Optimizing Low Band Receiving Antenna Performance

- Small antennas
- High performance antennas
- Diversity reception

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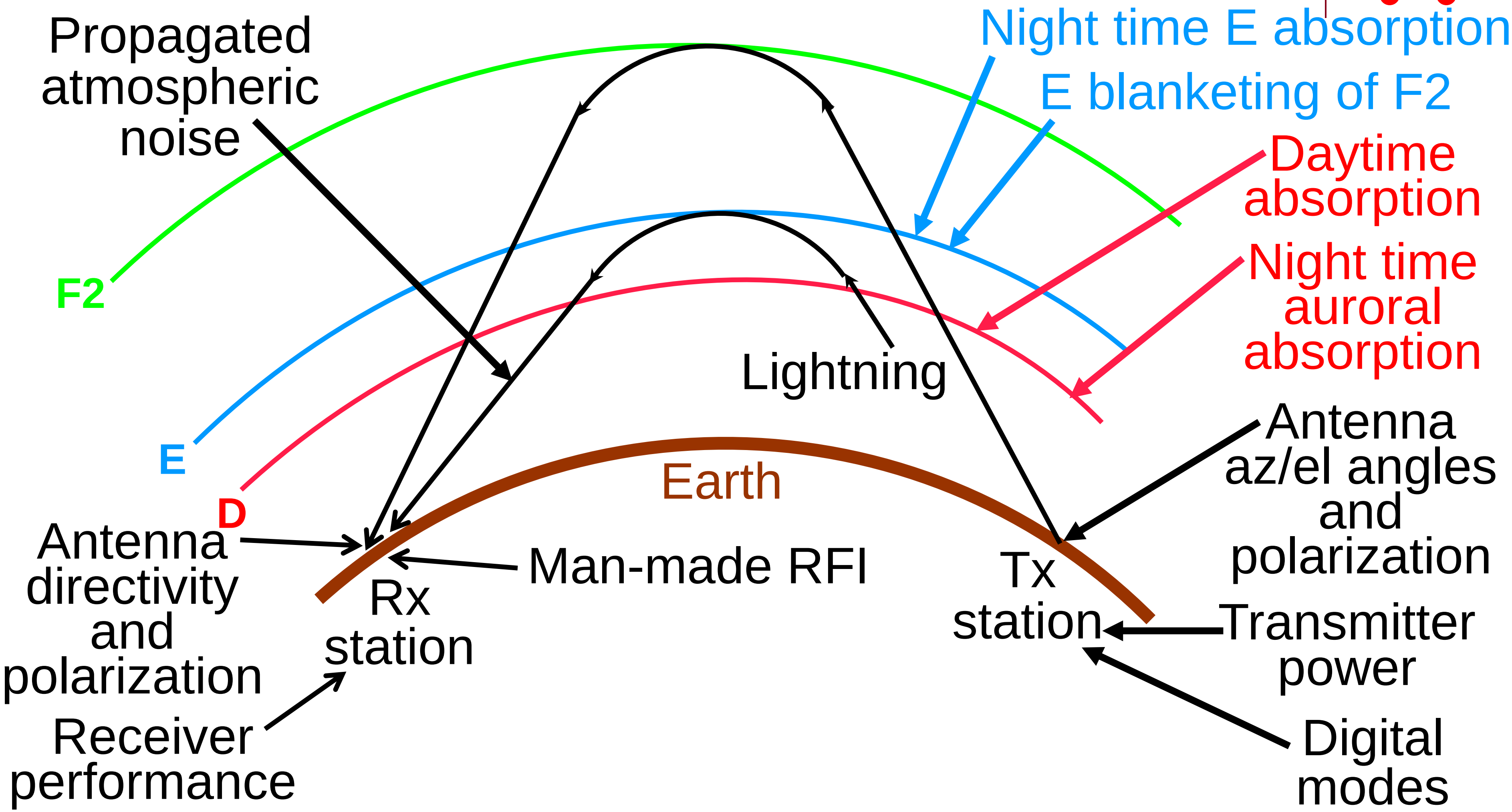
160 Meter Propagation

What's So Hard About Communicating Near or Below the Lowest Usable Frequency?



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 receiving 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 Beverages and phased 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 at specific azimuths

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

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 to 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) *poor low angle sensitivity*

7 dB: 250 foot Beverage about 7 feet high better low angle response

7 dB: Unidirectional terminated small loop *close to the ground*

- flag, pennant, EWE, VE3DO

8 dB: Two switchable small terminated loops at right angles to each other

- K9AY Array
- Shared Apex Loop Array

8 dB: Pair of 250 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: two phased vertical loops *close to the ground*

Small antennas provide better RFI reduction when local RFI sources are within about 1000 feet

High Performance Receiving Antennas

10 to 14 dB RDF

10 dB: Pair of 400 foot staggered Beverages about 7 feet high
10 dB: 500 to 600 foot Beverage about 7 feet high ideal for both 160 and 80 meters
11 dB: Two or three close spaced 500 to 600 foot Beverages, staggered 125 feet
11 dB: Vertical Waller Flag: 2 phased close spaced vertical loops close to the ground
12 dB: 700 to 1000 foot Beverage about 7 feet high *too long for 80 meters*
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 *100 feet high minimum*
13 dB: 1100 to 1300 foot Beverage about 7 feet high *much too long for 80 meters*
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 750-1000 foot Beverages 750 ft x 330 ft

Large antennas are less effective than small antennas for suppressing local RFI sources within about 1000 feet

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Single Small Loop Antennas

4 - 7 dB RDF 120 to 150º 3 dB beam width

8 foot diameter bidirectional "magnetic" loop 4 dB RDF

- *bi-directional* 150º 3 dB beam width
- 24 dB deep vertically polarized null with very narrow 2º null width
- must be installed *close to the ground* to optimize the depth of the null by suppressing horizontally polarized signals
- a specialized antenna for steering a deep narrow null onto the RFI source onto a single ground wave propagated vertically polarized RFI source
- a 17 foot diameter loop has better DX sensitivity but only 20 dB deep nulls

Unidirectional terminated small loop antennas 6 - 7 dB RDF

- Flag Pennant EWE K9AY VE3DO
- 120º 3 dB beam width

Mechanically rotatable unidirectional terminated small loop antenna

- rotatable flag 6 - 7 dB RDF
- 120º 3 dB beam width

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

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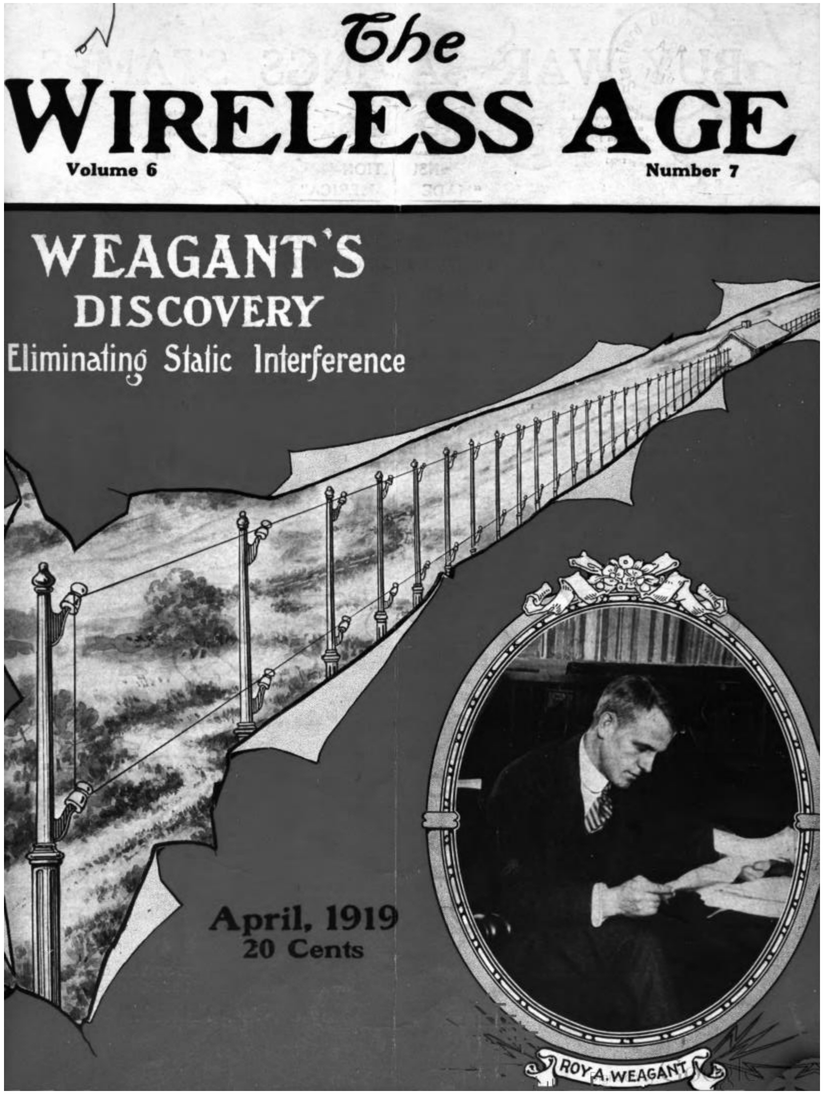
Two End-Fire Phased Vertical Loops 1919



Two End-Fire Phased Vertical Loops 1919

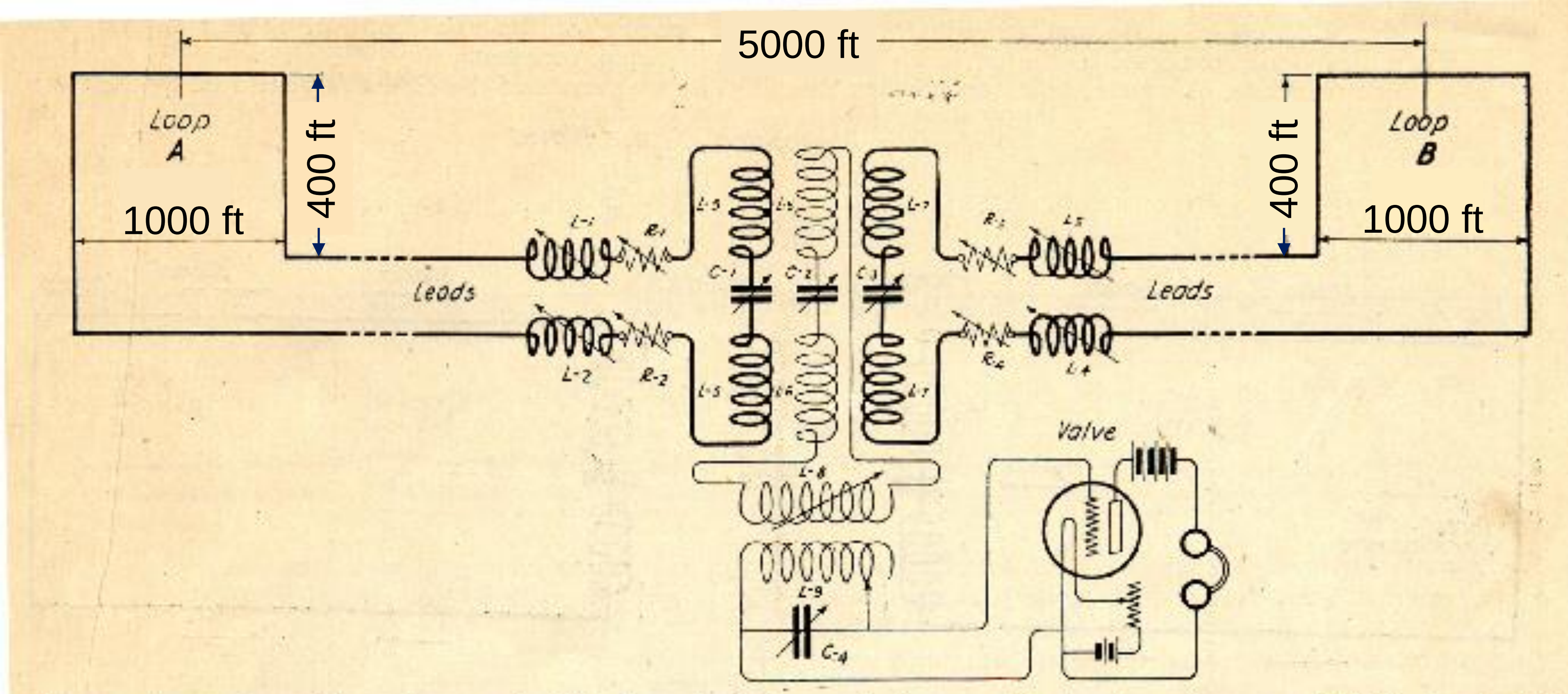


Figure 6—An early form of Weagant's system for eliminating static interference showing two single turn loop antennae spaced 5,000 feet apart. Each loop was 1,000 feet long at the base and 400 feet high. The leads from each loop were connected to the primary coils, L-5 and L-7, of the radio goniometer which were coupled to the secondary coil L-6. By rotating L-6, a position was found where the static currents neutralized and the signal currents were retained. This apparatus and antennae permitted the reception of signals from stations in Europe under conditions of static interference which with ordinary receiving apparatus and antennae would render reception impossible.

Wireless Age April 1919 Page 11

Arrays of Two Small Loops

8 - 11 dB RDF   80 to 120º 3 dB beam width

Electrically switchable compact arrays of two small loops

- two switchable K9AY loops installed close to the ground — 8 dB RDF
- Shared Apex Loop Array installed close to the ground — 8 dB RDF
- 120º 3 dB beam width

350 ft broadside spaced small terminated loops — 9 - 10 dB RDF

- Flag   pennant   EWE   K9AY   VE3DO   installed close to the ground
- 80º 3 dB beam width

Mechanically rotatable array of two end-fire close spaced small loops

- Vertical Waller Flag: 2 phased vertical loops close to the ground — 11 dB RDF
- Horizontal Waller Flag >100 feet high - superb RFI suppression — 11 dB RDF
- 80 degree 3 dB beam width
- Close spaced end-fire small loops produce extremely low signal levels
  - requires at least 40 dB of preamp gain and 2 dB preamp noise figure or less
  - extreme attention to common mode signal suppression – invest in ferrites

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Small antennas are the best RFI reduction antenna when RFI sources are within a few thousand feet

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BOGs and Arrays of BOGs

BOGs have poor low angle sensitivity

6 to 8 dB RDF 60 - 90º 3 dB beam width

BOG 100º 3 dB beam width 6 dB RDF

- 225 foot wire supported *just above* ***but not on*** the surface of the ground

Switchable bi-directional BOG 100º 3 dB beam width 6 dB RDF

- 225 foot coax cable supported *just above* ***but not on*** the surface of the ground

Close spaced staggered BOGs 100º 3 dB beam width 7 dB RDF

- 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 60º 3 dB beam width 8 dB RDF

- 350 foot broadside spaced BOGs reduces beam width to 60º

BOGs are very low sensitivity antennas especially at low angles requiring excellent suppression of coaxial cable common mode signals

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Beverages and Beverage Arrays

only 7 feet high to suppress horizontally polarized signals
single wire Beverage or two wire reversible Beverage

6 to 14 dB RDF 45 to 120º 3 dB beam width

250 foot Beverage	120º	3 dB beam width	8 dB RDF
400 foot Beverage	100º	3 dB beam width	9 dB RDF
500 to 600 foot Beverage	80º	3 dB beam width	10 dB RDF
600 to 750 foot Beverage	70º	3 dB beam width	11 dB RDF
750 to 1000 foot Beverage	60º	3 dB beam width	12 dB RDF

Staggered Beverage arrays 80º 3 dB beam width 11 dB RDF

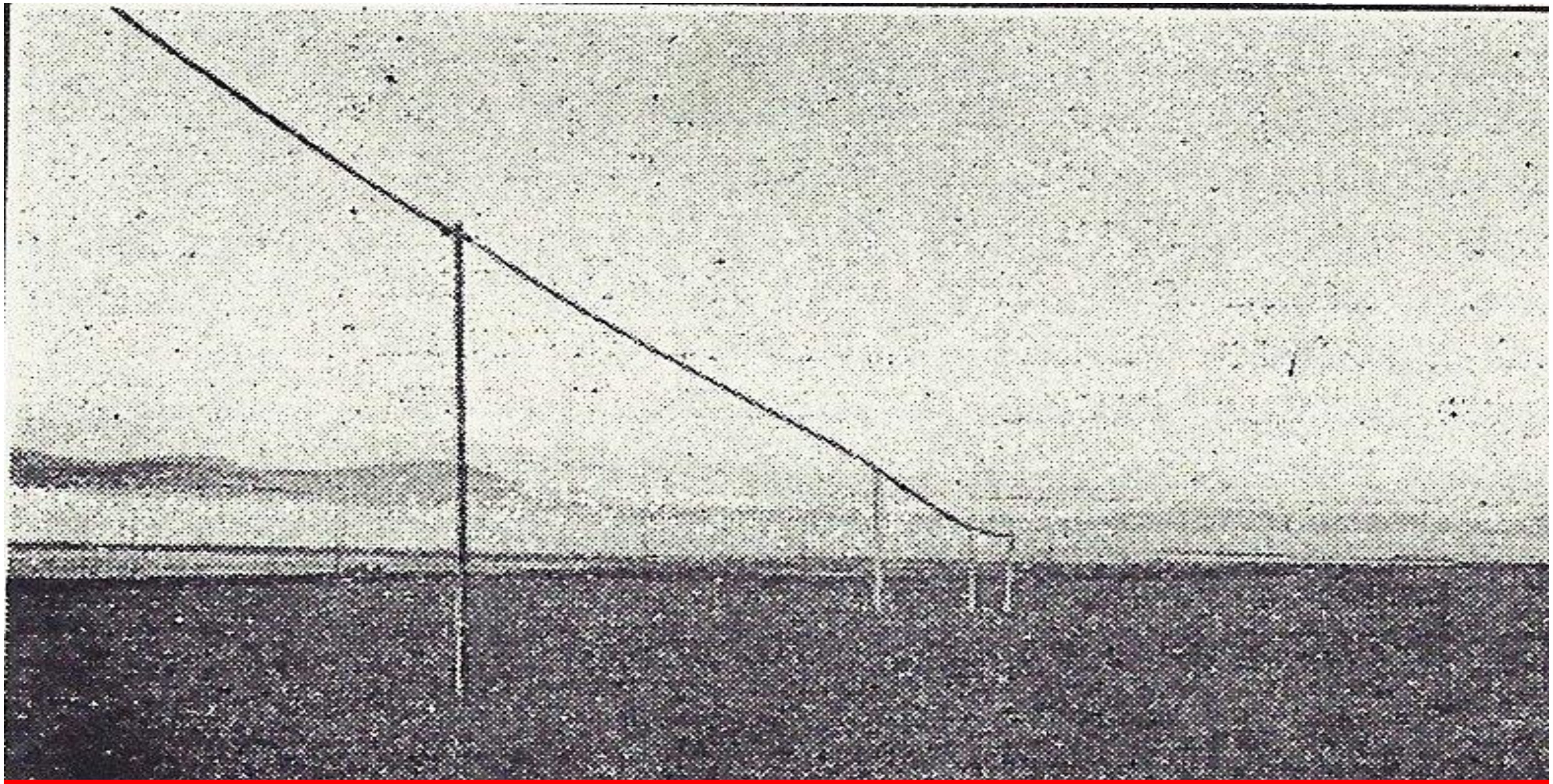
- two or three 500-600 foot Beverages with 125 foot end-fire spacing
- significantly improves front-to-back ratio with a variable phase controller

Broadside Beverage arrays 45 - 60º 3 dB beam width 12-14 dB RDF

- two Beverages with 350 foot broadside spacing, or
- four Beverages with 125 foot end fire spacing and 350 foot broadside spacing
- significantly improves front-to-back ratio with a variable phase controller

1300 Foot Beverage installed by Paul Godley 2ZE

Near the waterfront in Ardrossan, Scotland
During the successful 1921 Transatlantic 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 Phased Verticals

9 - 14 dB RDF   50 to 135º 3 dB beam width

<u>Active</u> high impedance 20 foot verticals

- capable of multi-band operation with some performance compromise
- no radials
- requires a high input impedance amplifier *at the base of each vertical*

----- or ----

<u>Passive</u> low impedance 25 foot verticals

- <u>mono-band</u> operation only
- very easy to troubleshoot and repair   low parts count   very reliable
- eight 70 foot or sixteen 35 foot radials <u>*at the base of each vertical*</u>
  - stabilizes the feed point impedance during all weather conditions
  - decouples the coax shield to suppress common mode signals
- four 25 foot umbrella wires
  - reduces the required height to 25 feet
  - increases the array bandwidth
  - or 35 foot verticals with no umbrella wires

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 for precisely locating RFI very small loops have deeper nulls

Bi-directional figure-8 pattern very broad 150º 3 dB beam width

- Must be installed close to the ground to suppress horizontally polarized signals

Very deep approximately 2º wide nulls 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 20-30 dB gain, very low noise figure preamplifier
- a low sensitivity receiving antenna for DX, limited by preamp noise figure

All attached cables must be choked to suppress 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

8 Foot Diameter Loop Antenna

4 dB RDF 150º 3 dB beam width deep 2º nulls

Inexpensive and very easy to build and use

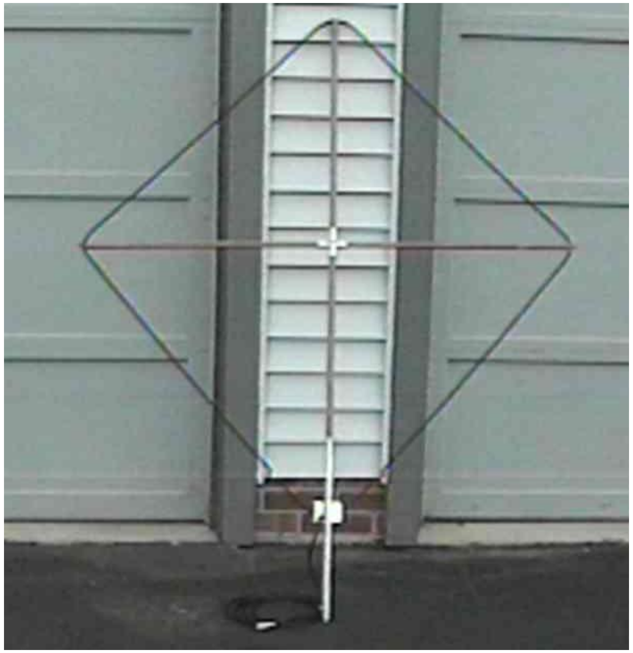
Good compromise size with 24 dB null depth and fairly good sensitivity

24 dB nulls 2º wide broadside to the loop for local RFI suppression

Very broad 150º figure-8 bidirectional 3 dB beam width

Poor sensitivity for weak DX signals

Needs a preamplifier with 20-30 dB gain and 2 dB noise figure



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

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Electrically Steerable Small Loops

- Two K9AY loops
  - switchable in four directions
  - footprint is only 25 x 25 feet and 25 feet tall
  - 120º 3 dB beam width
  - 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 beam width
  - 8 dB RDF
- All small loop antennas 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 beam width

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

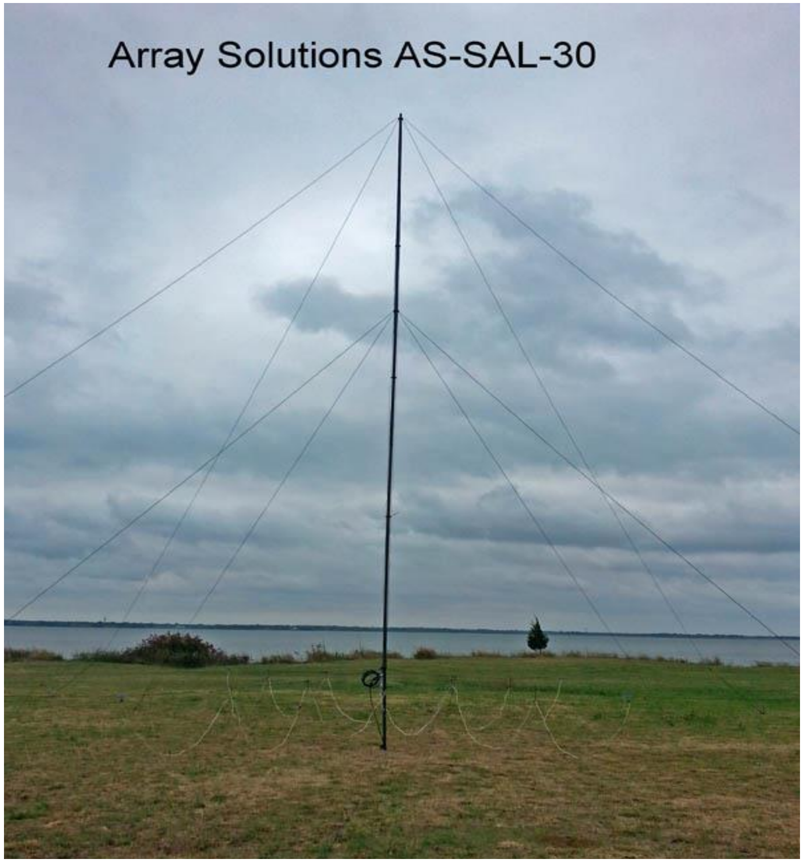
Shared Apex Loop Array

8 dB RDF in only 2500 square feet

50 x 50 foot square x 25 feet high

switchable in eight directions

75º 3 dB beam width



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

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Waller Flag Array – Vertical or Horizontal

11 dB RDF in only 30 feet of length

Two small terminated loops with very close end-fire phasing
For most locations: 14 feet tall and 30 feet long
For quiet locations: 20 feet tall and 50 feet long
80º 3 dB beam width
Requires a 30-40 dB gain preamp with very low 2 dB noise figure
A horizontal Waller Flag must be at least 100 feet high but higher is better

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

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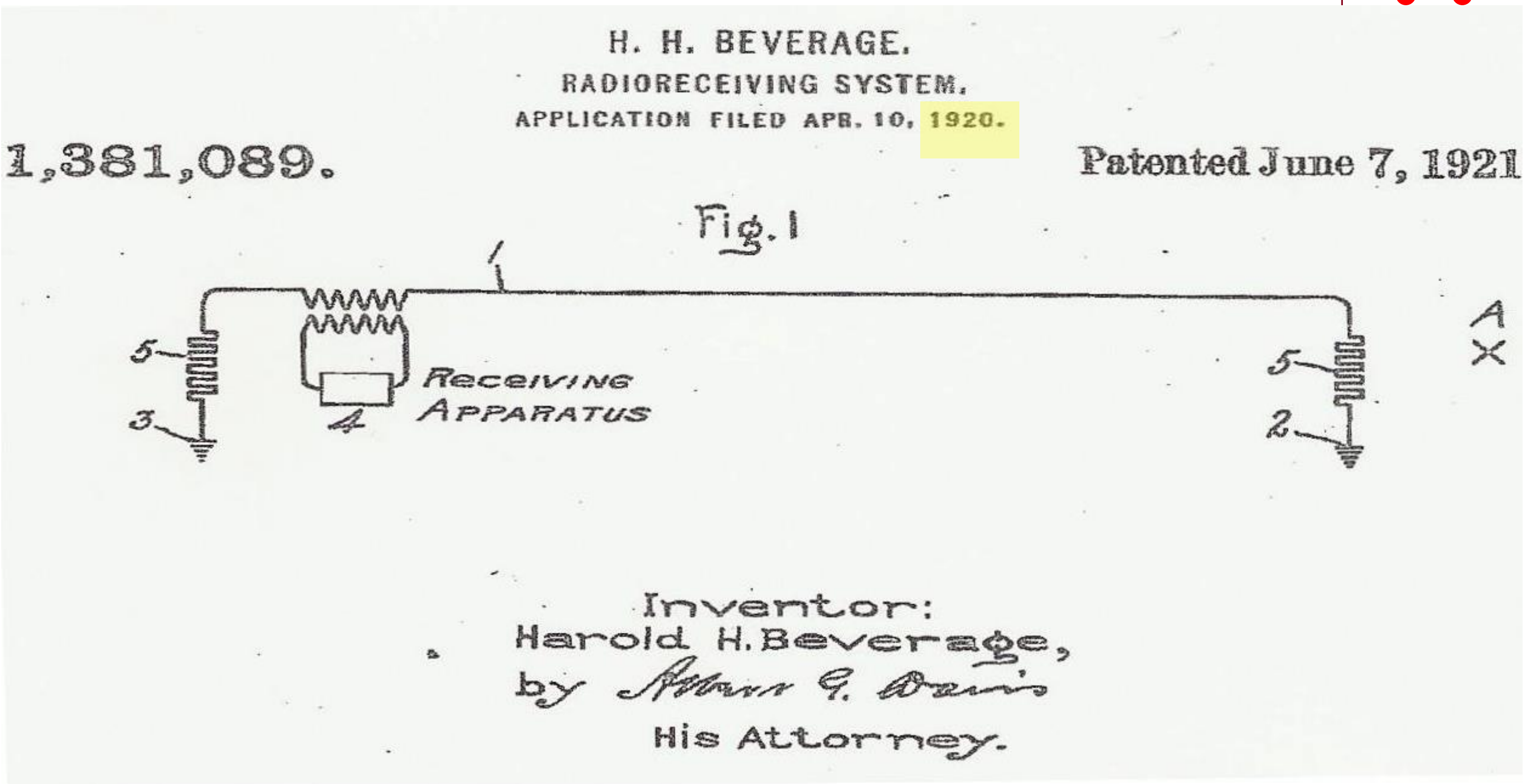
Single Wire Beverage Antenna 1920

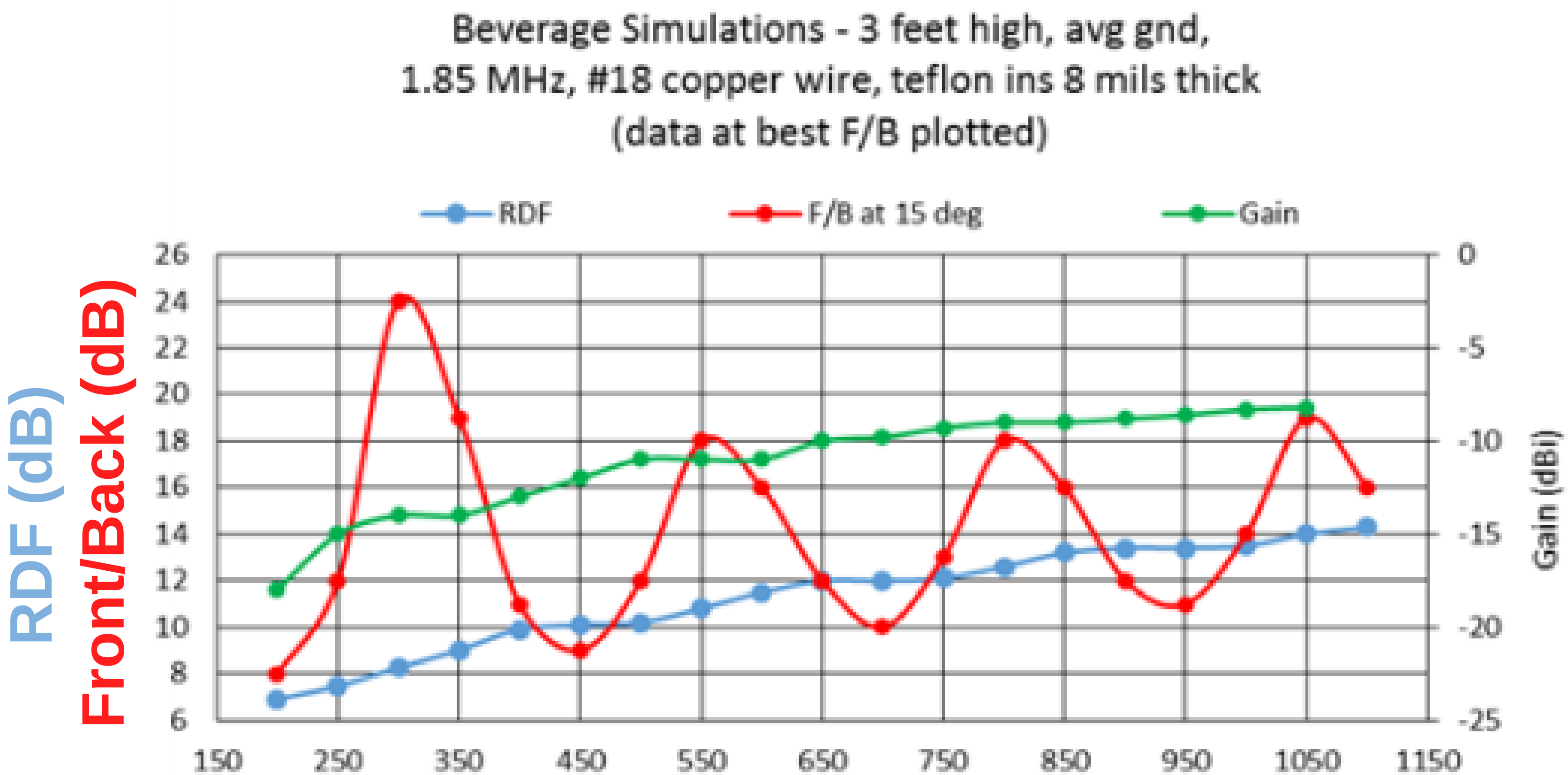


www.w8ji.com/beverages.htm

Single Wire Beverage

The simplest and most reliable high performance receiving antenna

250 to 400 feet long	100º-120º 3 dB beam width	7-10 dB RDF
500 to 750 feet long	70-80º 3 dB beam width	10-12 dB RDF
750 to 1000 feet long	60º 3 dB beam width	12-13 dB RDF



Beverage Length (feet)

k9la.us/Trends_in_Beverage_and_BOG_Performance.pdf

Beverage on (or very near) Ground

6 dB RDF with only 225 feet of length

a good choice when stealth is important

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

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

90 to 100º 3 dB beam width

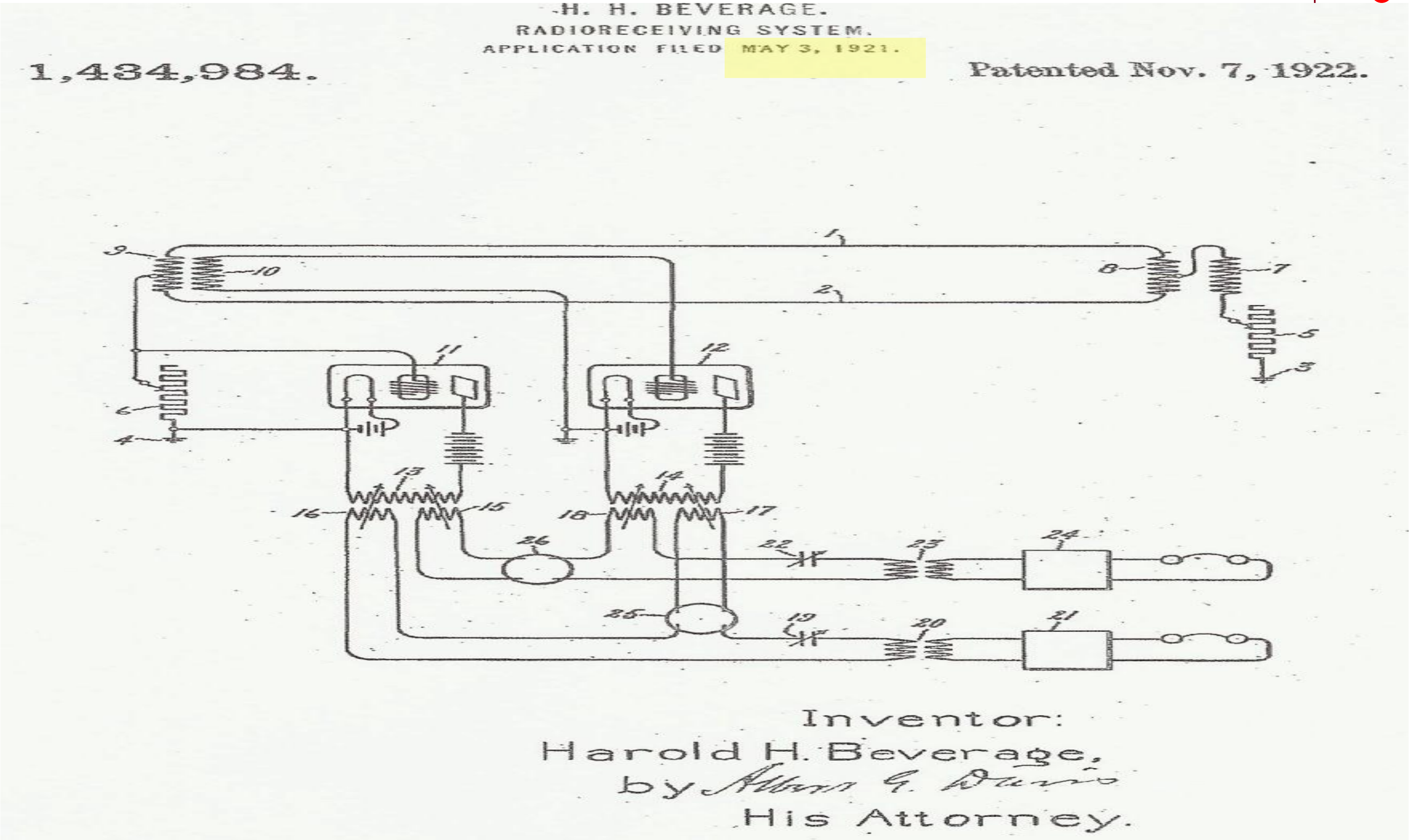
Very low signal levels – requires a high gain preamp with very low noise figure

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



w0btu.com/Beverage_antennas.html

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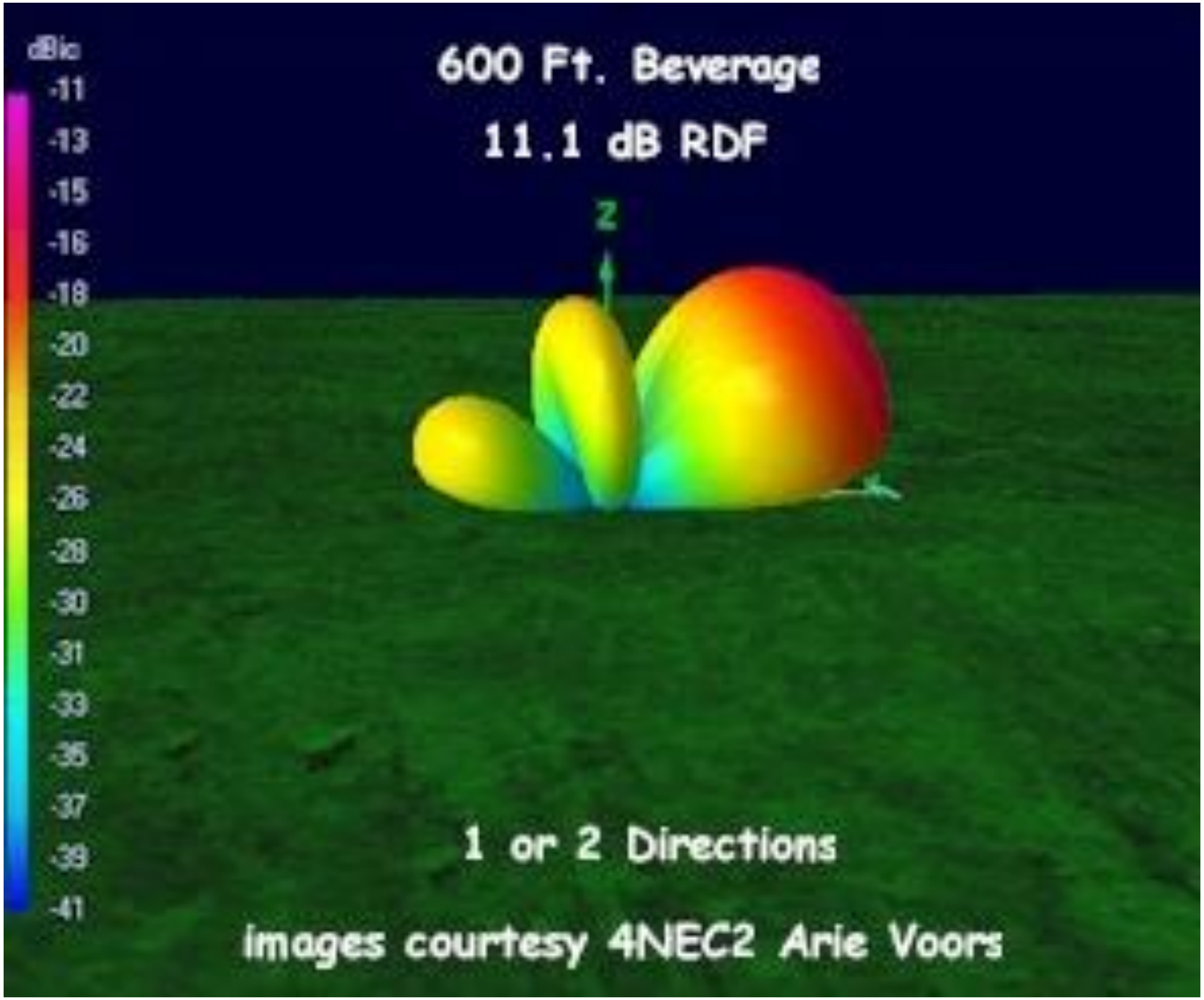
Radiation Pattern of a 600 Foot Beverage



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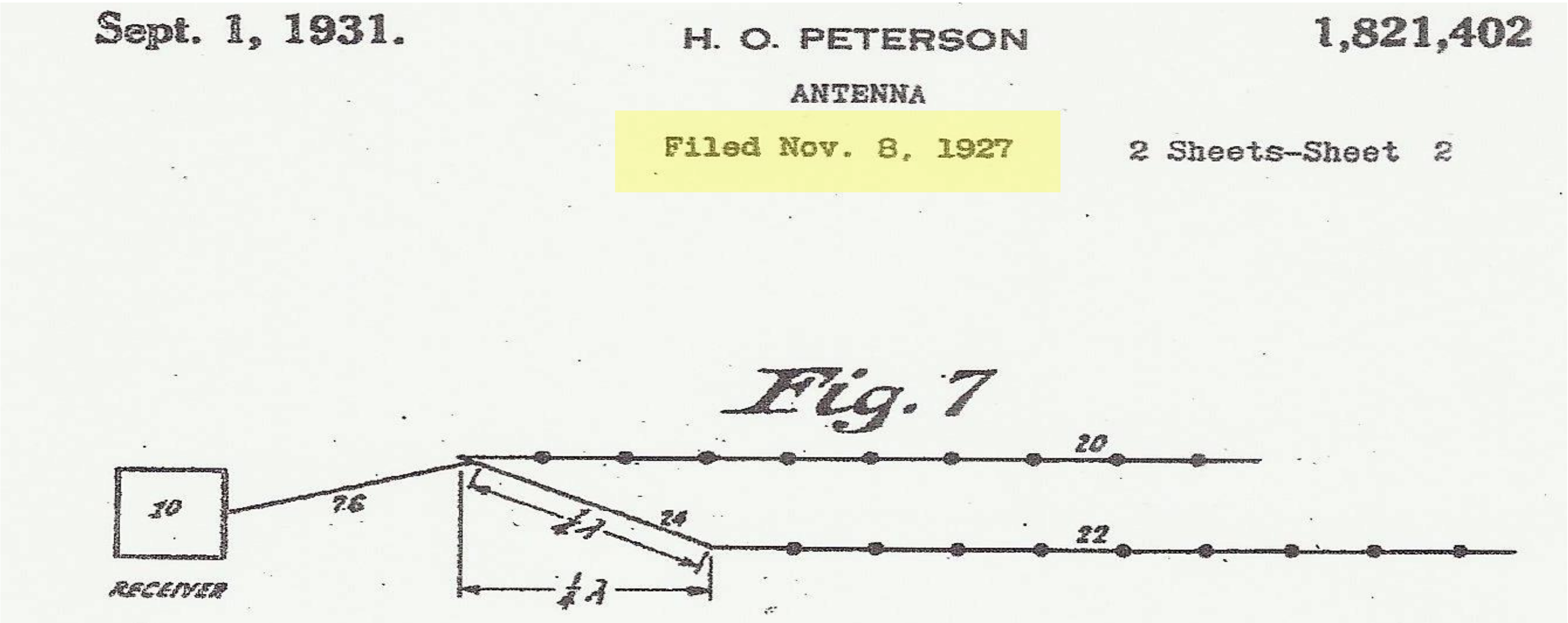
Staggered Beverage Array - 1927

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 – but only 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



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

Broadside Pair of Staggered Beverages - 1927

14 dB RDF on 8 Acres

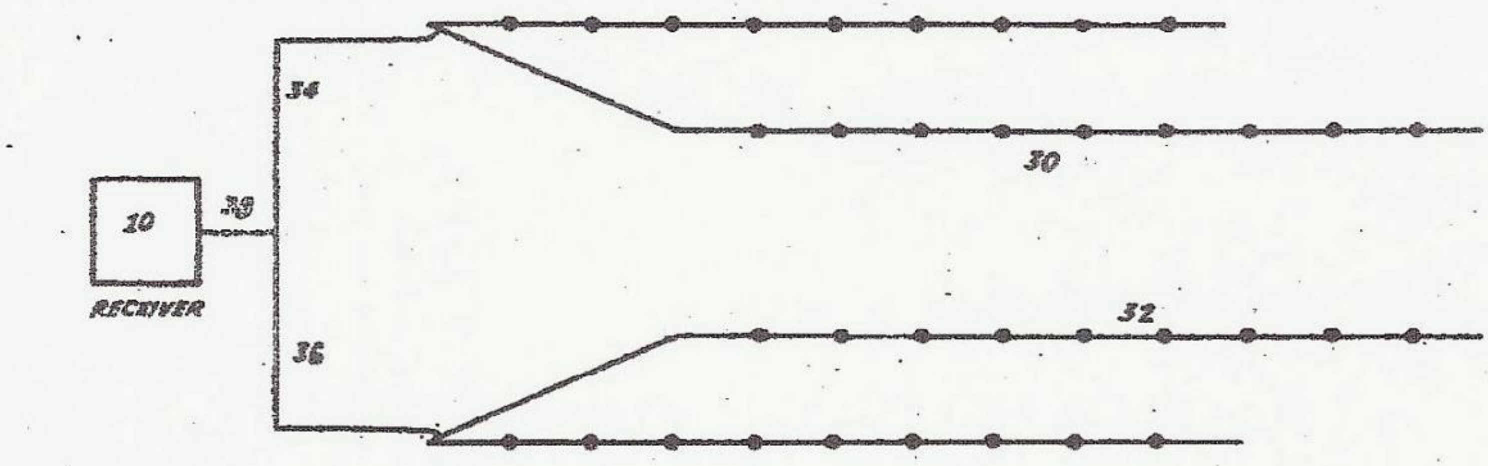
800 foot Beverages, 350 foot broad side spacing

50º 3 dB beam width

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

ANTENNA

Filed Nov. 8, 1927 2 Sheets-Sheet 2



Phased *High Impedance* Verticals

Two or More 20 Foot Verticals

No radials

No umbrella wires

Switchable in multiple directions

Multi-band operation with compromise 65 foot element spacing

80 foot element spacing for improved 160 meter performance

- somewhat closer spacing is possible by using a variable phase controller

High input impedance amplifier at the feed point of each vertical

- stray capacitance must be reduced to a very low amount in the construction of the feed point of each vertical and amplifier input

Verticals must not be installed within ten feet of nearby objects

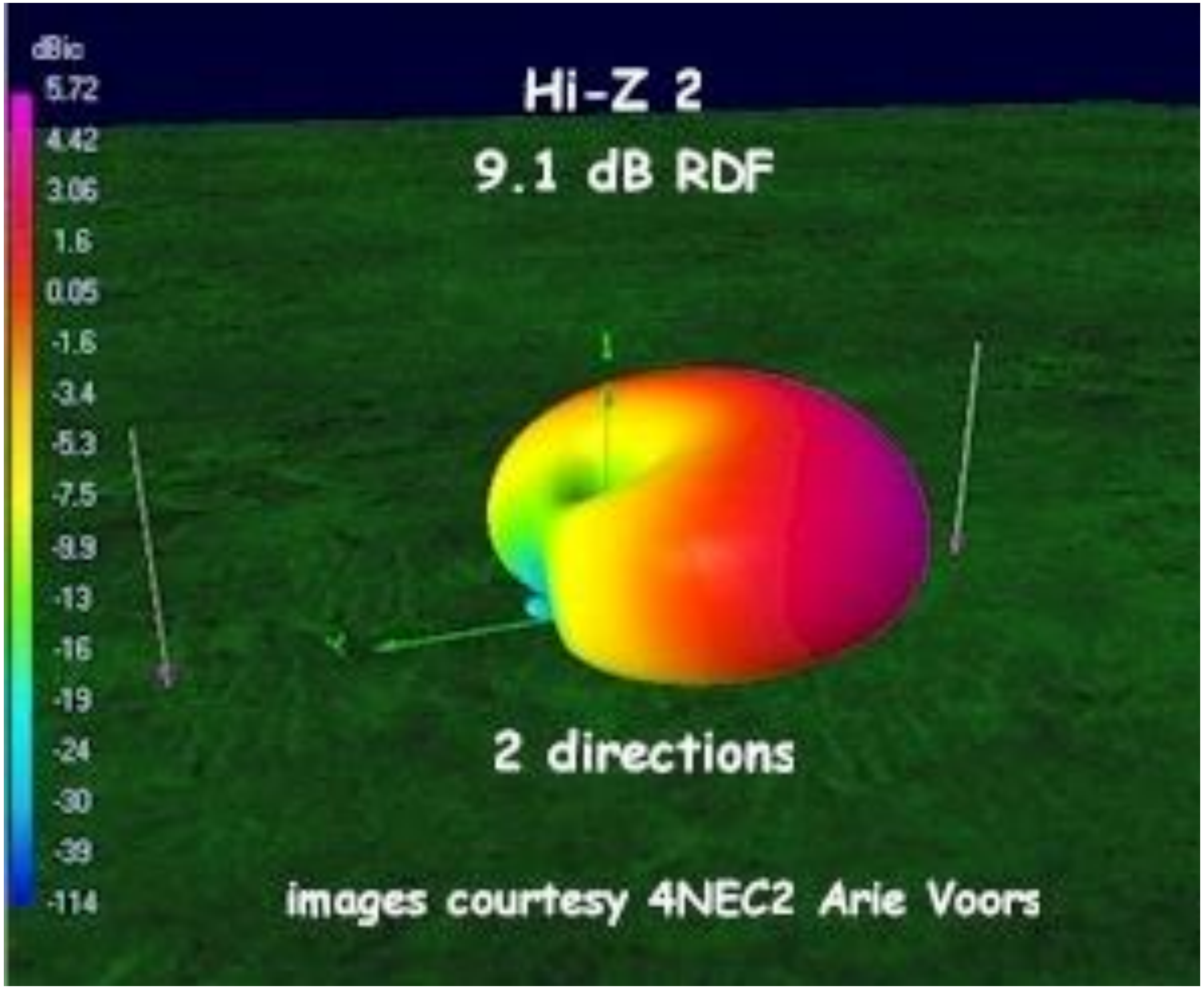
- Avoid nearby trees or any conductive or partially conductive structure

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

9 dB RDF in 80 feet or less



Electrically Steerable 4-Square Vertical Array

12 dB RDF on less than ¼ acre

four *high impedance* 20 foot verticals

no radials   no umbrella wires

80 x 80 foot square x 20 feet high

high input impedance amplifier at the base of each vertical

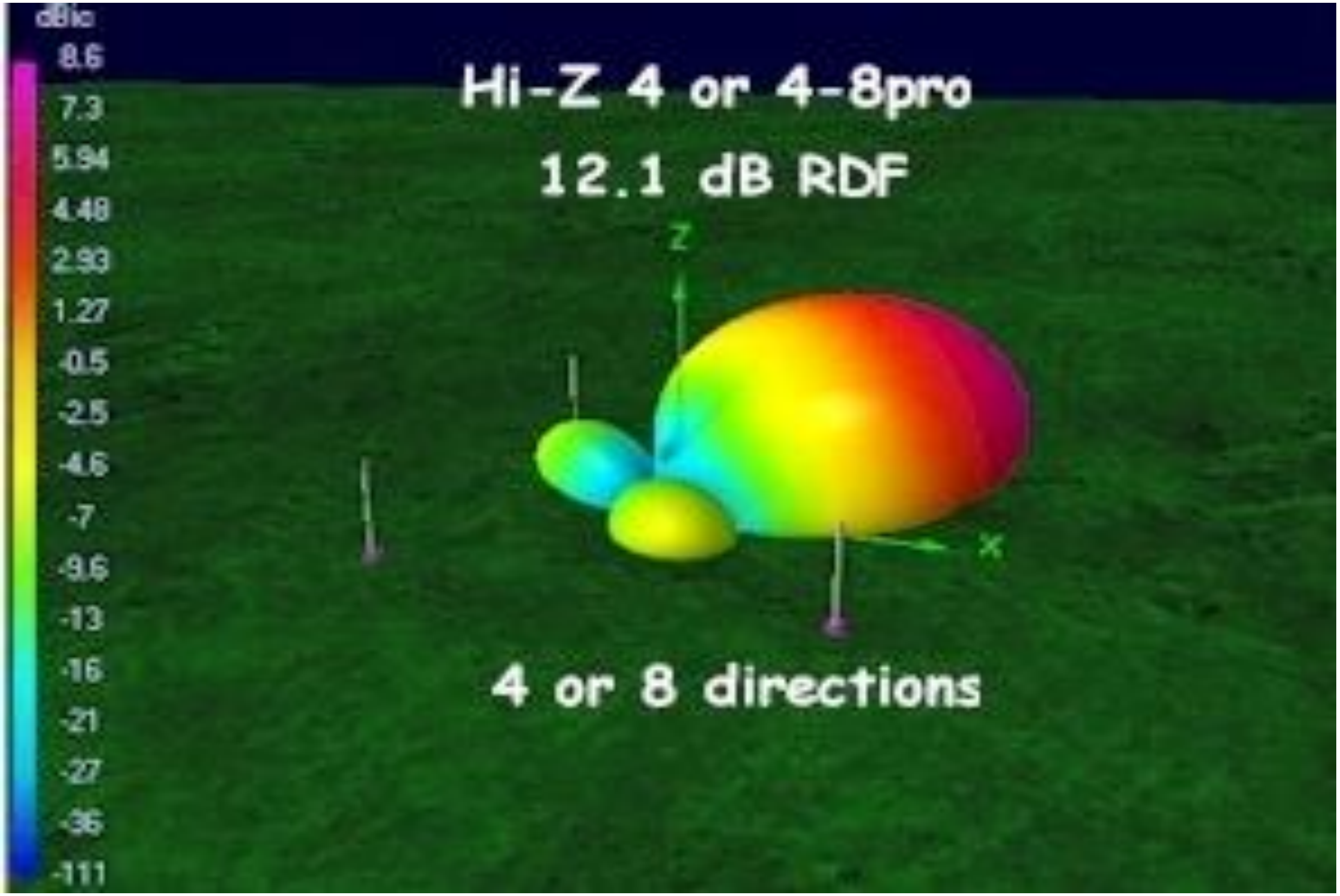
switchable in four or eight directions

100º 3 dB beam width

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

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

12 dB RDF on less than ¼ acre



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

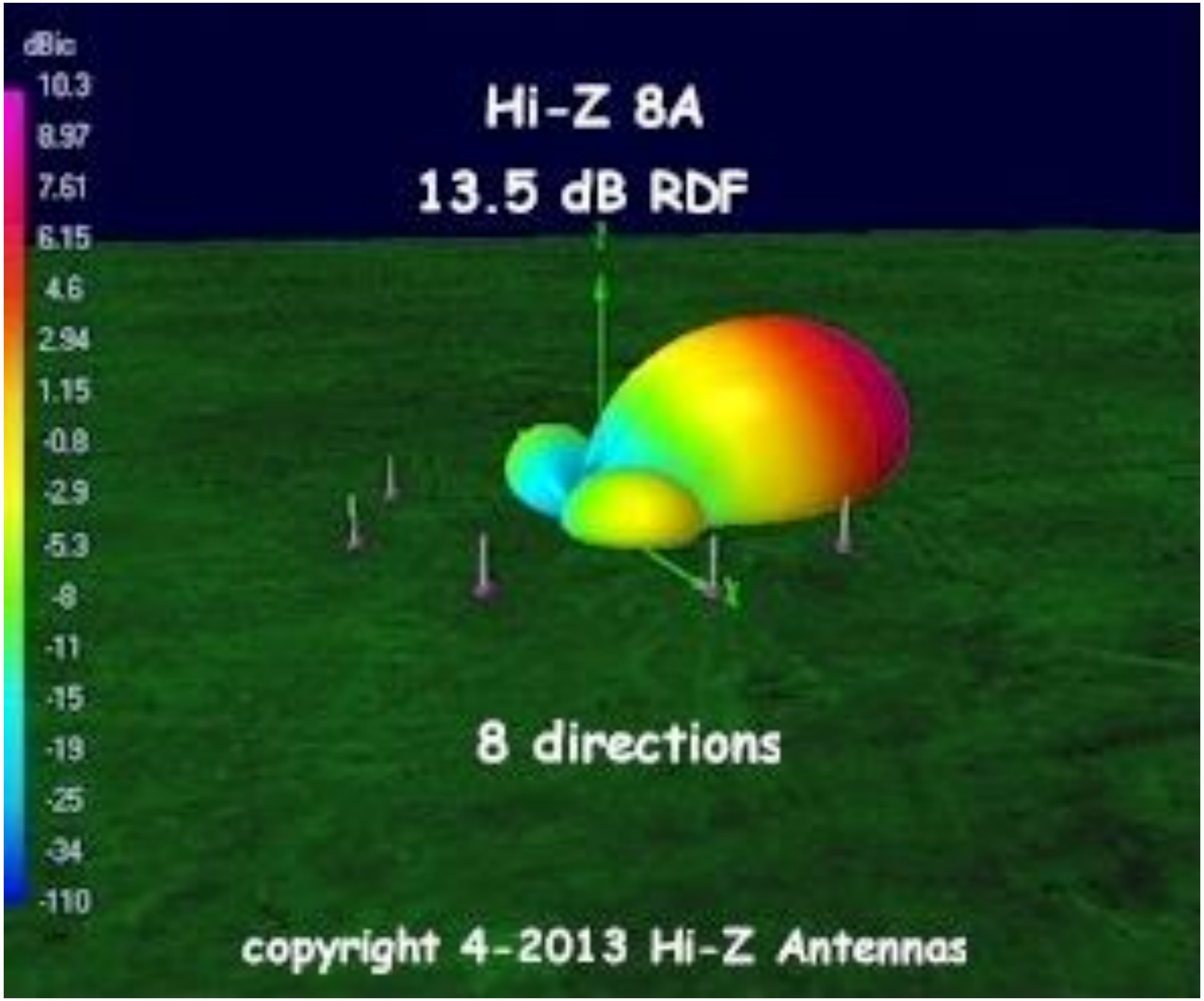
requires a high input impedance amplifier at the base of each vertical

only 200 feet in diameter

switchable in eight directions with 106º phasing

50º 3 dB beam width, equivalent to a 5 element Yagi

200 Foot Diameter 8-Circle Array Radiation Pattern



High impedance verticals with 106^{o} phasing

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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 azimuth steps respectively
- 80º 3 dB beam width
- slightly wider beam width and slightly lower RDF on 80 and 40 meters

120 feet in diameter

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

static.dxengineering.com/global/images/instructions/dxe-yccc-3inline.pdf

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
- or use 35 foot verticals with no umbrella wires

As little a 65 foot element spacing

- small spacing works best when used with a variable phase controller

Amplifiers not needed at the base of each vertical - better 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

Excellent Performance and High Reliability

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 radials or sixteen 35 foot radials per vertical
65 x 65 foot square footprint plus additional space for short radials
switchable in four directions
easy and inexpensive to build
100º 3 dB beam width

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

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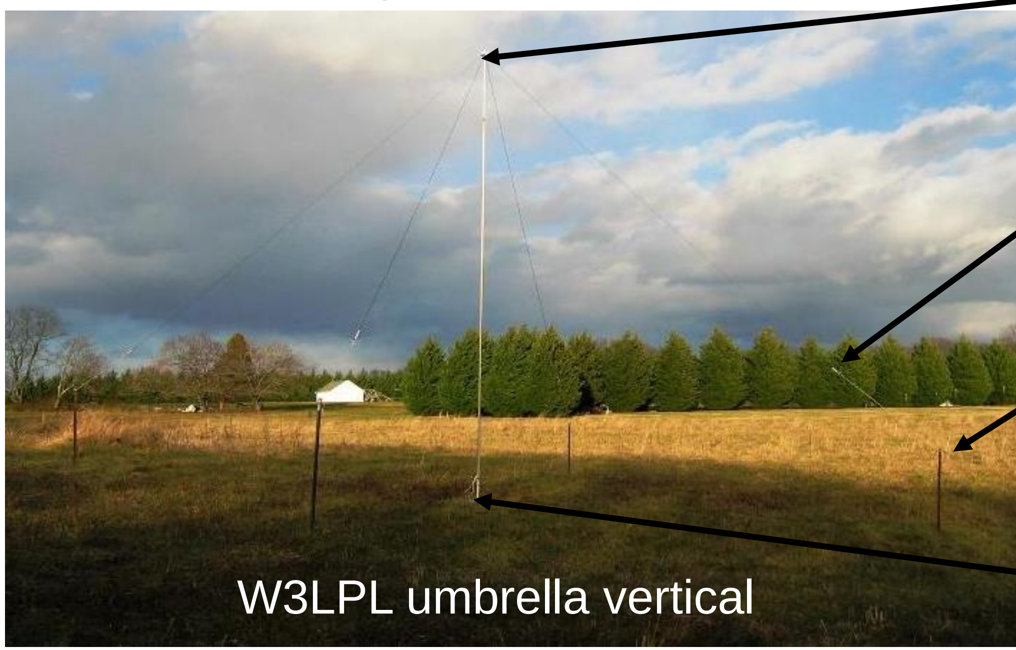
Electrically Steerable 8-Circle Vertical Array

13.5 dB RDF on four acres

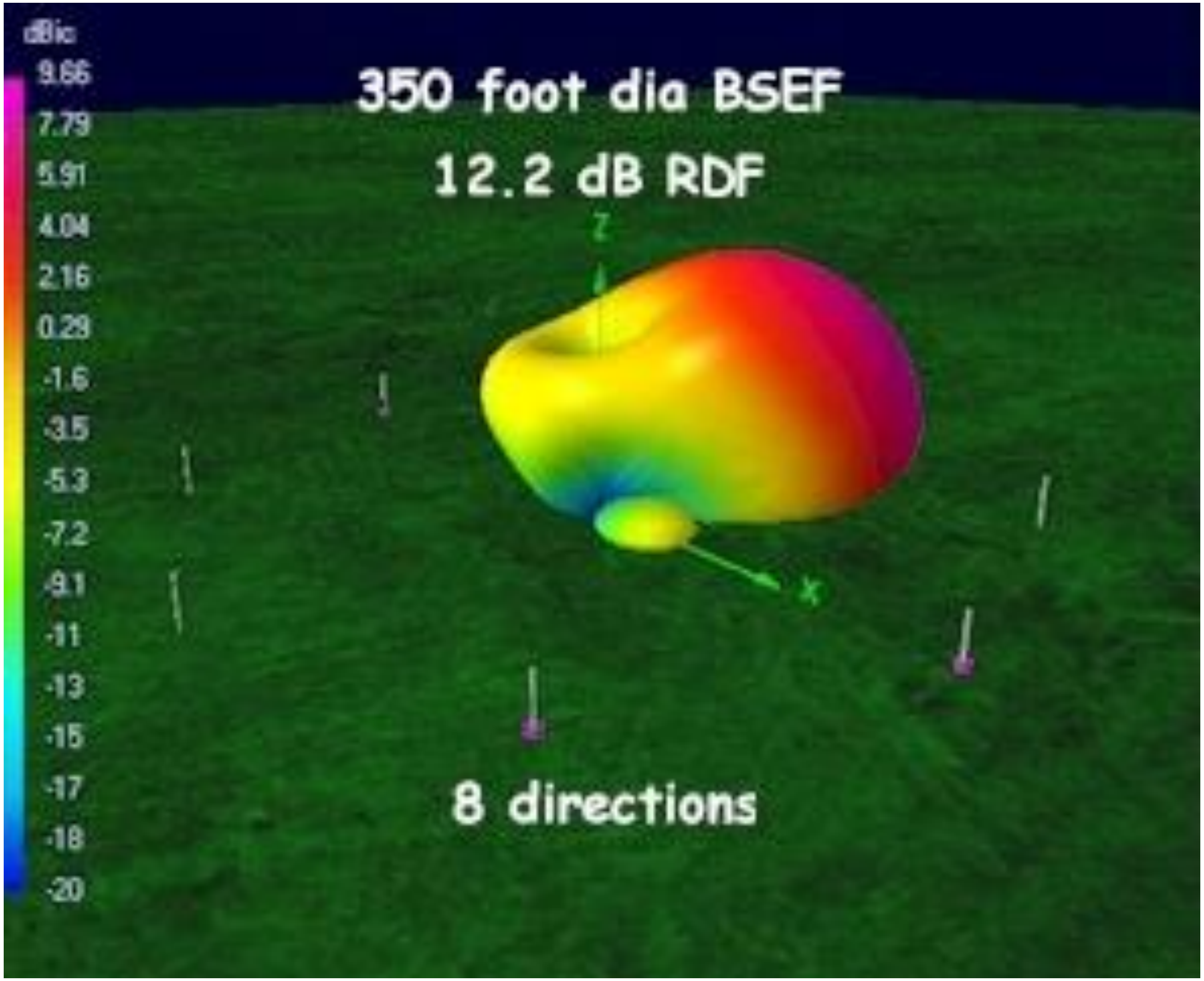
eight *low impedance* 25 foot umbrella verticals
four 25 foot umbrella wires installed on each vertical
eight 70 foot radials or sixteen 35 foot radials installed under each vertical
350 foot diameter plus space for radials
or only 200 foot diameter when used with a Hi-Z 106º phasing controller
switchable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



W3LPL umbrella vertical

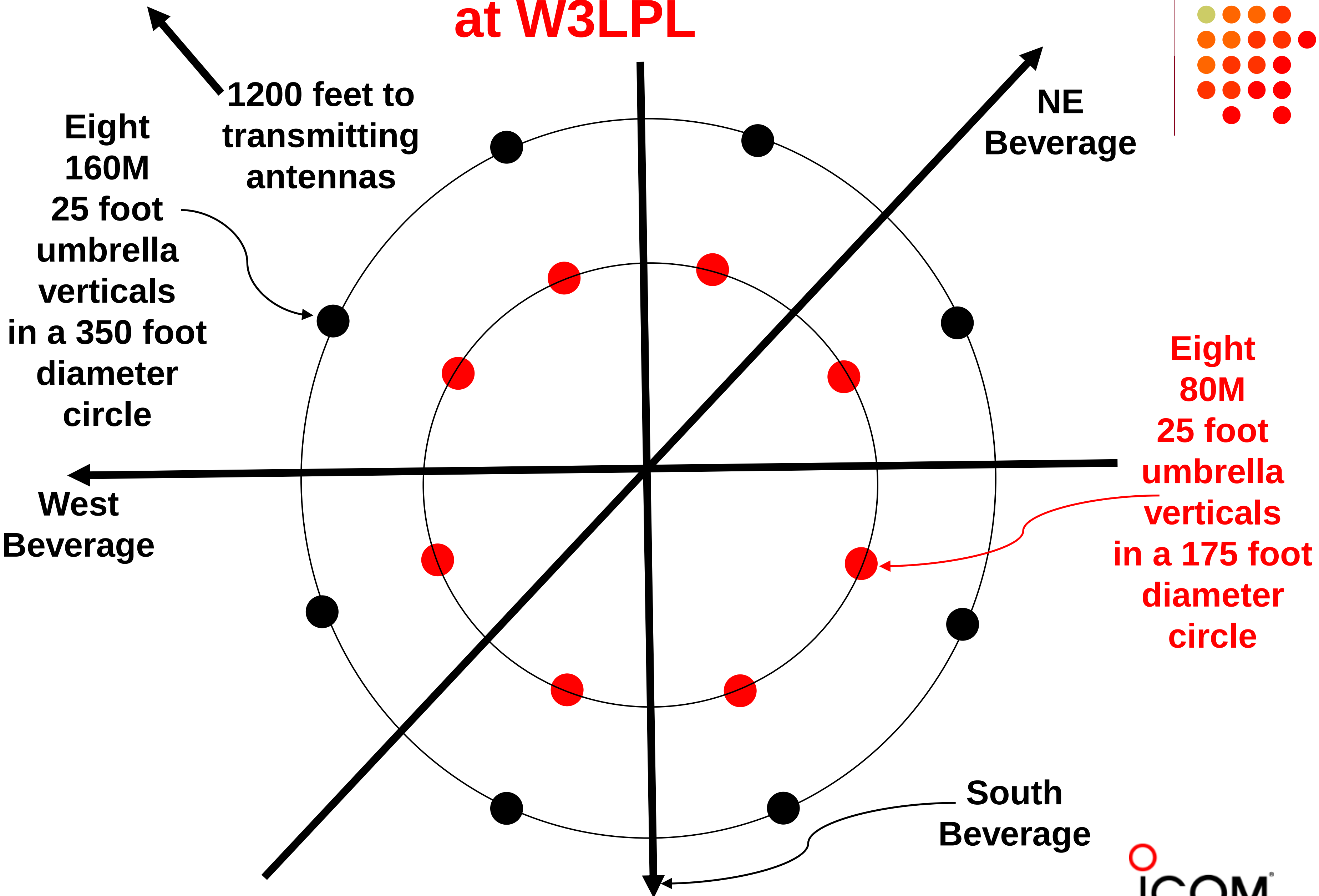
construction details: www.w5zn.org

350 Foot Diameter 8-Circle Array Radiation Pattern



Four phased elements with 115^{o} end fire phasing

160 and 80 Meter Receiving Antenna Layout at W3LPL



Receiving Antenna Phasing System
DX Engineering NCC-2

Combines the inputs from two antennas
- creates a directional pattern with steerable deep nulls
- significantly improves the performance of phased Beverages and phased verticals
- very well engineered and exceptionally easy to use

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dxengineering.com/parts/dxe-ncc-2

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Phase Synchronous Diversity Reception

Two widely spaced antennas (at least 500 foot spacing) feed two identical high performance phase locked receivers

Elecraft K3s transceiver with KRX3 sub-receiver

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