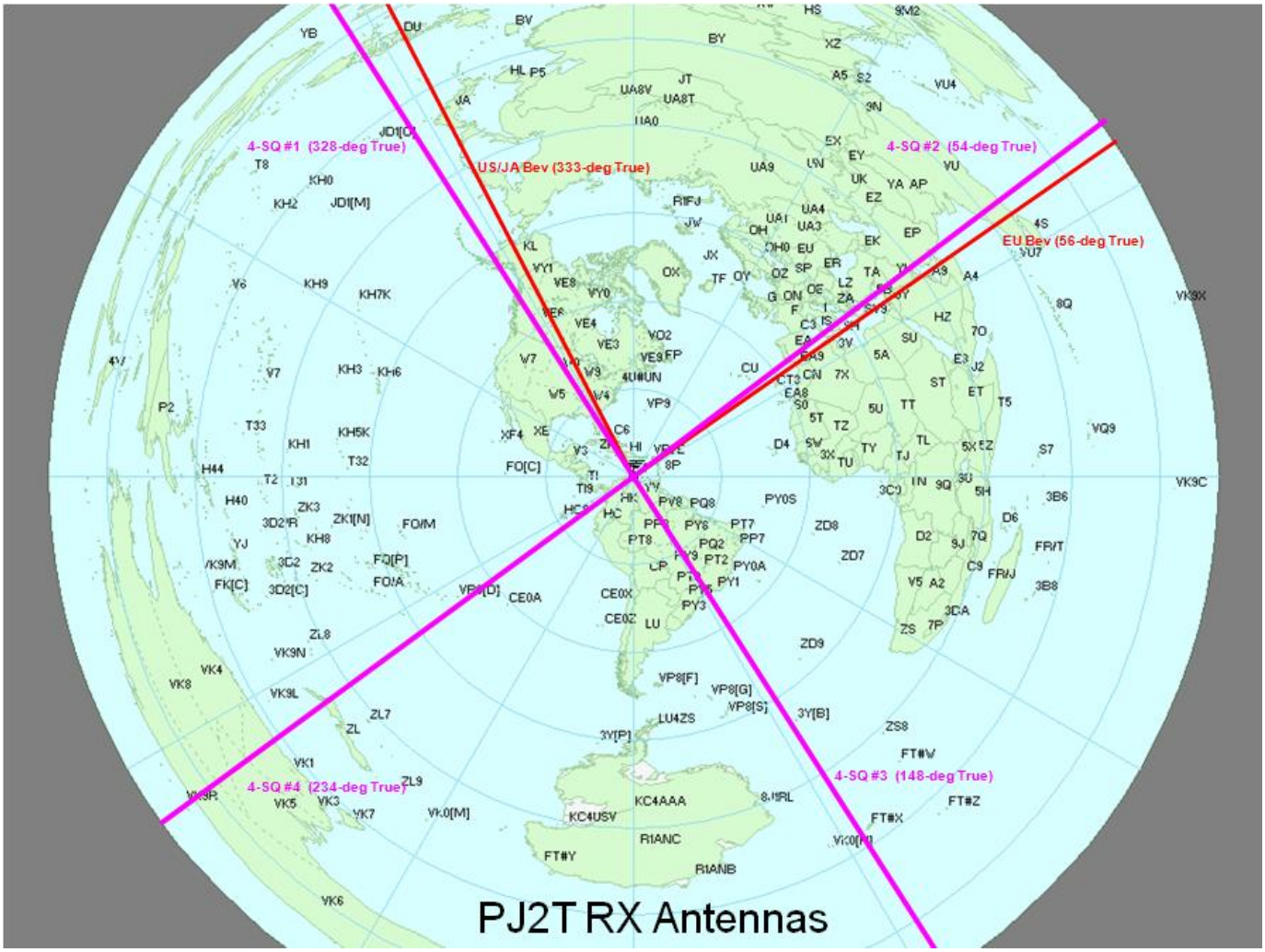
Jeff Maass K8ND

The Problem

K8ND did not properly apply magnetic declination to a compass reading while standing in The Flats. The (then) 10.1-degree-West magnetic declination on Curacao was applied to the incorrect side of the magnetic bearing, which resulted in a nominal 20.2-degree error in alignment.

GPS and compass measurements of the 4-square elements and Europe Beverage has revealed the error, which means that the 4-square lobes are as shown in the map below: much less useful in filling in coverage gaps.

Because no receive antenna has very-narrow lobes, and because each receive antenna provides different signal elevation and noise performance, the use of the 4-square has still proven invaluable during the contests in which it has been used over the past several years. The #3 and #4 lobes covered South America and Australia when no other antenna would. However, the benefit of the DXE 4-Square array could be much better if it were pointed correctly and not duplicating the bearings of the Beverage antennas!



DX Engineering 4-Square Receive Antenna Review & Realignment

Caribbean Contesting Consortium (PJ2T)

Jeff Maass K8ND

The Correction / Realignment Tasks & Tools

In order to realign the DXE 4-square to point the four lobes in the preferred directions, it will be required to perform the following tasks on-site:

1. Measure to identify the new correct element mounting locations;
2. Drill new mounting holes for the rebar element mounts;
3. Insert the rebar in the holes and make it secure;
4. Re-spread the radial wires in the new location.

The following tools are to be used to perform these tasks:

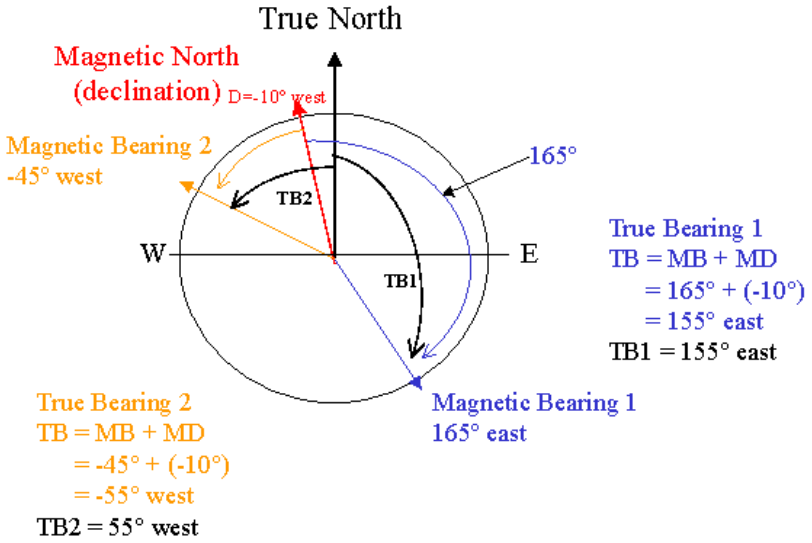
1. Two (2) lengths of string ("Measurement Strings") cut to 138' 7-3/16" with a knot in the exact center (at 69' 3-1/2"), to use in measuring diagonal element-to-element distance;
2. Large cordless drill with ½-inch bit for drilling in rock;
3. Compass with competent operator, preferably a compass with built-in magnetic declination adjustment;
4. Fluorescent surveyors' tape, to use in temporarily marking during direction and distance measurements;
5. Corrected diagram showing distances and bearings of the array. The magnetic bearing, if marked, should be calculate with a magnetic declination valid for the time the installation is to be performed.

Magnetic Declination and Magnetic Bearings Calculations

OK, applying magnetic declinations to bearing calculations is not rocket science, but it can be confusing. Simple discussion and examples are available from NOAA at http://www.ngdc.noaa.gov/geomag/faqgeom.shtml: see item 5d.

> "You can compute the true bearing from a magnetic bearing by adding the magnetic declination to the magnetic bearing. This works so long as you follow the convention of degrees west are negative (i.e. a magnetic declination of 10-degrees west is -10 and bearing of 45-degrees west is -45)."

Sample calculations for a site with West magnetic declination (as is Curacao) are provided, as shown below.



DX Engineering 4-Square Receive Antenna Review & Realignment

Caribbean Contesting Consortium (PJ2T)

Jeff Maass K8ND

Determining the magnetic declination for any location on Earth depends on the date. The US National Oceanic and Atmospheric Administration (NOAA) provides an online calculator which can be used to identify the correct magnetic declination from the latitude and longitude and the date. It can be found online at http://www.ngdc.noaa.gov/geomag-web/#declination.

Providing the coordinates of Signal Point and the date of the 2012 CQWW CW Contest (11/25/12), the magnetic declination at the site is returned by the tool as shown below.

Declination

Latitude:	12.2613° N
Longitude:	69.1235° W
Date	**Declination (+ E | - W)**
2012-11-25	-10.7309° changing by -0.0894° per year

So the current magnetic declination for Signal Point is 10.7309-degrees West (-10.7309 degrees). The magnetic declination is changing by 0.0894 degrees West (-0.0894 degrees) per year. So, the declination values for the next ten years (calculated for November 25) are:

2012	10.7314-deg West	(-10.7314-deg)	2017	11.1784-deg West	(-11.1784-deg)
2013	10.8208-deg West	(-10.8208-deg)	2018	11.2678-deg West	(-11.2678-deg)
2014	10.9102-deg West	(-10.9102-deg)	2019	11.3572-deg West	(-11.3572-deg)
2015	10.9996-deg West	(-10.9996-deg)	2020	11.4466-deg West	(-11.4466-deg)
2016	11.0890-deg West	(-11.0890-deg)	2021	11.5360-deg West	(-11.5360-deg)

For purposes in realigning the PJ2T 4-square, I'll use a value of 11-degrees West (-11.0000).

TB = MB + (-11.0 degrees)
MB = TB - (-11.0 degrees)

4-Square Lobe	True Bearing (TB)	Magnetic Bearing (MB)
# 1	350	1
# 2	80	91
# 3	170	181
# 4	260	271

An updated "PJ2T Receive-Only 4-Square positioning" sheet, utilizing the corrected bearings, is shown on the next page. The magnetic bearings shown on it should be applicable (+/- 0.5 degrees) through year 2020.

DX Engineering 4-Square Receive Antenna Review & Realignment

Caribbean Contesting Consortium (PJ2T)

Jeff Maass K8ND

PJ2T Receive-Only 4-Square Positioning

98-Foot Sides (160/80 Meter Compromise)

K8ND 121028a

Default Direction
350-deg True Bearing
(1-degree Magnetic)

1

98-feet

98-feet

260-deg True Bearing
(271-degrees Magnetic)

4

2

80-deg True Bearing
(91-degrees Magnetic)

98-feet

98-feet

3

170-deg True Bearing
(181-degrees Magnetic)

138.6-feet

Positioning Notes

1. Locate the closest element of the array at least 275 feet from transmit antenna.

2. Locate the entire array as far away from other receive antennas as practicable.

3. When locating square, be aware that there are 15 radials to be run beneath each vertical. Note density of brush.

4. Measure carefully to make sure the square shape is retained when installing. Establish locations of North and South verticals first, then use 98-foot measuring ropes to position other ellements. Measure sides (98 feet) and across diagonals (138 ft 7 inches).

Curacao: 12.2613-deg N 69.1235-deg W
Magnetic Declination ~11.0000-deg West (2012 – 2020)

DX Engineering 4-Square Receive Antenna Review & Realignment

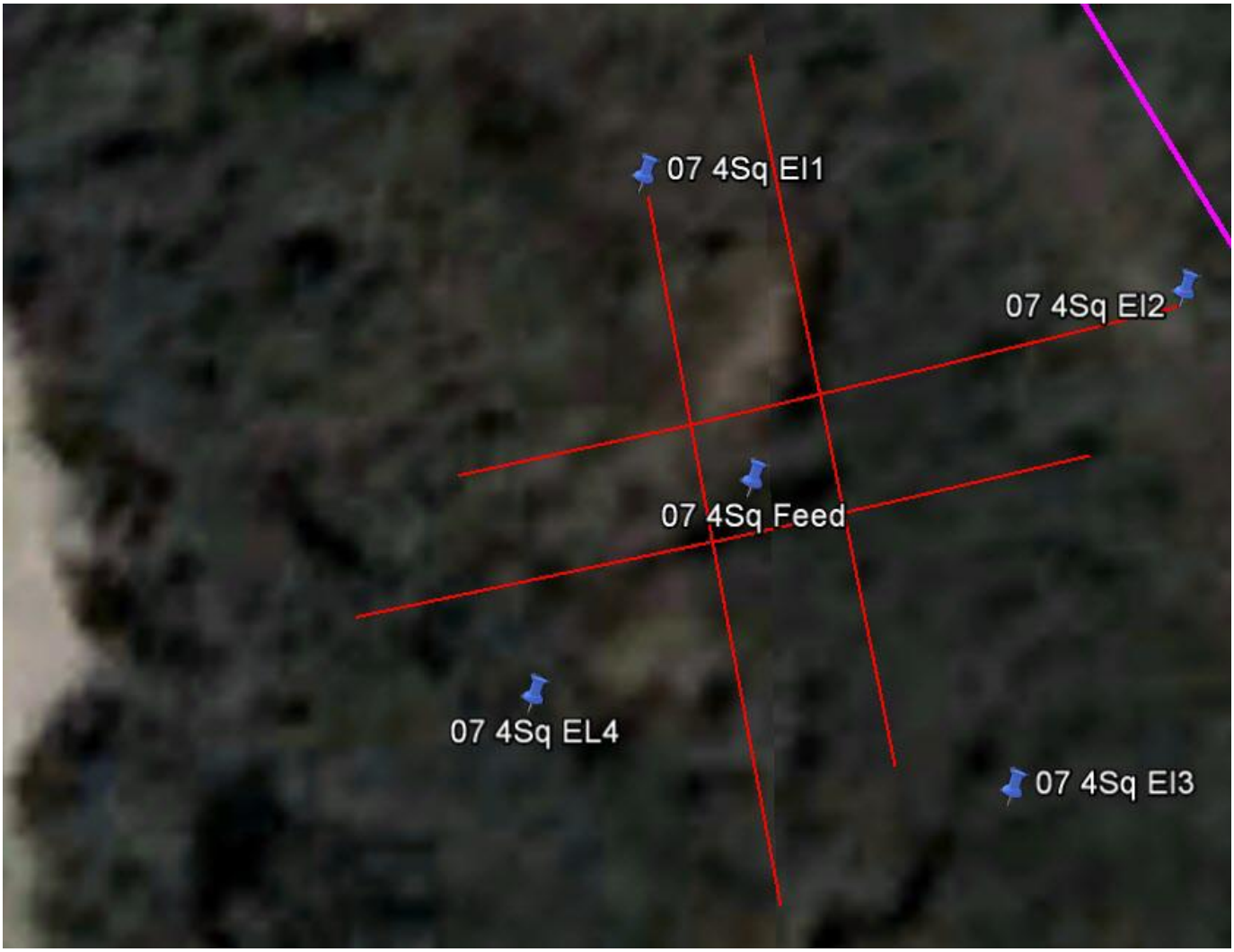
Caribbean Contesting Consortium (PJ2T)

Jeff Maass K8ND

Practical Array Realignment

When surveying the site to determine where each of the element are to be mounted in the new alignment, we want to minimize the difficulties in 1) fitting the array in the space, 2) drilling as few holes as possible in the rock-hard ground, and 3) working with the plant life in the area. It's also important to set a fixed reference point from which to locate all other element mounting points.

I believe that using the current Element #2 mounting point (near the road) as the fixed reference point is most likely to minimize the chance of having the Element #3 point fall at a point "over the cliff". The diagram below shows the GPS-mapped locations of the current Element mounting points, and red lines denoting possible new diagonals between elements (using Elements #1 and #2 as fixed references).



DX Engineering 4-Square Receive Antenna Review & Realignment

Caribbean Contesting Consortium (PJ2T)

Jeff Maass K8ND

Using Element #2 as the fixed reference, here are the steps to identifying and marking the other three Element locations, and installing the rebar masts for the elements. This procedure is written so that one person could perform the required steps; it would be *much* easier if done by two or more people.

The process of making straight lines between points in The Flats is much more difficult that it would be doing it on a field of grass! Take your time and get the lines straight and in the correct directions!

1. Tie a length of fluorescent surveyors' tape directly over the Element #2 mounting point;
2. Stretch one of the prepared 138' 7-3/16" Measurement Strings taught from the Element #2 in the direction of Element #4 (260-degrees True/271-degrees Magnetic), as determined with the compass;
3. Mark the spot on the ground for Element #4, and tie a length of surveyors' tape over the Element #4 mounting point.
4. Take a reverse sighting to Element #2 (as visible with the surveyors' tape) to confirm the bearing of the line (should be 80-degrees True/91-degrees Magnetic);
5. Attach the string above the Element #4 mounting point so it is taught;
6. Find the center of the string just run (marked with a knot and surveyors' tape);
7. Mark the ground under the knot: this will be the location of the feedpoint;
8. Attach the center-point (at the knot) of the second Measurement String to the center-point of the taught string;
9. From this center point, take a sighting in the direction of Element #1 (350-degree True/1-degree Magnetic);
10. Walk one end of the second Measurement String to the point sighted.
11. Take a reverse sighting to the center point (170-degree True/181-degreee Magnetic) and mark the Element #1 mounting location;
12. Attach the string to the mounting point for Element #1;
13. Mark the location of Element #1 with a length of fluorescent surveyors' tape;
14. Walk back to the center point;
15. From this center point, take a sighting in the direction of Element #3 (170-degree True/181-degree Magnetic);
16. Walk the loose end of the Element #1 to #3 string to the point sighted;
17. Take a reverse sighting to Element #1 (350-degree True/1-degreee Magnetic) and mark the Element #3 mounting location;
18. Attach the string to the mounting point for Element #3;
19. Mark the location of Element #3 with a length of fluorescent surveyors' tape;
20. Review the marked locations with compass.
21. Once all four element locations have been identified and verified (repeatedly), then a new hole in the rock for the rebar mounting mast for each element can be drilled. Make the hole as deep as possible.
22. Insert the rebar in the hole, and verify that it is vertical;
23. Mount the element to the rebar.
24. Tie a length of surveyors' tape to the element so it can be seen from the opposite element and the center point;
25. Once all element bases are installed and elements mounted n them, confirm the bearings once again, and correct if you must.
26. Spread the radials around the base of each Element mounting point. Keep them as close to the ground and evenly-distributed as possible.
27. Record the location of each Element with GPS, taking several measurements over a period of days.

DX Engineering 4-Square Receive Antenna Review & Realignment

Caribbean Contesting Consortium (PJ2T)

Jeff Maass K8ND

Final Target PJ2T Receive Antenna Alignments

The azimuthal map below shows the center of the lobes of the two Beverages and the DXE 4-square once the 4-square array is realigned to point in the correct directions.