Easy to Build Low Band Receiving Antennas for Small and Large Lots

- Small antennas
- High performance antennas
- Quantitative performance evaluation

Frank Donovan

W3LPL

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Why Receiving Antennas?

- Much better performance than most transmitting antennas
  - much lower cost
  - greatly reduced footprint
  - greatly reduced height (7 to 25 feet)
  - good directivity on as little as 650 to 2500 square feet
  - excellent directivity on less than an ¼ acre
  - directivity equivalent to a 5 element Yagi on less than 3/4 acre
  - greatly reduced mutual coupling between individual verticals
  - greatly reduced need for efficient matching and extensive radial systems
- High performance arrays perform equivalent to a 5 element Yagi!
- Combining two antennas with a variable phase controller
  - steerable nulls
  - optimizes the front-to-back ratio of phased arrays of Beverages and verticals
- Diversity reception with dual phase locked receivers

All receiving antennas dimensions are for 160 meters - simply scale them to 80 meters

Receiving Directivity Factor (RDF)

proven measure of receiving antenna performance

- Compares forward gain at the desired azimuth and elevation angle to average gain over the entire hemisphere
  - EZNEC computes antenna RDF
- Assumes noise is equally distributed over the entire hemisphere
  - an invalid assumption for suburban and especially urban locations where noise is often concentrated on the horizon
- Assumes that RFI is more then 1000 feet away, in the far field of the antenna
  - where the antenna pattern of large antennas is fully formed, and
  - RFI sources look more like a point sources

https://www.w8ji.com/receiving

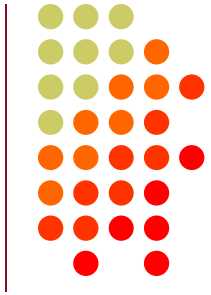
Re-radiation from antennas, towers and power lines within about 1000 feet can degrade your actual RDF **especially for high RDF arrays**

Small Receiving Antennas
4 - 11 dB RDF

- 4 dB: Bidirectional 8 foot diameter “magnetic” loop *close to the ground*
- 5 dB: Single vertical antenna (short vertical or ¼ wavelength vertical)
- 6 dB: 225 foot Beverage on Ground (BOG)
- 6 dB: 250 to 400 foot Beverage about 7 feet high
- 7 dB: Unidirectional terminated small loop
  - flag, pennant, EWE, VE3DO
- 8 dB: Close spaced arrays of two small terminated loops
  - K9AY Array
  - Shared Apex Loop Array
- 8 dB: Pair of 250 to 400 foot staggered Beverages about 7 feet high
- 9 dB: Two phased short verticals with 60 to 80 foot spacing
- 9 dB: Triangle array of phased short verticals with 60 to 80 foot spacing
- 11 dB: Vertical Waller Flag

Small antennas are the best RFI reduction antennas when RFI sources are within about 1000 feet

High Performance Receiving Antennas
10 - 14 dB RDF



- 10 dB: 500 to 600 foot Beverage about 7 feet high
- 11 dB: Two or three close spaced 500 to 600 foot Beverages, staggered 125 feet
- 11 dB: Vertical Waller Flag array
- **12 dB: 4 square array of active or passive short verticals 80 x 80 ft**
- **12 dB: 3 element YCCC tri-band array of short active verticals 120 ft long**
- **12 dB: 5 element YCCC tri-band array of short active verticals 84 x 84 ft**
- **12 dB: 9-circle YCCC tri-band array of short active verticals 120 ft diameter**
- 12 dB: Horizontal Waller Flag: 2 phased horizontal loops *at least 100 ft high*
- 13 dB: BSEF array of 4 short verticals switchable in two directions 350 ft x 65 ft
- 13 dB: 8-circle array of short verticals with 106º phasing 200 ft diameter
- 13 dB: 8-circle BSEF array of short passive verticals 350 ft diameter + radials
- 14 dB: Four broadside/end-fire 800 foot Beverages 800 ft x 330 ft

Large antennas are less effective than small antennas at suppressing local RFI sources within a few thousand feet

Small Single Loop Antennas

4 - 7 dB RDF 120 - 150º 3 dB Beamwidth

- 8 foot diameter bidirectional “magnetic” loop 4 dB RDF
  - *bi-directional* 150 degree beamwidth
  - installed close to the ground to suppress horizontally polarized RFI
  - a specialized antenna for steering a very deep null onto a single ground wave propagated RFI source
  - poor sensitivity for DX compared to larger antennas
- Unidirectional *terminated* small loops 6 - 7 dB RDF
  - flag
  - pennant
  - EWE
  - K9AY
  - VE3DO
- Mechanically rotatable unidirectional terminated small loops
  - rotatable flag

Small antennas are the best RFI reduction antenna when RFI sources are within 1000 feet

Arrays of Two Small Loops
8 - 11 dB RDF 80 - 120º 3 dB Beamwidth

- Electrically steerable compact arrays of two small loops
  - Two switchable K9AY loops — 8 - 9 dB RDF
  - Shared Apex Loop Array — 8 - 9 dB RDF
- 350 foot broadside spaced pair of small loops — 9 - 10 dB RDF
  - pennant
  - EWE
  - K9AY
  - VE3DO
- Mechanically rotatable array of two small end-fire loops
  - Vertical Waller Flag — 11 dB RDF

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Small antennas are the best RFI reduction antenna when RFI sources are within 1000 feet

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BOGs and BOG Arrays

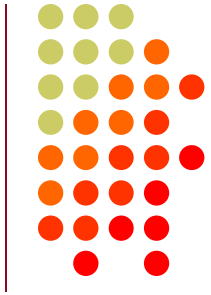
6 to 8 dB RDF 60 - 90º 3 dB Beamwidth

- BOG 6 dB RDF 90º beamwidth
  - 225 foot wire laid *just above* the surface of the ground
- Switchable bi-directional BOG 6 dB RDF 90º beamwidth
  - 225 foot coaxial cable laid *just above* the surface of the ground
- Close spaced staggered BOGs 7 dB RDF 90º beamwidth
  - two or three close spaced BOGs with 125 foot end fire spacing
  - significantly improves front-to-back ratio especially if a variable phase controller is used
- Two wide spaced BOGs 8 dB RDF 60º beamwidth
  - 350 foot broadside spacing

BOGs are low sensitivity antennas requiring significant suppression of common mode signals from the coaxial cable feed line

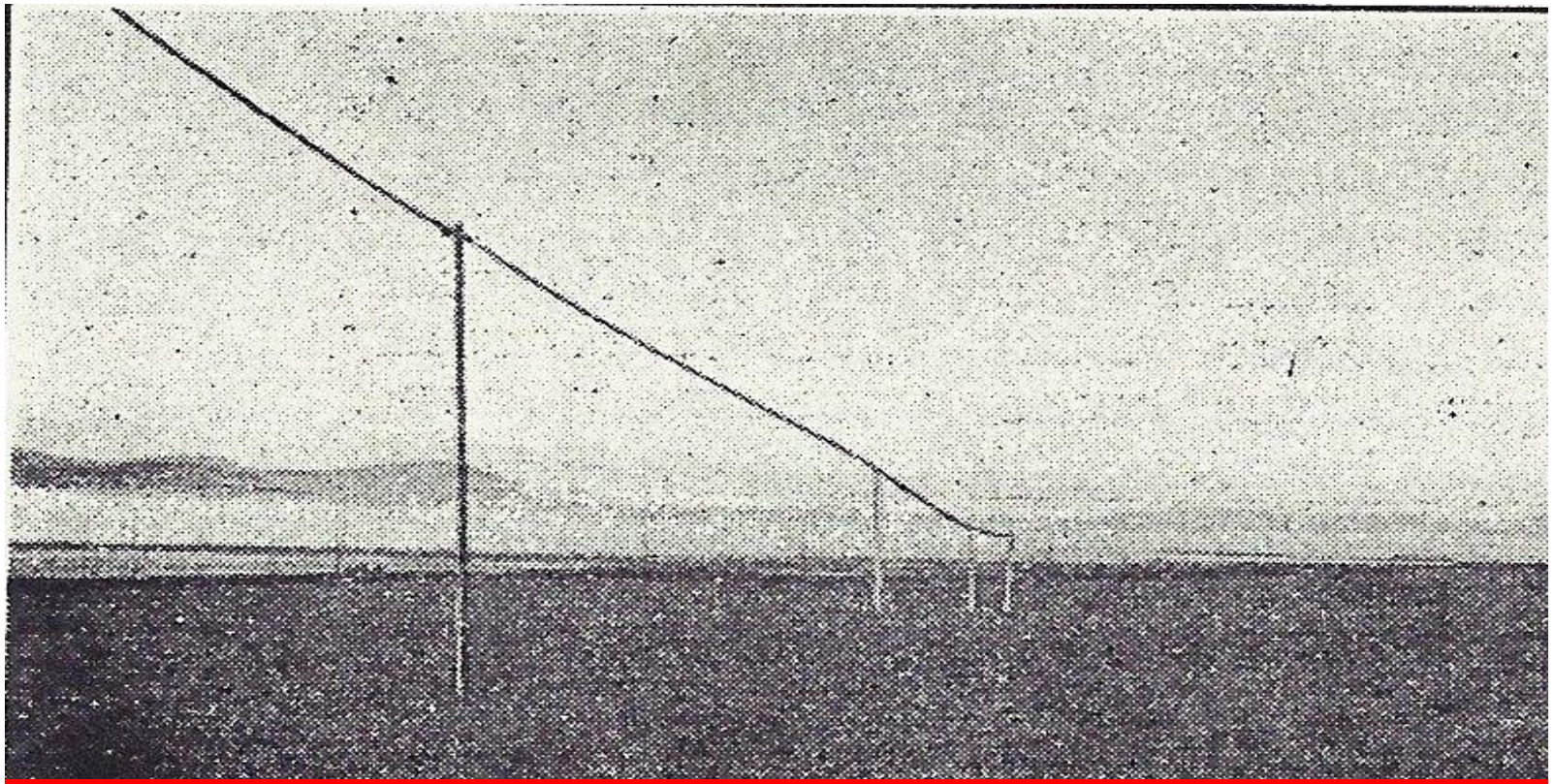
Beverages and Beverage Arrays

6 - 14 dB RDF 45 - 120º 3 dB Beamwidth



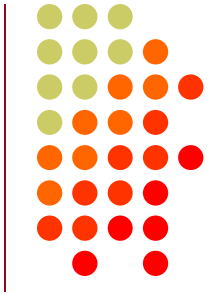
- 250 to 400 foot Beverage 6 dB RDF 90 - 120º 3 dB beamwidth
  - approximately 7 feet high
  - single wire or two wire bi-directional
- 500 to 900 foot Beverage 8 - 10 dB RDF 50 - 70º 3 dB beamwidth
  - approximately 7 feet high
  - single wire or two wire bi-directional
- Staggered Beverage arrays 11 dB RDF 50 - 70º 3 dB beamwidth
  - two or three Beverages with 125 foot end-fire spacing
  - significantly improved front-to-back ratio especially with a variable phase controller
- Broadside Beverage arrays 12-14 dB RDF 45 - 60º 3 dB beamwidth
  - two Beverages with 350 foot broadside spacing, or
  - four Beverages with 125 foot end fire spacing and 350 foot broadside spacing

1300 Foot Beverage installed by Paul Godley 2ZE on a beach in Androssan, Scotland during the successful 1921 Trans-Atlantic Tests



Beverages were all but forgotten by hams for 45 years until K1PBW re-introduced them to 160 meter DXers in 1967

Arrays of Short Verticals
9 - 14 dB RDF 50-135º 3 dB Beamwidth



- Active high impedance 20 foot verticals
  - capable of multi-band operation
  - requires a high input impedance amplifier *at the base of each vertical*

----- or ----

- Passive low impedance 25 foot verticals
  - mono-band antenna only
  - **easy to troubleshoot and repair low parts count very reliable**
  - eight 70 foot or sixteen 35 foot radials *at the base of each vertical*
    - stabilizes the feed point impedance during all weather conditions
    - decouples the coax shield
  - four 25 foot umbrella wires
    - reduces the required height to 25 feet
    - increases the array bandwidth
    - *if necessary*, 35 foot verticals with no umbrella wires can be substituted

Any monoband array of phased short verticals can use either high or low impedance verticals

Small Diameter Loop Antenna

Eight Foot Diameter "Magnetic" Loop

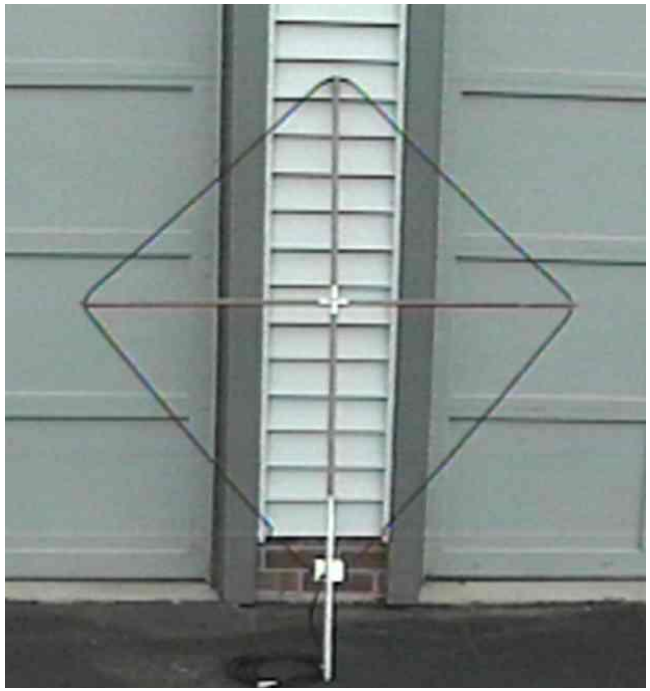
- Excellent for nulling a *single* nearby RFI source
  - RFI to be nulled must be vertically polarized and received via *ground wave*
- Superb antenna for precisely locating RFI sources
- Bi-directional figure-8 pattern 150º 3 dB beamwidth
  - must be installed close to the ground to suppress horizontally polarized signals
- Very deep nulls (only about 2º wide) off both *sides* of the loop
  - mechanically rotate the loop until the single local RFI source is nulled
  - the null is not as deep for skywave propagated signals
- Small loop antennas produce very low signal levels
  - requires a high gain, low noise figure preamplifier
  - a poor low sensitivity DX receiving antenna
- All attached cables must be choked for common mode signals
  - install common mode chokes on the coaxial feedline and preamp power cable
  - bury cables about 12 inches deep for optimum null depth
- Avoid re-radiated signals from nearby antennas and power lines
  - locate the antenna as far as possible from other antennas and power lines

The "Magnetic" Loop is a specialized antenna

Small Diameter Loop Antenna

4 dB RDF 150º 3 dB beamwidth

Inexpensive and very easy to build and use
Compact 8 foot diameter
Very deep 2º beamwidth broadside nulls for local RFI suppression
Very broad 150º figure-8 bidirectional 3 dB beamwidth
Poor sensitivity for DX



www.seed-solutions.com/gregordy/Amateur%20Radio/Experimentation/160loop.htm

Electrically Steerable Loop Arrays

- Two K9AY loops
  - switchable in four directions
  - footprint is only 25 x 25 feet and 25 feet tall
  - 120º 3 dB beamwidth
  - 7 dB RDF
- Shared Apex Loop Array
  - switchable in eight directions
  - footprint is only 50 x 50 feet and 25 feet tall
  - 75º 3 dB beamwidth
  - 8 dB RDF
- Small loops produce very low signal levels
  - a high gain, low noise figure preamplifier is essential
  - requires very careful attention to choking unwanted common mode signals
    - choke the coaxial cable feed line and filter the control cable and power cable
    - bury the cables about 12 inches deep for best unwanted signal suppression
- Avoid re-radiated signals from nearby antennas, towers and power lines
  - locate the antenna as far as possible from antennas, towers and power lines

Two K9AY Loops

7 dB RDF in only 625 square feet

very small 25 x 25 foot square x 25 feet high
switchable in four directions
120º 3 dB beamwidth

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www.arraysolutions.com/antennas/as-ayl-4-ant

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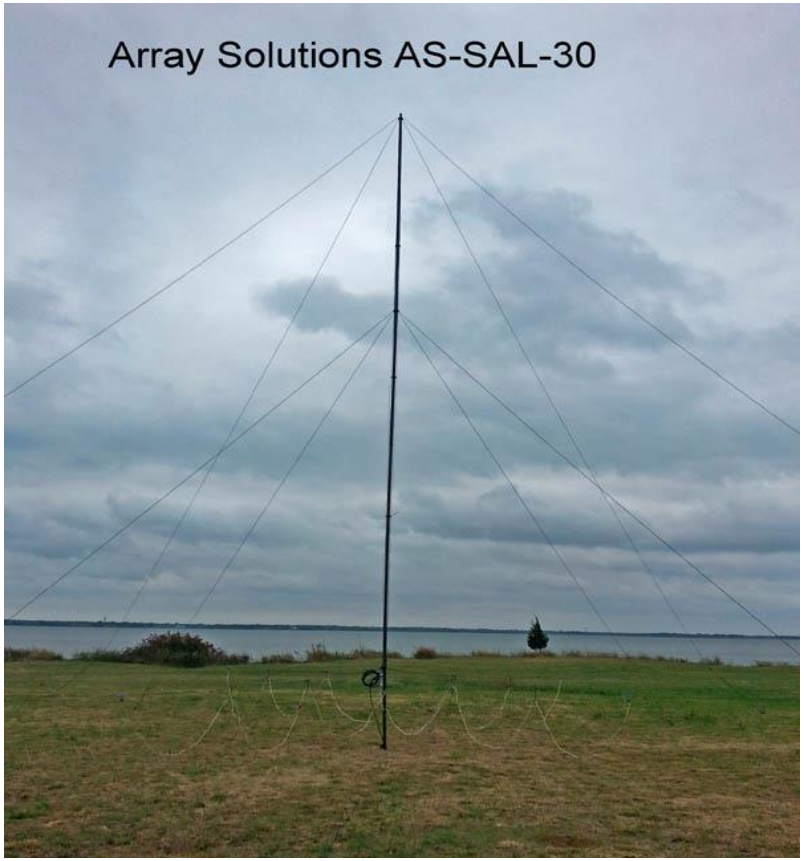
Shared Apex Loop Array

8 dB RDF in only 2500 square feet

50 x 50 foot square x 25 feet high
switchable in eight directions
75º 3 dB beamwidth

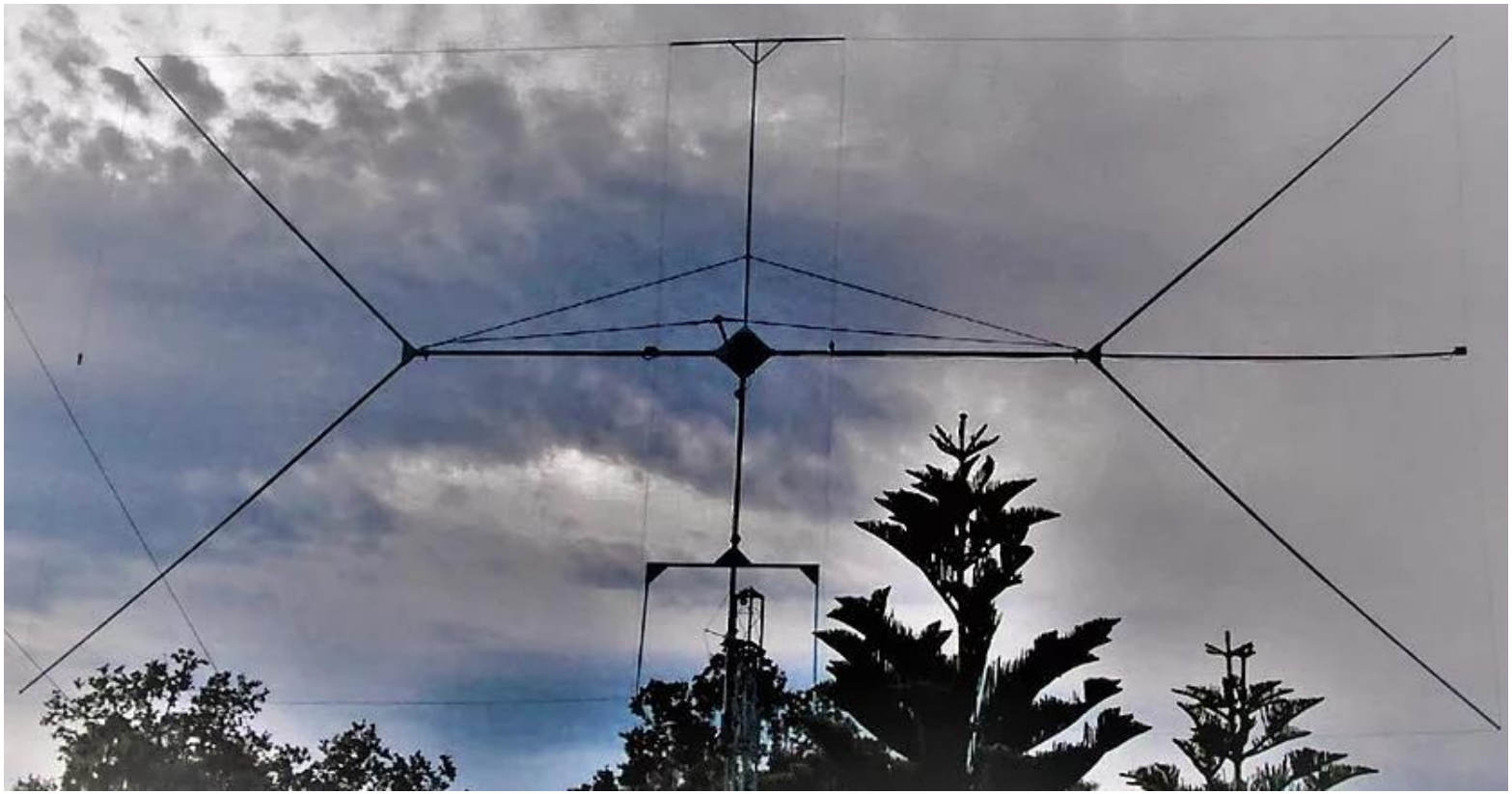


www.arraysolutions.com/antennas/as-sal-30

Waller Flag Array – Vertical or Horizontal

11 dB RDF in only 30 feet of length

Two small terminated loops with end-fire phasing
For most locations: 14 feet tall and 30 feet long
For quiet locations: 20 feet tall and 50 feet long
At least 100 feet high for horizontal polarization
80º 3 dB beamwidth



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http://wwrof.org/wp-content/uploads/2016/03/WWROF-WEBNAIR-RX-Antennas-for-a-Small-Lot-.pdf

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Single Wire Beverage

The simplest and most reliable high performance receiving antenna

250 to 400 feet long	4 - 6 dB RDF	100º 3 dB beamwidth
500 to 700 feet long	10 - 11 dB RDF	70º 3 dB beamwidth
800 to 900 feet long	12 dB RDF	60º 3 dB beamwidth

2
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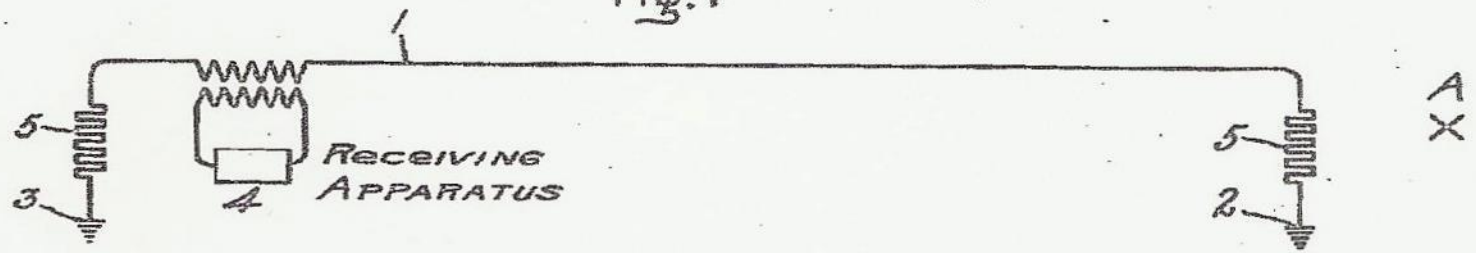
H. H. BEVERAGE.
RADIORECEIVING SYSTEM.
APPLICATION FILED APR. 10, 1920.

1,381,089. Patented June 7, 1921.

Fig. 1



Inventor:
Harold H. Beverage,
by Albert G. Davis
His Attorney.

http://www.w8ji.com/beverages.htm

Beverage on (or near) Ground

6 - 8 dB RDF with only 225 feet of length

a good choice when stealth is important

signal levels are *significantly stronger* if the wire is elevated a few inches

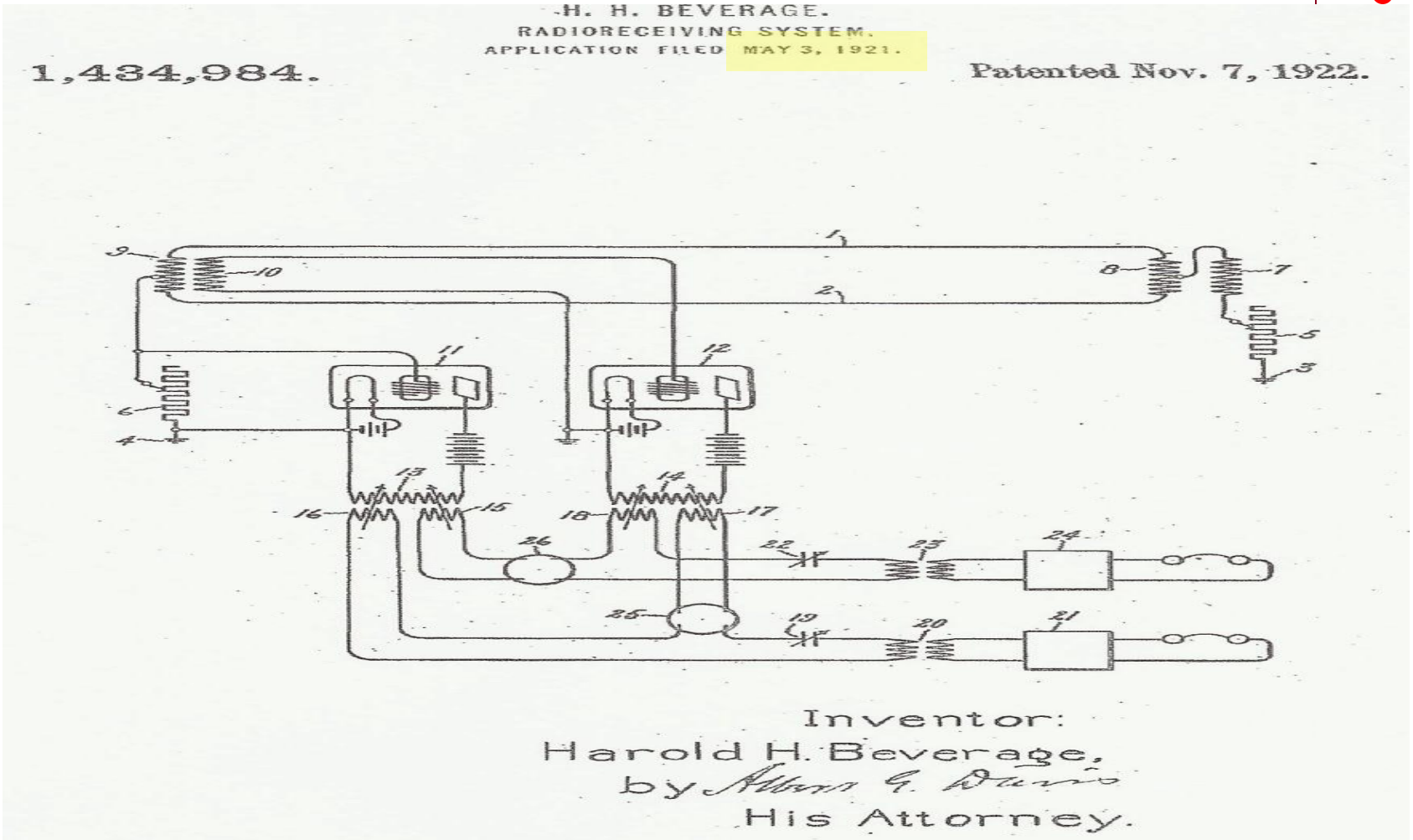
only about 225 feet long -- longer lengths *significantly degrade* performance

70 - 100º 3 dB beamwidth

https://vimeo.com/199235390

Two Wire Bi-directional Beverage - 1921

Switchable in two directions with one feed line
deep steerable rear null if both feed lines feed a variable phase controller



H. H. BEVERAGE.
RADIORECEIVING SYSTEM.
APPLICATION FILED MAY 3, 1921.

1,434,984. Patented Nov. 7, 1922.

Inventor:
Harold H. Beverage,
by Albert G. Davis
His Attorney.

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www.w0btu.com/Beverage_antennas.html

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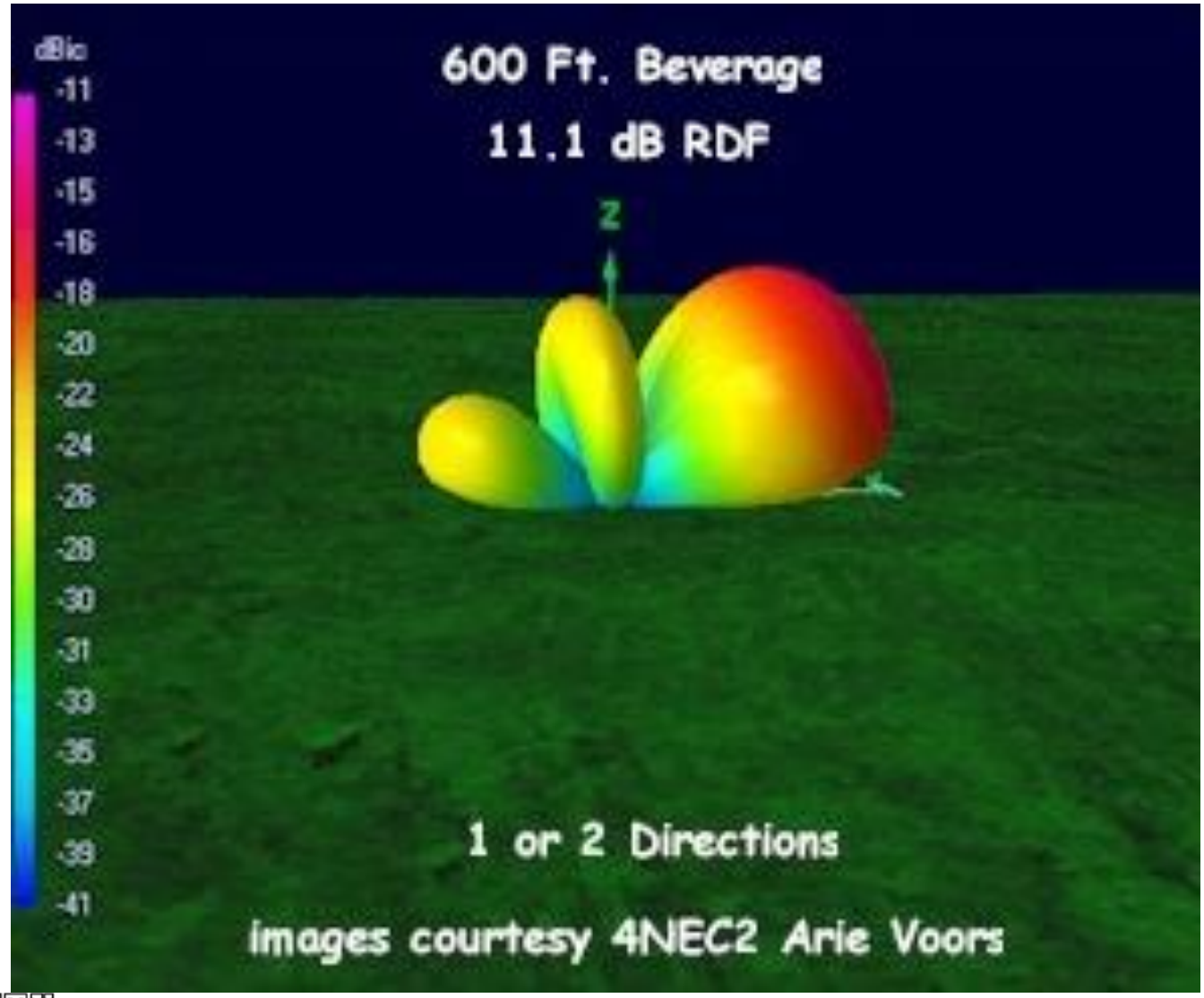
Radiation Pattern of a 600 Foot Beverage



Staggered Beverage Array - 1927

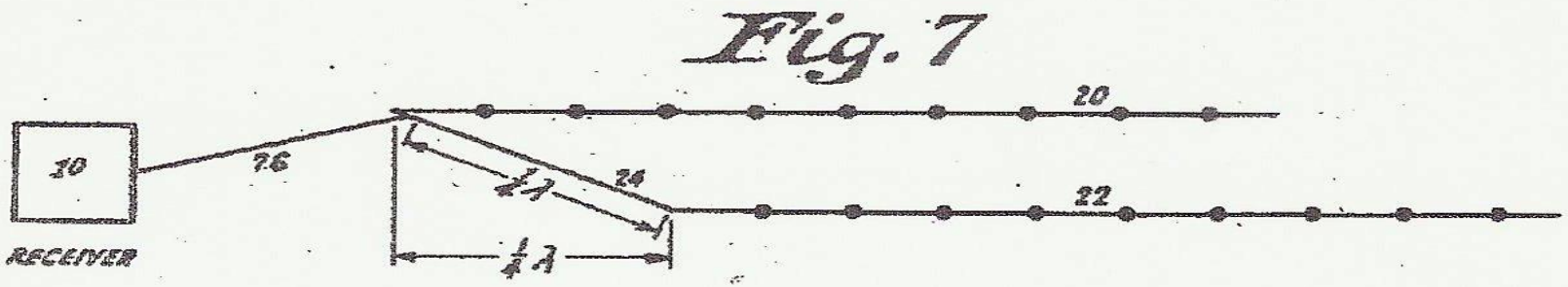
11 dB RDF on one acre

two or three close spaced, 500 to 600 foot staggered Beverages
or two or three close spaced 225 foot BOGs -- 7 dB RDF
enhanced front-to-back ratio compared to a single Beverage or BOG
the deep rear null can be steered by a variable phase controller

Sept. 1, 1931. H. O. PETERSON 1,821,402

ANTENNA

Filed Nov. 8, 1927 2 Sheets-Sheet 2



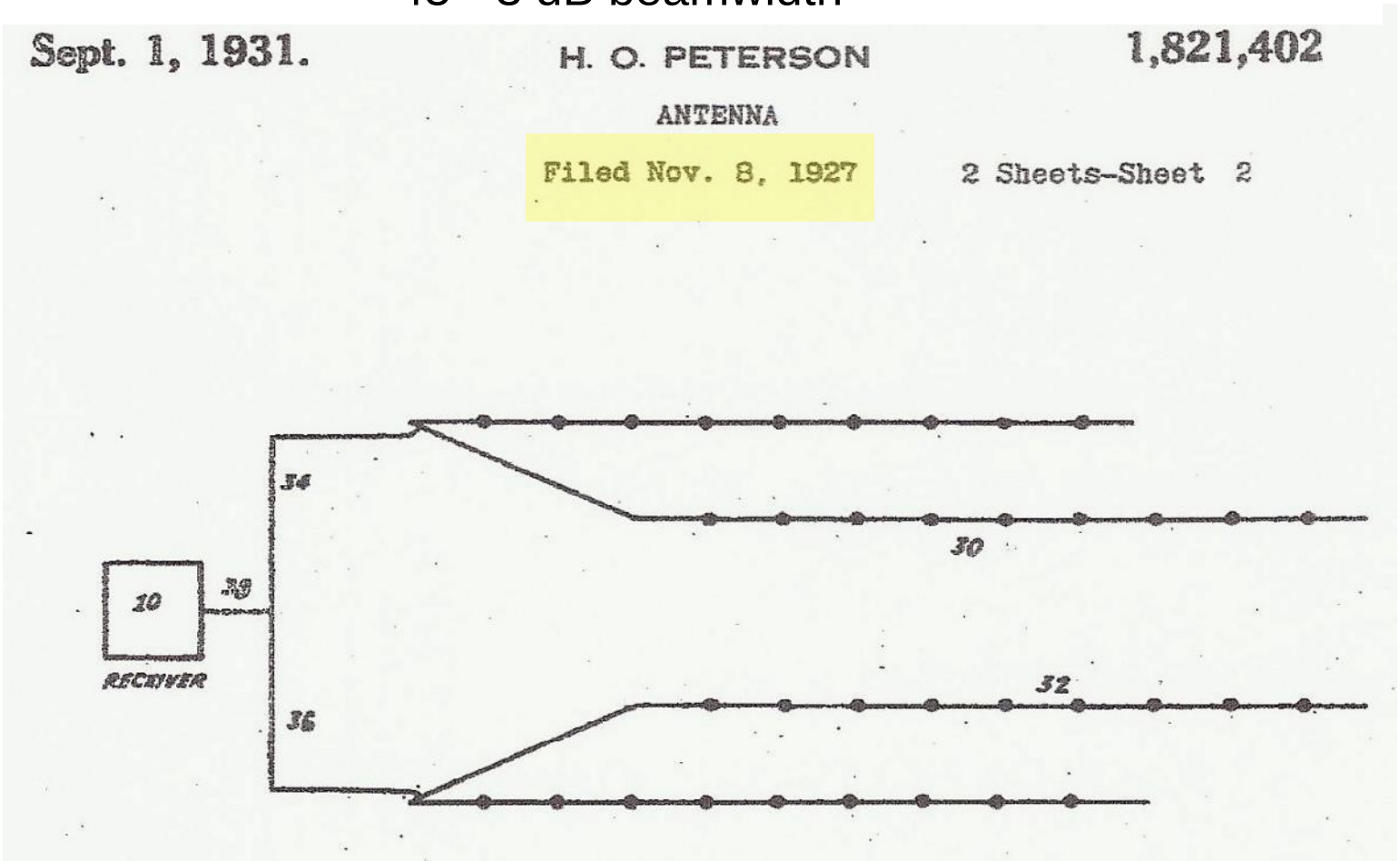
http://ncjweb.com/features/sepoct11feat.pdf

Broadside Pair of Staggered Beverages - 1927

14 dB RDF on 8 Acres

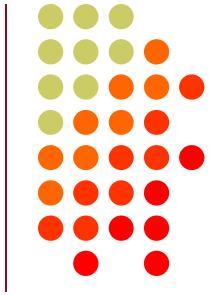
800 to 900 foot Beverages, 330 foot broad side spacing

45º 3 dB beamwidth



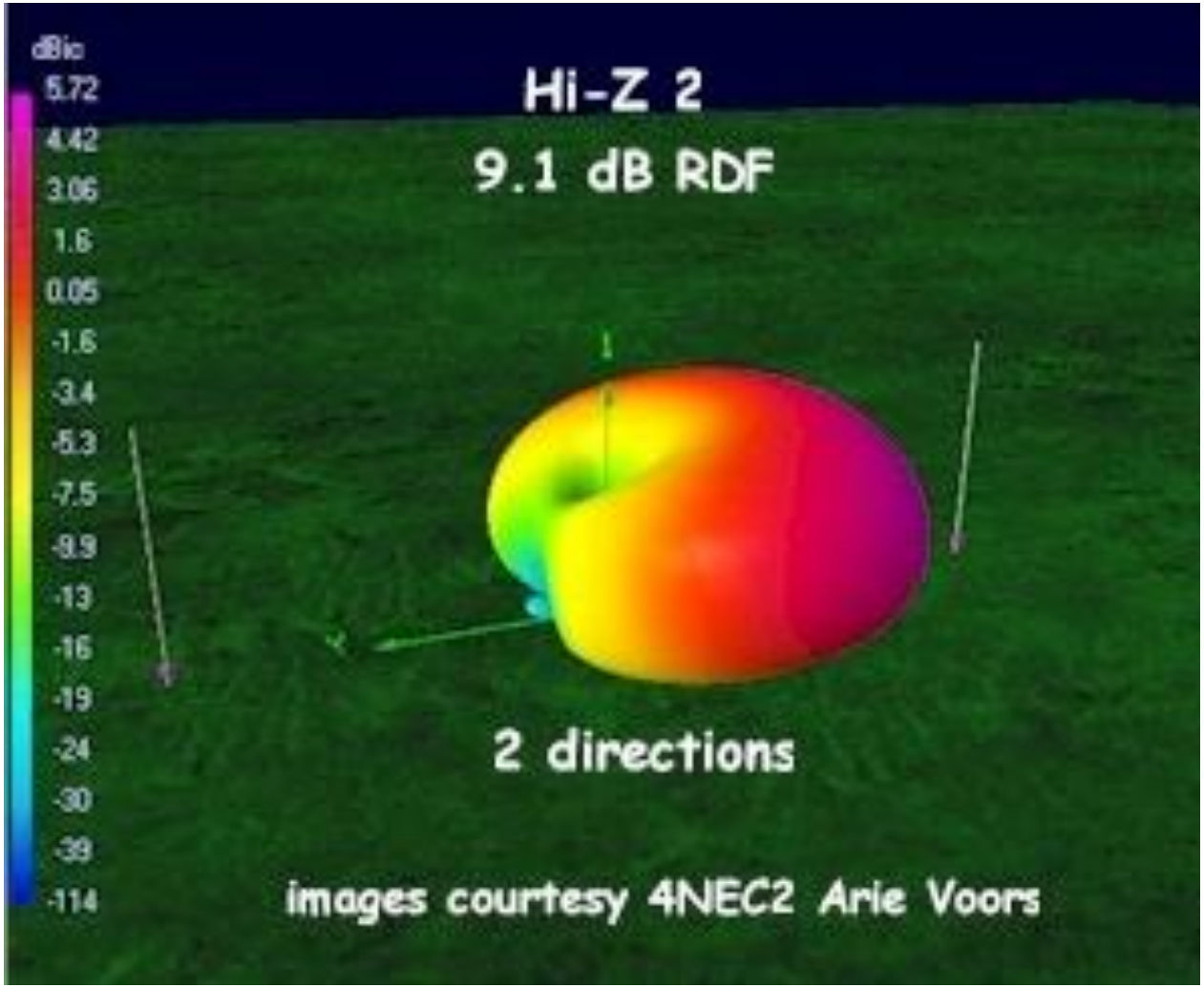
Phased *High Impedance* Verticals

Two or More 20 Foot Verticals



- No radials
- No umbrella wires
- Dual band operation with compromise 65 foot element spacing
- 80 foot element spacing for improved 160 meter performance
  - closer spacing is possible by using a variable phase controller
- High input impedance amplifier at the feed point of <u>each</u> vertical
  - stray capacitance to nearby trees and other objects, at the feed point of each vertical and at the input to each amplifier must be as low as possible
- Switchable in multiple directions
- Verticals must not be installed within ten feet of nearby objects
  - Avoid nearby trees or any conductive or partially conductive structure
- Avoid re-radiated signals from nearby antennas and power lines
  - locate the antenna as far as possible from antennas, towers and power lines

Radiation Pattern of a Two Element Array of 20 Foot Verticals



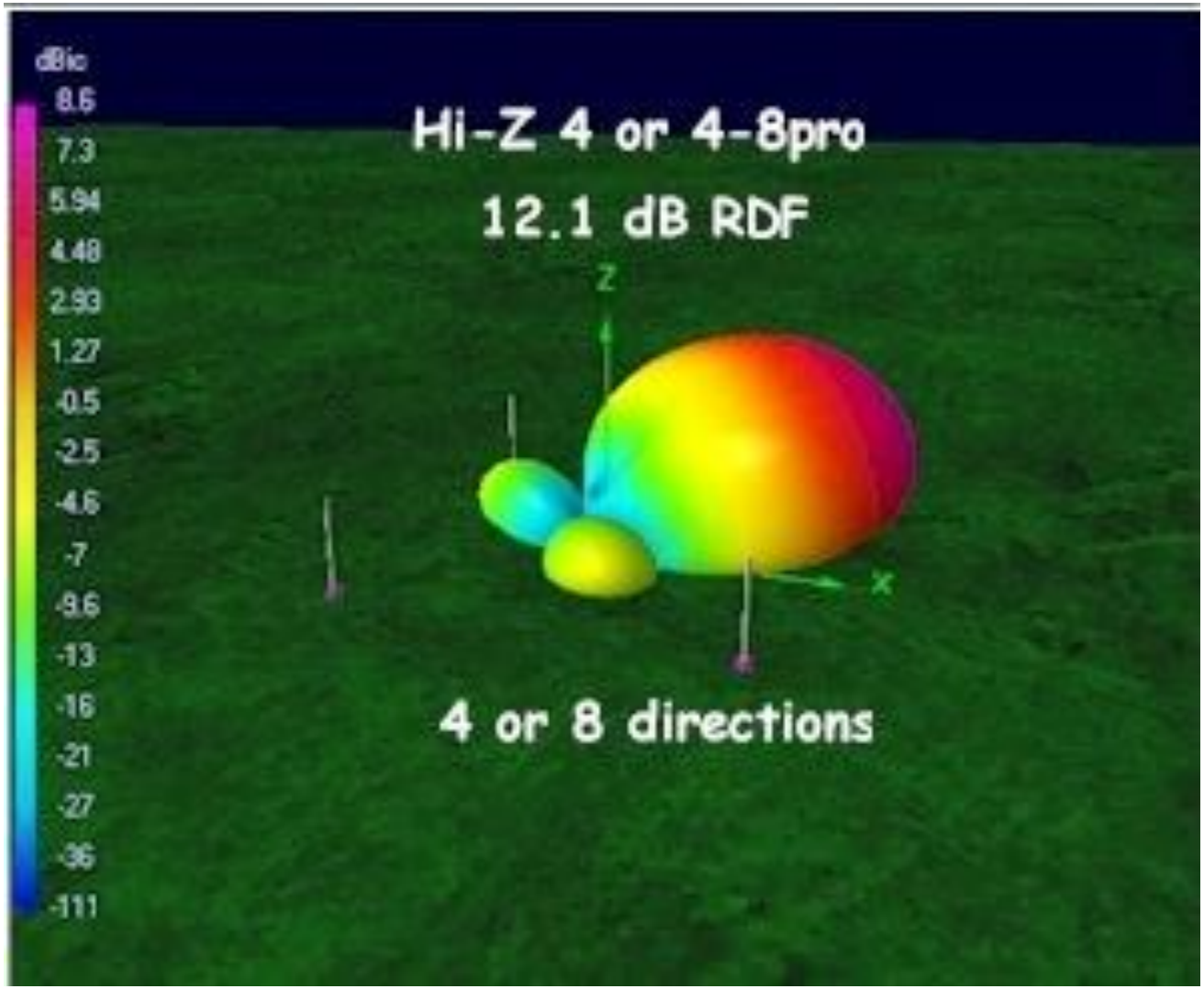
Electrically Steerable 4-Square Vertical Array

12 dB RDF on less than ¼ acre

four *high impedance* 20 foot verticals
no radials or umbrella wires
80 x 80 foot square x 20 feet high
high input impedance amplifier at the base of each vertical
switchable in four directions
100º 3 dB beamwidth

www.dxengineering.com/parts/hiz-4-lv2-80

Radiation Pattern of a 4-Square Array of 20 Foot Verticals

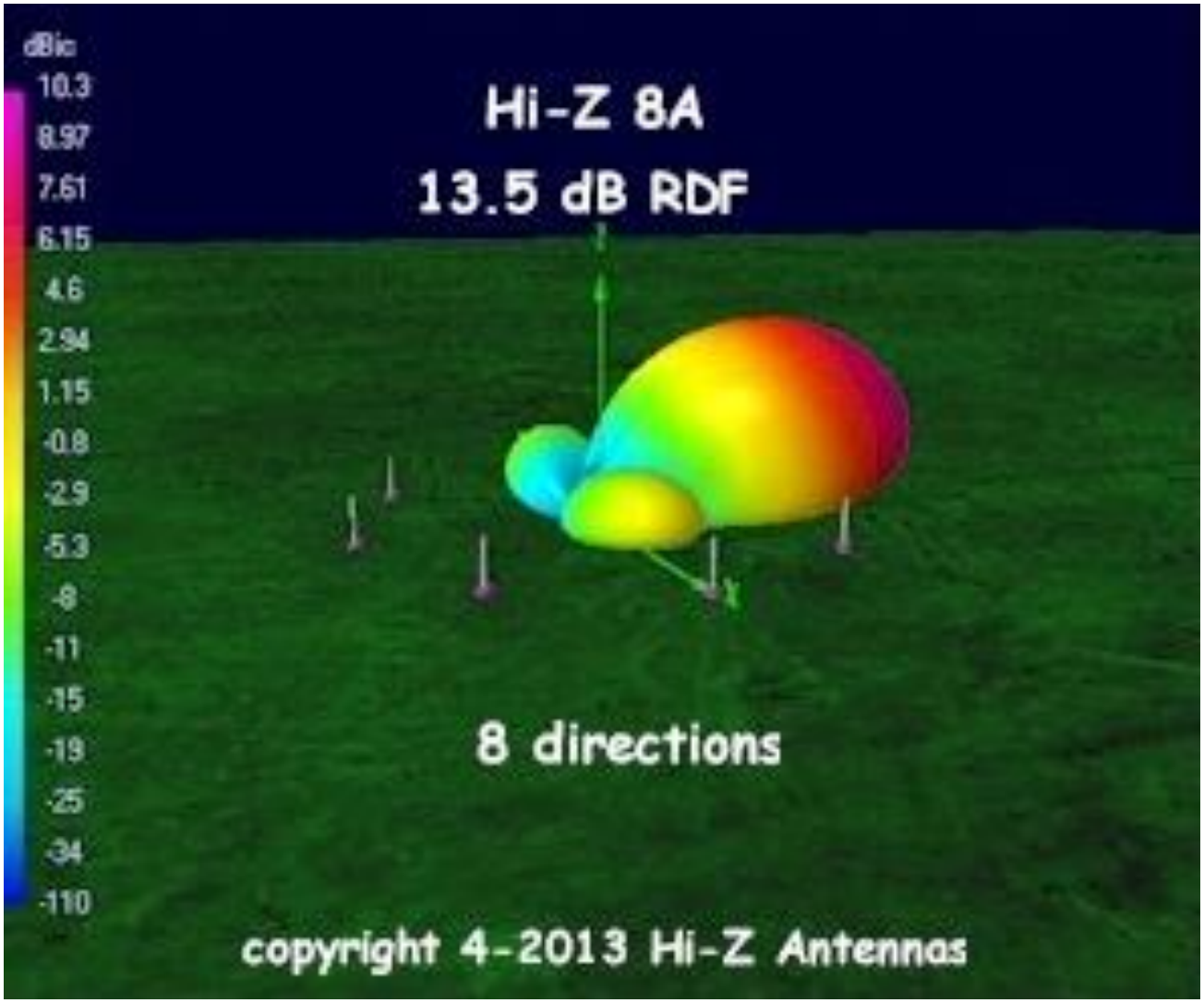


Electrically Steerable 8-Circle Vertical Array

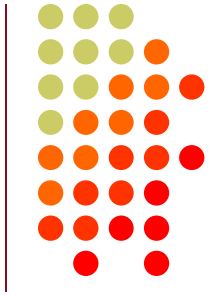
13.5 dB RDF on only ¾ acre

eight *high impedance* 20 foot verticals
no radials and no umbrella wires
requires a high input impedance amplifier at the base of each vertical
only 200 foot diameter array
switchable in eight directions with 106º phasing
50º 3 dB beamwidth, equivalent to a 5 element Yagi

Radiation Pattern of a 200 Foot Diameter 8-Circle Array



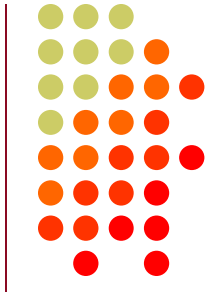
YCCC Triband Receiving Array
12 dB RDF on only ¼ acre



- 3, 5 and 9 element configurations with identical performance
  - switchable in 180º, 90º and 45º steps respectively
  - 80º 3 dB beamwidth
  - slightly wider beamwidth and slightly lower RDF on 80 and 40 meters
- 120 foot diameter array
- No radials
- No umbrella wires
- High impedance amplifier at the feed point of each 20 foot vertical
- A common mode choke must be attached to each feedline where it connects to the controller
- Install at least 10 feet from nearby trees and metallic structures
- Avoid re-radiation from nearby towers, antennas and power lines
  - locate the antenna as far as possible from other antennas and power lines

Phased *Low Impedance* Verticals

Two or More 25 Foot Monoband Umbrella Verticals

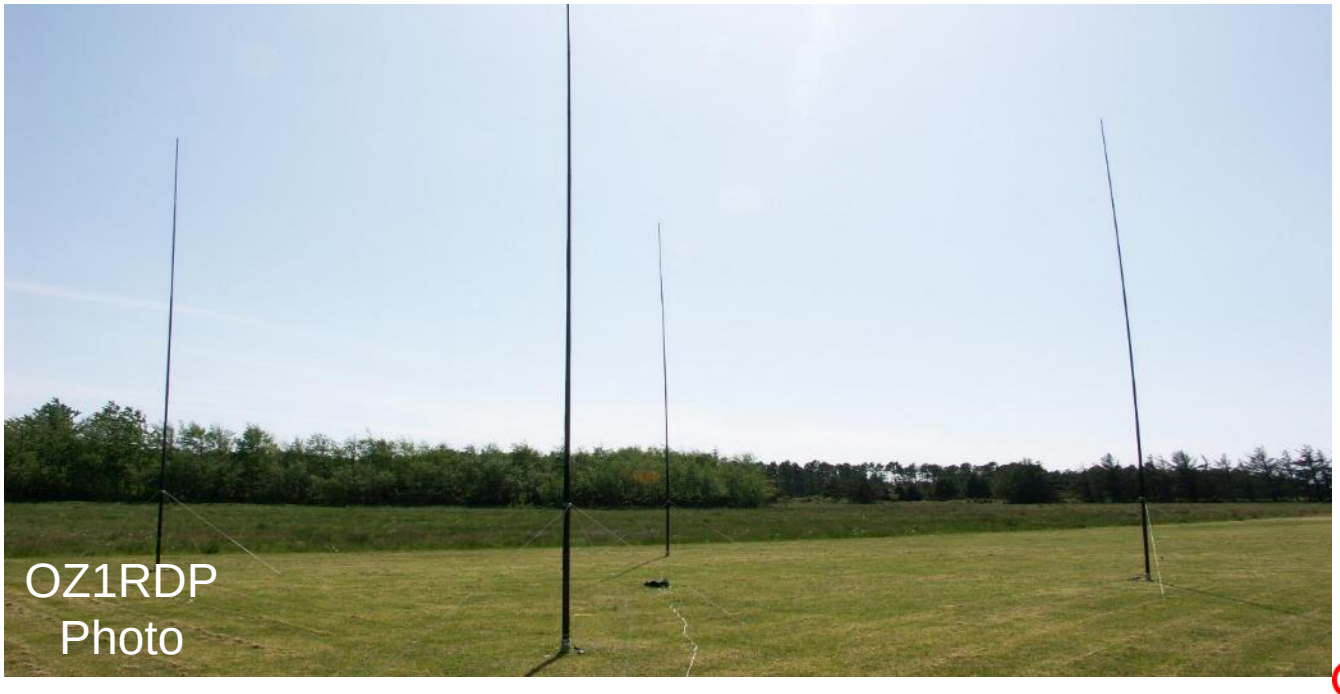


- Short radials are required at the base of each vertical
  - eight 70 foot radials, sixteen 35 foot radials or chicken wire
  - randomly laid on the ground or shallow buried, symmetry is not important
- Four 25 foot umbrella wires attached to the top of each vertical
  - umbrella wires reduce antenna height and improve array bandwidth
  - *if necessary*, use 35 foot verticals with no umbrella wires
- As little a 65 foot element spacing
  - but more difficult to achieve stable, repeatable performance with small spacing
- Amplifiers not needed at the base of each vertical – higher reliability
- Switchable in multiple directions
- Very easy and low cost to homebrew your own antenna
  - large diameter arrays are very tolerant of moderate amplitude and phase errors
- Low impedance verticals are tolerant of nearby trees and buildings
- Avoid re-radiated signals from nearby towers, antennas and power lines
  - locate the antenna as far as possible from other antennas and power lines

Electrically Steerable 4-Square Vertical Array

12 dB RDF on ¼ acre

four *low impedance* 25 foot umbrella verticals
four 25 foot umbrella wires attached to the top of each vertical
eight 70 foot or sixteen 35 foot radials per vertical
65 x 65 foot square footprint plus additional space for radials
switchable in four directions
easy and inexpensive to build
100º 3 dB beamwidth



www.iv3prk.it/user/image/site2-rxant.prk_4-square_1.pdf

Electrically Steerable 8-Circle Vertical Array

13.5 dB RDF on four acres

eight *low impedance* 25 foot umbrella verticals
four 25 foot umbrella wires installed on each vertical
eight 70 foot or sixteen 35 foot radials installed under each vertical
350 foot diameter with 1/4 wavelength spacing plus space for radials
or only 200 foot diameter with a Hi-Z 106 degree phasing controller
switchable in eight directions
Very easy and inexpensive to build
50º 3 dB beamwidth, equivalent to a 5 element Yagi

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construction details: http://www.w5zn.org

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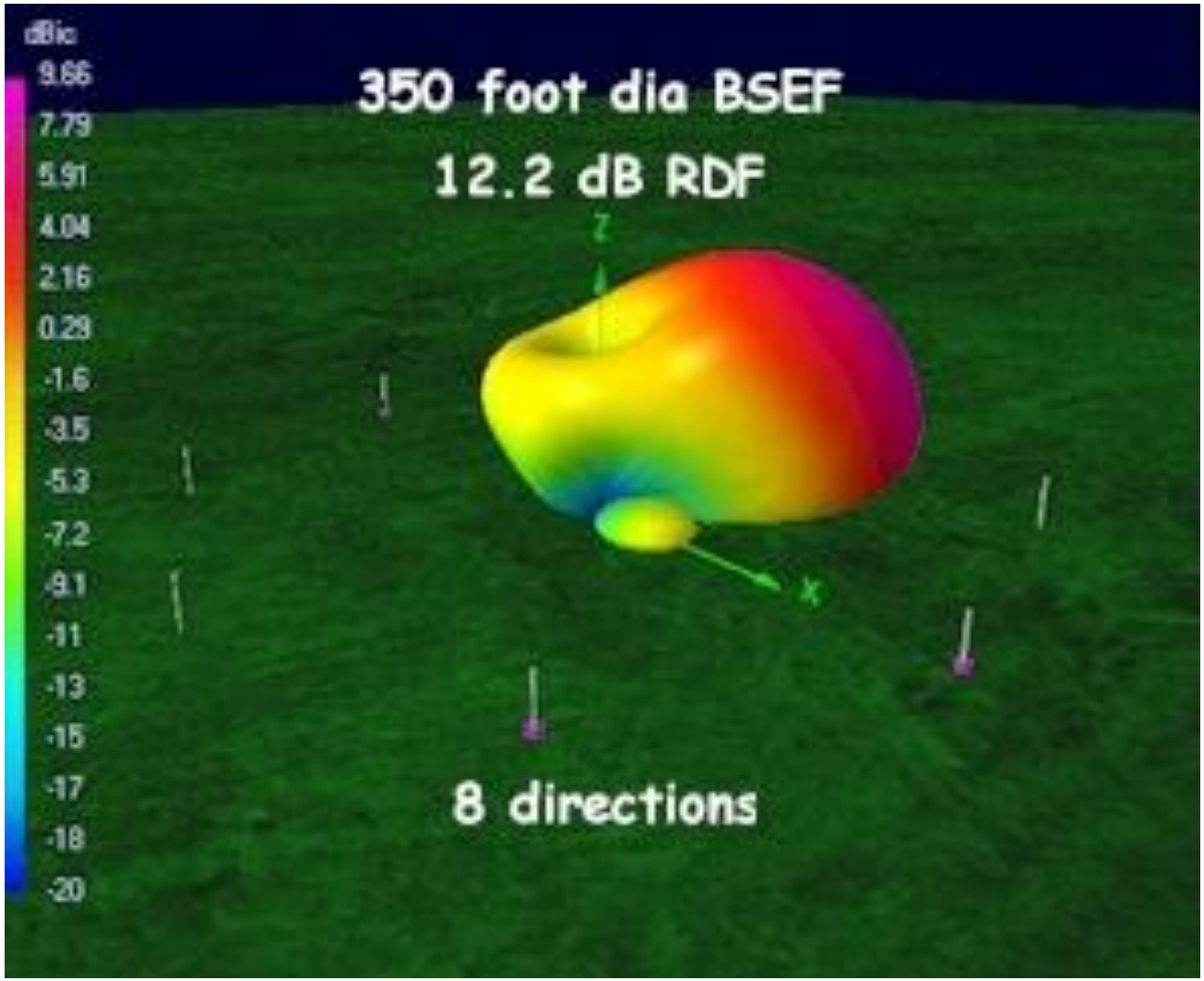
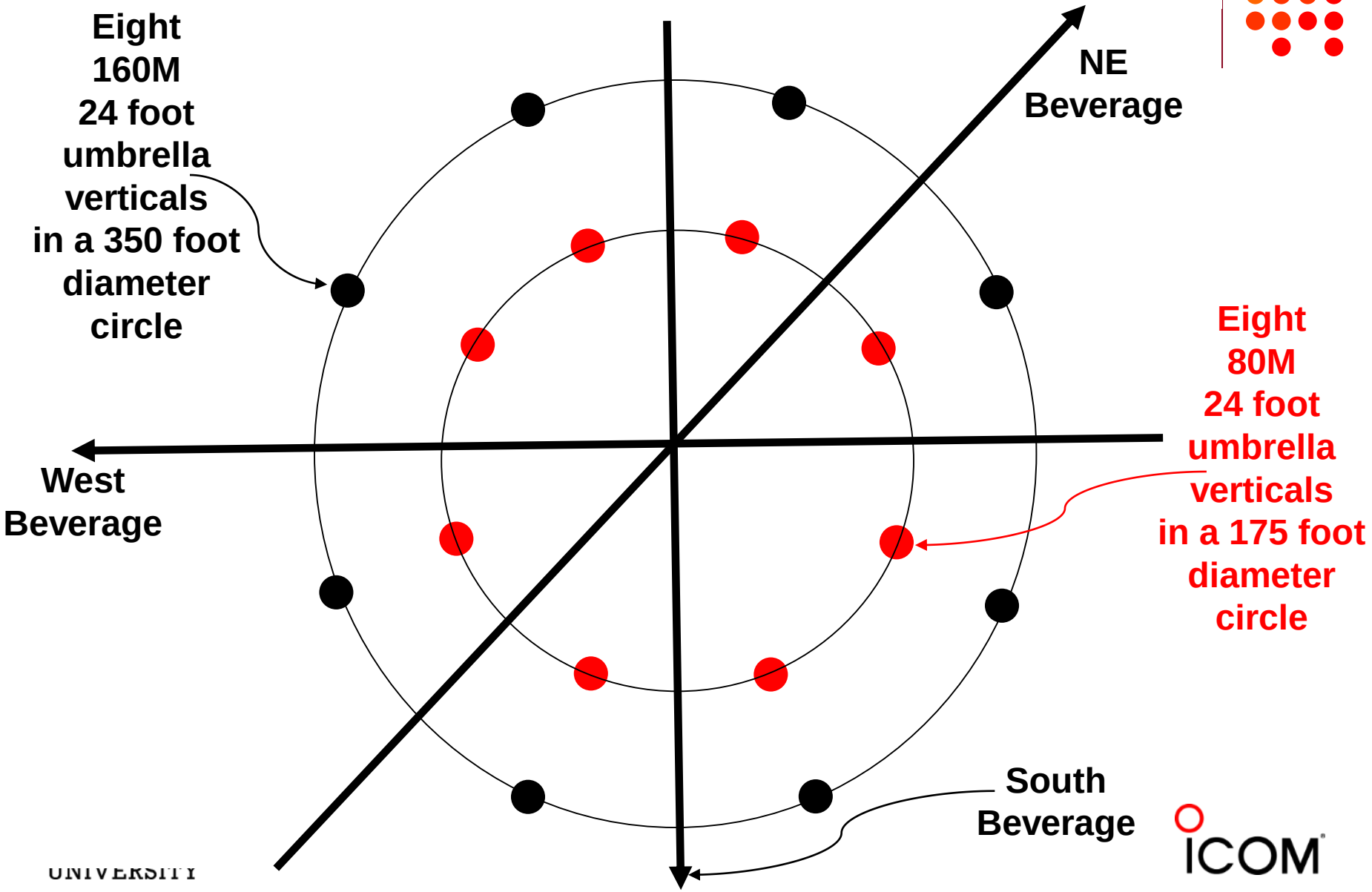
Radiation Pattern of a 350 Foot Diameter 8-Circle Array



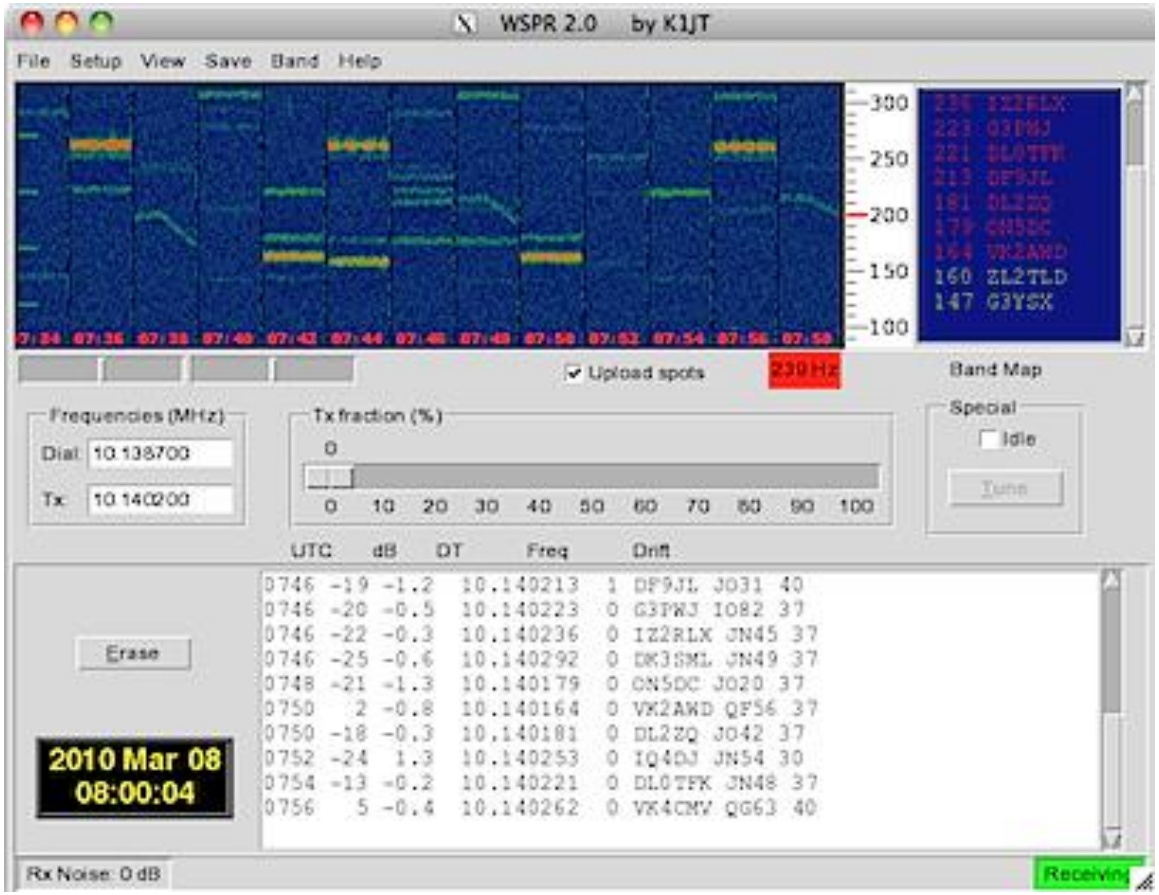
Four phased elements with 115 degree phasing

160 and 80 Meter Receiving Antenna Layout at W3LPL



Quantitative Performance Evaluation
Using K1JT's WSJT-X

Use two instances of WSPR or FT-8
to compare the performance of two receiving antennas



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http://physics.princeton.edu/pulsar/K1JT/WSPR_2.0_User.pdf

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Receiving Antenna Variable Phasing Controller

DX Engineering NCC-2

Combines the inputs from two antennas

- creates a directional pattern with deep steerable nulls
- optimizes the performance of phased Beverages and phased verticals
- very well engineered and exceptionally easy to use

Phase Synchronous Diversity Reception

two widely spaced antennas (500 to 1000+ feet) feeding
two identical high performance phase locked receivers

Elecraft K3s transceiver with KRX3 sub-receiver