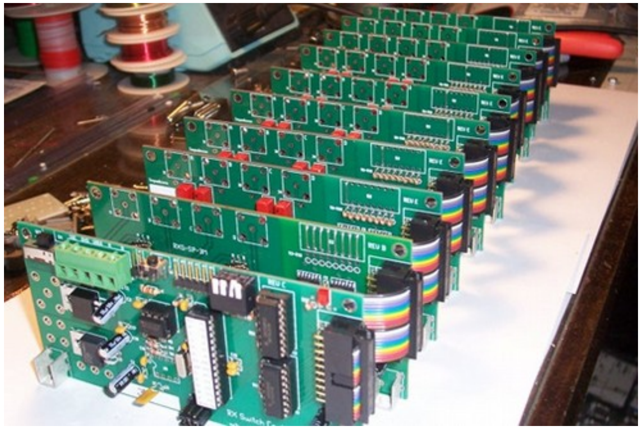
THIS DOCUMENT WAS PRESENTED AT HAM-COM 2016. AS SUCH, SOME INFORMATION PERTAINING TO REGULATIONS MAY NOT REFLECT CURRENT PART 97 RULES.

Low and Medium Frequency

Receive Antennas

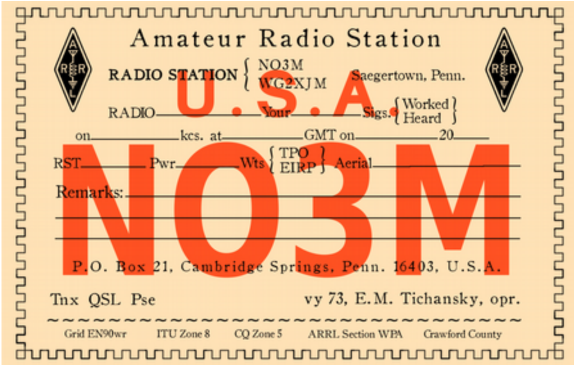
and related topics....



Eric Tichansky
NO3M - WG2XJM

… about NO3M

- Licensed in May 1995 (13 yrs old); Extra Feb 1996
- Activities primarily Contesting and DXing
- Favorite band 160M
- **241 confirmed entities** on 160M since Dec 2010
- **TOP TEN 160M** Contest finishes
    - **ARRL 160M**; 2010 (#7), 2012 (#9), 2013 (#5), 2014 (#4), 2015 (#3)
    - **CQ 160M CW**; 2011 (#9 US), 2012 (#5 US), 2013 (#6 US), 2014 (#4 US), 2015 (#5 US)
    - **Stew Perry - TBDC**; 2010 (#3 SOLP), 2011 (#3 SOQRP), 2012 (#5 SOHP), 2013 (#1 SOHP NA), 2014 (#3 SOHP), 2015 (#4 SOHP)



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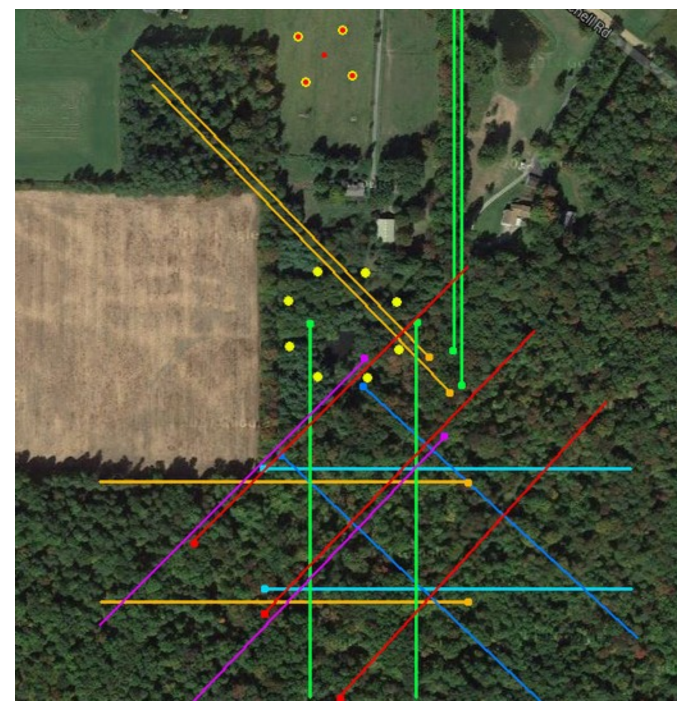
… NO3M 160M Antennas

- **Transmit Antenna**
  - Four Square
  - 90-ft top loaded elements
  - 22,000-ft radials

- **Receive Antennas**
  - E, SE, S, SW, W
    - ➔ Broadside array of two 1000-ft beverages, spaced 300-ft between elements
  - N, NW
    - ➔ Two element echelon end-fire array, 1200-ft elements, 100-ft staggering, 15-ft spacing, 130 deg phasing
  - NE
    - ➔ Broadside array of three 1000-ft beverages, spaced 300-ft between elements, 1 : 2 : 1 current feed

  - BSEF 8-circle Vertical Array
    - ➔ 20-ft elements, each with (4) 20-ft top loading wires. Base loading accomplished with T94-3 toroid inductor (~ 31 uH) to resonate at 1828 kHz
    - ➔ W9RE phasing / switching controller

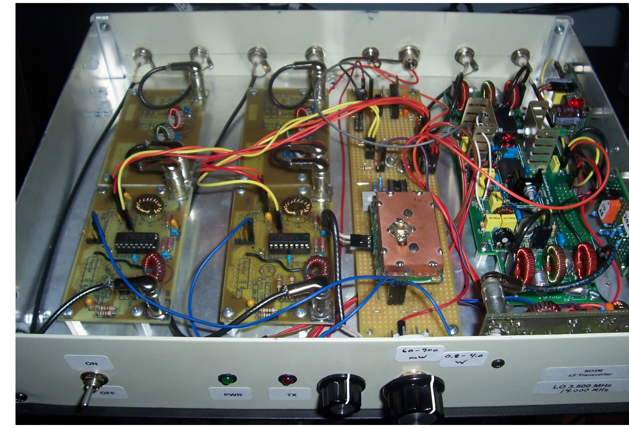
NO3M



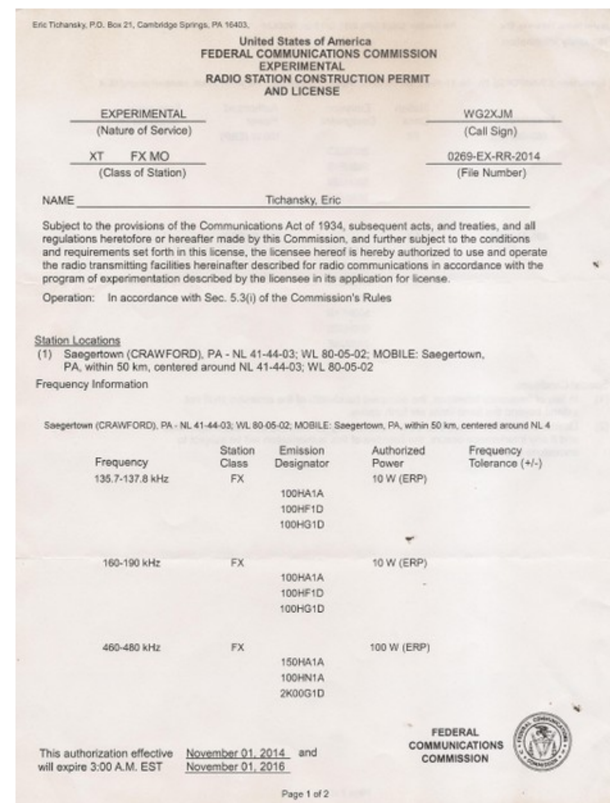
NO3M

… WG2XJM Story

- **Winter 2011**
  - **Receive only**
    - 630M, NDB, 2200M
    - AMRAD up-converter and K3
- **Spring 2012**
  - **Issued WD2XSH/46 under ARRL's Part 5 Experimental grant**
    - Shared geographic allocation with WD2XSH/29
    - Part 5 grant allows "mobile" station within 50 km (31 mi) of base coordinates
    - NO3M QTH 28 mi (45 km) from WD2XSH/29 in Conneaut OH
- **Fall 2012**
  - **Applied for and granted WG2XJM**
    - Higher power limit (100W ERP)
    - More emission modes



NO3M



Eric Tichansky, P.O. Box 21, Cambridge Springs, PA 16403.

United States of America
FEDERAL COMMUNICATIONS COMMISSION
EXPERIMENTAL
RADIO STATION CONSTRUCTION PERMIT
AND LICENSE

EXPERIMENTAL (Nature of Service) — WG2XJM (Call Sign)

XT FX MO (Class of Station) — 0269-EX-RR-2014 (File Number)

NAME Tichansky, Eric

Subject to the provisions of the Communications Act of 1934, subsequent acts, and treaties, and all regulations heretofore or hereafter made by this Commission, and further subject to the conditions and requirements set forth in this license, the licensee hereof is hereby authorized to use and operate the radio transmitting facilities hereinafter described for radio communications in accordance with the program of experimentation described by the licensee in its application for license.

Operation: In accordance with Sec. 5.3(i) of the Commission's Rules

Station Locations

(1) Saegertown (CRAWFORD), PA - NL 41-44-03; WL 80-05-02; MOBILE: Saegertown, PA, within 50 km, centered around NL 41-44-03; WL 80-05-02

Frequency Information

Saegertown (CRAWFORD), PA - NL 41-44-03; WL 80-05-02; MOBILE: Saegertown, PA, within 50 km, centered around NL 4

Frequency	Station Class	Emission Designator	Authorized Power	Frequency Tolerance (+/-)
135.7-137.8 kHz	FX	100HA1A 100HF1D 100HG1D	10 W (ERP)	
160-190 kHz	FX	100HA1A 100HF1D 100HG1D	10 W (ERP)	
460-480 kHz	FX	150HA1A 100HN1A 2K00G1D	100 W (ERP)	

This authorization effective November 01, 2014 and will expire 3:00 A.M. EST November 01, 2016

FEDERAL COMMUNICATIONS COMMISSION

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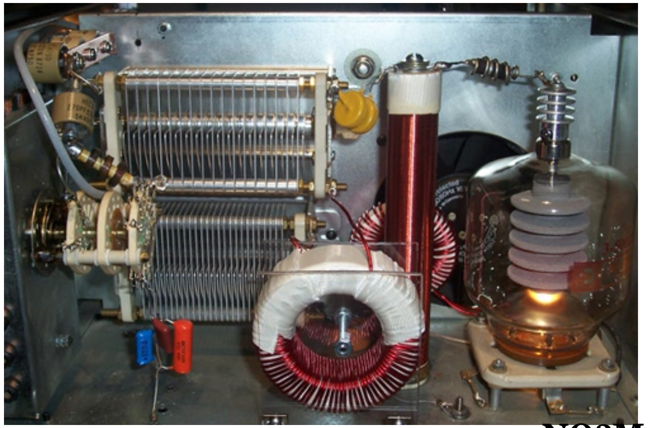
NO3M

… NO3M 630M Station

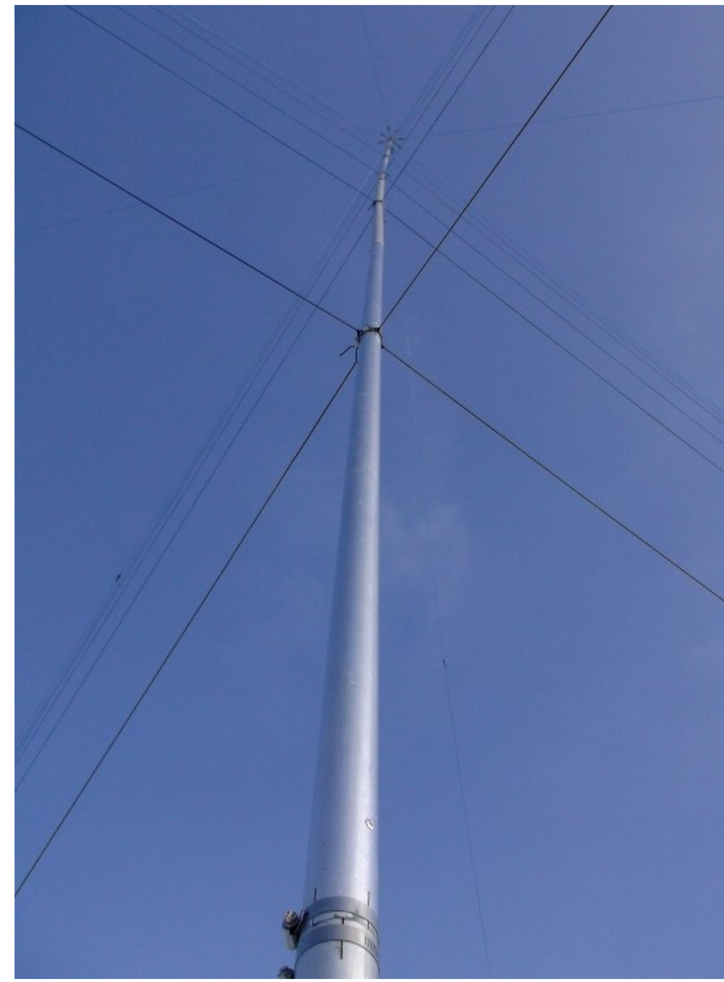
- **Transceiver**
  - Elecraft K3 with sub-receiver
  - 1 mW output (10.475 MHz) from transverter port
  - Setup for direct freq. readout
- **Transverter**
  - VK3XDK design
  - Dual RX channels
  - +17 dBm Mixers (Mini-Circuits ADE-1H)
  - 10.0 MHz GPS disciplined LO (Trimble Thunderbolt)
  - 12W maximum output
- **Amplifiers**
  - 100W Linear; VK3XDK design
  - Modified Heathkit SB-1000 (single 3-500Z) - 1kW



… NO3M 630M Antennas

- **Transmit**
    - 67-ft (20.4m) aluminum tubing
    - Eight (8) 35-ft (10.7m) toploading wires
    - 22,000-ft radials (shared with 160M Four Square)
    - 5-6 ohms ground loss; approx. 15% efficiency
    - Remote tuning
        - ➔ 410 uH inductor, #12 AWG copper, 6 in. dia
        - ➔ 1000 pF vacuum capacitor
        - ➔ 10 uH roller inductor (auto-transformer)

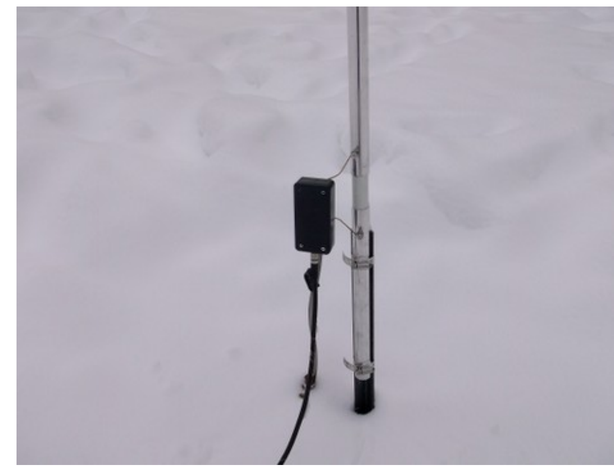
NO3M



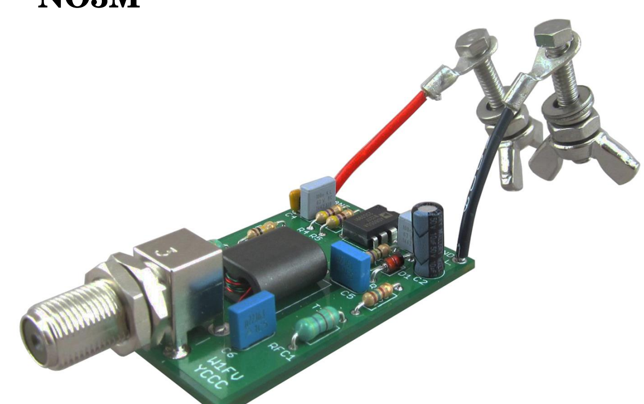
NO3M

… NO3M 630M Antennas, cont.

- **Receive**
  - 160M beverage arrays
  - 27-ft vertical; YCCC hi-impedance amplifier
  - 630M BSEF 8-circle Vertical array
    - 1140-ft (348m) broadside spacing
    - Contained in 30 acre (12 ha) square
    - Believed to currently be the largest Amateur circular array in the world based on required area
  - Antenna routing
    - Custom remote switching matrix
    - 24 antennas (expandable) to 4 receivers
    - Desktop controllers connect via RS-485
    - Main switching hub located 600-ft from shack



NO3M



DX Engineering

NO3M

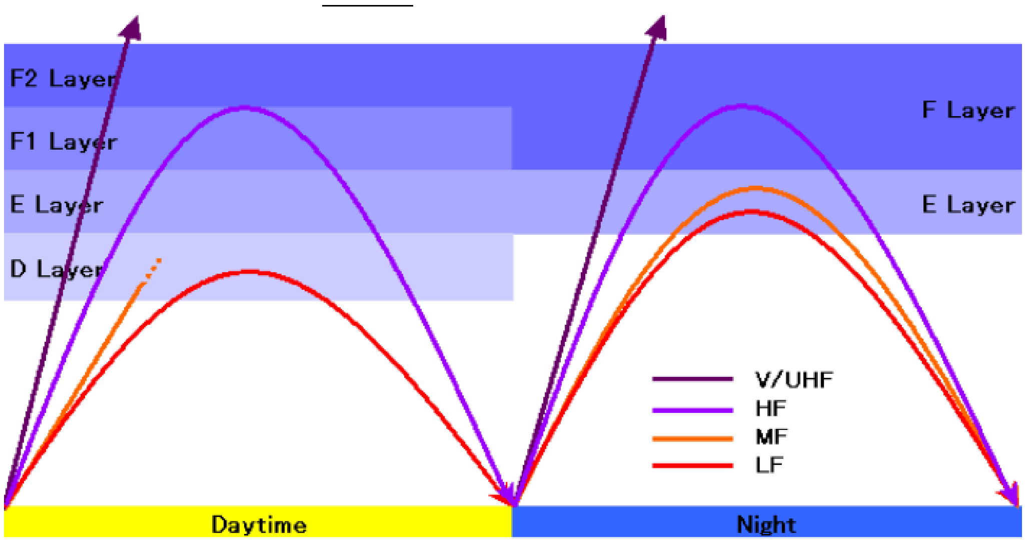
NO3M

… about 2200M / 630M

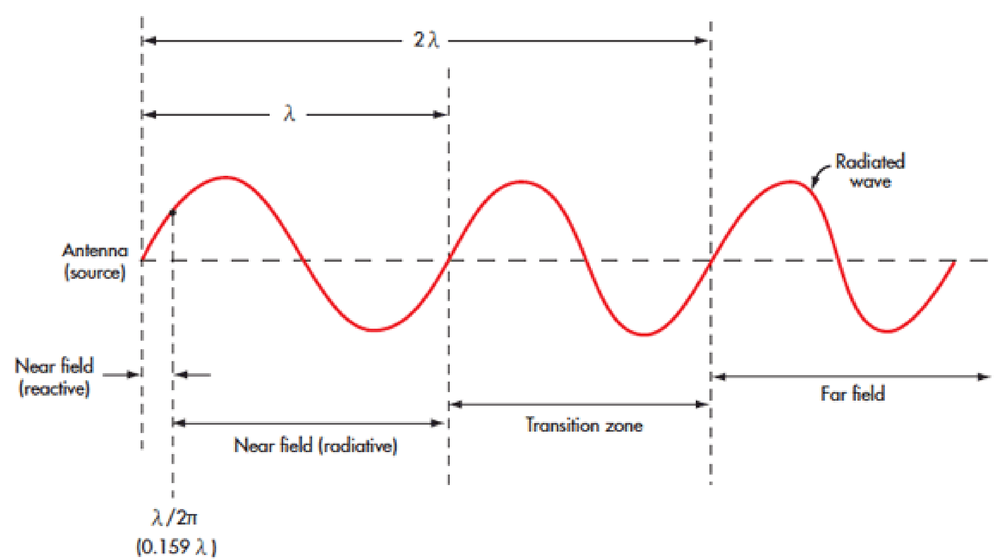
- **LF (Low Frequency)**
  - ITU designation for frequency range of 30 – 300 kHz
  - Includes 2200M band
  - Ground wave ranges up to 1200 mi
  - Daytime D-layer reflection
  - Night-time E-layer reflection

- **MF (Medium Frequency)**
  - ITU designation for frequency range of 300 kHz – 3 MHz
  - Includes 630M band, AM BC, 160M band
  - Daytime D-layer absorption
  - Night-time E-layer reflection

- **Wavelengths**
  - 2200M
    - → 1λ = 7235ft, 1/2λ = 3618ft, 1/4λ = 1809ft
  - 630M
    - → 1λ = 2071ft, 1/2λ = 1036ft, 1/4λ = 517ft
  - → 160M
    - → 1λ = 547 ft, 1/2λ = 273 ft, 1/4λ = 137 ft
  - Near-field generally within 1λ radius
  - Far-field begins 1λ - 2λ radius

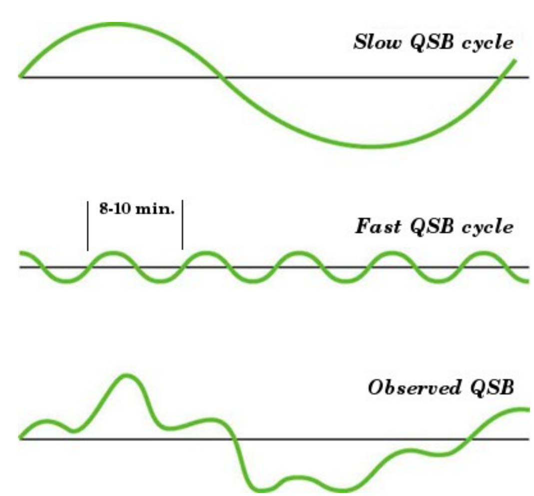


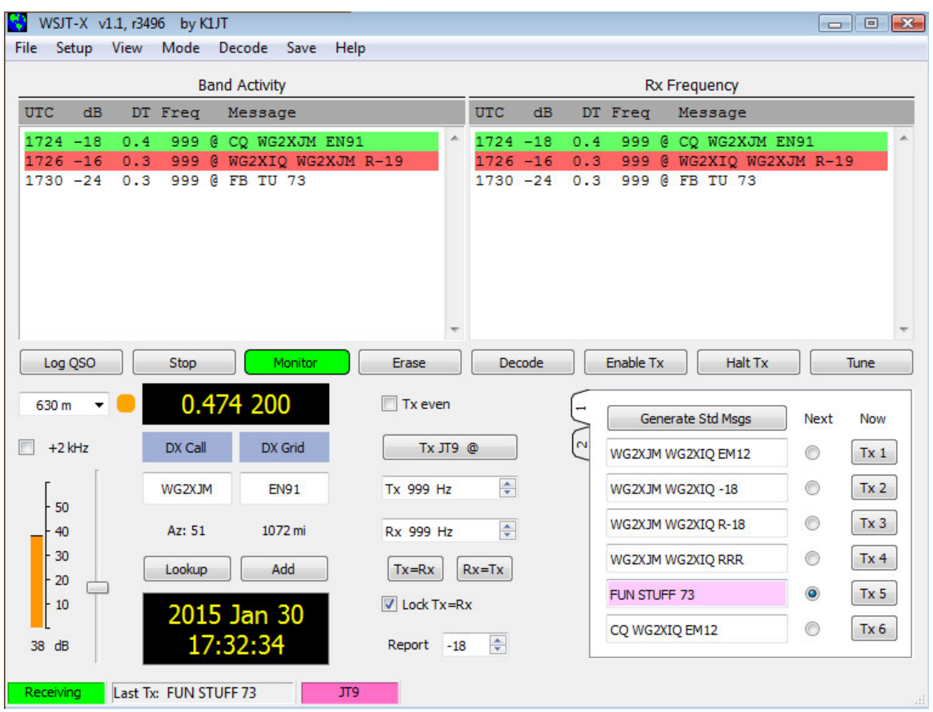
Ionospheric reflection
(under normal condition)



… observations on 630M

- **Overall propagation similar to 160M**
  - *Gray line*
  - *Solar event enhancements*
- **Prominent N/S and E/W paths at times**
- **Two superimposed cycles of QSB generally observed**
- **Long range 2-way openings during daytime in winter**
  - *JT-9 QSO between WG2XJM (PA) and WG2XIQ (TX) on Jan 30, 2015 at 1724 GMT;* ***1116 mi.***





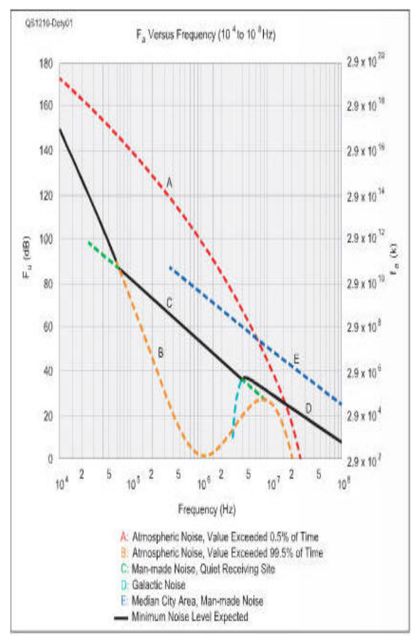


Figure 1 — Signal strength of cosmic noise (D) and atmospheric noise (A) plotted against frequency. From ITU Recommendation ITU-R P.372.

- **QRN (atmospheric)** generally 6-24 dB (*1-4 S-units*) greater than 160M

160M

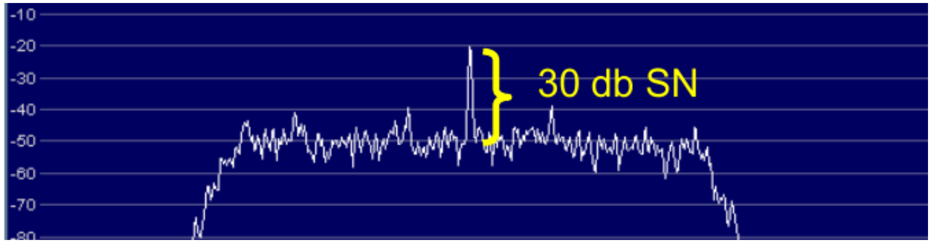
630M

KB5NJD

… why Receive Antennas at LF / MF

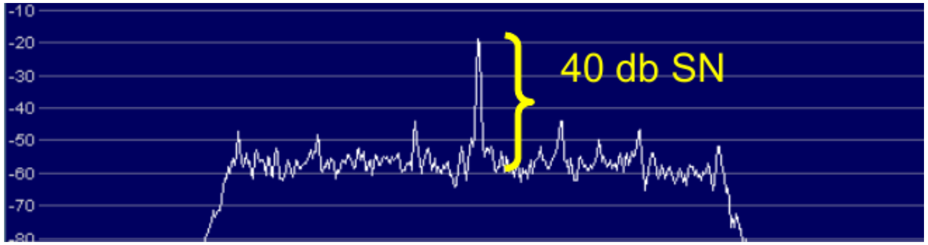
- **Improve Signal to Noise Ratio (SNR) as compared to transmit antenna(s)**
  - Most transmit antennas used on 630M and 2200M are omni-directional, therefore no noise discrimination in the azimuthal plane at a particular elevation angle
  - Due to the nature of an EIRP power limit, directional transmit arrays don't make sense
  - Everyone limited to 5W EIRP on transmit, therefore biggest rewards will be from improving reception abilities
  - Improved SNR facilitates:
    - increased signal intelligibility combating QRN, QRM, and QSB
    - ability to pull-out weak signals
  - Gain and efficiency are not important as long as propagated noise exceeds "system" noise (LNA, receiver, et.al.). This allows for smaller size, less mutual coupling (simplifies overall design of arrays), and reduced overall cost compared to transmit type arrays

Omni-directional Transmit Vertical



N4IS

Directional Receive Antenna



N4IS

… *why not directional transmit antenna on 2200M / 630M*

- **EIRP (*Equivalent Isotropic or Effective Isotropic Radiated Power*) limit pertains to RADIATED power, therefore TPO (*Transmitter Power Output*) can be increased to compensate for lack of efficiency**

  - EIRP equation using approximations derived from modeling

  ➔ $\mathbf{P_{EIRP} = P_{TPO} * \eta * G_a}$

  ➔ Units: P (watts), R (ohms)
  ➔ $\mathbf{P_{TPO}}$ is transmitter output power
  ➔ $\boldsymbol{\eta} = \mathbf{R_{RAD}} / \mathbf{R_{feed}}$ (ie. efficiency)
  ➔ $\mathbf{R_{RAD}}$ = *modeled* radiation resistance of antenna
  ➔ $\mathbf{R_{feed}}$ = total *measured* feedpoint resistance (includes $\mathbf{R_{RAD}}$, ground loss, coil loss, etc.)
  ➔ $\mathbf{G_a = 10 \wedge (G_{dBi} / 10)}$
  ➔ $\mathbf{G_{dBi}}$ = *modeled* peak antenna gain in dBi

… why not directional transmit antenna on 2200M / 630M, cont.

- **In accordance with WRC-12, FCC is likely to enforce a 1W EIRP limit for 2200M and a 5W EIRP limit for 630M**

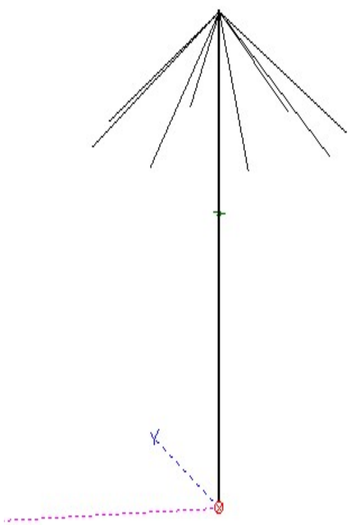
- **Speculation of a 1500W transmitter output power limit**

- **EIRP power limits perhaps more misunderstood by some Amateurs than SWR!**
  - *Directional transmit arrays provide no benefit since increased directivity / gain are countered by a lower transmitter power required to stay within EIRP limit*
  - *Example: Four Square antenna on 60M;* ***good for RX, must reduce power for TX***

- **Effective directivity can be produced by a dedicated receive antenna at generally less cost and complexity than a comparably performing transmit system**
  - full sized 1/4λ spaced transmit Four Square with large radial field vs. 1/8λ spaced receive Four Square using short verticals, hi-impedance buffer/amps and no radials

… example *630M transmit antennas*

NO3M 67-ft vertical, 8x35-ft toploading, low ground loss

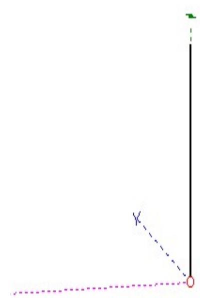


$P_{EIRP} = 5.0$ W
$R_{RAD} = 0.891\ \Omega$
$R_{feed} = 6.0\ \Omega$
$\eta = 0.149$ (14.9%)
$G_a = 1.95$ (2.91 dBi)

$P_{TPO} = P_{EIRP} / (\eta * G_a)$

$P_{TPO} =$ **17.3 W**

33-ft vertical, no toploading, high ground loss



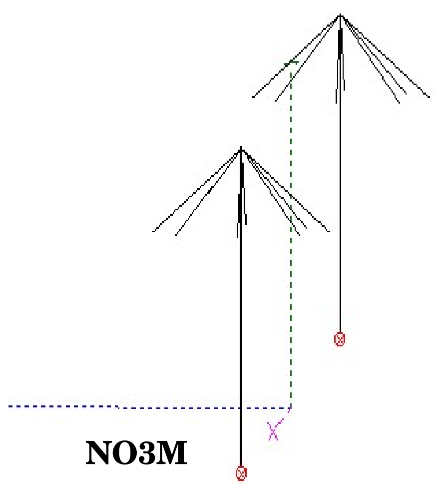
$P_{EIRP} = 5.0$ W
$R_{RAD} = 0.095\ \Omega$
$R_{feed} = 50.0\ \Omega$
$\eta = 0.002$ (0.2%)
$G_a = 1.71$ (2.33 dBi)

$P_{TPO} = P_{EIRP} / (\eta * G_a)$

$P_{TPO} =$ **1539 W**

****Extremely high voltage at base of element**

Phased 67-ft verticals with 8x35-ft toploading, spaced 518-ft, 100-deg phasing, low ground loss



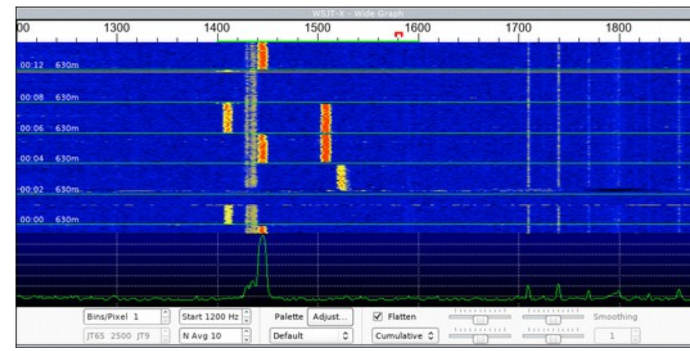
$P_{EIRP} = 5.0$ W
$R_{RAD} = 0.389\ \Omega$
$R_{feed} = 3.0\ \Omega$
$A\eta = 0.13$ (13.0%)
$G_a = 4.71$ (6.73 dBi)

$P_{TPO} = P_{EIRP} / (\eta * G_a)$

$P_{TPO} =$ **8.2 W**

… *benefits of improved SNR from receive antennas*

- **Quantity**
  - Potential to contact more overall stations that would otherwise be buried in noise on transmit antenna
- **Quality**
  - Decipher weaker stations aurally (CW) or digitally (JT-9, WSPR, etc.)
  - Deal with QSB better
  - More sustainable ragchewing sessions
  - Work stations further away (more DX!)



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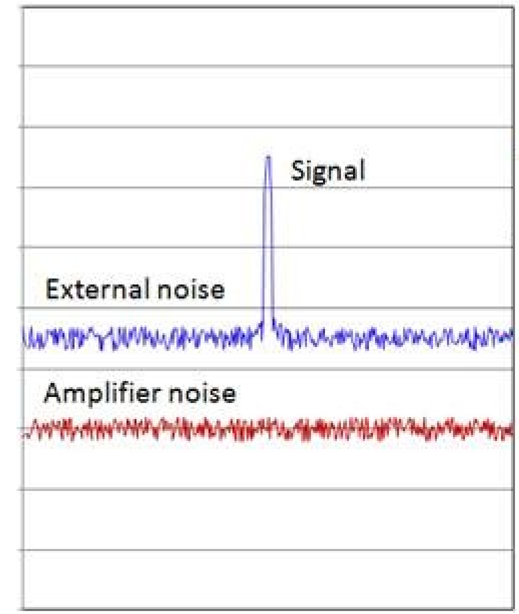
… how do we *improve SNR*

- **NOT BY INCREASING GAIN OR EFFICIENCY!**
  - Only important for transmit antennas when we **ARE NOT** limited by EIRP / ERP
  - Gain only needs to be sufficient to exceed "system" noise (ie. amplifier, receiver, et.al.)
  - Generally down to -18 to -20 dBi without a LNA (low noise amplifier, ie. preamp)
    - *Received noise increases for antenna under test vs. dummy load at quietest time of day*
  - Reduced efficiency (ie. loss) can actually be beneficial in receive antennas by increasing SWR bandwidth and reducing mutual coupling
    - *Useful for minimizing relative phase excursions in mutli-element arrays by purposely swamping elements with additional resistance*



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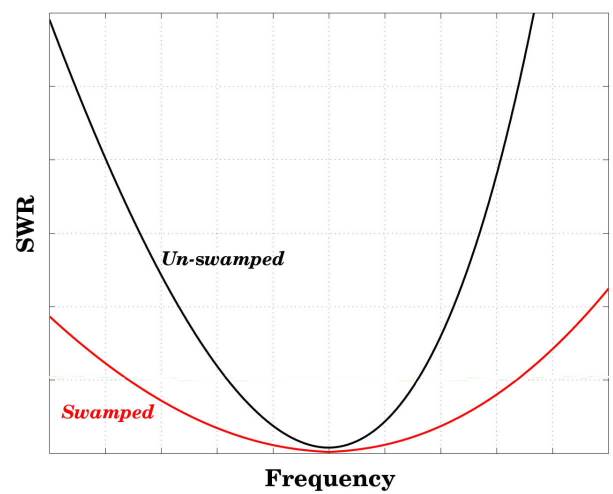
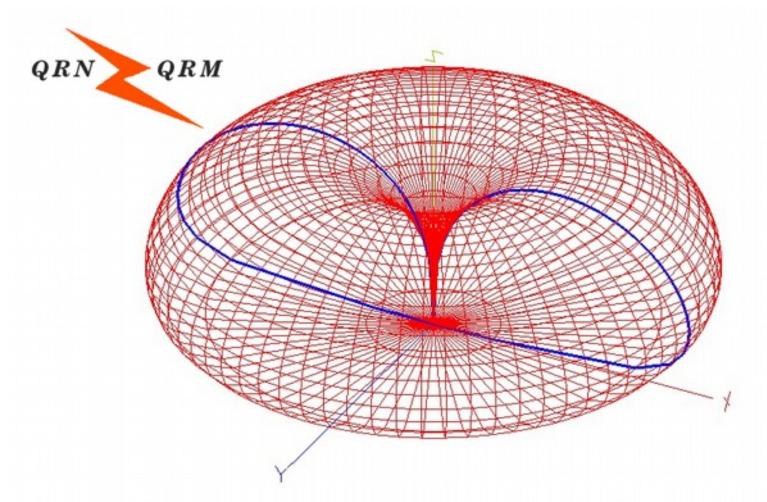


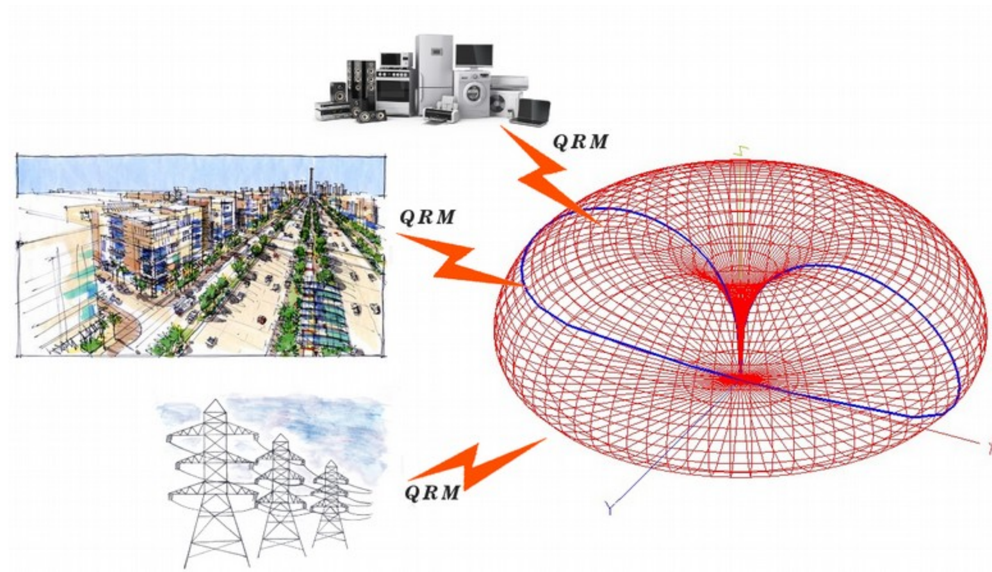
NO3M

… how do we *improve SNR,* cont.

- **Identify the type of noise we need to discriminate against**
  - **Propagated (atmospheric) noise vs. Locally Generated, man-made noise (RFI)**



NO3M

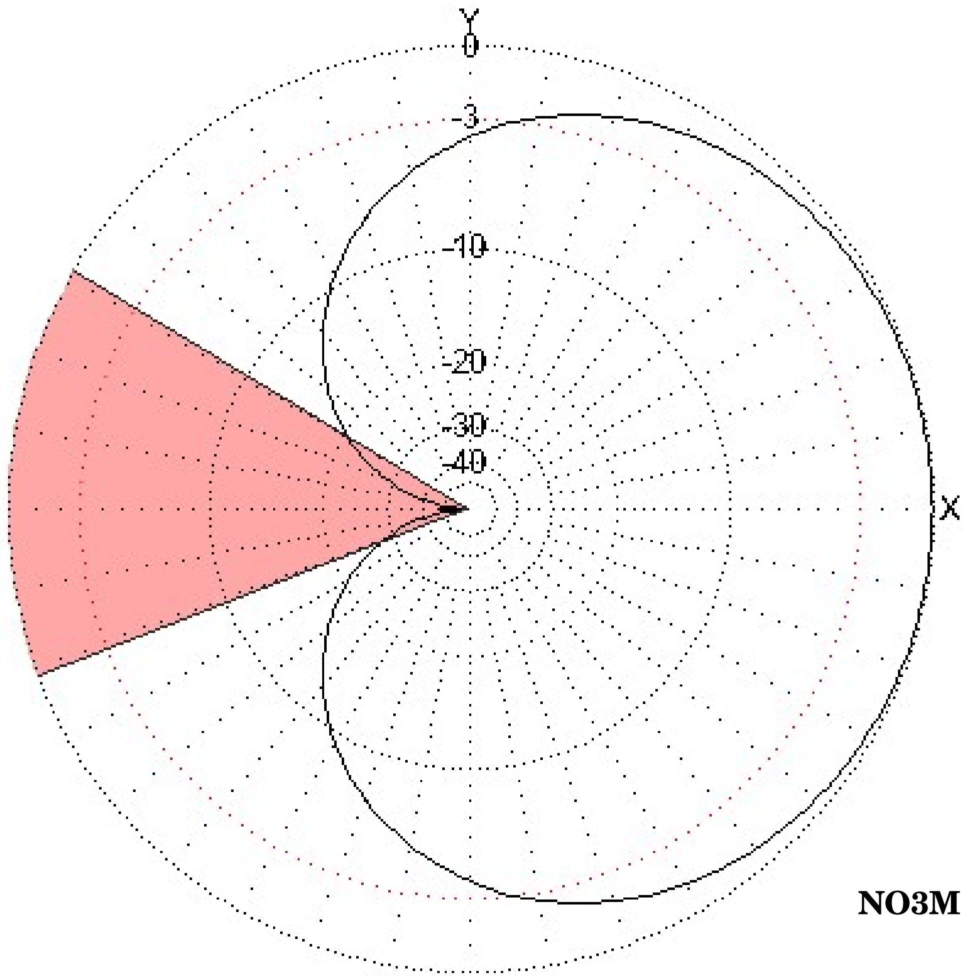


NO3M

- **Understand behavior of noise**
  - **Far-field propagated noise (atmospheric)** is randomly polarized. Same ratio of electric and magnetic fields as “signal”. Culmination of thousands of point sources. Can use antenna pattern to mitigate.
  - **Far-field groundwave noise** is vertically polarized due to conductive earth “short circuiting” horizontal electric field components. Can use antenna pattern to mitigate.
  - **Near-field (*within 1-2λ*) noise** is randomly polarized. Either electric (E) or magnetic (H) field dominate. Couples to antenna by mutual inductance (H-field) or capacitance (E-field), not E-M radiation. Best to eliminate source by removal, replacement, or RFI mitigation techniques of offending device(s) or noise cancellation

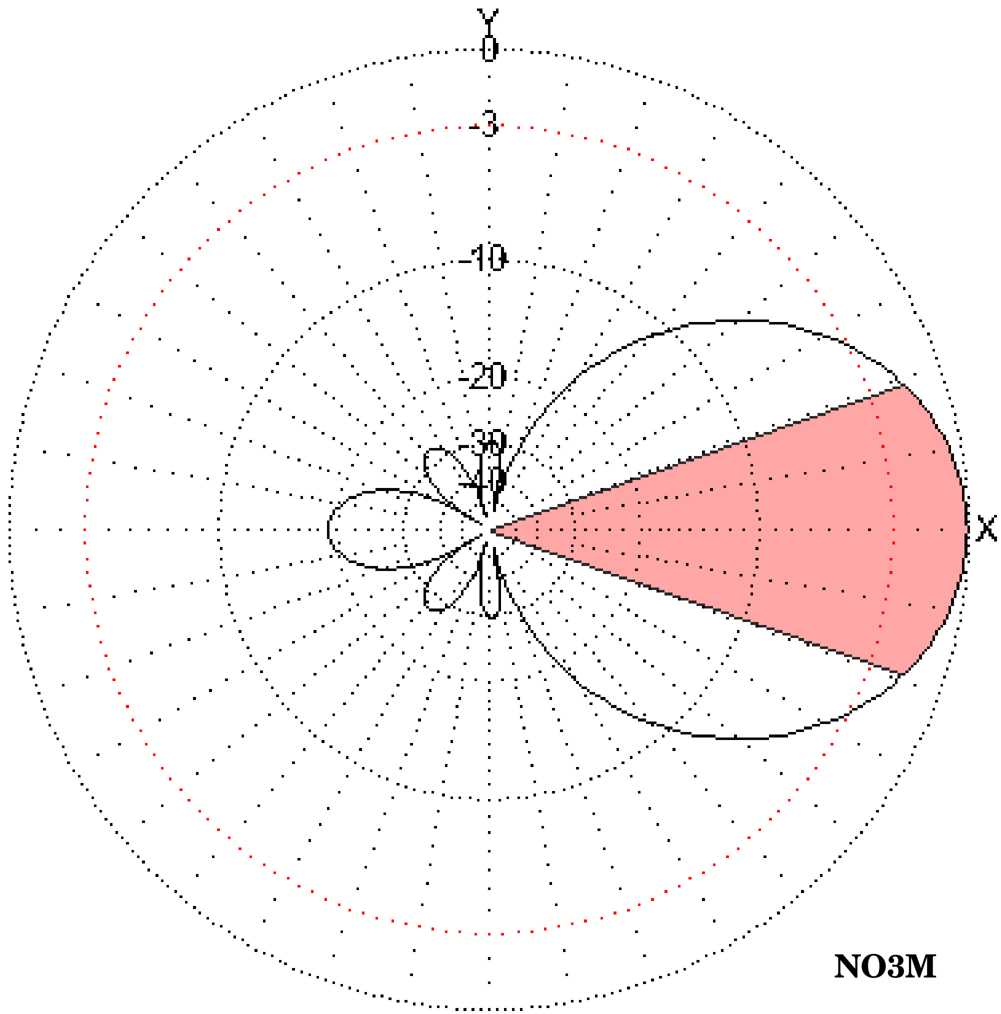
… how do we *improve SNR,* cont.

- **Antenna Radiation Pattern Characteristics**
  - **Nulls**
    - Minima in the antenna's pattern
    - Useful for discriminating against **local, man-made point sources (RFI) and propagated noise** in the far field from a ***specific azimuthal region (null sector)***



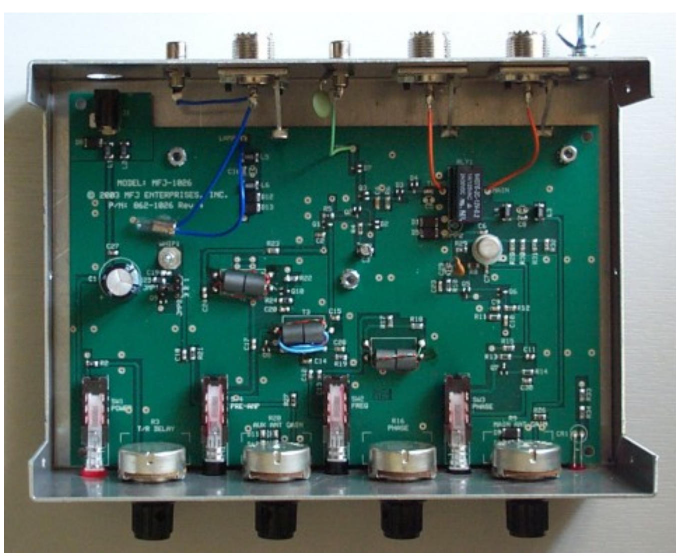
… how do we *improve SNR,* cont.

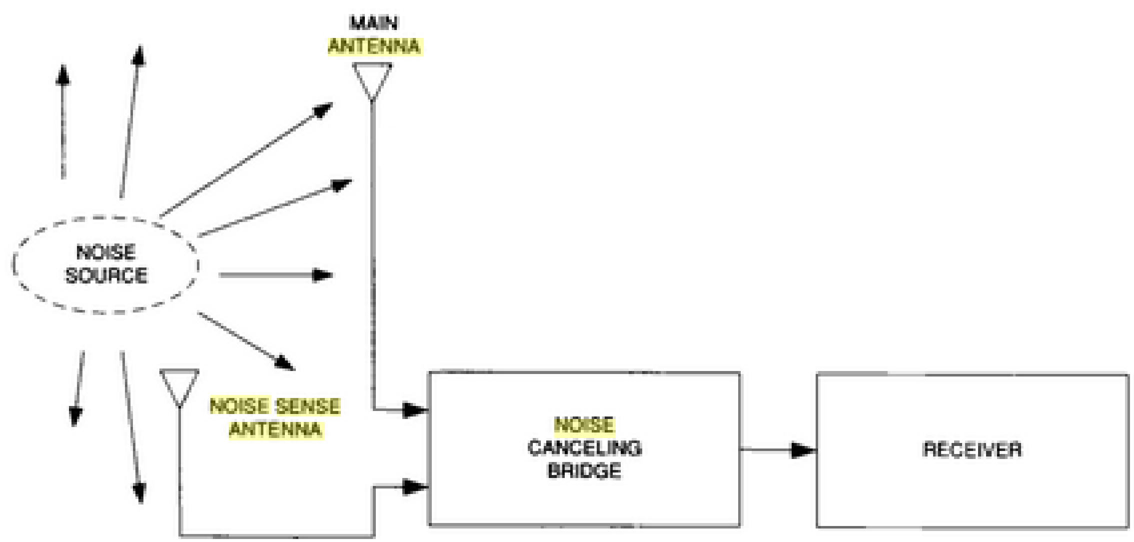
- **Antenna Radiation Pattern Characteristics**
  - **Directivity**
    - Lobes (increased sensitivity) in the antenna's pattern
    - Useful for discriminating against **evenly distributed, propagated** noise in the far field not in the direction of the main lobe
    - Quantified using RDF (Receive Directivity Factor)



… how do we *improve SNR,* cont.

- **Noise cancellation**
  - Effective for local, man-made point sources (RFI) from a ***specific azimuthal region in the near field*** (before antenna pattern is fully formed)
    - Common issue in urban and many sub-urban environments
  - **PRIMARY INTENTION NOT TO MITIGATE PROPAGATED NOISE** (could be a side-effect, however)
  - Generally implemented with dis-similar antennas, main receive antenna and "noise" sensing antenna placed closer to noise source(s)
  - Variable phase controller (eg. ANC-4, MFJ-1026, DXE NCC-1)
    - Amplitude and phase adjusted so "noise" is electronically canceled
    - Due to vector summation of arriving signals from spatially separated antennas, cancellation is only effective for noise sources from a single direction, however, other directions may be adequately attenuated
  - Results are generally unpredictable and requires experimentation with noise antenna type and location

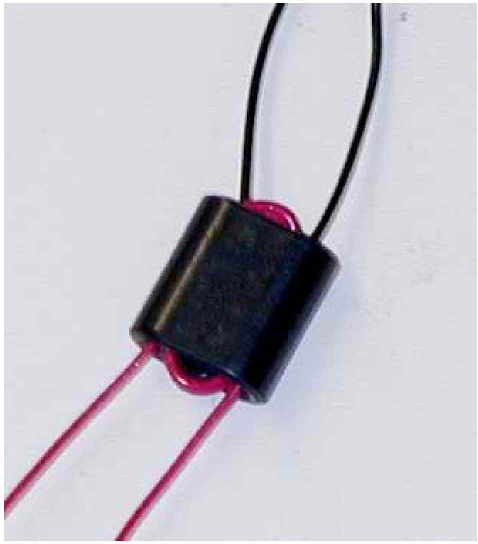




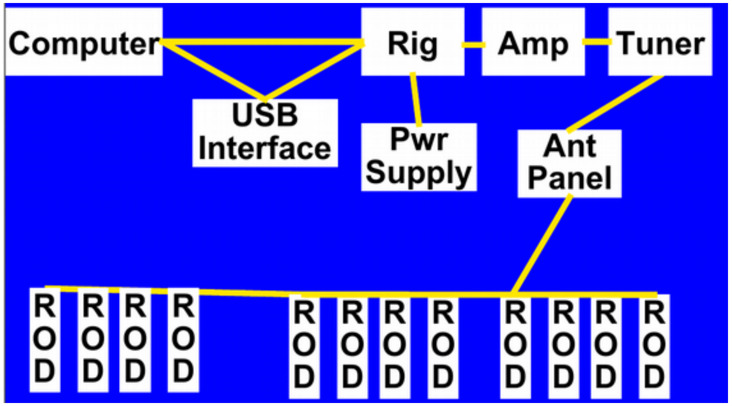
… *how do we avoid SNR degradation*

- **Common-mode noise suppression**
  - Feedline isolation and choking
    - Isolated Pri:Sec
    - Stacked (end-to-end) BN73-202 cores to increase choking impedance for LF/MF
    - Type #75, J, #31 cores
  - Feedline grounding (rods, earth proximity decoupling)

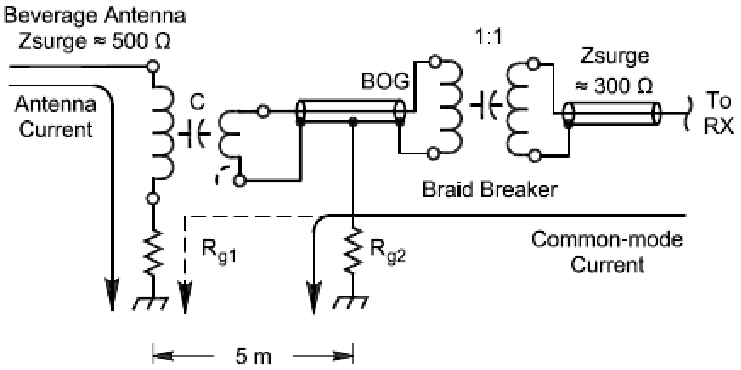
- **Station Bonding**
  - Reduce differential voltages between equipment, power mains, etc.
  - Excellent tutorials by **K9YC**: *http://audiosystemsgroup.com/publish.htm*



W8JI



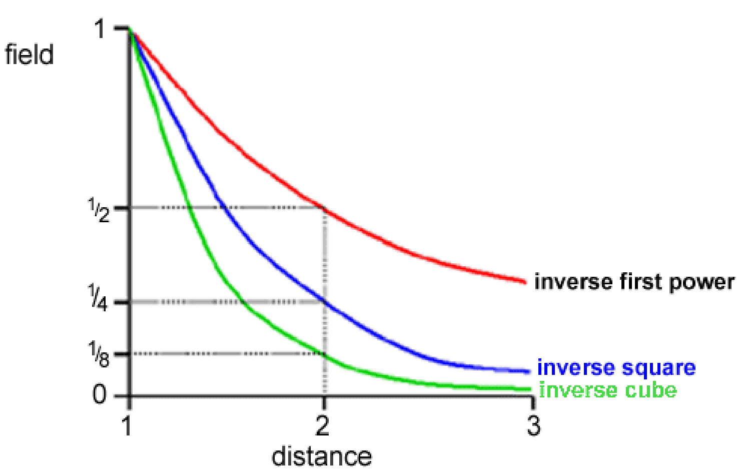
K9YC



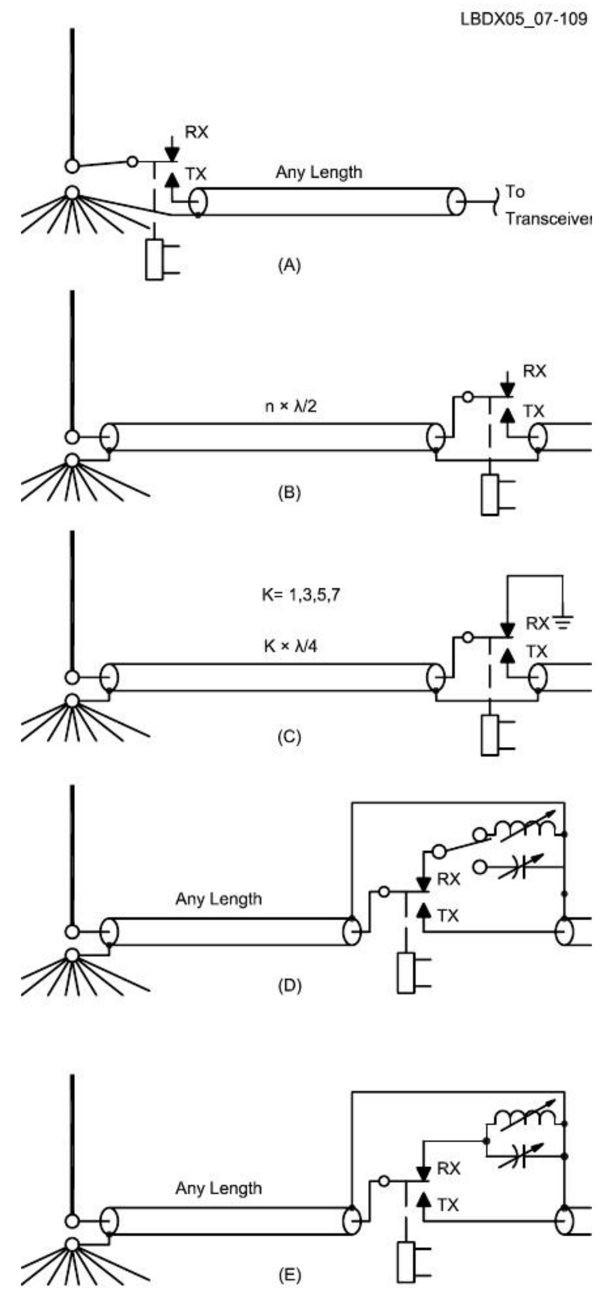
ON4UN

… *how do we avoid SNR degradation, cont.*

- **Antenna Location**
  - Separation from local noise sources (near field)
    - H-field (magnetic) strength **1 / d³**
    - E-field (electric) strength **1 / d²**
    - Use portable LF/MF receiver to find "quiet" spot
  - Separation from transmit antenna
    - Generally **more than 1/4λ - 1/2λ**
    - De-tune transmit antenna while receiving to prevent unintentional parasitic coupling or re-radiation



WA3TTS



ON4UN

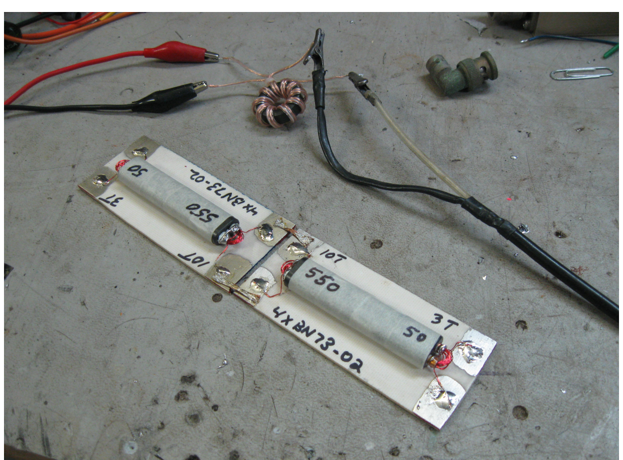
… how do receive antennas for 2200M / 630M compare to 160M

- **Generally larger near-field radius**
  - Susceptible to more "local" RFI sources not discriminated against by antenna pattern

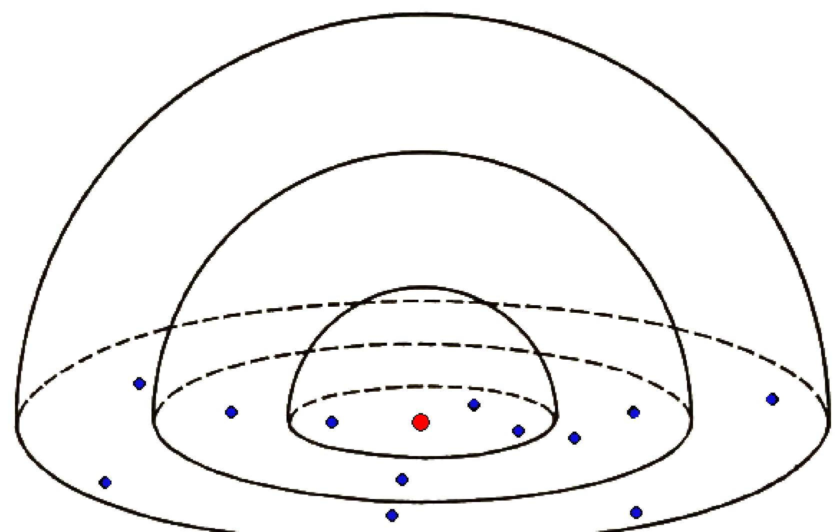
- **Generally physically larger to maintain comparable directivity (far-field)**
  - eg. beverages (*length*), phased arrays (*spacing*)
  - *Exceptions: terminated loops, verticals, "magnetic" loops where pattern is generally maintained but with lower gain*

- **Higher choking impedances required for common-mode suppression**

- **Generally lower antenna gains can be tolerated (less sensitivity) due to higher ambient noise**
  - Exception: quiet rural locations

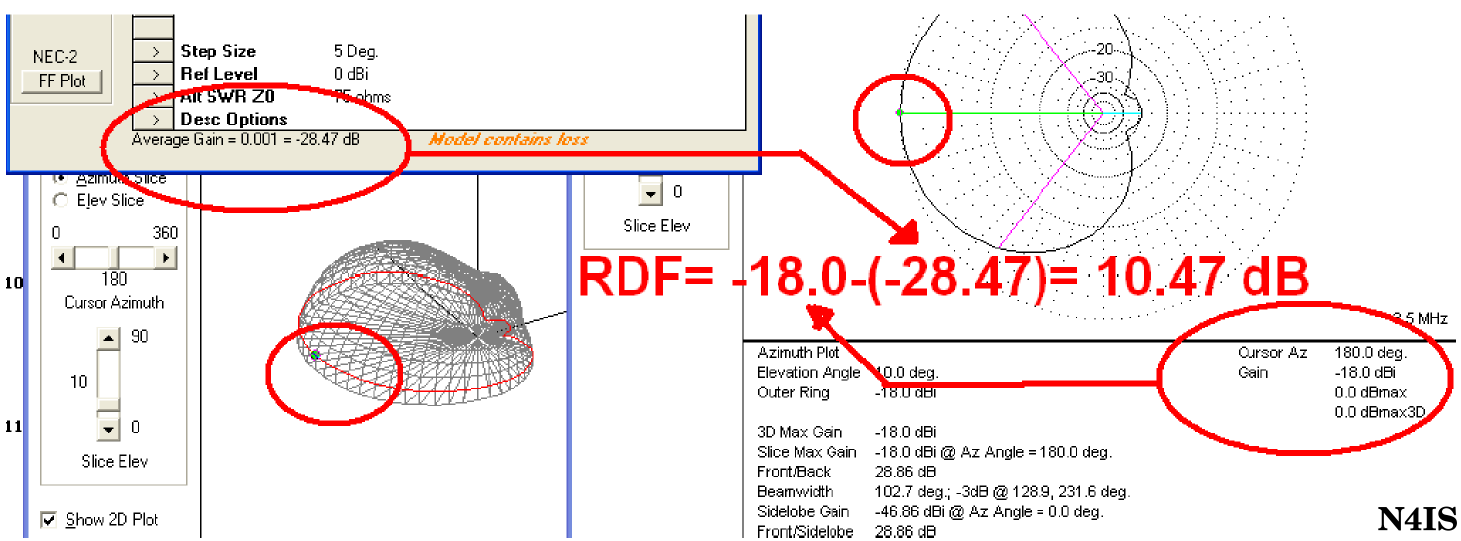


WA3TTS



… how do we *quantify receive antennas*

- Measure of effective directivity: **RDF (Receive Directivity Factor)**
- **Developed by Tom Rauch, W8JI**
- Compares forward gain at desired azimuthal and elevation to average again over entire hemisphere
- **Average gain as defined by EZNEC documentation**
  - *the total power in the far field (determined by integrating the far field in all directions) divided by the power delivered to the antenna by the sources*
- **RDF = Gain – Average Gain**
- **1 dB considered noticeable** (*W8WWV*)
  - However, if antennas are within two dB of each other in RDF, the lesser ranked antenna may outperform a better ranked antenna in some situations (*W8JI*)
    - Direction and polarization of arriving signals and noise constantly vary, so the relative relationship between any two individual antenna's responses will vary
    - Margin of error between modeled and real-world performance



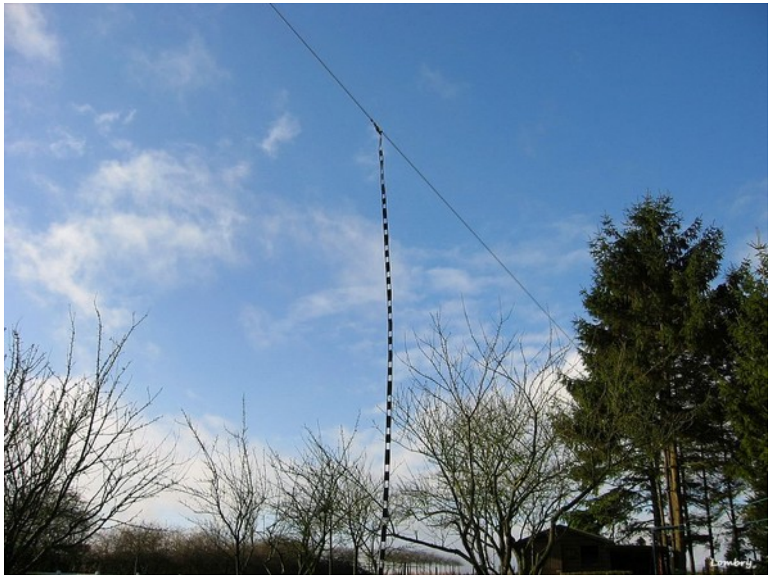
N4IS

… comparing receive antennas based on RDF

RDF (dB)	Antenna	Notes
??	Ferrite-rod / coil	
5.05	Verticals, E-probes	
5.0 – 6.0	Small Loop	
6.0 - 6.5	1/2λ Beverage	
7.4 – 7.7	EWE / Pennant / Flag / K9AY	Terminated Loops
8.0	Shared Apex Loop Array	30x30-ft or 50x50-ft footprint
9.2 - 10.0	2-el End-Fire Phased verticals	1/16λ, 1/8λ, 1/4λ spacing
9.0 - 10.0	1λ Beverage	
10.7 – 11.5	Four Square	1/16λ, 1/8λ, 1/4λ spacing
11.7	6-el Hex Array	
11.0 - 12.0	1.5λ Beverage	
12.5	.625λ x .125λ spaced BS/EF vertical array	BSEF 8-circle Array
12.5 - 13.0	2λ Beverage	
13.4	Hi-Z™ 8-circle	
13.5	Broadside 1.75λ Beverages .75λ spacing	

… Haphazard Receive Antennas

- **Any existing antenna can be used for receive**
  - *Random wire*
  - *HF Dipole*
  - *Delta Loop*
  - *Horizontal Loop*
  - *etc…….*
- **Not purpose built, therefore….**
  - *May have some effect on SNR by mitigating near-field noise, but unpredictable and incidental*
  - *Usually no useful directivity on LF/MF to manage far-field noise*
- **Better to design and install receive antenna(s) with predictable performance benefits**
  - *Despite the low frequencies involved and perceived size requirements, respectable performance can be had in compact designs*

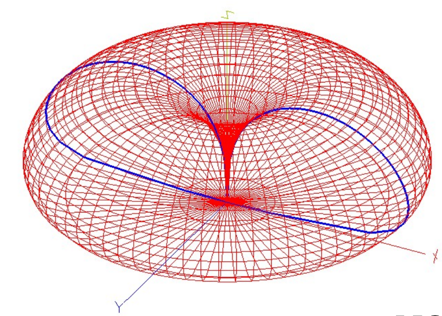


… *Vertical and E-Probe Receive Antennas*

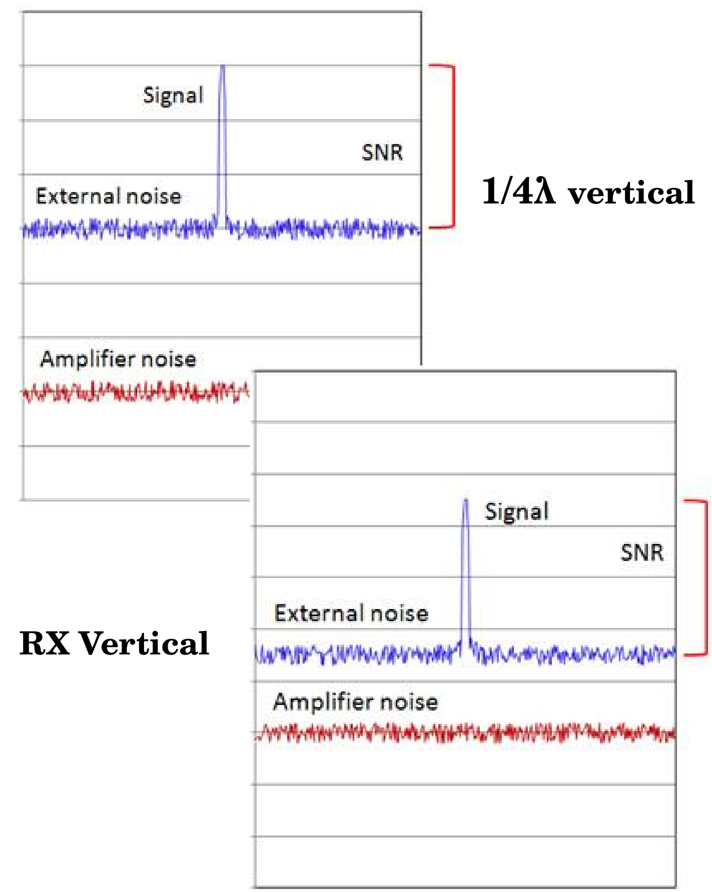
- **Far-field radiation pattern**
  - Same as transmit vertical
  - Omni-directional
  - No improvement in RDF (approx 5 dB)
  - Low-angle peak, null at 90-deg

- **Observable performance differences vs. transmit vertical, one may appear better than the other due to:**
  - Near-field noise coupling
    - Location of vertical in relation to noise sources in it's near-field
      - *Small vertical may be easier to re-locate vs. transmit vertical to find "quiet" spot*
  - Common-mode noise
    - Inadequate choking impedance on transmit vs. receive vertical feedlines

- **Optimal elements for phased arrays**
  - Compact, small space requirements, easy to erect/support (vs. beverage, terminated loops, etc.)



NO3M



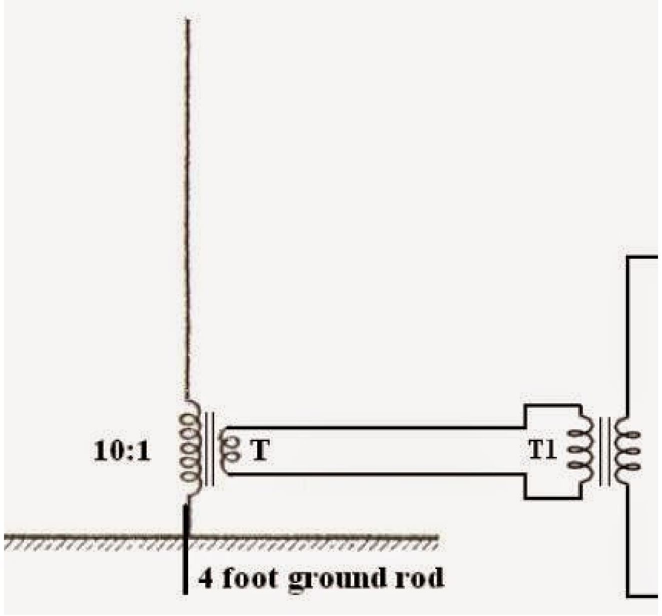
DL1DBC

… *Vertical and E-Probe Receive Antennas, cont.*

- **Resonant, passive vertical**
  - Similar to transmit verticals, but lower efficiency
  - 25 – 35 ft elements
  - Capacitive top-loading wires (30-ft)
  - Base loading coil (toroid, molded, etc.)
  - Radials to stabilize ground loss variations
  - Sometimes resistively swamped (esp. in arrays)
    - → *Dampens ground loss changes*
    - → *Increases VSWR bandwidth*

- **Non-Resonant LNV (Low Noise Vertical)**
  - 15 – 18 ft element
  - No top-loading wires
  - 10:1 step-down transformer at base
  - Twisted-pair "balanced" feedline (90-110Ω), ie. CAT5
  - 1:1 isolation transformer at shack end
  - P-P LNA (Low noise amplifier) in shack
  - Better counterpoise (ie. *radials*) can improve performance

NO3M

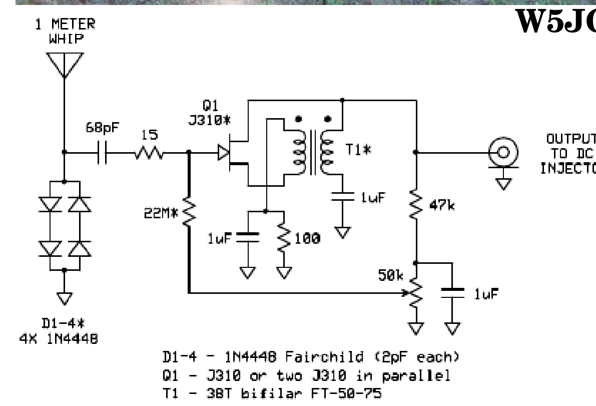


VE7SL

… Vertical and E-Probe Receive Antennas, *cont.*

- **Non-Resonant Hi-impedance (*Active*) Verticals**
  - 3 – 25 ft tubular, whip, wire element or plate
  - No top-loading wires
  - Hi-impedance buffer / amplifier
    - *Medium gain*
      - YCCC, Hi-Z™, DXE
      - Taller tubular, whip, or wire elements
    - *Higher gain / "E-probe"*
      - PA0RDT, W1VD, homebrew J310
      - Shorter elements or plate
  - Typically powered through coax
    - *1:1 isolation transformer at amplifier input*
    - *Bias-T at receiver end of feedline*
  - No radials, just "ground" reference via rod, mounting pole or stake
  - Good alternative to passive elements for phased arrays if *phase delays are consistent* amongst amplifiers
  - Clearance from nearby objects that may distort pattern

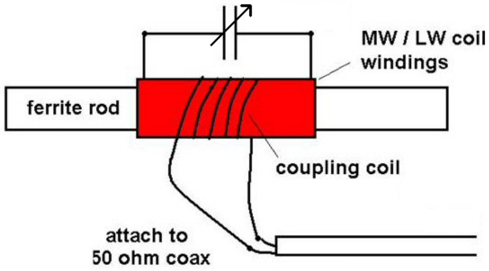
W5JGV

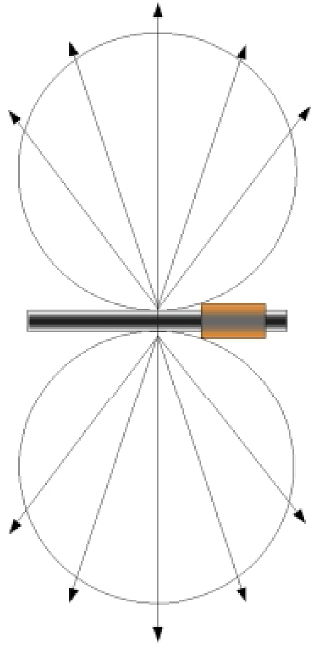


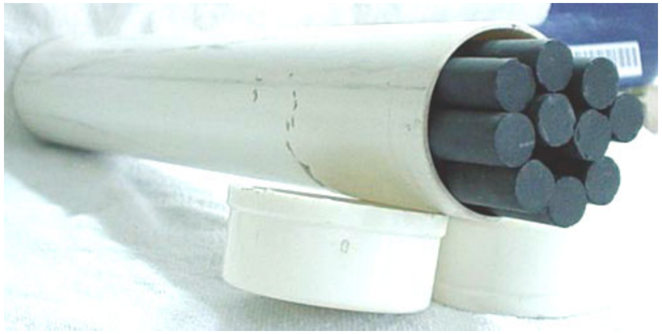
W1VD

… *Ferrite Rod Receive Antennas*

- **Popular antenna in LF/MF portable receivers**
- **Bi-directional far-field pattern**
  - *Similar to dipole*
  - *Nulls off the ends of rod, perpendicular to coil axis*
- **Hi-Q tuned circuit**
- **Low output**
  - *Generally inductively coupled via link coil*
  - *Hi-impedance input amplifier, light loading*
- **Alternative for severely space restricted locations, portable operations, or RFI location**
  - *Usually deep, well defined nulls*

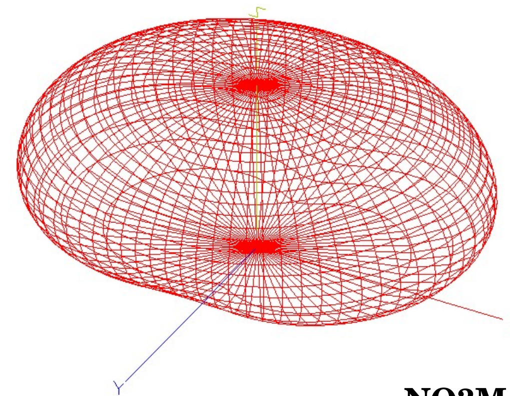






… *Small Loop Receive Antennas*

- **Various geometric configurations**
  - *circle, square/diamond, hexagon, octagon, etc.*
- **Different electrical configurations**
  - *Shielded / Unsheilded*
  - *Single or multi-turn (increased sensitivity, NOT directivity)*
  - *Directly connected or inductively coupled output*
- **Resonant, tuned circuit**
- **Low output,** *requires LNA (preamplifier)*
- **Broadside pattern,** nulls perpendicular to plane of loop
- **RDF 5.0 – 6.0 dB**
- **Contrary to some popular folklore, magnetic loops are no less prone to near-field RFI (quieter) than verticals/ E-probes**
  - ***AA5TB: offending source must be in reactive near-field ($\lambda/2\prod = 0.159\lambda$) AND truly be of electric field origin***
  - ***W8JI: difference in noise response can be caused by common-mode rejection differences and pattern***
- **Usually built to be rotatable**
- **Good option for small gardens or backyard lots**

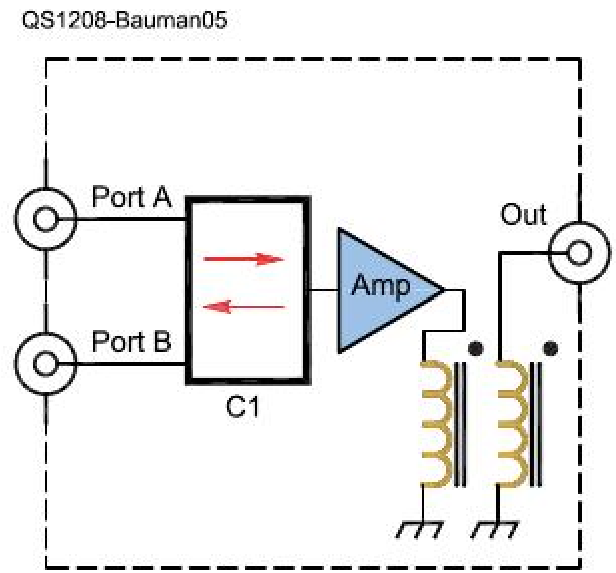


NO3M

KB5NJD

… *Small Loop Receive Antennas, cont.*

- **Shared Apex Loop Array**
  - Developed by KB7GF
  - Pair of co-planar small triangular loops
  - Time delay signal combining
  - Switchable in 8 directions
    - *Uses a pair of orthogonal arrays (Four (4) loops)*
  - **RDF: 8 dB** (3 dB over vertical)
  - LF/MF version
    - *32-ft center support*
    - *50x50-ft footprint*



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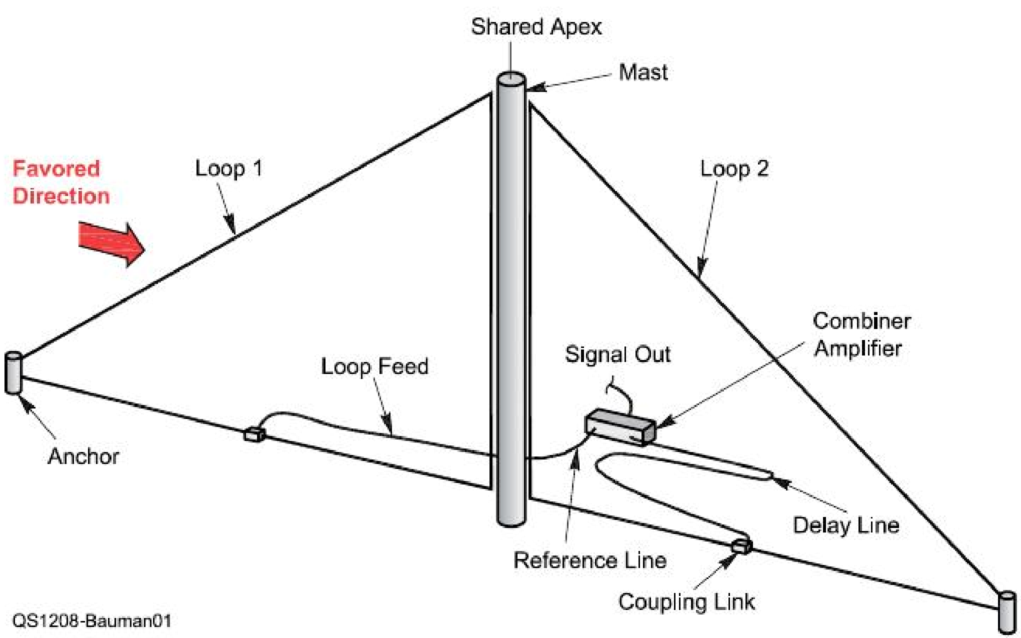

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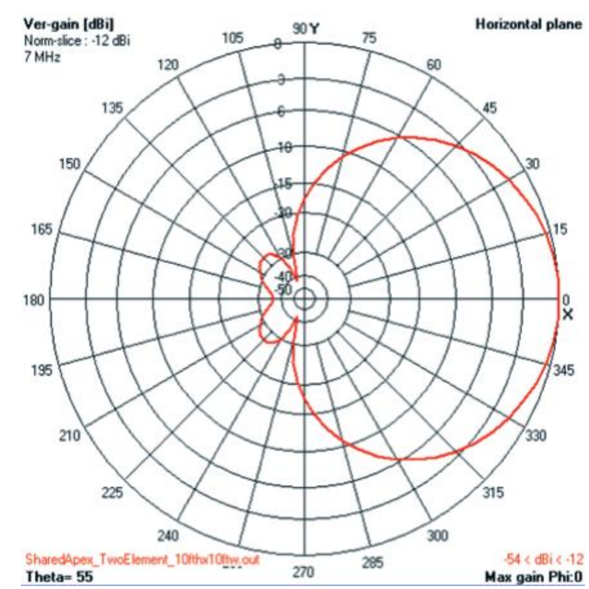
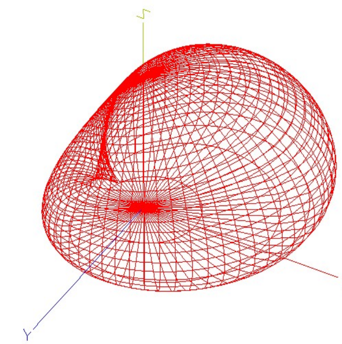
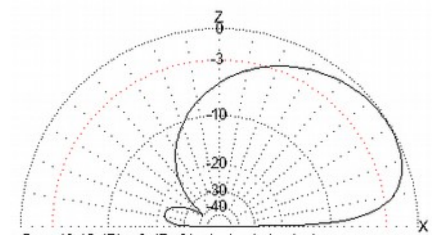


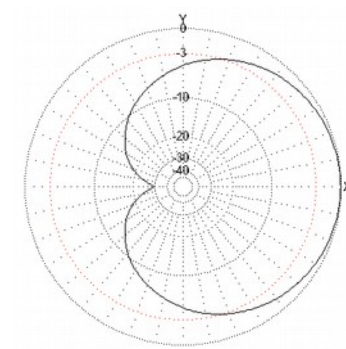
QST Oct 2012

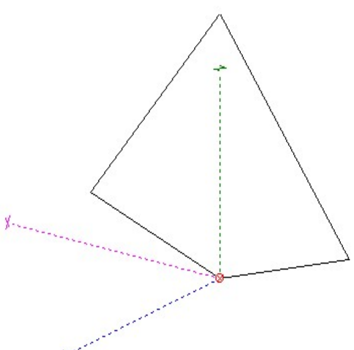
… *Terminated Loop Receive Antennas*

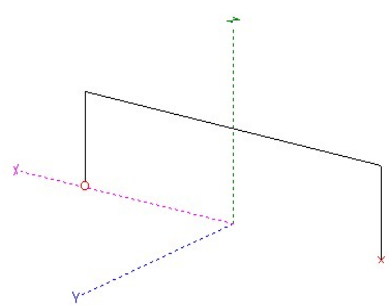
- **Cardioid pattern similar to 1/2λ beverage**
- **RDF 7.4 – 7.7 dB (2.4 – 2.7 dB over a vertical)**
- **Forward lobe from end opposite the termination**
- **Low gain**
  - *Requires LNA (preamplifier)*
  - *Can be scaled to larger dimensions to increase gain*
- **Termination optimized for best F/B (null)**
- **Ground dependent:**
  - *K9AY*
  - *EWE*
  - *Requires an orthogonal pair to cover entire azimuthal*
  - *Sensitive to ground characteristic changes*
- **Ground independent (also rotatable):**
  - *Flag*
  - *Pennant*
- **Good for small to medium sized lots**

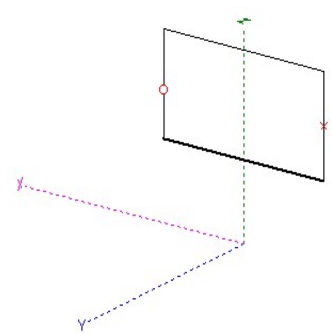


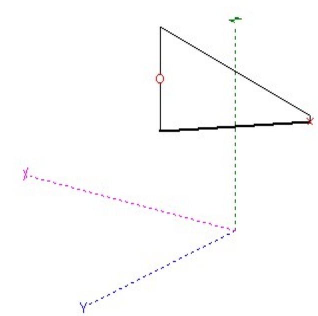






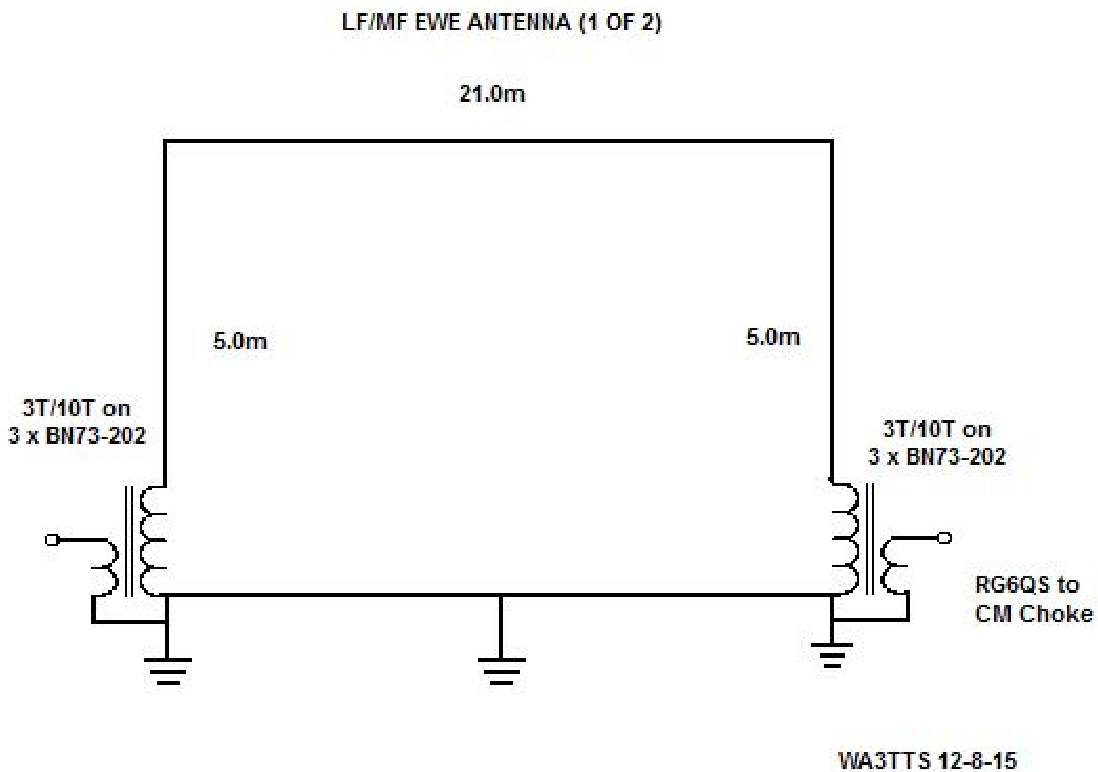






… *Terminated Loop Receive Antennas,* *cont.*

- **WA3TTS EWE**

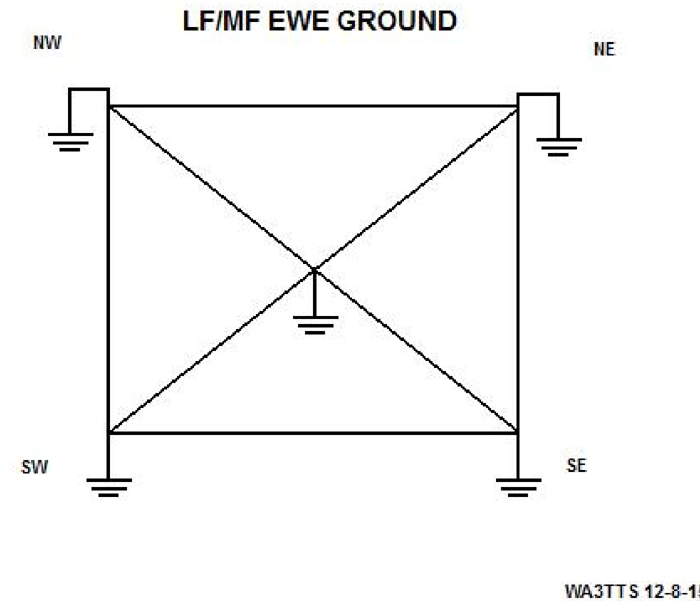


- *WA3TTS has reported good directivity and F/B on 630M and 2200M and overall impressive results from a small sub-urban lot (Pittsburgh)*

- *WA3TTS (80M) successfully worked VE7SL (5W EIRP 630M) during crossband activity night using CW*

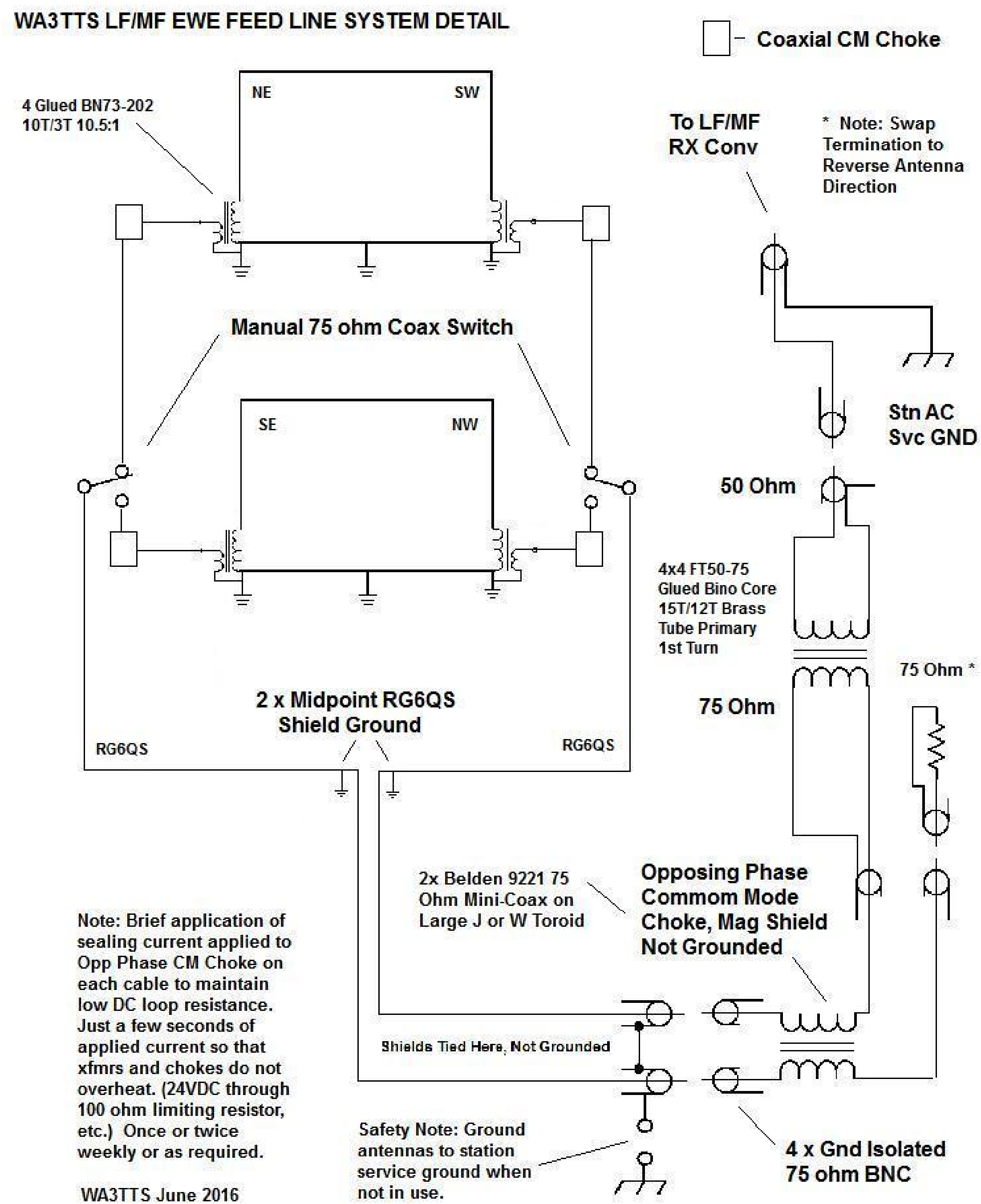
- *Slightly scaled up from standard 160/80M dimensions*

- *Ground return wires between all rods to minimize performance changes due to ground characteristic changes (EA3VY)*



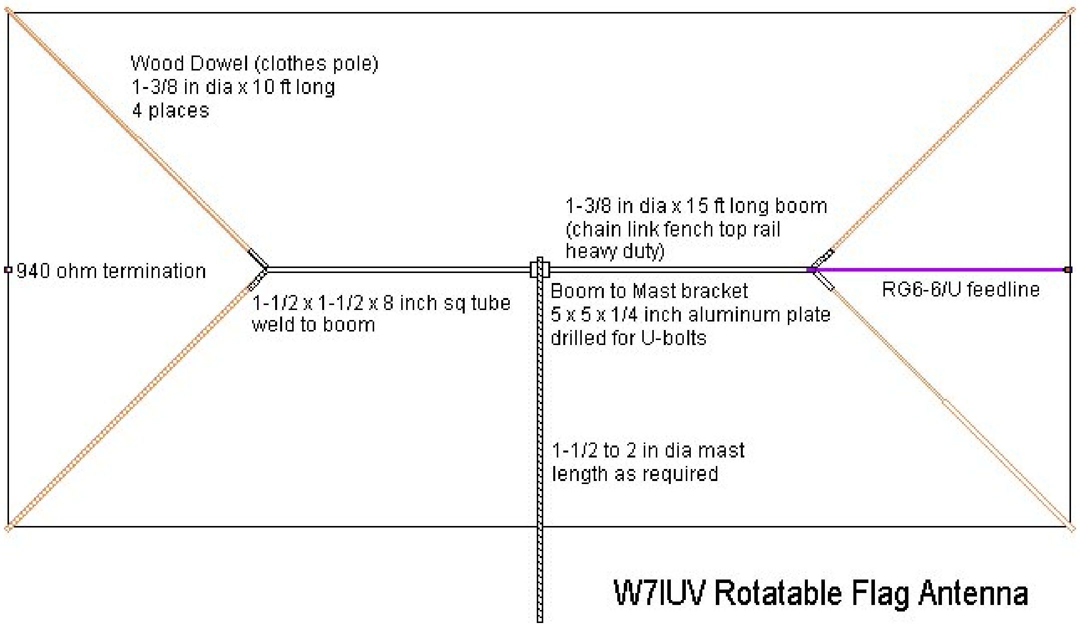
… *Terminated Loop Receive Antennas,* *cont.*

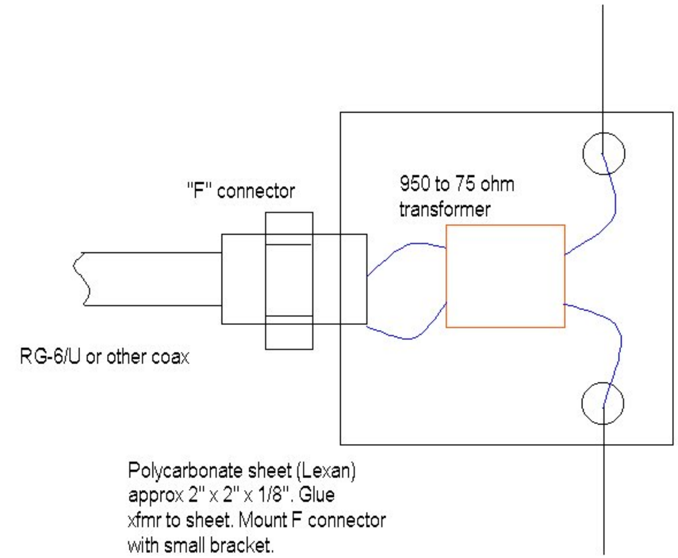
- **WA3TTS EWE, cont.**
- *Careful attention to common-mode supression and extensive grounding / bonding techniques*
- *Reversible direction EWEs with termination resistance located in the shack*
- *Orthogonal EWEs to cover NE, SE, SW, NW directions*
- *Many incremental changes to improve performance over several seasons*



… *Terminated Loop Receive Antennas, cont.*

- **W7IUV Rotatable Flag**

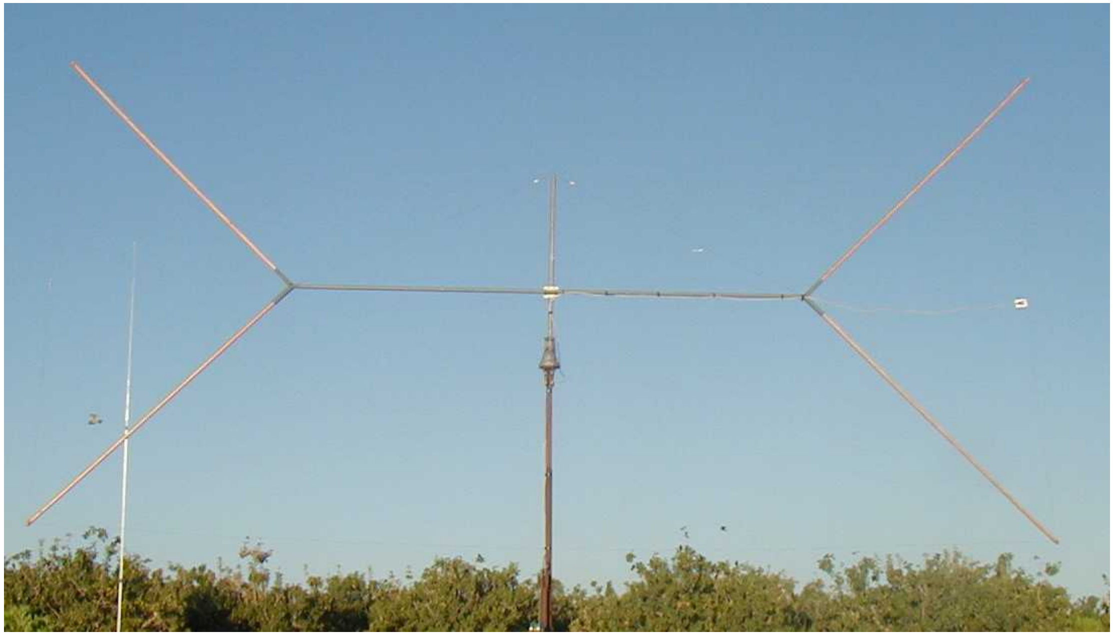




W7IUV

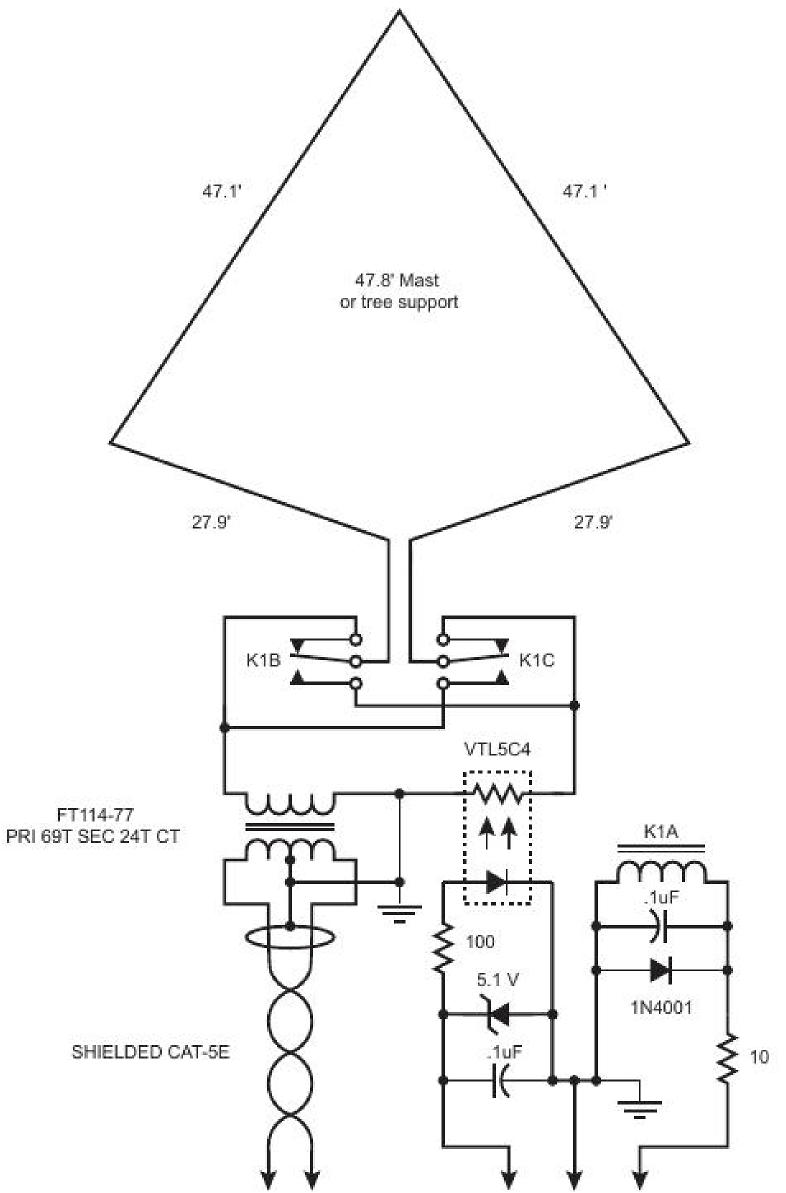
- *Based on standard K6SE optimized dimensions*
- *W7IUV reports good directivity and F/B on 630M*

W7IUV



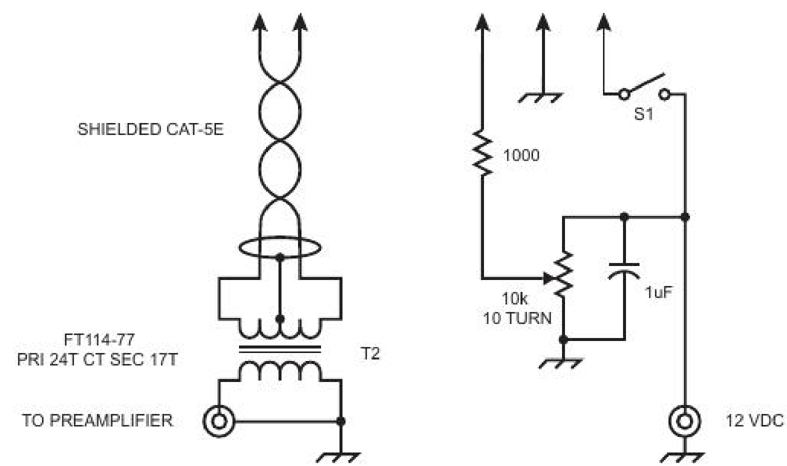
… Terminated Loop Receive Antennas, *cont.*

- **K9AY modified by W1VD**



W1VD

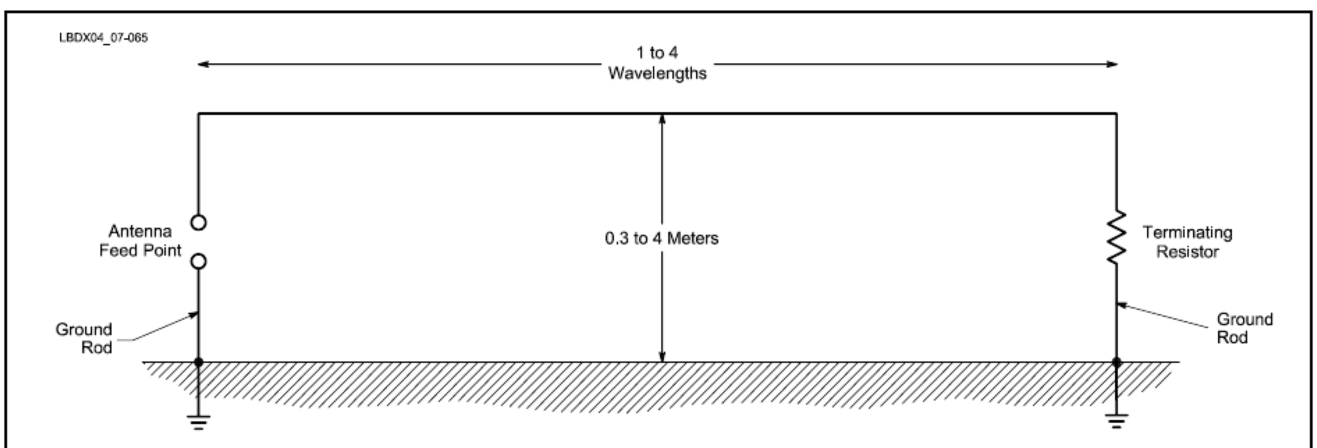
- *Scaled up version for LF/MF*
- *Twisted pair feedline with grounded shield*
  - *Shielded CAT-5E*
  - *110Ω braided shield digital audio cable (Belden / Gepco) [**K9YC**]*
- *Remotely controlled variable termination resistance (F/B, null optimization)*
- *W1VD reports excellent results on 2200M and 630M*



W1VD

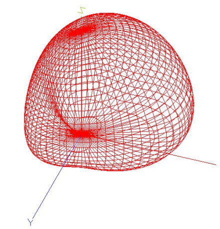
… *Beverages Receive Antennas*

- **Classic Beverage**
  - Long wire terminated at far end in resistor equal to antenna’s surge impedance, typically 400-500Ω
  - Typically 1-10 ft above ground
  - Works best over average to poor ground conductivity
  - As length increases:
    - Narrower forward beamwidth (*increased directivity*)
    - Peak elevation response decreases (*lower take-off*)
  - As height decreases:
    - Lower gain
    - Smaller side lobes
    - Narrower forward beamwidth (*increased directivity*)
    - Peak elevation response decreases (*lower take-off*)
  - Point of diminishing returns after about 3λ due to current losses

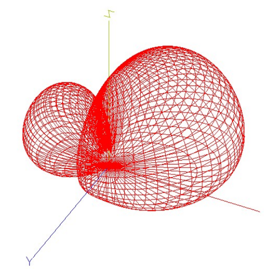


ON4UN

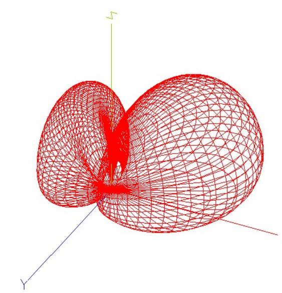
1/2λ



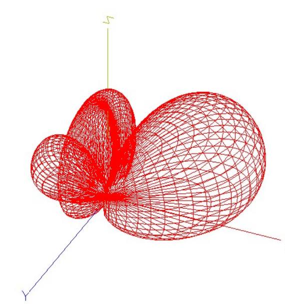
3/4λ



1λ



1-1/4λ



NO3M

… *Beverages Receive Antennas, cont.*

- **Classic Beverage**
  - Recommended feedpoint uses split winding transformer (*eg. BN73-202 binocular*)
    - *50Ω system: 9:1 imped. ratio*
    - *75Ω system: 6:1 imped. ratio*
  - Non-inductive, high surge current termination resistor

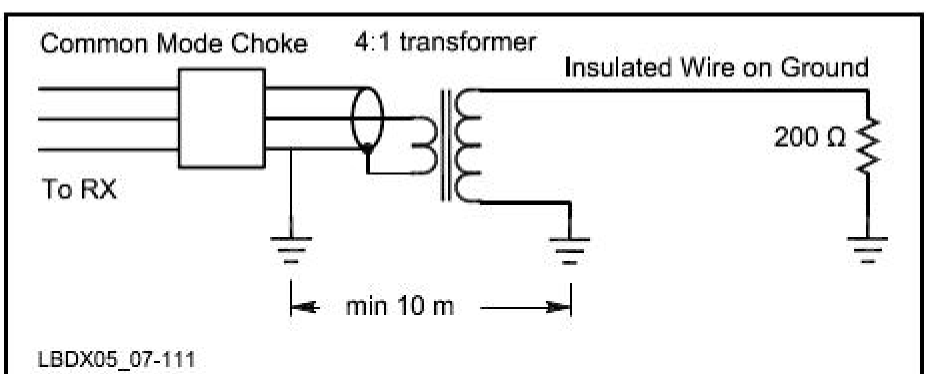
  - **PRACTICAL?**
    - Even on large lots, lengths will generally be limited to a couple or few thousand feet
    - ***630M: 0.5λ = 1035-ft, 1λ = 2070-ft, 1.5λ = 3100-ft***
    - ***2200M: 0.5λ = 3600-ft***

W8JI

    - 0.5λ beverage only has 1 – 1.5 dB RDF advantage over a vertical
    - May be an option for existing stations with 2λ or longer beverages for 160M, ***but better RDF can be realized with terminated loops or phased verticals requiring much less real estate vs. a 0.5λ beverage (630/2200M)***

… *Beverages Receive Antennas, cont.*

- **BOG (Beverage on Ground), a shorter alternative to the classic beverage…..**
  - Insulated wire lying on the ground surface or slightly buried
  - Surge impedance / termination resistance around 200-300 ohms
  - Lower gain than elevated beverage, usually requires LNA (preamp)
  - Lower velocity factor than elevated beverage
    - *53-63% length of comparable elevated beverage, but varies widely depending on ground characteristics*
    - ***630M: length can vary from 550-ft – 2000-ft***
    - ***2200M: length can vary from 1900-ft – 3800-ft***
  - Optimal performance (RDF, F/B) more single-banded unlike elevated beverage
  - Rapid, exponential decay of current along wire
    - *BOG can be un-terminated and still maintain it's directivity and F/B if "right" length, where current at end of wire is very low*
  - Performance can be adversely affected if buried too deeply as noted by actual experiments and NEC4 modeling by N6LF after a wet winter season and sod absorption of wire
  - EXPERIMENTATION REQUIRED!! ***Start long and cut back for best F/B***



ON4UN

- Extra precautions necessary to avoid common-mode:
  - *4:1 isolated winding feedpoint transformer (single or stack BN73-202)*
  - *Feedline choke*
  - *Feedline grounded between choke and feedpoint transformer*
  - *Very good ground at feedpoint, multiple rods or screen*

… *Phased Array Receive Antennas*

- **Combine similar "simple" elements to form a larger array for increased directivity (higher RDF)**
  - *Verticals*
  - *Terminated or small loops*
  - *Beverages / BOGs*
- **Phasing schemes**
  - *Broadside*
  - *End-fire*
  - *Broadside + End-fire (BSEF)*

- **Steerable arrays**
  - *Cover entire azimuthal by selecting different phasing / element combinations*
  - *Must be equilateral and equiangular*
    - ➔ *Triangular Array*
    - ➔ *Four Square*
    - ➔ *"Circular" Arrays (eg. HEX, 8-circle)*
- **Reaslistic RDF ranges:**
  - *630M: 8.9 dB (2-el end-fire verticals) to 13.4 dB (Hi-Z™ 8-circle)*
  - *2200M: 8.9 dB (2-el end-fire verticals) to 11.8 dB (1/16λ Four Square)*

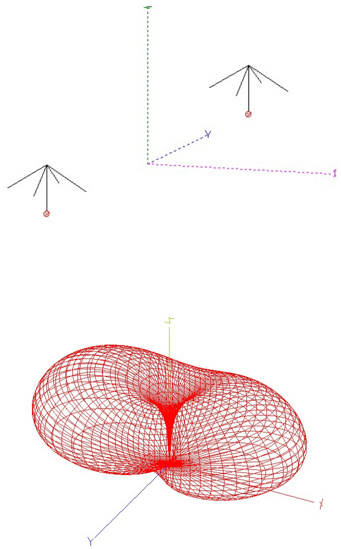
AC0C

K7TJR

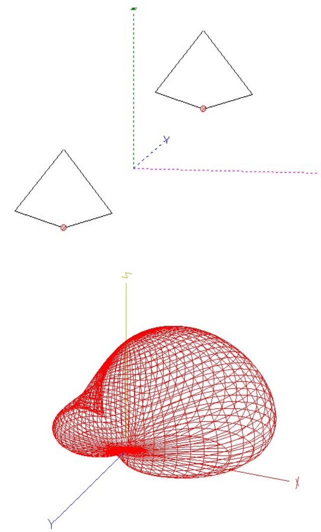
… *Phased Array Receive Antennas*

- **Broadside examples** (*1/2λ broadside spacing; 1035-ft @630M; prob not feasible on 2200M)*

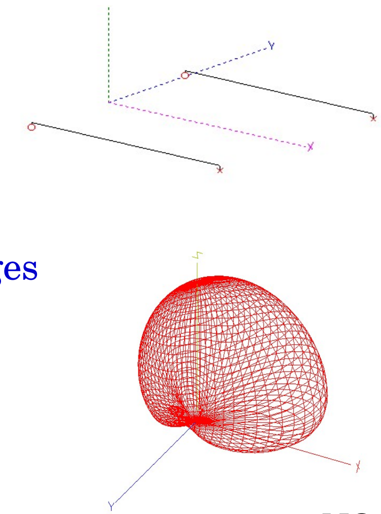
Verticals
RDF 8.3 dB
60-deg -3dB
Bi-directional



Term. Loops
RDF 10.1 dB
60-deg -3dB



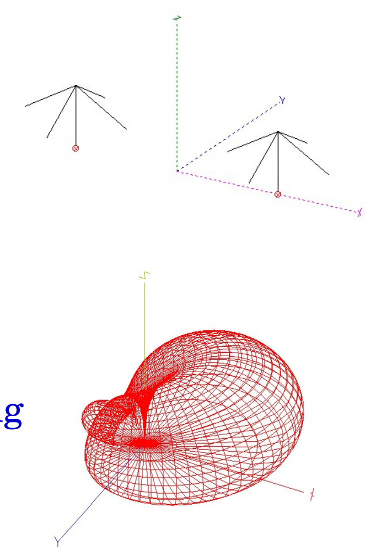
1/2λ Beverages
RDF 8.11 dB
50-deg -3dB



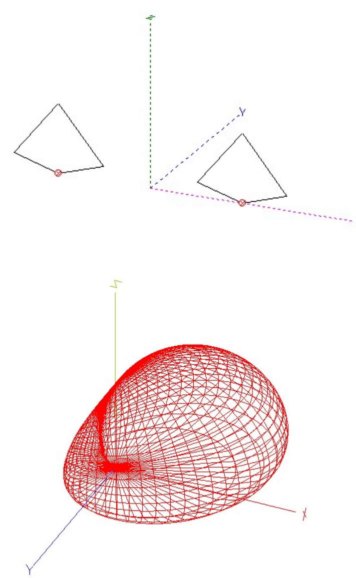
NO3M

- **End-fire examples** (*1/8λ end-fire spacing; note: 1/16λ may be feasible on 2200M, 450-ft)*

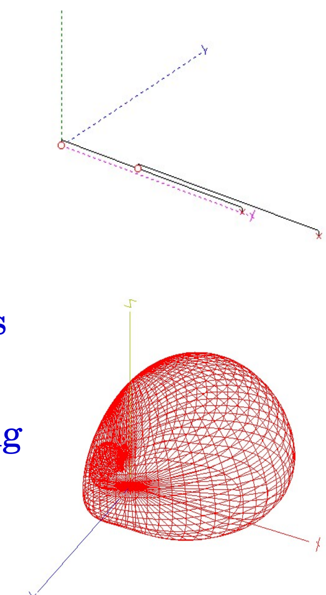
Verticals
RDF 8.9 dB
140-deg -3dB
135-deg phasing



Term. Loops
RDF 8.4 dB
120-deg -3dB
90-deg phasing



1/2λ Beverages
~*1/6λ* stagger
10 ft spacing
135-deg phasing
RDF 9.28 dB
75-deg -3dB

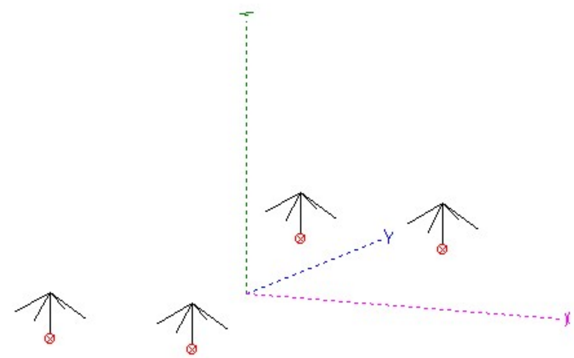


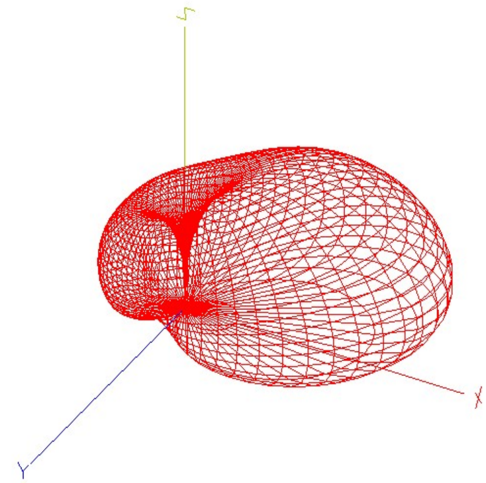
NO3M

… *Phased Array Receive Antennas*

- **Broadside / End-fire example (verticals), 630M**

Verticals
RDF 11.5 dB
56-deg -3dB
120-deg phasing
1/2λ broadside
1/8λ end-fire





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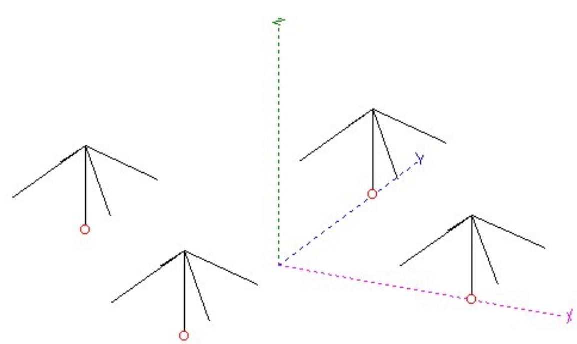
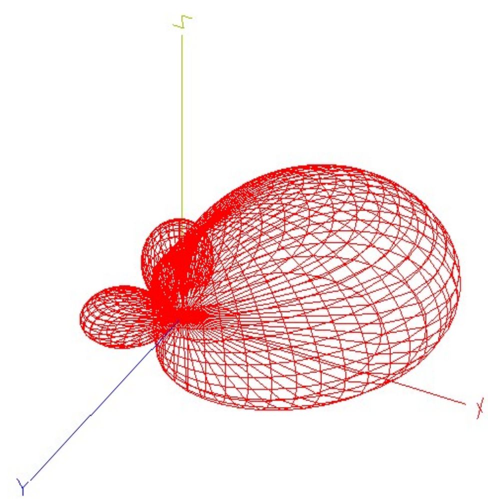
- **Four Square example (verticals), 630M and 2200M *(1/16λ feasible)***

Verticals
RDF 11.8 dB
76-deg -3dB
0,150,300-deg phasing
1/8λ spacing





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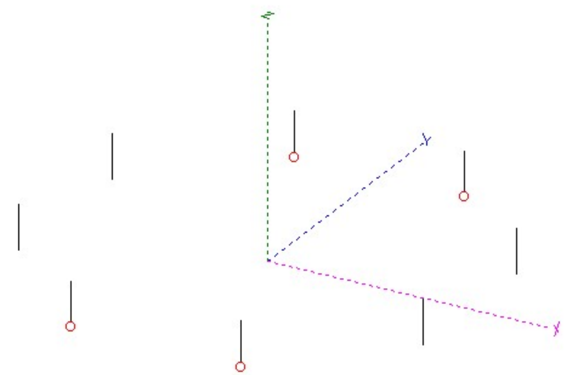
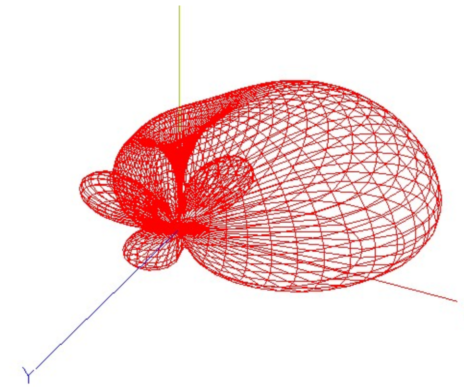
… *Phased Array Receive Antennas*

- **Circular Arrays**
  - ***BSEF 8-circle (4 elements active), 630M***

Active Verticals
RDF 12.5 dB
55-deg -3dB
115-deg phasing
1200-ft dia.





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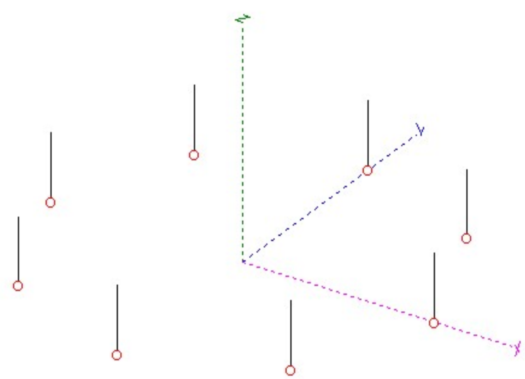
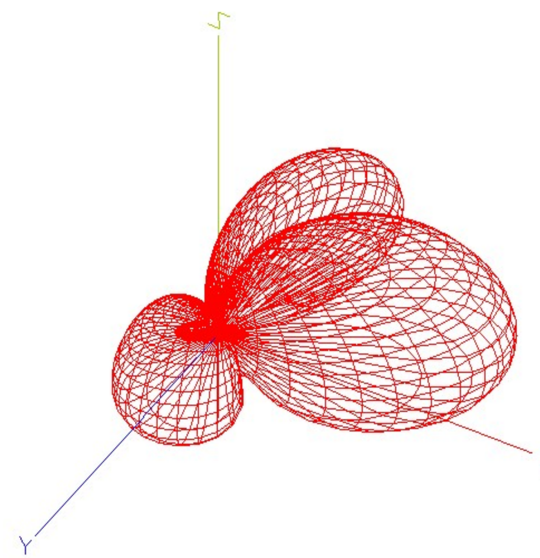
  - ***Hi-Z™ phased 8-circle (all elements active), 630M***

Active Verticals
RDF 13.4 dB
53-deg -3dB
0,106,-106 deg phasing
800-ft dia.





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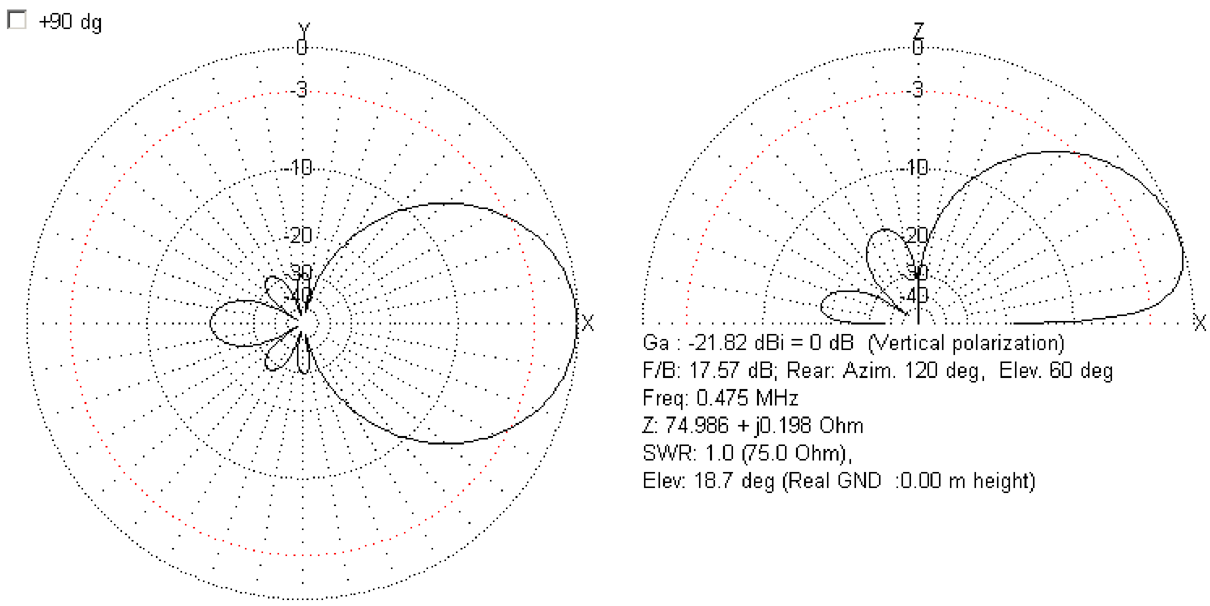
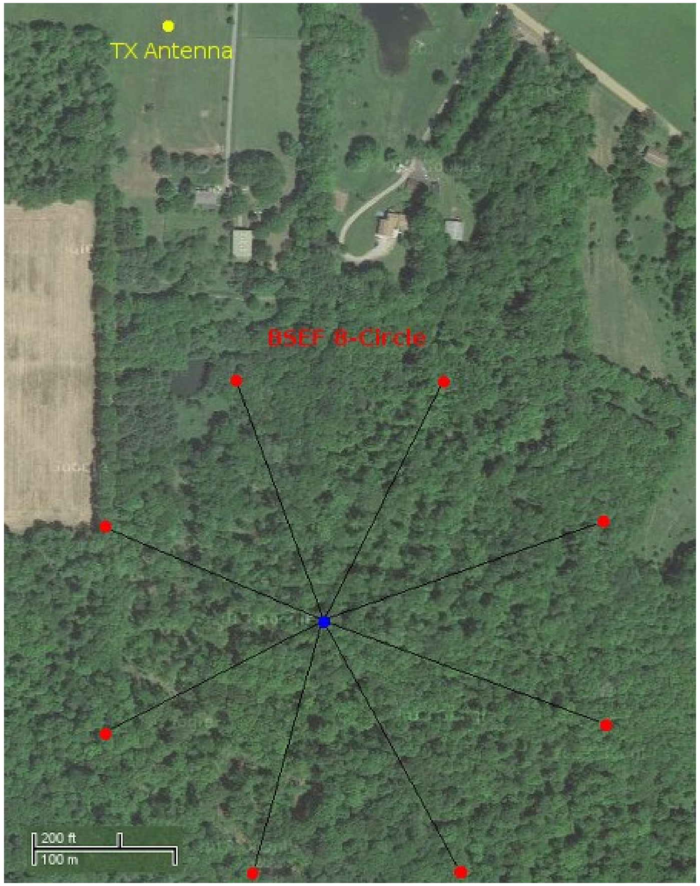
… about the NO3M 630M passive BSEF 8-circle array

- **1140 ft (348m)** of broadside spacing
- **470 ft (143m)** end-fire spacing
- Requires a square area of nearly 30 acres (12 ha)

- **Materials**
    - RG6 phasing lines + delay cable: 5912 ft (1802m)
    - 1 in. alum. tubing; elements: 192 ft (58.5m)
    - #17 Fence wire; radials + top-hat wires: 7200 ft (2195m)



NO3M



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- **RDF 12.5**
- -3 dB beamwidth is 55 degrees
- **F/B 25 dB**

… about the NO3M 630M passive BSEF 8-circle array, cont.

- **Elements**
  - Four (4) 6-ft sections of 1 inch dia. aluminum tubing (24 ft height)
  - Four (4) 30-ft wires for toploading
  - Top wires are tied off with fishing line
  - 0.875 inch fiberglass rod insulator between element and 12 inch piece of 1 inch tubing
  - Bottom 1 ft tubing section is clamped to an aluminum 1 inch angle, driven into the ground approx 2.5 ft
  - 12-16 radials (approx 60-75 ft long)

- **Tuning**
  - Homebrew, slug tuned coil for fine tuning
  - Fixed, jumper-able molded inductors for course tuning: 390 uH, 22 uH, 10 uH, 4.7 uH, 2.2 uH
  - Resistance 468-470Ω, swamped with 350Ω fixed + 32Ω variable resistors and approx. 90-95 ohm ground loss
  - Split winding transformer, wound 4:10 turns Pri:Sec (6.25 impedance ratio) on a stack of two (2) BN73-202 cores

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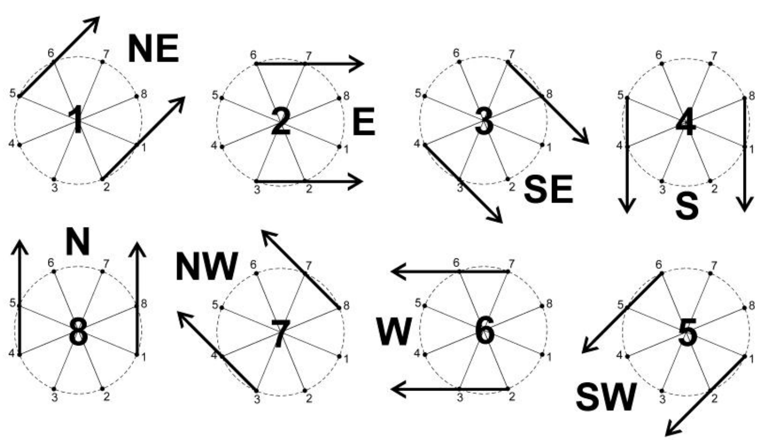
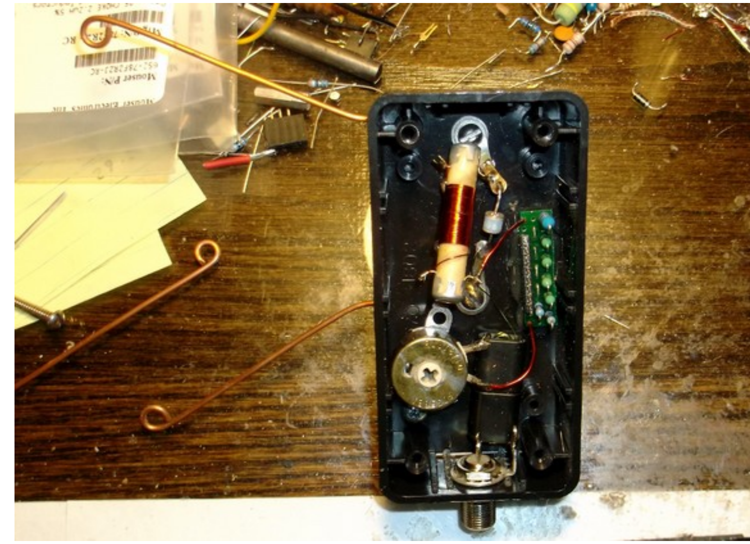
… about the NO3M 630M passive BSEF 8-circle array, cont.

- **Tuning, cont.**
  - Swamping the feedpoint with additional resistance
    - Increases operating bandwidth
    - SWR of 1.15:1 or less over the 472-479 kHz
    - Ensures consistent phase relationships between elements when using arbitrary, equal length phasing lines to controller
    - Helps to dampen the effects of ground loss changes
- **Switching / Phasing controller**
  - W9RE BS-EF PCB
  - 180 degree transformer and delay cable
  - Delay cable cut for 65 degrees at 475 kHz (approx 318 ft)
  - Phase shift of 115 degrees between front and back elements
  - Feedlines from each element approximately 700-710 ft long





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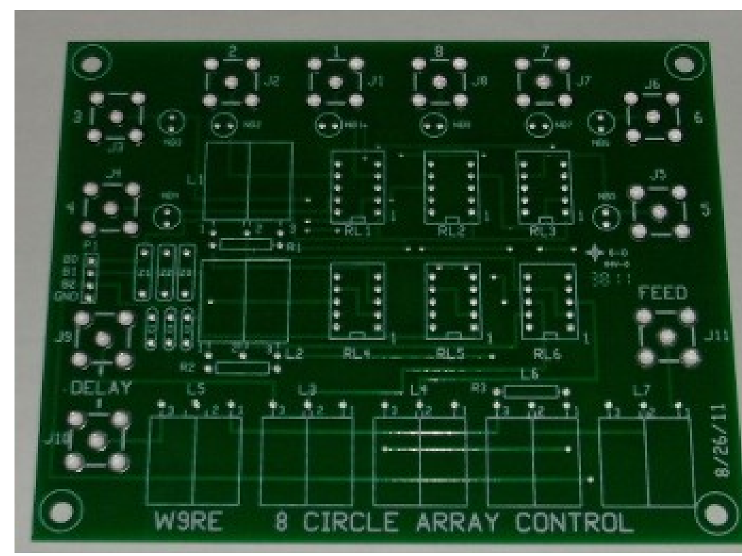

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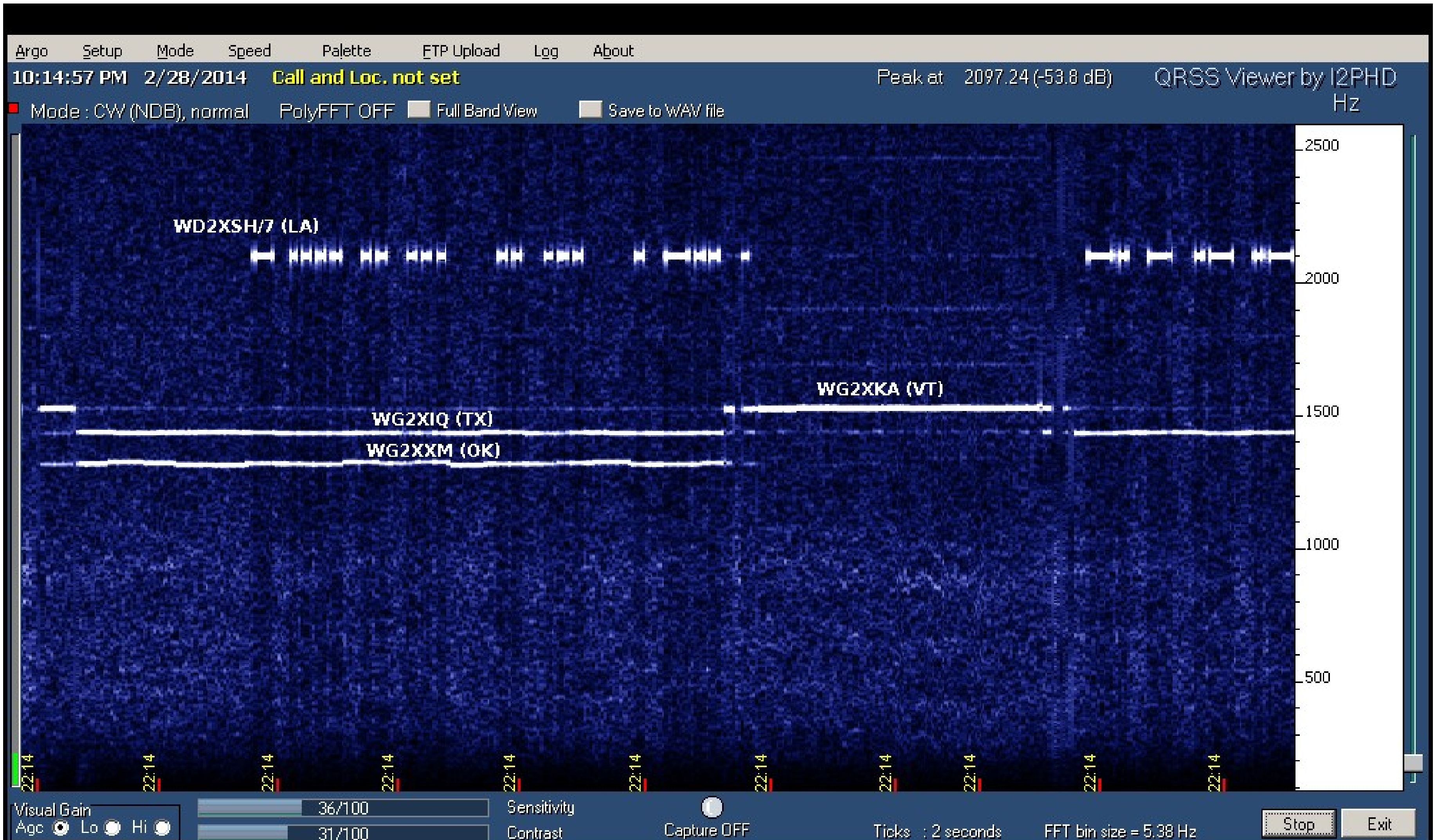
… about the NO3M 630M passive BSEF 8-circle array, cont.

- **Performance**
  - On-air tests indicate a F/B of at least 22-28 dB, but is very dependent upon whether a station off the back is in one of the deeper nulls



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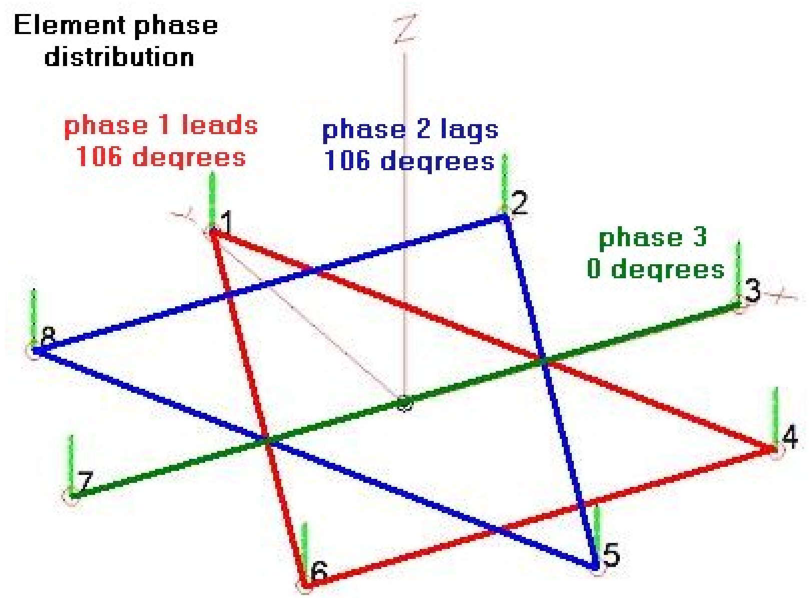
… about the NO3M 630M passive BSEF 8-circle array, cont.

- **Future Improvements**
  - Replace passive elements with active elements (YCCC amplifier)
    - improve operating bandwidth
    - Further reduce phasing errors
    - Less maintenance without radials or top loading wires
  - Use all-active, 0, -106, +106 deg (Hi-Z™) phasing
    - Smaller diameter "circle" (800ft)
    - Increased RDF



K7TJR

… NO3M's Picks

- **630M**
  - **100ft x 100ft Lot**
    - Orthogonal, reversible EWEs (*WA3TTS dimensions*)
    - K9AY (*W1VD dimensions*)
    - Shared Apex Loop Array
  - **200ft x 200ft Lot**
    - 1/16λ Four Square, active or passive elements
  - **300ft x 300ft Lot**
    - 1/8λ Four Square, active or passive elements
  - **Over 800ft x 800ft**
    - Hi-Z™ 8-circle (800ft broadside), active elements
    - BSEF 8-circle (1100ft broadside), active or passive elements

- **2200M**
  - **100 ft x 100ft Lot**
    - Orthogonal, reversible EWEs (*WA3TTS dimensions*)
    - K9AY (*W1VD dimensions*)
    - Shared Apex Loop Array
  - **Over 500ft x 500ft**
    - 1/16λ Four Square (450 ft), active elements
    - 1/8λ Four Square (900 ft), active elements

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Special thanks to KB5NJD, K9YC, and WA3TTS

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