A Pragmatic Approach to

630m Antennas

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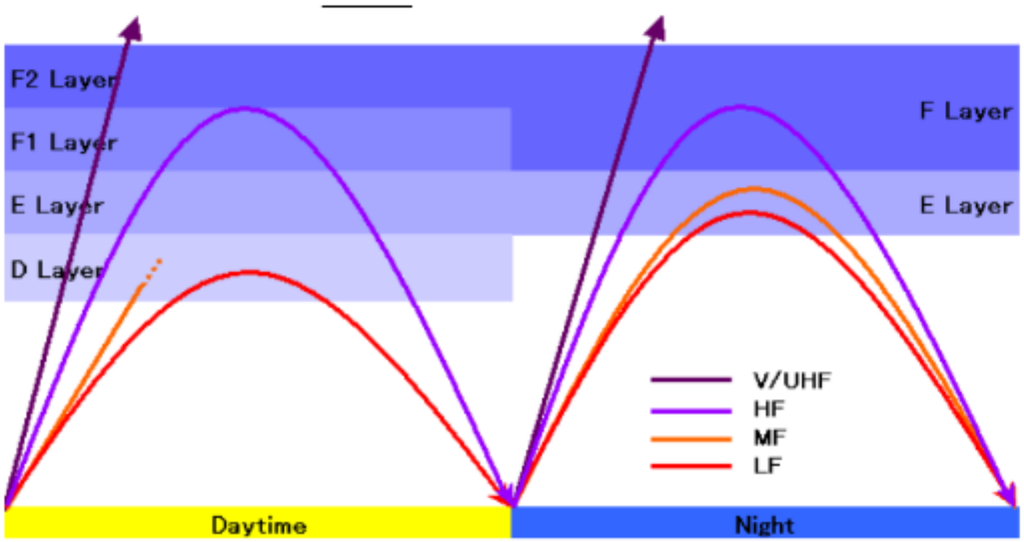
NO3M

Dayton 2018

… quick introduction to 630m

- **472 – 479 kHz**
- **MF (Medium Frequency)**
  - ITU designation for 300 kHz – 3 MHz
  - Includes AM BC and 160M band
  - Daytime D-layer absorption
  - Night-time E-layer reflection
- **Wavelength**
  - 1λ = 2071ft, 1/2λ = 1036ft, 1/4λ = 517ft

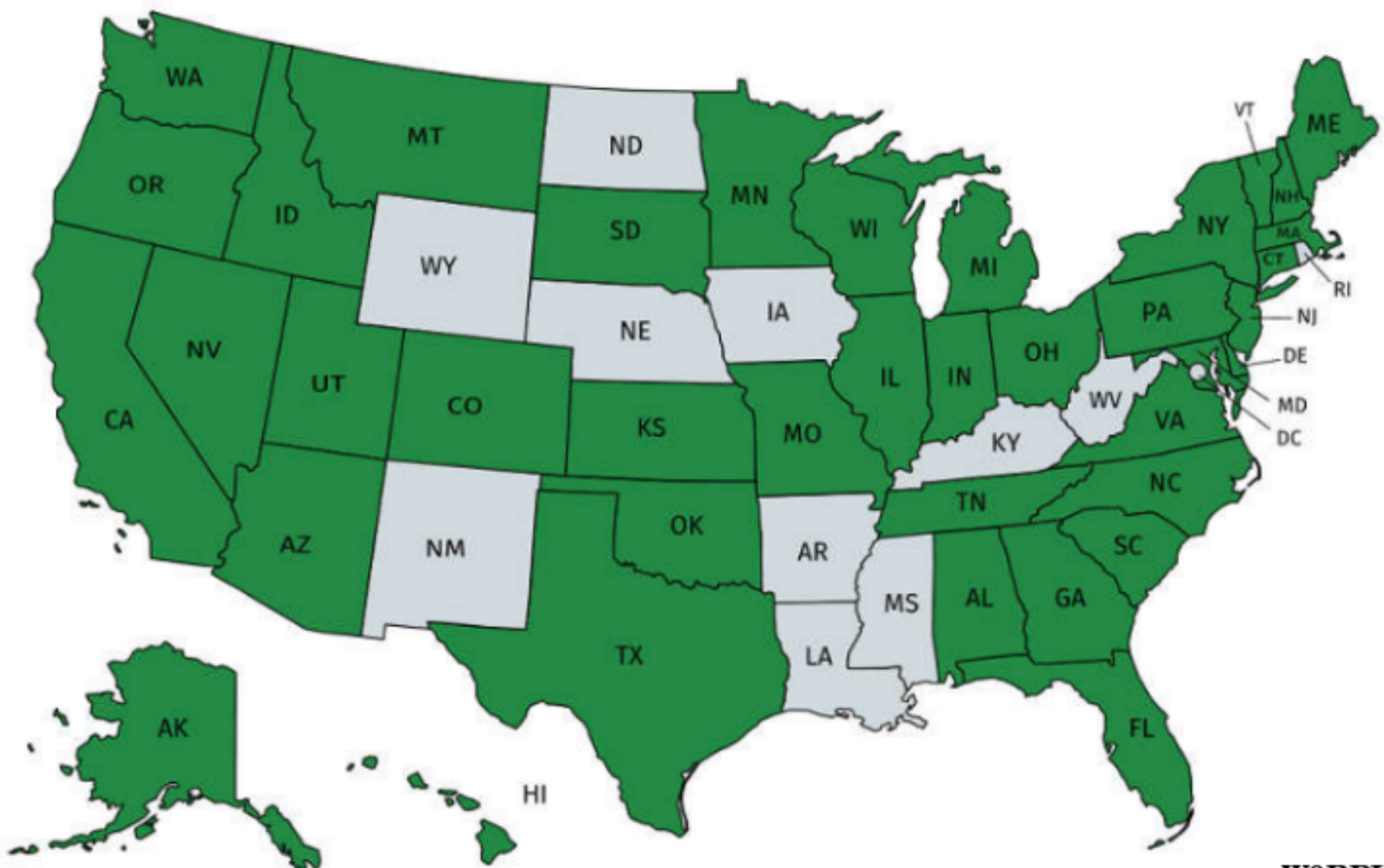


Ionospheric reflection
(under normal condition)

- **Amateur Operation (U.S.)**
  - Spark prior to 1912
  - Radio Act of 1912 limits Amateurs to 200m
  - **Part 5 Experimental Grants**
    - *a few in late 90s and early 2000s*
    - *ARRL establishes group in 2006 (WD2XSH)*
    - *dozens of grants issued to Amateurs throughout 2000s*
  - **WRC-12**
    - *formally allocated by ITU to Amateurs in 2012*
  - **FCC Secondary Allocation**
    - *September 15, 2017*
    - *Must notify Utilities Technology Council (UTC)*
      - 30 day waiting period for reply
    - *First transmissions on October 14*

… *quick introduction to 630m, cont.*

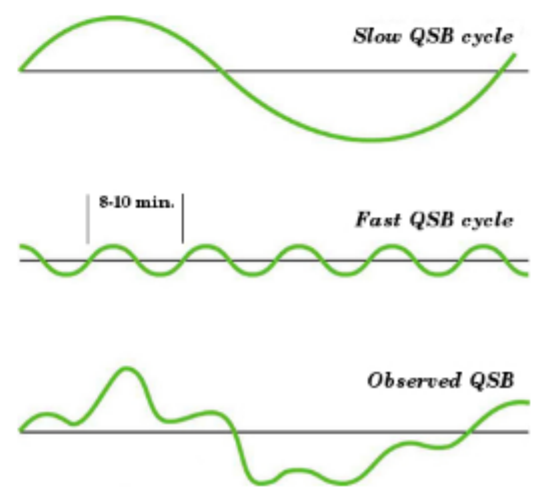
- **U.S. Activity (May 2018)**
  - 111 stations (with recorded QSOs)
  - 39 states
    - *Alaska (KL7)*
    - *Hawaii (KH6)*
  - Many operators from VHF/UHF/EME background

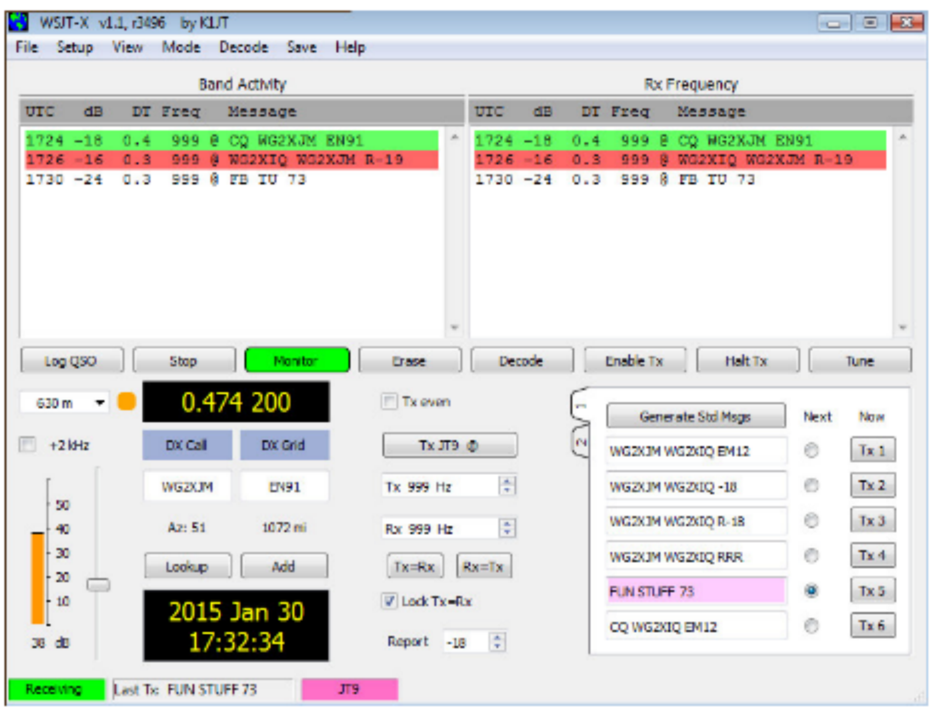


W0RPK

… *quick introduction to 630m, cont.*

- **Propagation similarities with 160M**
  - *Gray line, sunset / sunrise enhancements*
  - *Solar event enhancements*
- **Vertical polarization generally provides best power coupling with ionosphere** (*medium to high latitudes*)
- **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.***





KB5NJD

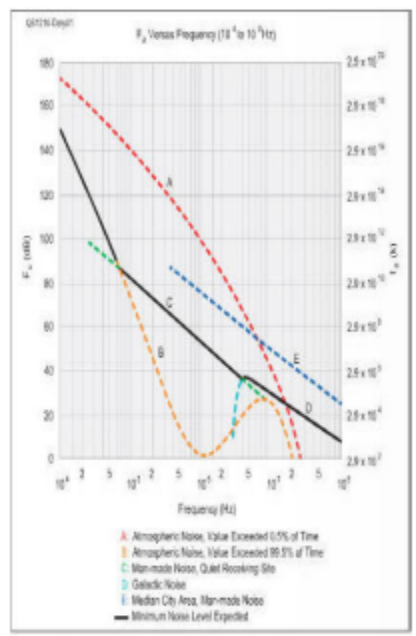


Figure 1 — Signal strength of cosmic noise (D) and atmospheric noise (A) plotted against frequency. From ITU Recommendation ITU-R P.372.

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

160M

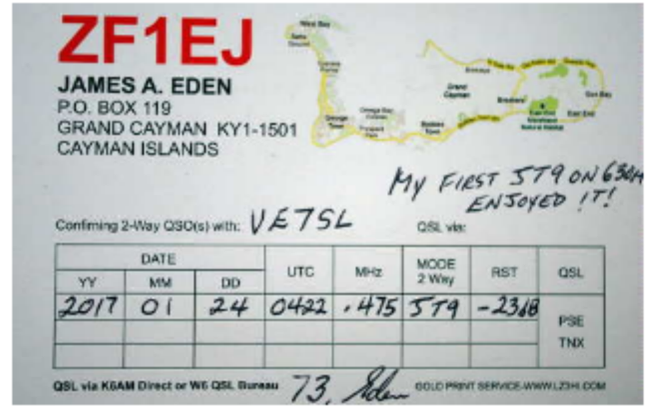
630M

… 630m *myths*

"Need a high efficiency transmit antenna…"

"Need loads of power…"

"Need acres of property…"



VE7SL

"5W EIRP is not enough to work DX…"

- *VE7SL ⇔ VK4YB*
  - *AA1A, N1BUG, NO3M, K9KFR ⇔ EU*
    - *ZF1EJ ⇔ many including west coast*

"It's only a digital mode band…"

- 112 CW QSOs in NO3M log in first 5 months
  - *Many ragchew sessions*
  - *Worked several western states and KH6 on CW*
- a few SSB QSOs

… limitations per Part 97 FCC Amateur Service Rules

§97.15 Station antenna structures

(c) Antennas used to transmit in the 2200 m and 630 m bands ***must not exceed 60 meters in height above ground level*** ***

§97.303 Frequency sharing requirements

(g) In the 2200 m and 630 m bands:

(1) Amateur stations in the 135.7-137.8 kHz (2200 m) and 472-479 kHz (630 m) bands shall only operate at fixed locations. Amateur stations ***shall not operate within a horizontal distance of one kilometer from a transmission line that conducts a power line carrier (PLC) signal*** in the 135.7-137.8 kHz or 472-479 kHz bands. Horizontal distance is measured from the station's antenna to the closest point on the transmission line

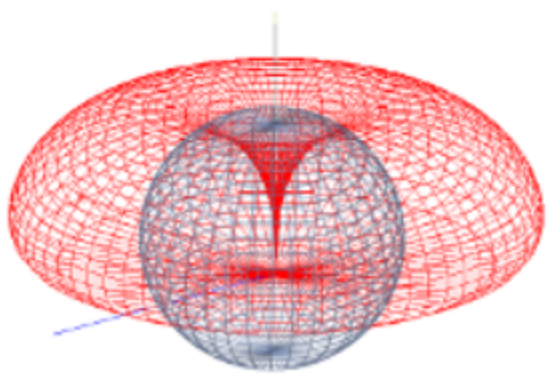
§97.313 Transmitter power standards

(l) No station may transmit in the 472-479 kHz (630 m) band with a ***transmitter power exceeding 500 W PEP or a radiated power exceeding 5 W EIRP***, except that in Alaska, stations located within 800 kilometers of the Russian Federation may not transmit with a radiated power exceeding 1 W EIRP

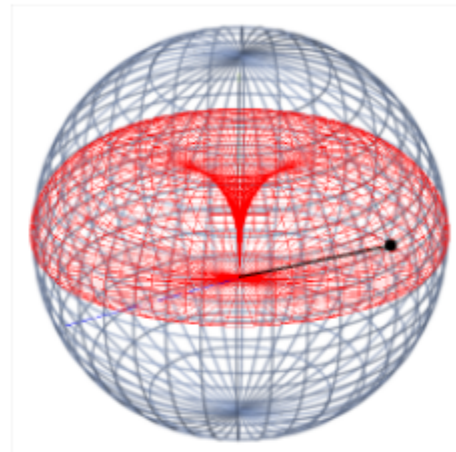
*** *196.85 feet*

… *what is EIRP?*

- ***E**ffective (or Equivalent) **I**sotropic **R**adiated **P**ower*
- Power radiated by an isotropic antenna resulting in the same radiation intensity (W/m^2) as actual antenna in the direction of it's highest gain



Same radiated power



Same radiation intensity

- Similar to ERP limit on 60m, but referenced to an isotropic radiator instead of dipole
- **EIRP(W) = 1.64 * ERP(W)** or **EIRP(dB) = 2.15 + ERP(dB)**

… *mathematical definitions of EIRP*

- Derived from power output and feedpoint measurement:

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

- Derived from base current measurement:

$$P_{EIRP} = I^2 * R_{RAD} * G_a$$

- Derived from field strength measurement (*FCC Pub. 412172*):

$$P_{EIRP} = (E * D)^2 / 30$$

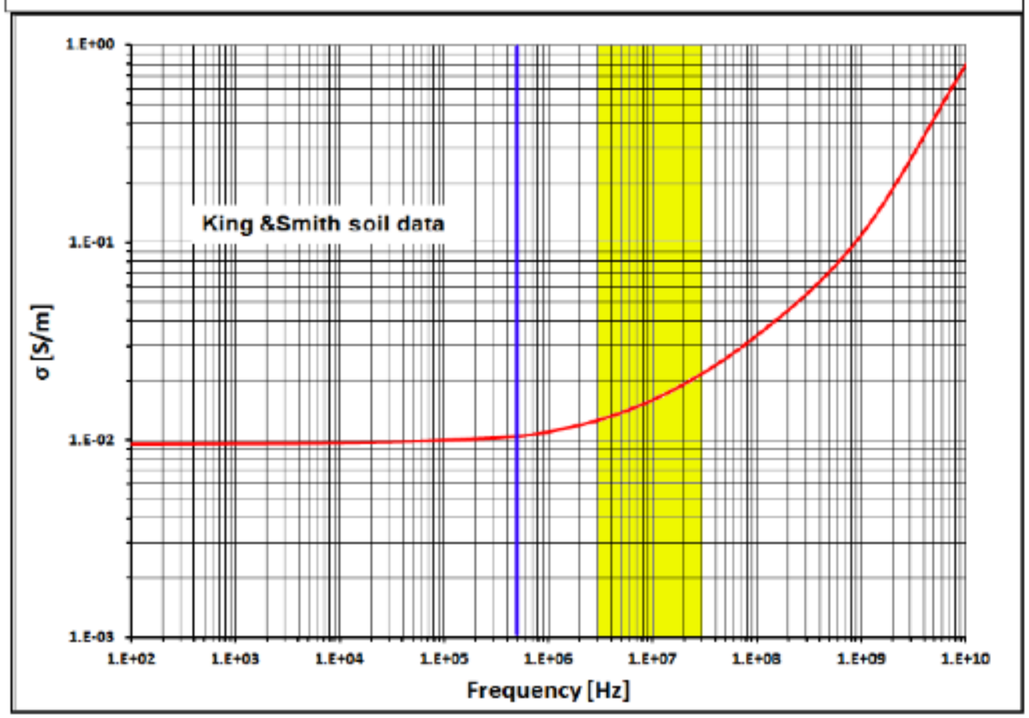
- Units: P (*watts*), R (*ohms*), I (*amperes*), E (*volts / meter*), D (*meters*)
- P_{TPO} = *measured* transmitter output power; **I** = *measured* base current
- $\eta = R_{RAD} / R_{FEED}$ (ie. efficiency)
- R_{RAD} = *modeled or calculated* radiation resistance of antenna
- R_{FEED} = *measured* feedpoint resistance (includes R_{RAD} , ground loss, coil loss, etc.)
- $G_a = 10 \wedge (G_{dBi} / 10)$; G_{dBi} = peak antenna gain in dBi
  - *assume perfect ground gain of 4.77dBi for a vertical ("monopole radiation factor" = 3)*
  - *assume perfect ground gain of 4.82 dBi for small loop (gain factor ≈ 3)*
- **E** = *measured* electric field strength; **D** = distance of measurement from antenna

… *why use* *perfect ground gain?*

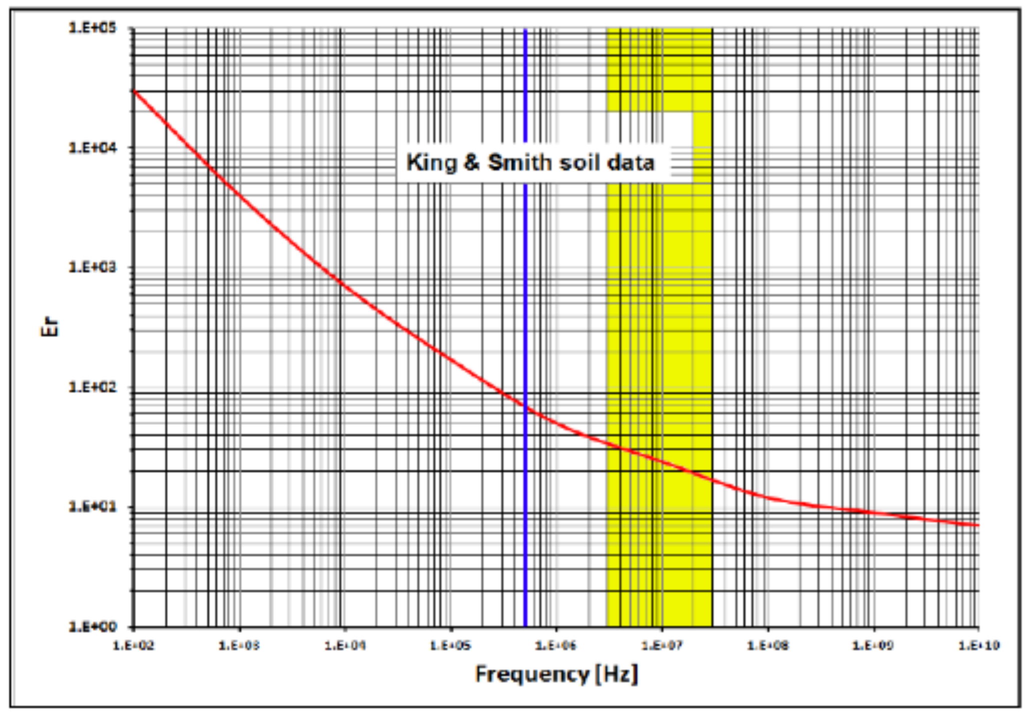
Can we use gain value derived from real ground modeling?

yes, ***BUT…***

- **Ground characteristics at LF and lower MF are different from HF**
  - Various studies incl. King/Smith, Brown/Lewis/Epstein
- ***Unless measurements are made at 475kHz or possibly extrapolated from graphs using HF measurements:***
  - *Perfect ground gain is a safe value*
  - *Theoretical limit that can not be exceeded*
  - *Always keeps us under the power limit when used in calculations*



King and Smith (src: N6LF)

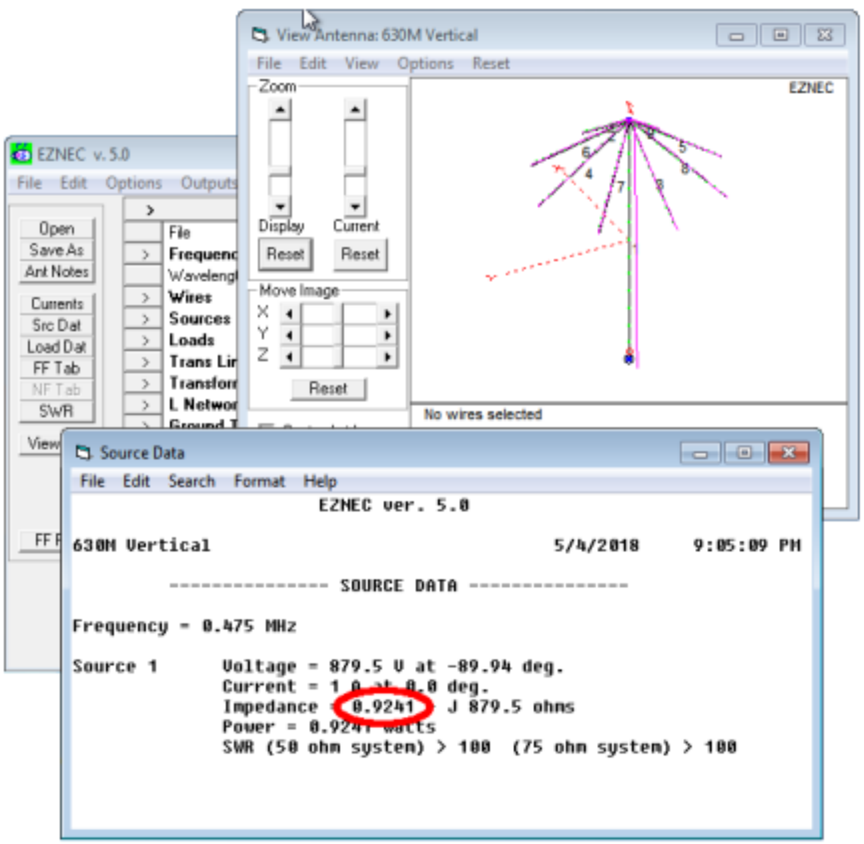


King and Smith (src: N6LF)

… how to determine *EIRP*

Radiation resistance (R_{RAD})

- ***Estimate since it can't be directly measured***
- **Modeling:**
  - EZ-NEC, MMANA-GAL, etc.
  - N6LF notes ‡:
    - *Soil characteristics for f < 1 MHz dominated by conductivity*
    - *R_{RAD} close to perfect ground model*



- **Equations:**
  - Unloaded: $R_{RAD} \approx 0.003 * G_V^2$; (*$G_V$= electrical height in degrees*)
  - N6LF notes, Ch. 3 (*www.antennasbyn6lf.com*)
- **Spreadsheet:**
  - *w0yse.webs.com / wg2xsvpage.htm*
- **Online Calculators:**
  - *www.472khz.org / pages / tools / antenna-simulator.php*
  - *people.physics.anu.edu.au / ~dxt103 / calculators / Rrad.php*

‡ www.antennasbyn6lf.com

… how to determine EIRP, cont.

Feedpoint resistance (R_{FEED})

- **Analyzers**
  - *Cover down to 475 kHz*
  - *ie. RigExpert, FA-VA4, MFJ-259B (mods)‡, etc.*
  - *Strong AM BC can effect measurements (opt. filters)*
  - *Easy to use*
- **Impedance bridge**
  - *ie. General Radio 916-A*
  - *Need external signal generator and detector*
  - *Requires more skill to use*

GR 916-A

RF Current (I)

- **Thermocouple RF ammeter**
- **Homebrew current transformer meter:** *www.w1tag.com/RFA.htm*
- **Measure on either side of loading inductor**
  - Current essentially equal (unless grossly high inductor stray capacitance)

‡http://njdtechnologies.net/modifying-an-mfj-259b-antenna-analyzer-to-operate-on-630-meters/

… *how to determine EIRP, cont.*

Field Strength (E)

- **In theory, best and most accurate method**
- **Notes from W1FR ‡**
  - *Good signal strength*
  - *Far enough to be out of near field*
  - *Near enough to be in inverse-distance (1/d), ie. free-space, region*
  - *Away from conductors and other objects that might alter the amplitude of the field*
  - ***500 – 1000 meters best for measurement on 630m***
- **5W EIRP at 500m produces 0.024 V/m (1.6 µW/m²)**
- **Cons:**
  - *Measurements must be made void of interference sources*
  - *Commercial calibrated meters expensive or designed for AM BC*
  - *Cheaper FSMs lack accuracy and/or sensitivity*
    - eg. Heliognosis EM2 RF Field Strength Meter
      - Min. sensitivity = ***0.005 µW/cm² = 50 µW/m²*** **not sensitive enough!!**
  - *Selective Level Meters (eg. HP-3586C) require elaborate procedure*
    - W1TAG notes: *www.w1tag.com/LF_FSM.htm*

Bottom Line:
<u>this method is probably out of reach for the average ham's resources</u>

‡ http://www.500kc.com/downloads/RN06-32.pdf

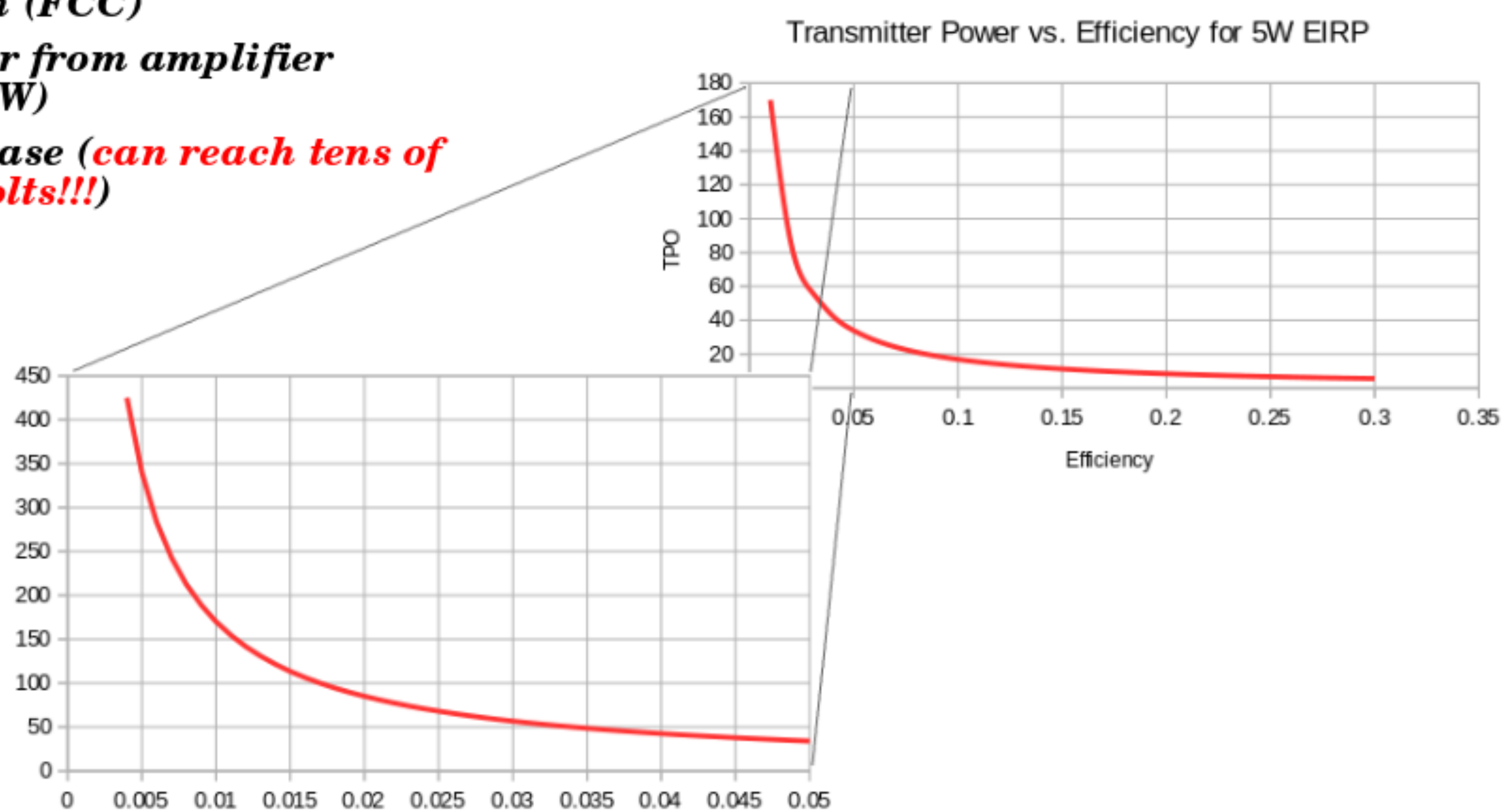
… *how important is efficiency on 630M?*

$$\eta = P_{EIRP} / (P_{TPO} * G_a) \Rightarrow 1 / P_{TPO}$$

- Transmitter power and efficiency are **inversely proportional**
- Diminishing returns on power reduction **after about 15-20% efficiency**

- ***Transmitter Power Output (TPO)*** can be increased to compensate for low efficiency
- Practical transmitter power limits:
  - ***500W maximum (FCC)***
  - ***Available power from amplifier (typically < 150W)***
  - ***RF voltage at base (can reach tens of thousands of volts!!!)***

A good target is 1% - 10%

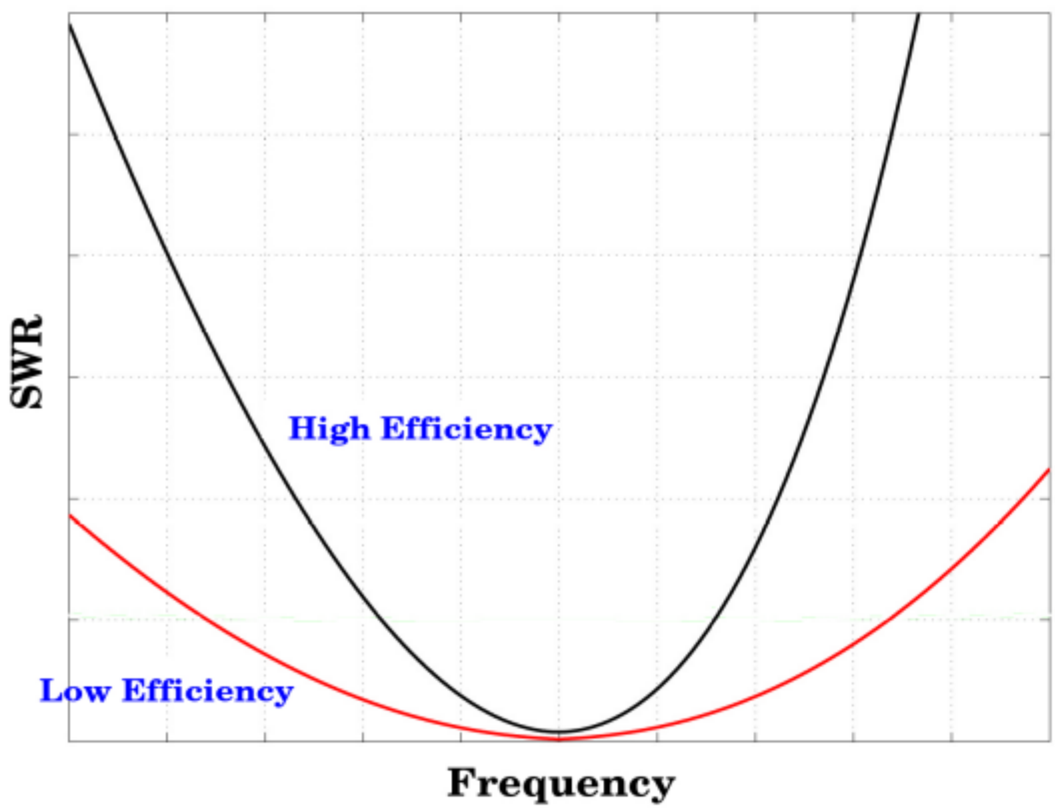


Benefit of lower efficiency?

…Wider SWR bandwidth

- Not having to re-tune for moderate QSY
- Saves wear and tear on tuning components:
  - *Switches, motors, variable caps, etc.*

not the best way of increasing bandwidth!!



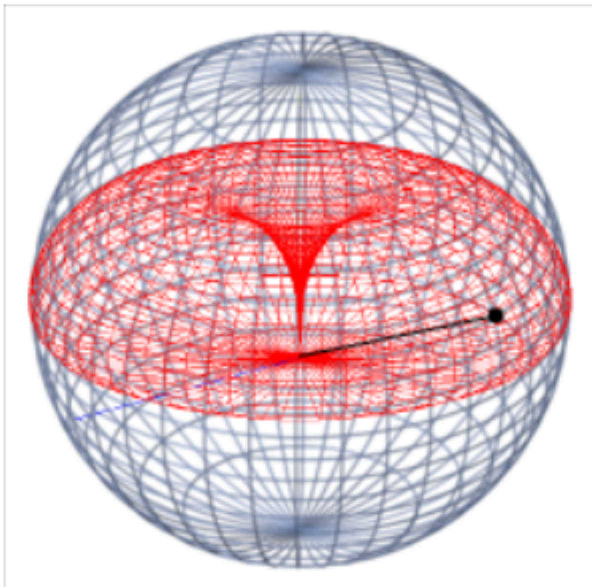
Example: *13% efficient vertical*

SWR	BW (kHz)
1.25:1	0.54
1.5:1	1.36
2:1	2.36

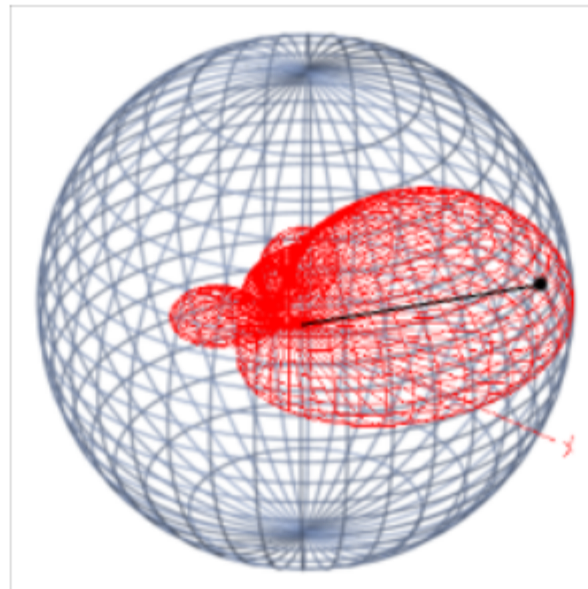
… *why not a directional transmit antenna on 630m?*

- Directional transmit array provides no benefit since increased directivity (gain) requires ***lowering transmitter power*** to stay within EIRP limit and reduces power in lower gain directions

- *Example:* Four Square antenna; **good for RX, but must reduce power for TX**



Omni-directional Vertical



Four Square Array
(*reduced power vs. vertical*)

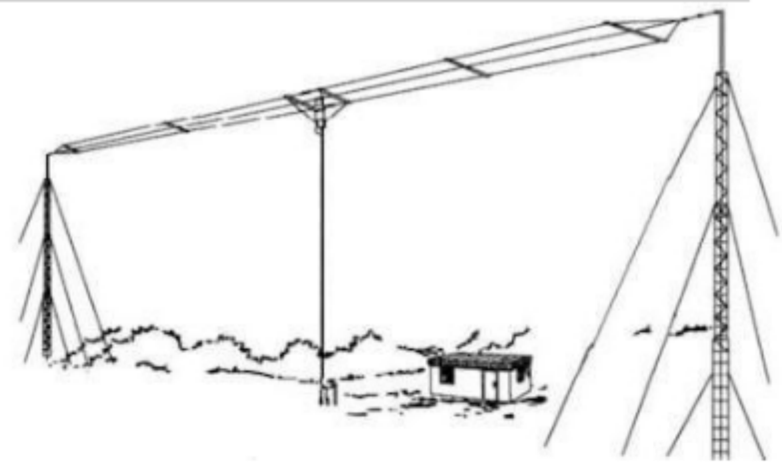
- **Effective directivity can be produced by a dedicated receive antenna at generally less cost, size and complexity than a comparably performing transmit system**

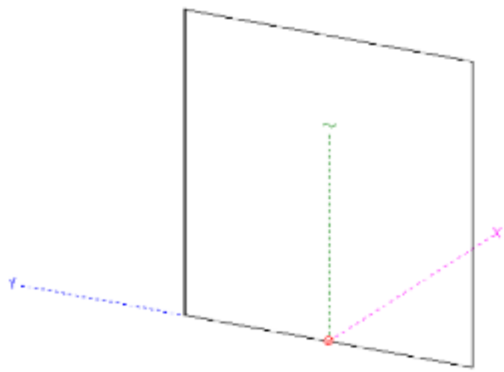
  - full sized 1/4λ spaced transmit Four Square with large radial field vs. 1/8λ spaced receive Four Square using short verticals, hi-impedance buffer/amps and no radials or tophats

… types of transmit antennas used on 630m

Vertical monopole

- Reasonable efficiencies can be achieved
- Many variations to fit almost any lot
- Omni-directional – maximizes azimuthal coverage



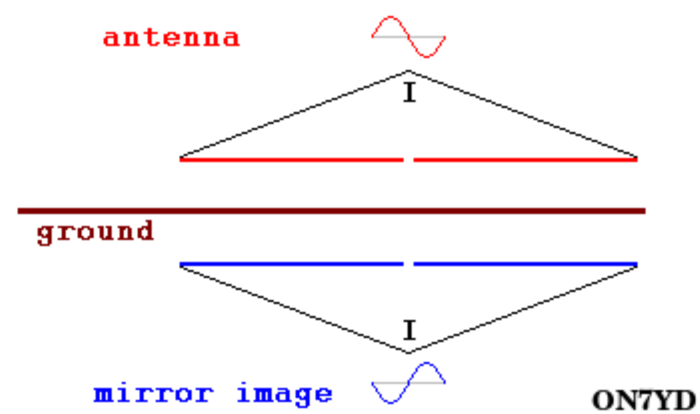


"Small" Loop

- Low efficiency
- Alternative for:
  - ➔ *heavily wooded areas*
  - ➔ *or when radial installation prohibitive*

Dipole

- Acts more like small loop due to low height
  - *radiation peaks off ends*
- Very low efficiency (low R_{RAD}, high losses)
- Considerable ground reflection cancellation
- Used with some success by W1IR (VT)



… *the ubiquitous "short" vertical monopole*

Most useful pattern to maximize <u>radiated power</u> on 630m

- *Ideal: omni-directional*
- *Ideal: minimal high-angle radiation*

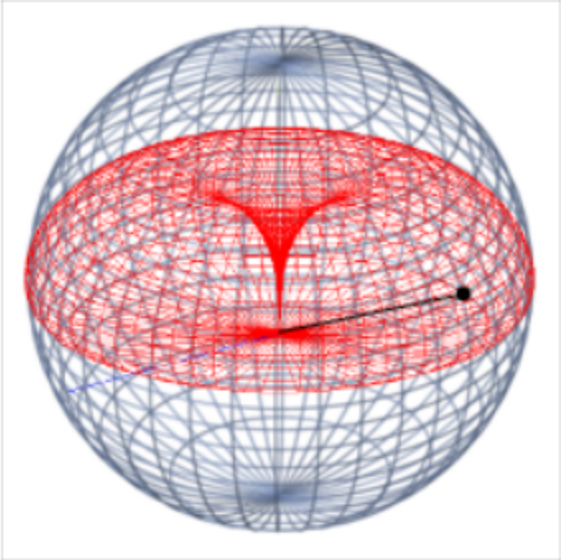
Electrically short on 630m

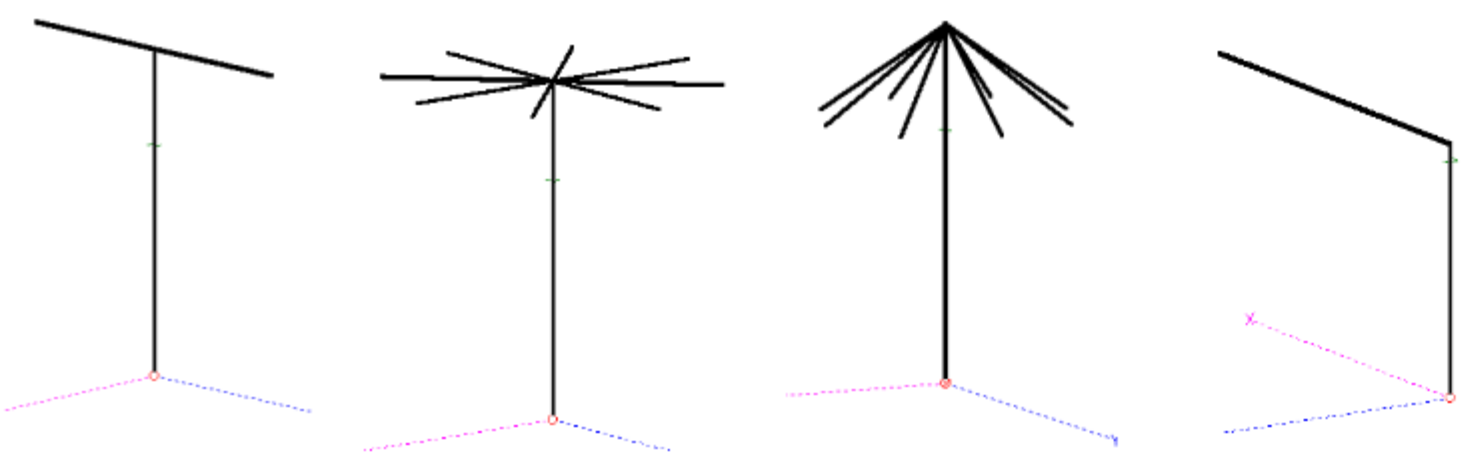
- *Limited to about 1/10 λ (60m)*
- *R_{RAD} typically < 1Ω, but higher achievable with effort*
- *Naturally high reactance (capacitive)*

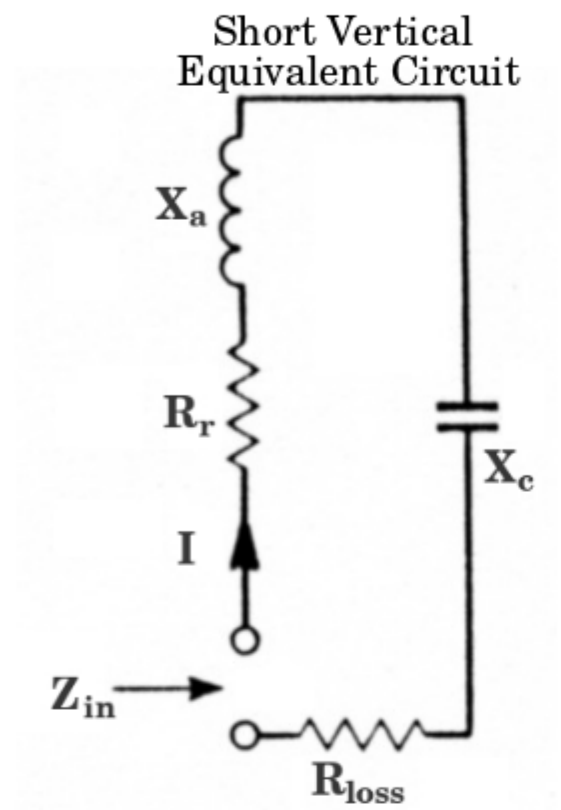
Capacitive toploading

- *Many geometries: Tee, "Disk", Umbrella, Inverted-L, etc.*
- *Lowers resonant frequency and increases R_{RAD}*

Reasonable efficiencies can be achieved



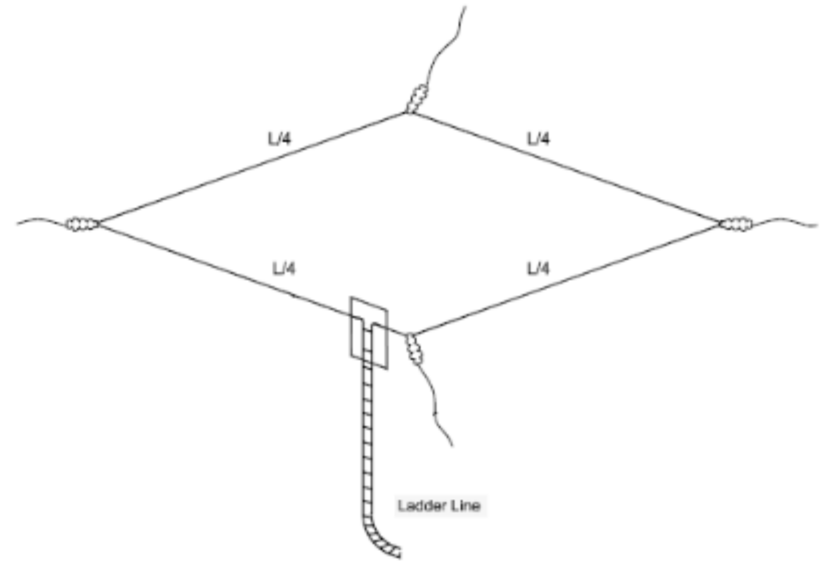




… re-purposing an *existing HF antenna for 630m*

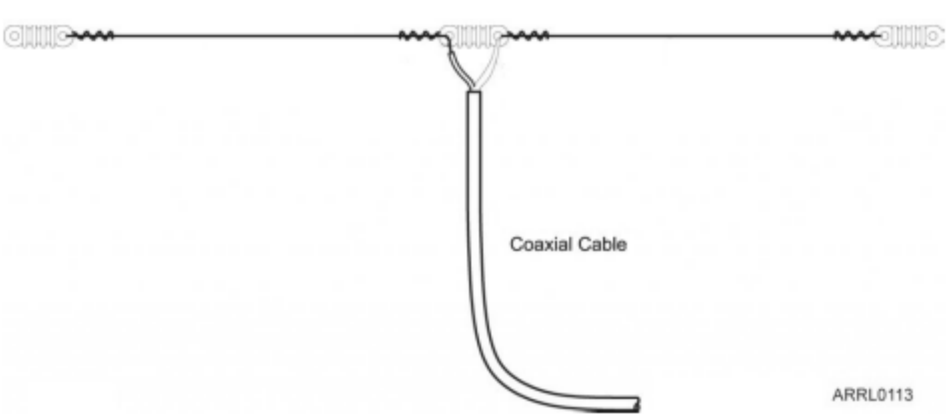
Transform antenna into top-loaded vertical

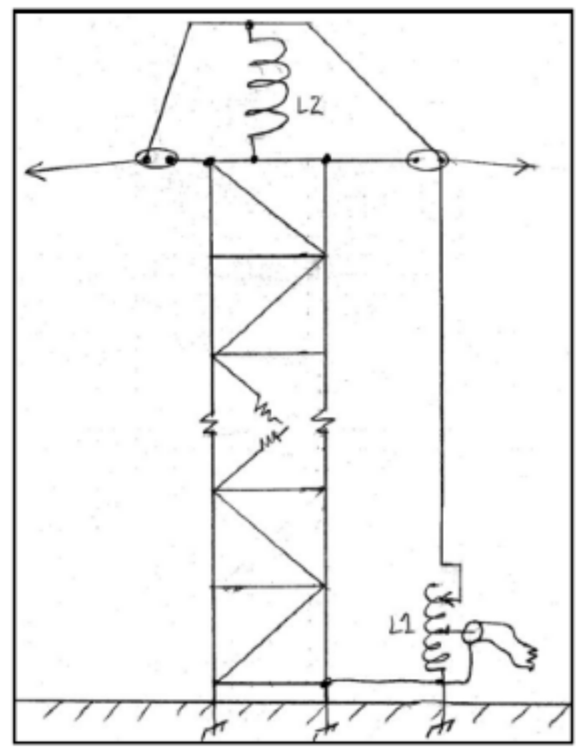
- Short feedline at ground level
  - Coax: *center to braid*
  - Balanced line: *conductor to conductor*
- **Examples:**
  - *80 or 160m dipole or Inverted-Vee*
  - *G5RV*
  - *Horizontal loop ("Skywire")*



Re-tune antenna for lower frequency

- Add or increase loading coil
- Change matching network / transformer
- Add top loading
- **Examples:**
  - *160m vertical or Inverted-L*
  - *Insulated or non-insulated tower*





N6LF

… methods to resonate a vertical

VK7TW

Coil

- *Reactance cancels antenna's capacitive reactance*
- *Common Types:*
  - → Fixed, Tapped, Roller
  - → Variometer: *rotating or sliding inner coil*
  - → Slug or disk tuned (eg. NDB) **LOSSY**
- *Remote tuning via relays (taps) or motor*

Series variable capacitor

- *Reactance cancels antenna's inductive reactance*
  - → eg. inverted-L with long top wire
- *Usually a vacuum variable with fixed parallel caps*

What size inductor (or capacitor)?

- *Measure feedpoint with analyzer between antenna base and ground*
  - → **-jX (capacitive) ⇒ X_L (inductance)**
  - → **+jX (inductive) ⇒ X_C (capacitance)**
- *Solve for L or C*

$$L = X_L \;/\; (2\pi f)$$

$$C = 1 \;/\; (2\pi f X_C)$$

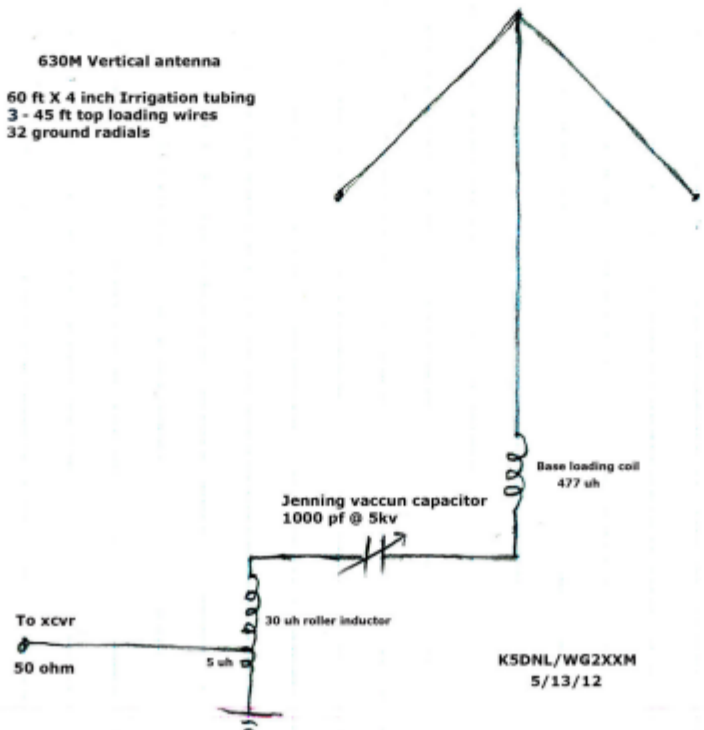
N1BUG

… *methods to resonate a vertical, cont.*

Fixed coil + series variable capacitor

- *Option to avoid inductor mechanical tuning methods*
- *Higher inductance coil than needed*
  - → **hi-Q coil to keep extra losses low**
- *Variable capacitor cancels extra inductive reactance*

K5DNL



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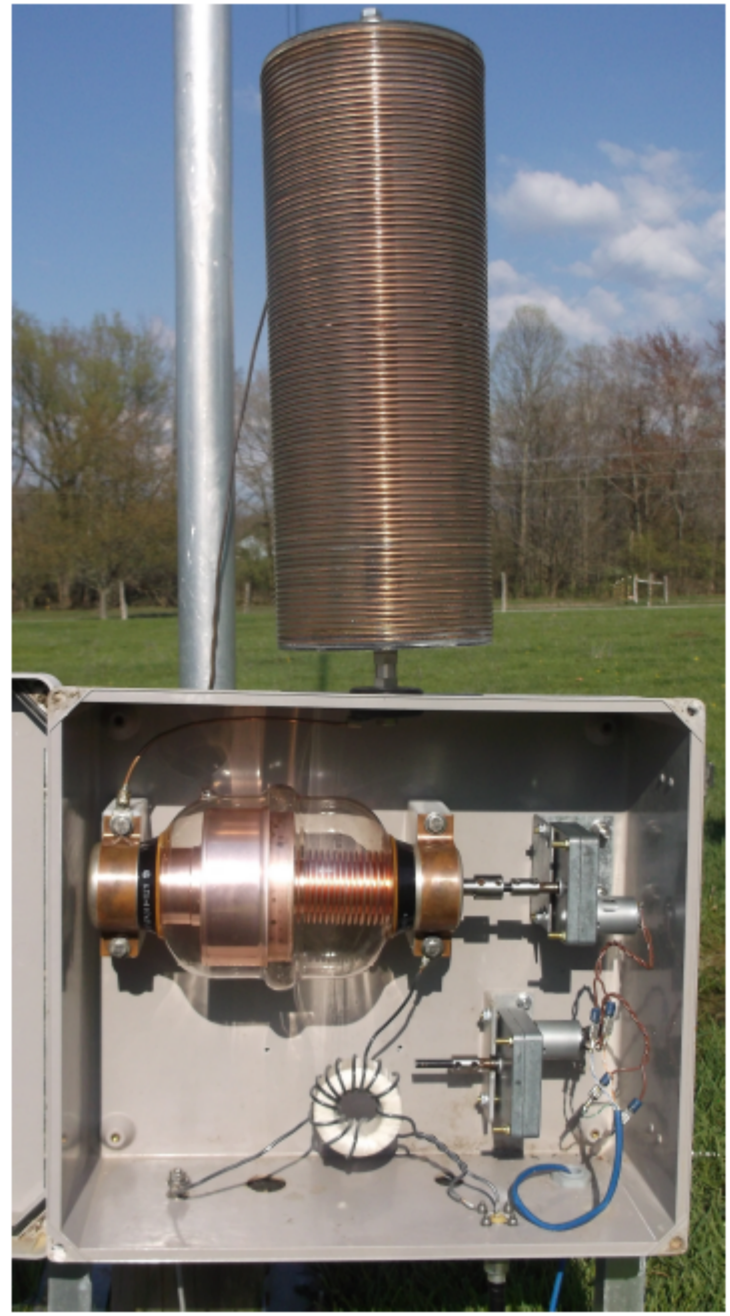


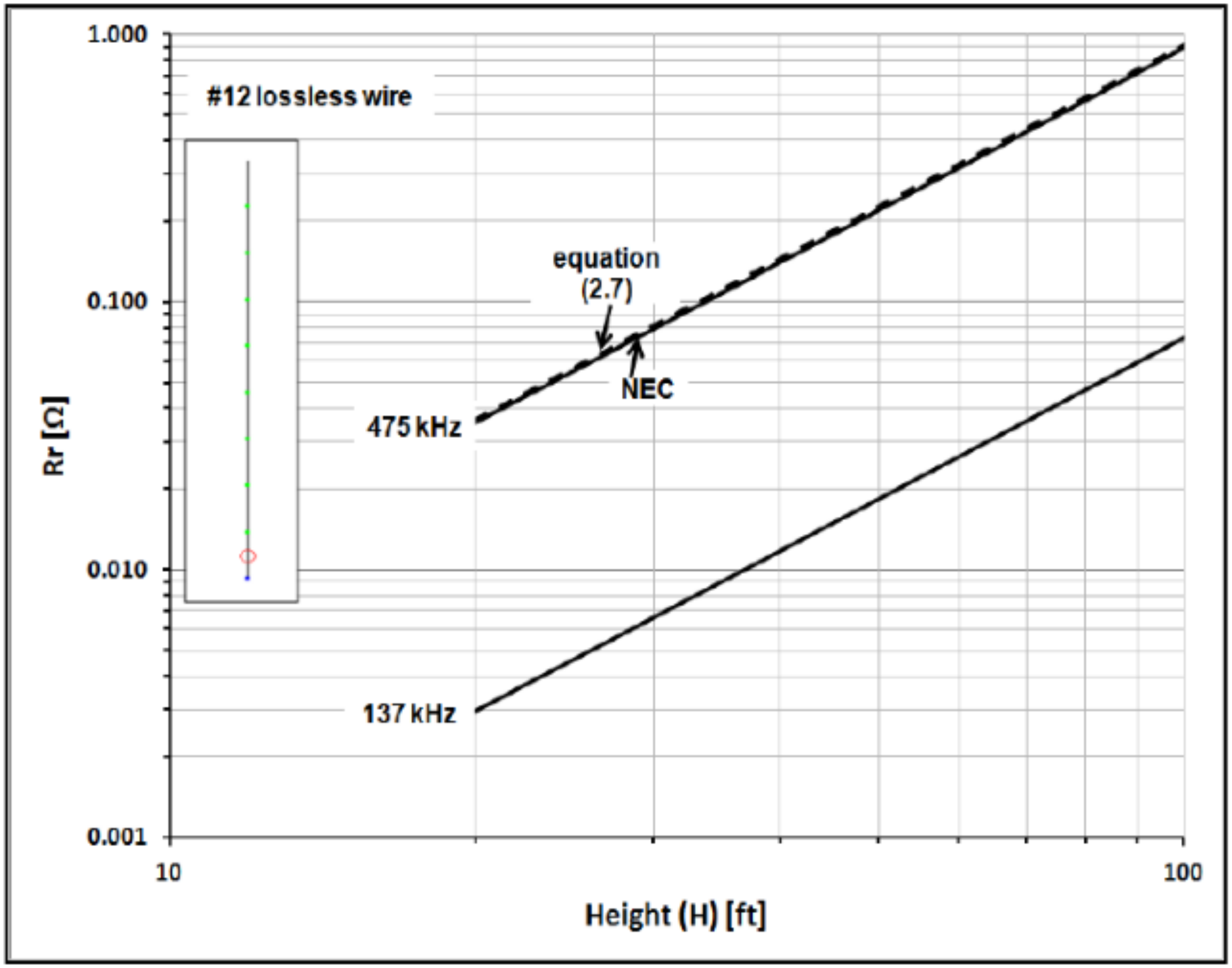
NO3M

... *basic rules regarding short verticals*

Vertical section

- R_{RAD} (and efficiency) increases with height
- Does not have to be perfectly vertical, ie. sloping ok

Make as tall as possible



N6LF

… *basic rules regarding short verticals, cont.*

Capacitive toploading

- **Most efficient (low loss) method of loading**
- Increases radiation resistance (and efficiency)
- Reduces amount of tuning coil inductance (and coil losses)
- **Does not have to be symmetrical**
- Flat top configuration is best
- Sloping wires
  - *R_{RAD} decreases as ends overlap vertical section*
  - *Avoid ends lower than 50% of vertical*
- 2-dimensional antenna (eg. Tee, Inv-L):
  - *Parallel wires*
- Skirt wire connecting ends (umbrella)

Get as much wire in the air as possible

… *basic rules regarding short verticals, cont.*

Loading coils

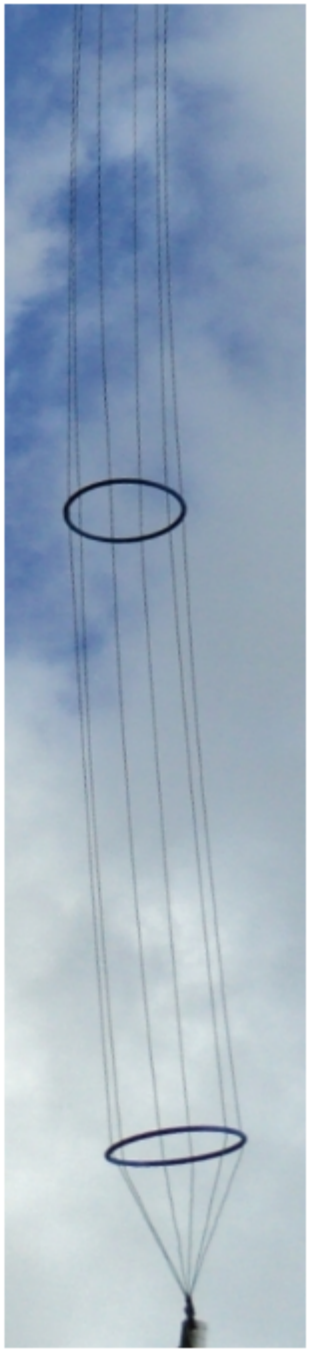
- Typically cylindrical, single layer or variometer
- **Keep clear of conductive objects** (incl. ground)
- **Use as large conductor as feasible**
- **Use low loss forms**
- **High Q** (*many variables, see N6LF notes*)
- Placement in antenna circuit
  - *Base of vertical is typical and convenient*
  - *Elevated can offer improvement … but with sufficient toploading, usually not worth it*
- **Antenna end of coil can have serious RF voltage!**
  - ***Use appropriately rated hardware!!***

NO3M

W5JGV

In-depth resource (N6LF): www.antennasbyn6lf.com

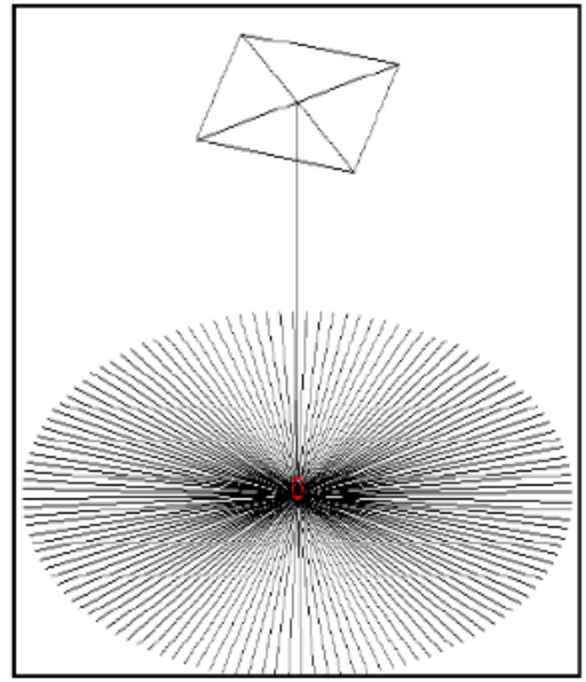
… basic rules regarding short verticals, cont.



W4NFR

Ground System / Radials

- **At least as long as vertical section** in directions w/o toploading
- **Under and extending from toploading**
- For spoked or umbrella types, **extend 25% beyond top-hat radius**
- **Radial density**
  - ***50+ for on-ground recommended***
  - ***16+ for elevated*** *(option if spaced restricted)*
- **For lack of wire:**
  - ***concentrate wire near base of vertical***
  - *ie. many short vs. few long*
- **If lengths are restricted (< 50ft):**
  - *adding ground rods at ends can help*
  - *Elevated counterpoise*



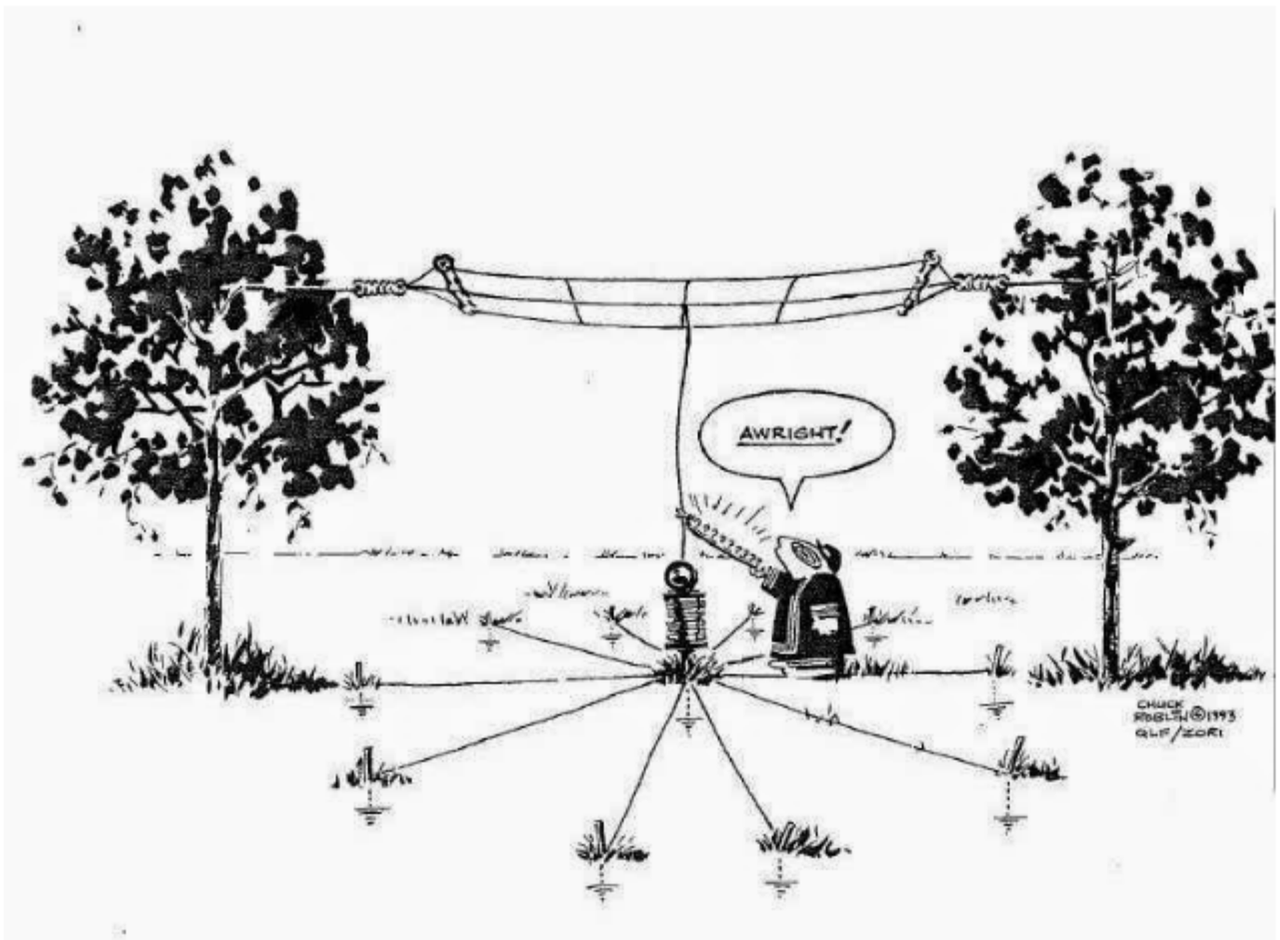
N6LF

Conductor Losses

- R_C (conductor loss) decreases with diameter
- Tubing, wire cage, tower
  - *Usually concerns vertical portion*
  - *Flat, parallel toploading more effective than cage*

... 630m vertical antenna danger

- **High RF voltage at base of vertical (top of coil) and/or ends of top loading wires**
- **Keep clear from contact during operation!** ***people, pets, trees***
- **Need good insulators!**
  - *best:* ***glass, ceramic,*** *ok:* ***delrin/teflon***
- **Due to high reactance**



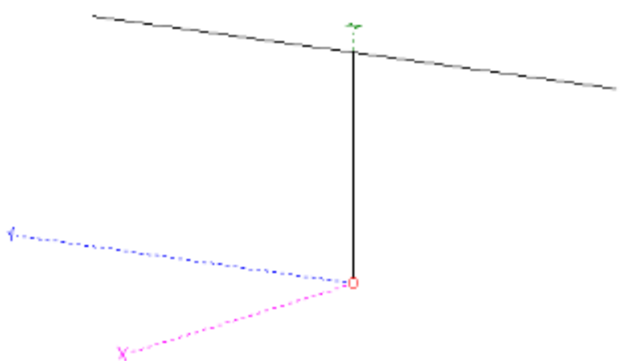
… 630m vertical antenna danger, cont.

$$\mathbf{V = I * X_i}$$

- I = *measured RF current* = $\sqrt{(P_{TPO} / R_{FEED})} = \sqrt{(P_{RAD} / R_{RAD})}$
- $X_i \approx X_C \approx$ *inductive reactance of loading coil* ≈ *modeled* ***jX***
- P_{TPO} = *transmitter output power*
- R_{FEED} = *total measured feedpoint resistance*
- P_{RAD} = *radiated power* = P_{EIRP} / G_a
- R_{RAD} = *modeled or calculated radiation resistance*

Effects: *insulator breakdown, coronal discharge, personal injury, fire…*

Recommend: *try to reduce antenna reactance (jX) as much as possible*



Example:

30ft high 40m dipole as Tee Vertical

Model: $Z = 0.227 - j1954\ \Omega$

When EIRP = 5W → P_{RAD} = 1.67W

$V \approx \sqrt{(1.67 / 0.227)} * 1954 \approx$ **5.3kV !!**

… *Hall of* *Flame*

K9FD

W5JGV

W0YSE

VK4YB

KB5NJD

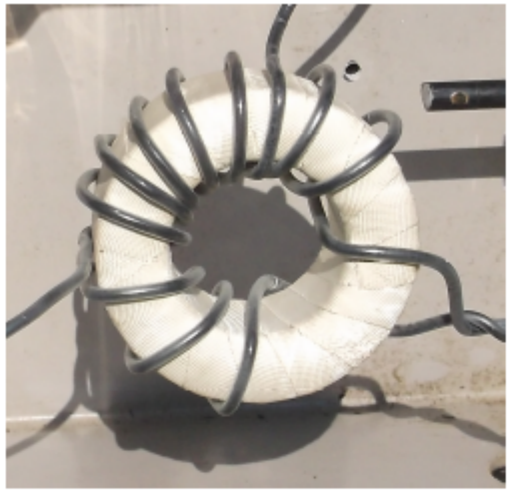
KL7L

Ref: http://njdtechnologies.net/hall-of-flame/

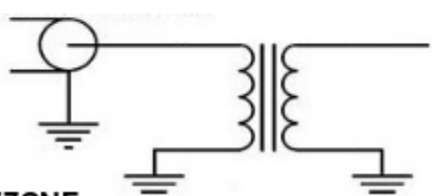
… *how to match the feedpoint*

UNUN or Autotransformer

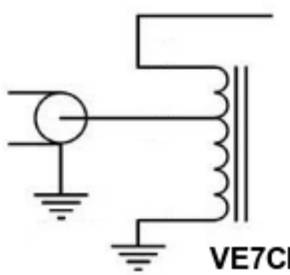
$$n_1 / n_2 = \sqrt{(Z_1 / Z_2)}$$



- FT240-77 core(s) recommended
- Winding reactance at least twice circuit impedance (x5-x10 better)
- DC ground circuit to discharge static
- Wideband
- Separate windings (vs. autotransformer)
  - *galvanic separation between feedline and antenna*
  - *isolates feedline from counterpoise*
  - *interleave windings*



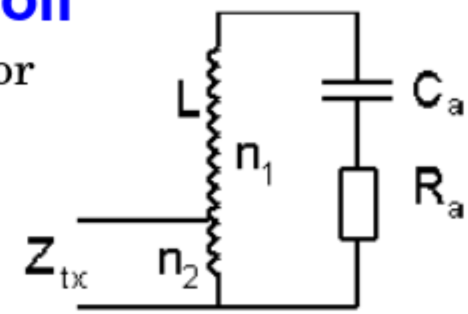
VE7CNF



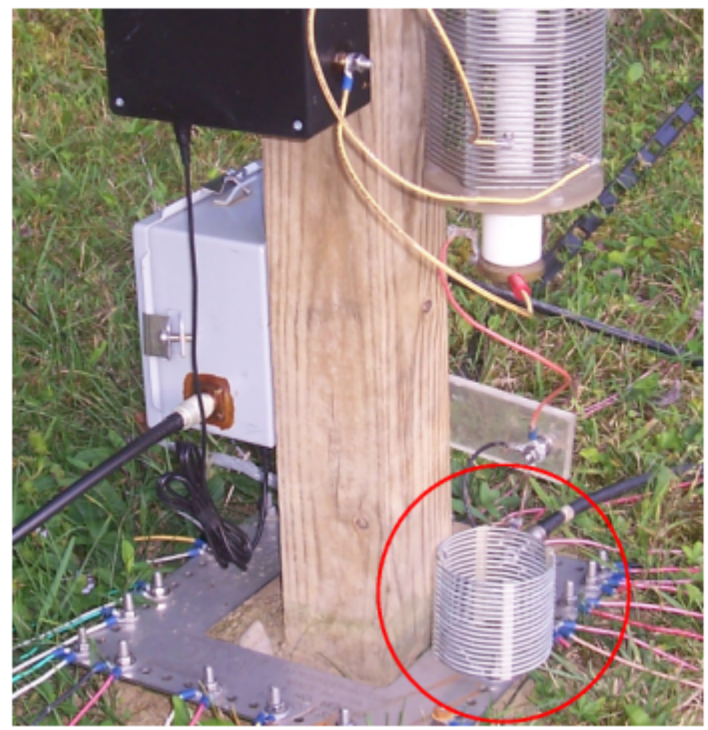
VE7CNF

Main coil tap or shunt coil

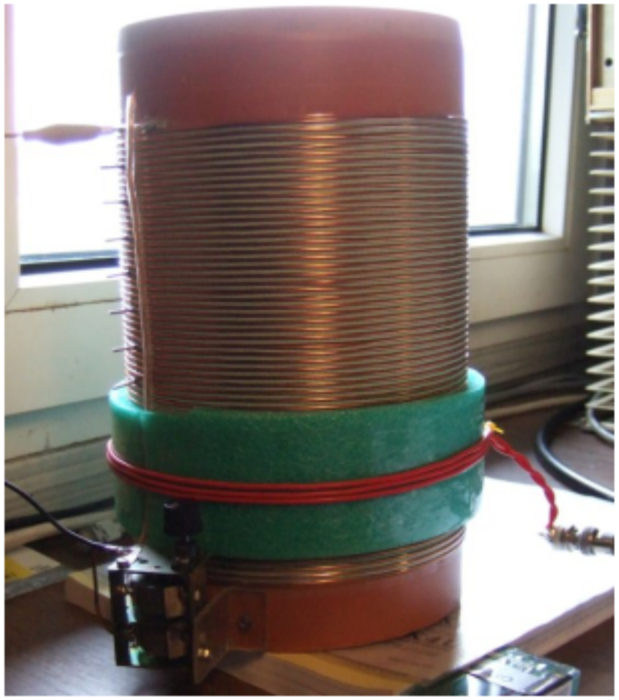
- 50Ω tap on main coil or separate coil between main coil and ground
- DC ground circuit to discharge static
- Resonance and impedance adjustments interact



ON7YD



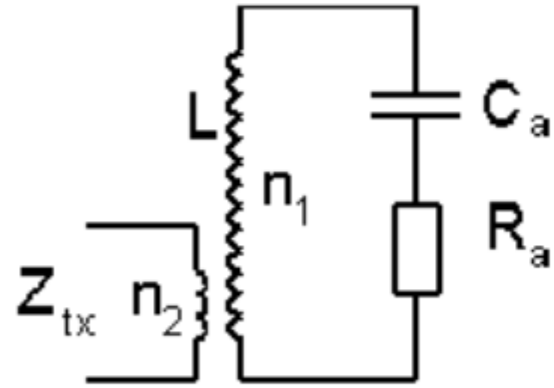
… *how to match the feedpoint*



DL4YHF

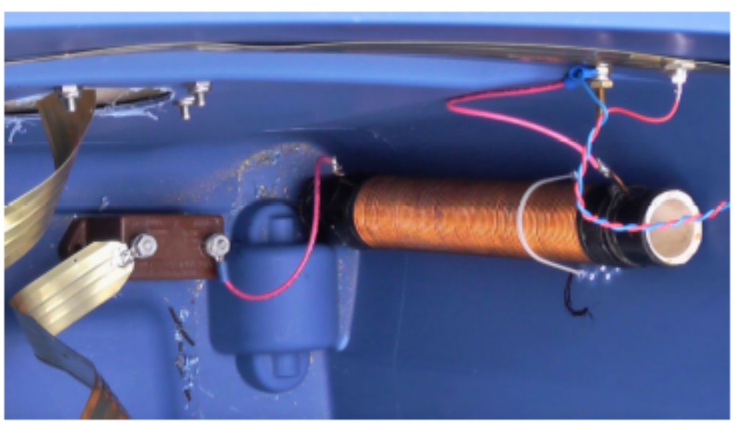
Inductive ("link") coupling

- Fixed input winding over "cold" end of coil
- Variable / "swinging" input link
- DC ground circuit to discharge static



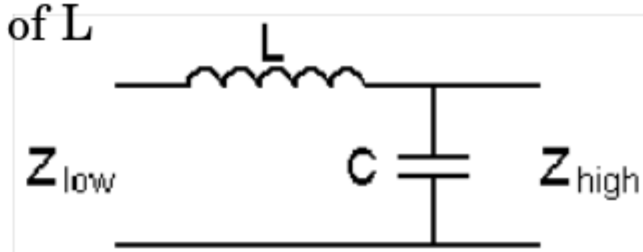
ON7YD

Shunt capacitor



KB5NJD

- Standard LC network
- Use good RF rated capacitor(s)
- Main coil can be all or part of L
- Narrowband

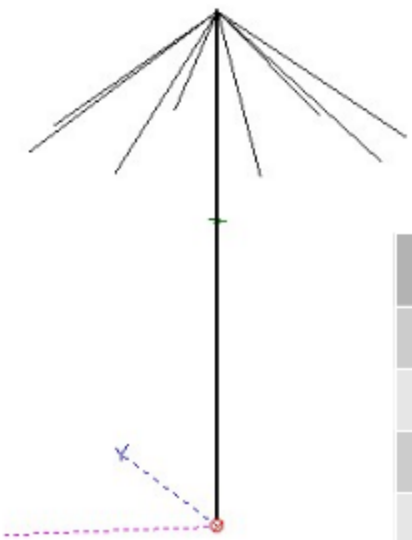


ON7YD

... *example* *vertical antennas*

$P_{EIRP} = 5W$

67-ft vertical, 8x35-ft toploading



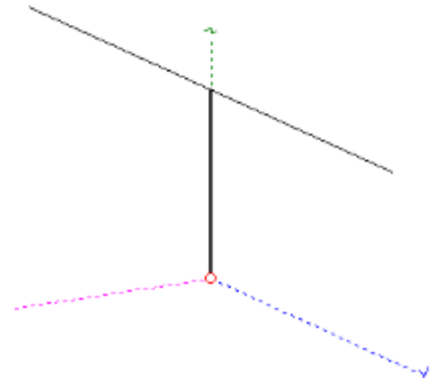
Z = 0.784 -j716 Ω

L ≈ 240μH

1.05kV at base

R_{FEED}	η	P_{TPO}
40Ω	2%	85W
30Ω	2.6%	64W
20Ω	3.9%	43W
10Ω	7.8%	22W

30-ft high 40m dipole



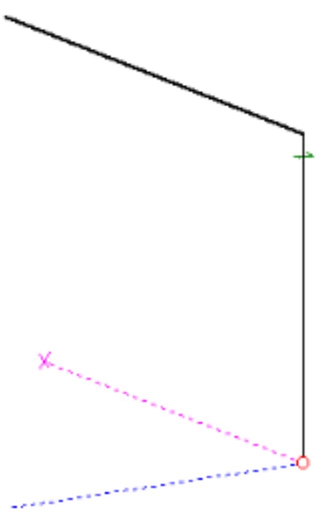
Z = 0.227 – j1954 Ω

L ≈ 650μH

!!! 5.3 kV at base !!!

R_{FEED}	η	P_{TPO}
40Ω	0.57%	294W
30Ω	0.76%	220W
20Ω	1.1%	147W
10Ω	2.3%	73W

160m Inverted-L, 50ft vertical



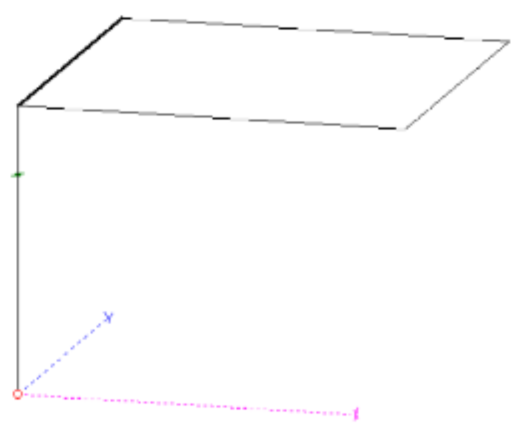
Z = 0.597 -j1351 Ω

L ≈ 450μH

2.3kV at base

R_{FEED}	η	P_{TPO}
40Ω	1.5%	111W
30Ω	2%	83W
20Ω	3%	56W
10Ω	6%	28W

80m Horizontal Loop, 40ft high



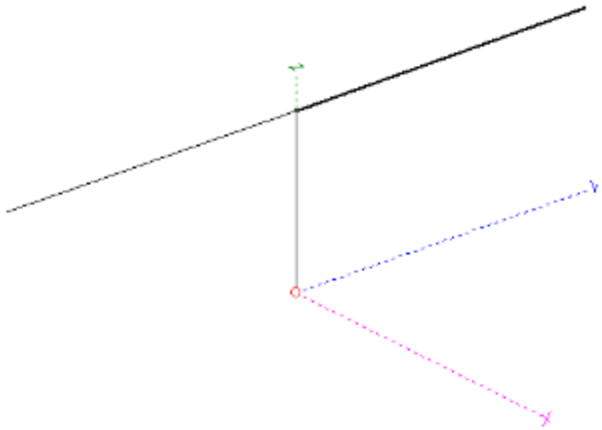
Z = 0.518 -j589 Ω

L ≈ 200μH

1.05kV at base

R_{FEED}	η	P_{TPO}
40Ω	1.3%	128W
30Ω	1.7%	98W
20Ω	2.6%	64W
10Ω	5.2%	32W

… *improve the 630m characteristics of a 80m dipole at 35ft*



Z = 0.356 -j1122 Ω

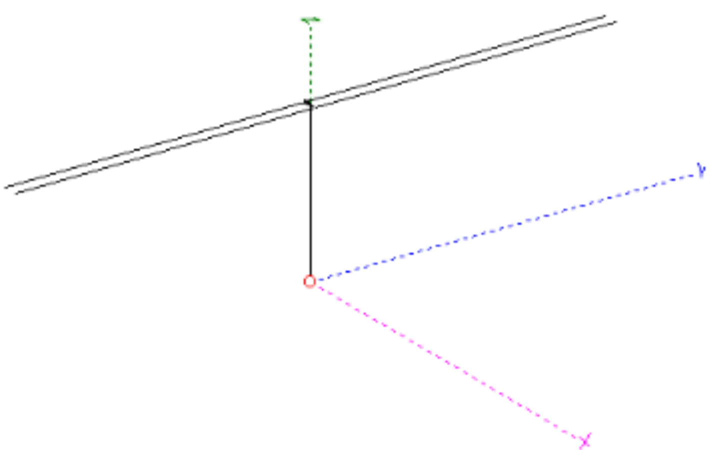
L = 375µH

2.4kV at base

R_{FEED}	η	P_{TPO}
40Ω	1.3%	128W
30Ω	1.7%	98W
20Ω	2.6%	64W
10Ω	5.2%	32W

P_{EIRP} = 5W

add a parallel wire on each side of the dipole, spaced 3 ft…



Z = 0.389 -j757 Ω

L = **255µH**

1.5kV at base

R_{FEED}	η	P_{TPO}
40Ω	1.5%	111W
30Ω	2%	83W
20Ω	3%	56W
10Ω	6%	28W

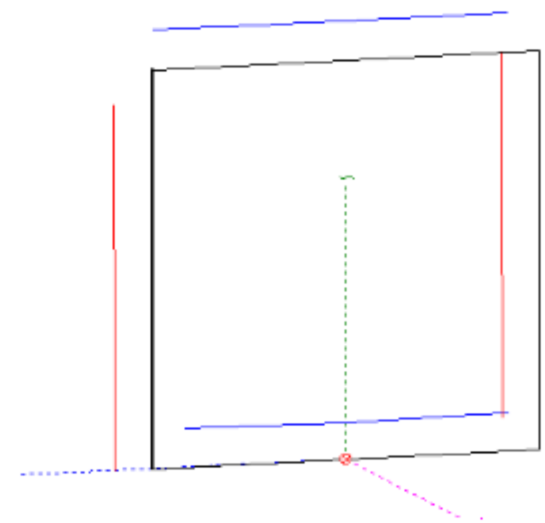
P_{EIRP} = 5W

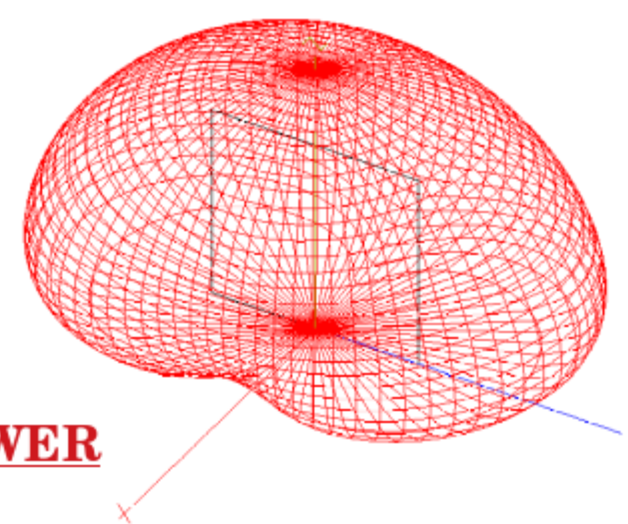
reduction in coil inductance (less R_L improves efficiency) and base voltage!

More broadband on 80m too!!

… *vertical loop antennas*

- **Less than 1 λ perimeter, any closed shape**
- **R_{RAD} depends on enclosed area**
  - *Usually in the mΩ range (inversely proportional to λ^4)*
- **Low efficiency; typically < 3% (limited to ≈ 4.2% ‡)**
- **Nearly uniform current distribution**
  - *Feedpoint location does not effect polarization*
  - *Polarization depends on orientation of loop plane*
- **Radiation pattern**
  - *Peak azimuthal radiation in the plane of loop*
  - *Lots of high angle radiation*



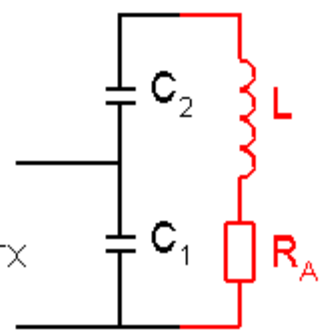


NOT THE MOST EFFECTIVE USE OF RADIATED POWER

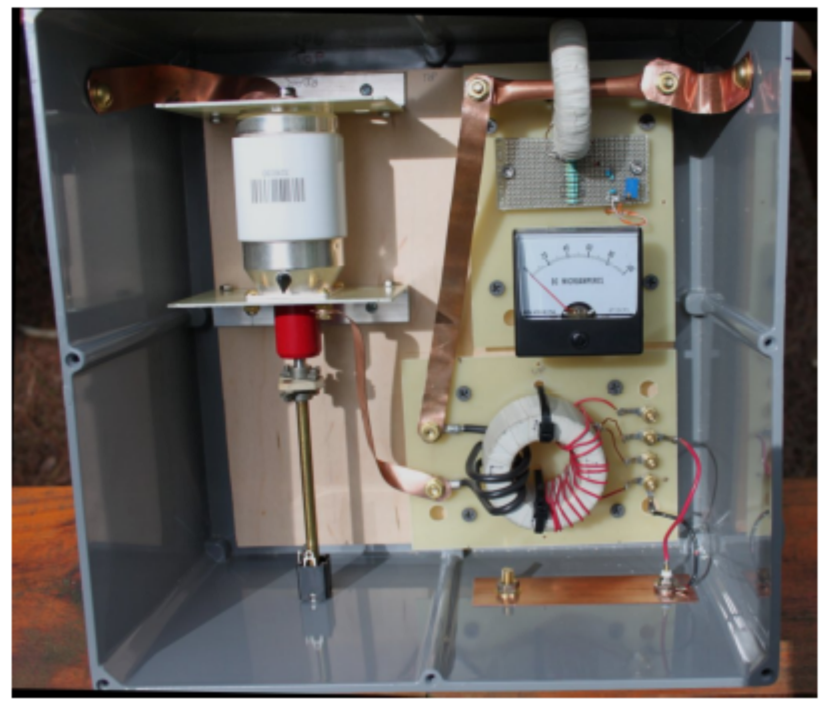
‡ www.antennasbyn6lf.com

… *vertical loop antennas, cont.*

- **High current**
  - *Large conductors (coax) or multiple wires to minimize loss*
- **Magnetic field dominates in near-field**
  - *Less environmental loss (trees, etc.)*
  - *Alternative for heavily wooded locations*
  - *QST: Feb 2018, "Live Trees Effect Antenna Performance", pg. 33*
- **Ground system not required**
  - *Near-field ground losses still high*
  - *Wires as far from ground as possible (use other geometries)*
  - N6LF*: ground screen can improve performance †*
- **Resonate with series capacitance**
  - *Rated to handle RF voltage (* $V = I * X_C$ *)*
  - *Rated to handle high RF current*
  - *Low ESR*
  - *eg. vacuum variable*
- **Matching**
  - ***UNUN:** FT240-77 core*
  - *C-C network (ON7YD)‡*



ON7YD

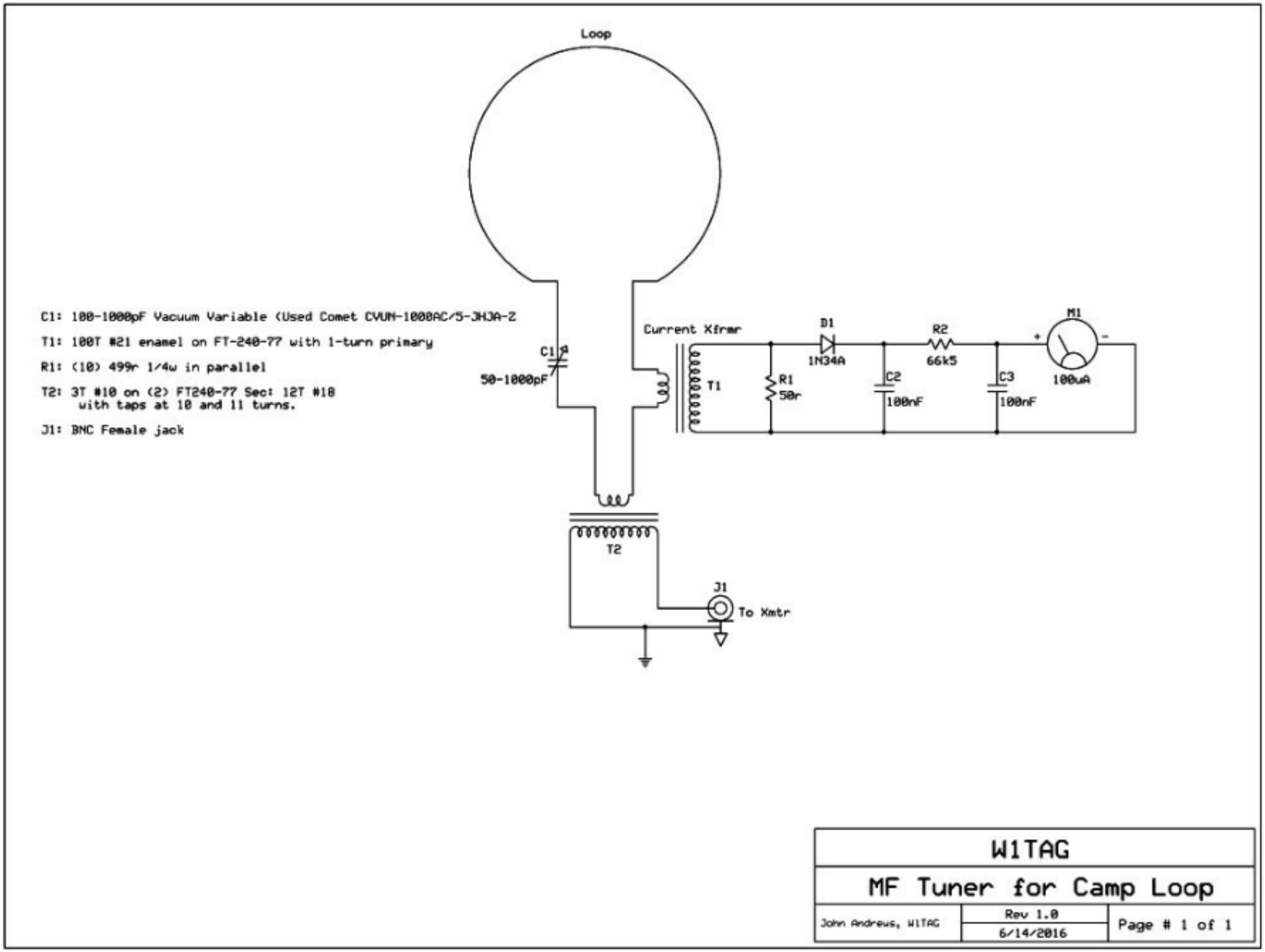


W1TAG

† www.antennasbyn6lf.com

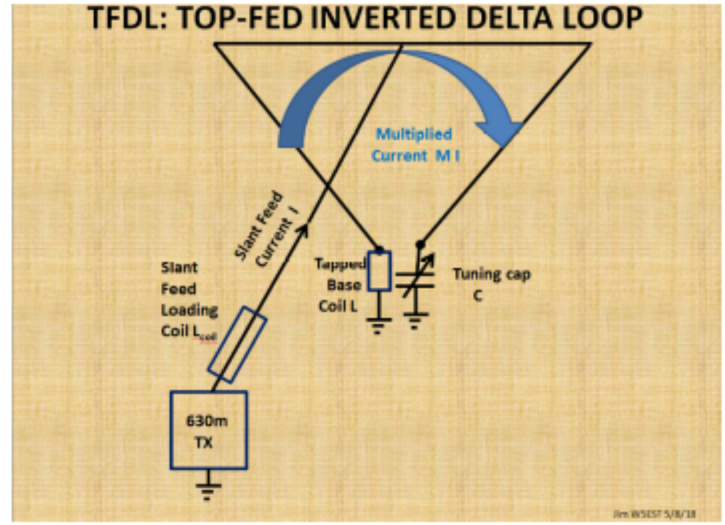
‡ http://www.strobbe.eu/on7yd/136ant/#LoopImpedance

… *vertical* *loop antennas*, *cont.*



… *experimental* *transmit antennas*

VK4YB: *voltage fed, linearly loaded vertical*
VK4YB: *Bottom-hat vertical*
W5EST: *top fed inverted delta loop*
N6LF: *inductor / capacitive loaded loop*



W5EST

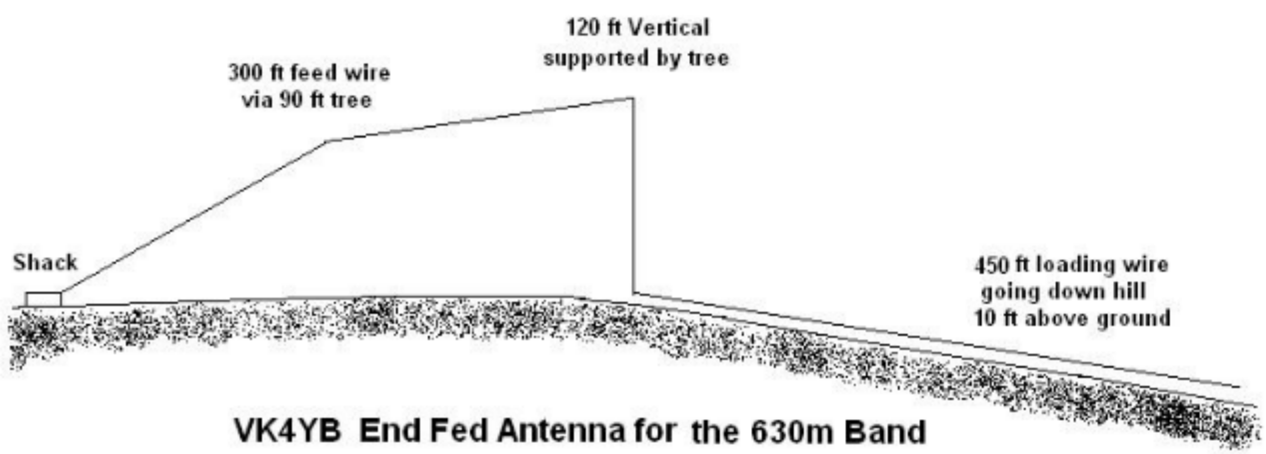
630m is an experimenter's band!

Many unexplored or unique designs remain to be analyzed:

K2AV FCP?

Other unique loading and counterpoise methods?

Make your own contributions!!



VK4YB End Fed Antenna for the 630m Band

The 450 ft loading wire brings the current maximum to the centre of the vertical section.
Feed impedance is high which is handled by a parallel tuned ATU with link coupling.

VK4YB

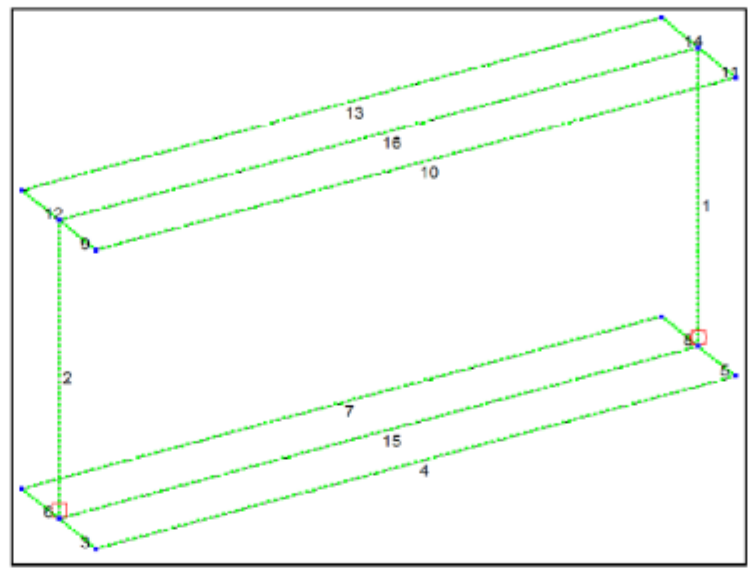


Figure 4.30 - Adding top and bottom capacitive loading.

N6LF

… *NO3M 630m transmit antenna*

- 67-ft (20.4m) aluminum tubing
- Eight 35-ft (10.7m) ≈ 45° sloping topload wires
- Beer bottle base insulator
- 22,000-ft radials (shared with 160M Four Square)
- $\mathbf{R}_{RAD}$ ≈ 0.784 ohms, 6 ohms feedpoint
- 13% efficiency
- 9:1 UNUN matching transformer (2x FT240-77)
- Resonance tuning
  - 410 uH inductor, #12 AWG copper, 6 in. dia
  - 1000 pF vacuum capacitor (≈ 700pF used), motor driven

… recommended reading on 630m transmit antennas

N6LF LF-MF Antenna Notes ***(6 chapters):***

- *www.antennasbyn6lf.com*

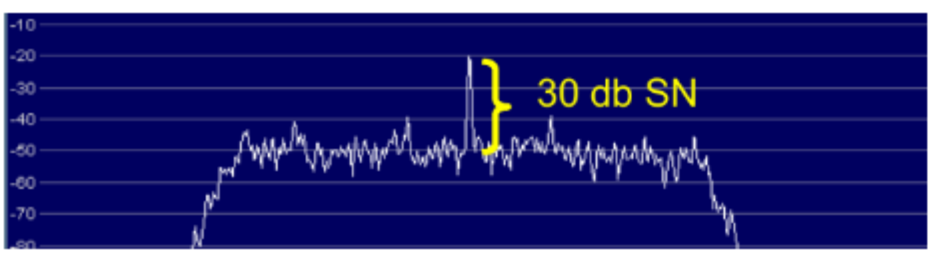
ON7YD "Antennas for 136kHz" ***(adaptable to 630m):***

- *www.strobbe.eu/on7yd/136ant/*

… *why receive antennas at LF / MF?*

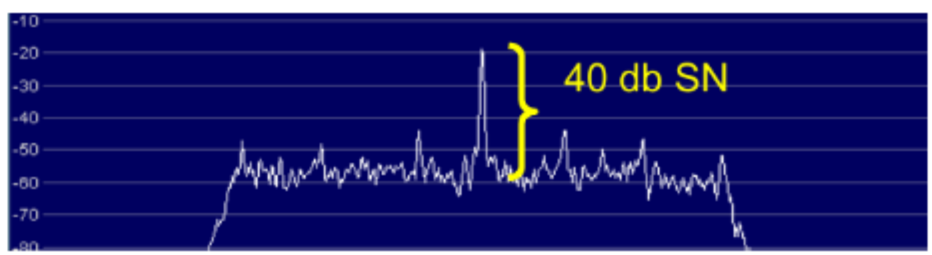
- **Improve Signal to Noise Ratio (SNR) as compared to transmit antenna(s)**
  - Most transmit antennas used on 630M and 2200M are omni-directional, therefore no noise discrimination in the azimuthal plane at a particular elevation angle
  - Due to the nature of an EIRP power limit, directional transmit 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

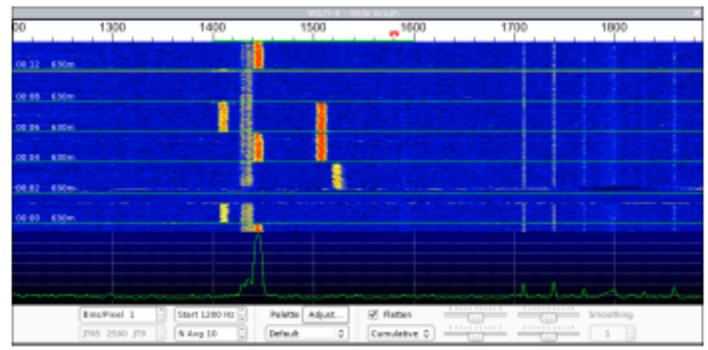
Directional Receive Antenna



N4IS

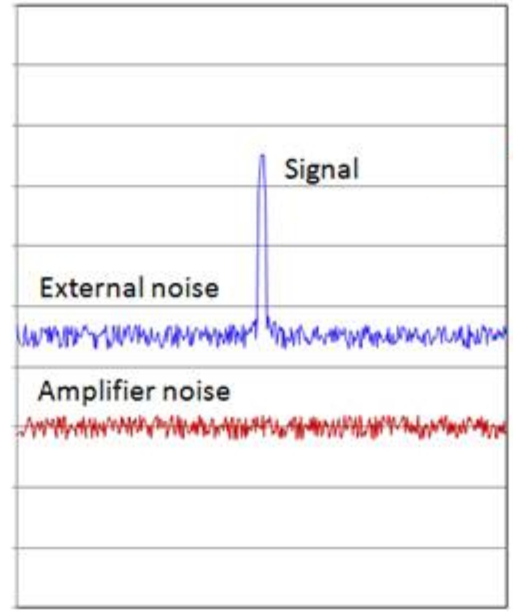
… *benefits of improved SNR from receive antennas*

- **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, FT-8, WSPR, etc.)
  - Deal with QSB better
  - More sustainable ragchewing sessions
  - Work stations further away (more DX!)

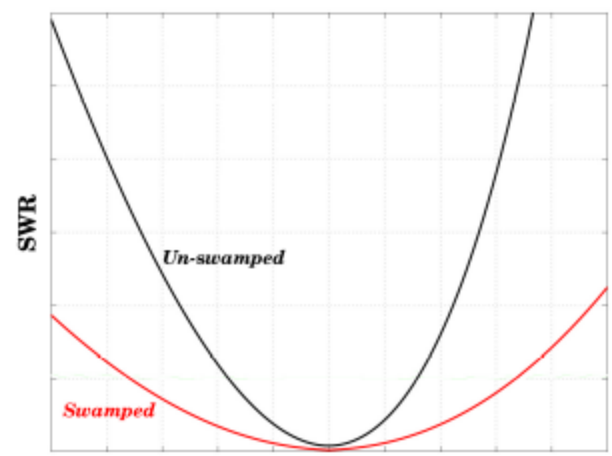


… how do we *improve SNR?*

- **NOT BY INCREASING GAIN OR EFFICIENCY!**
- **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*

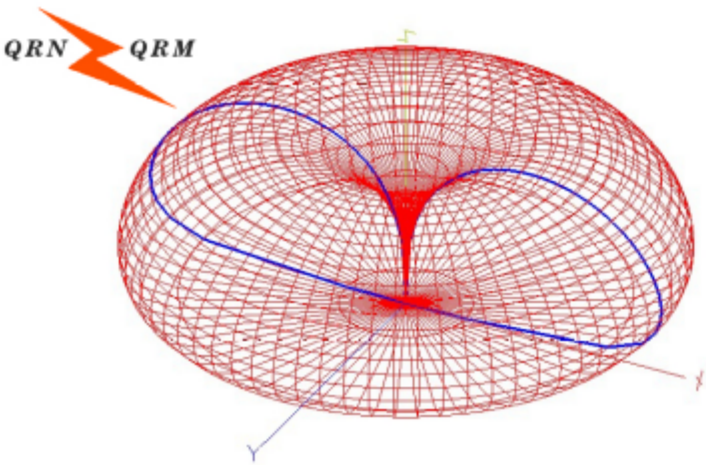


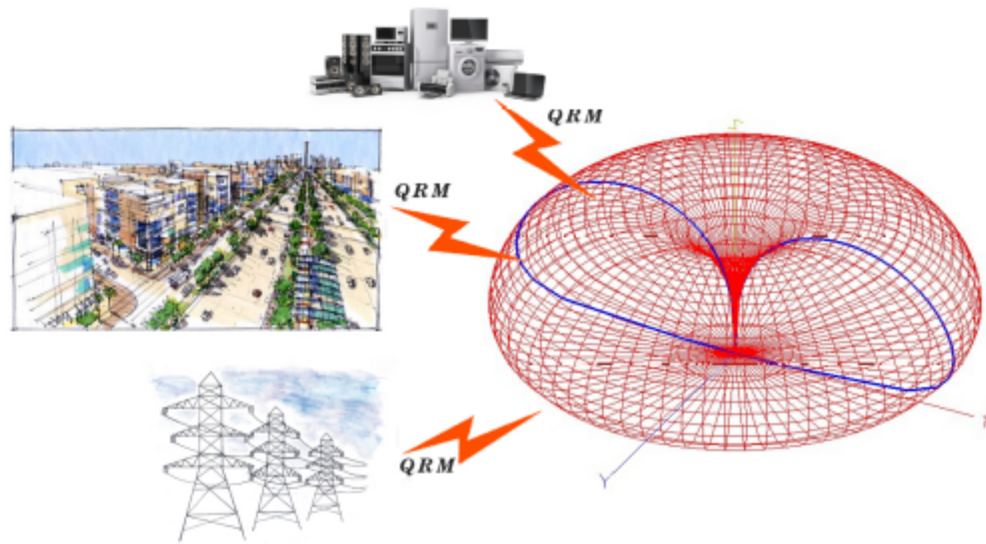
DL1DBC



… *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)

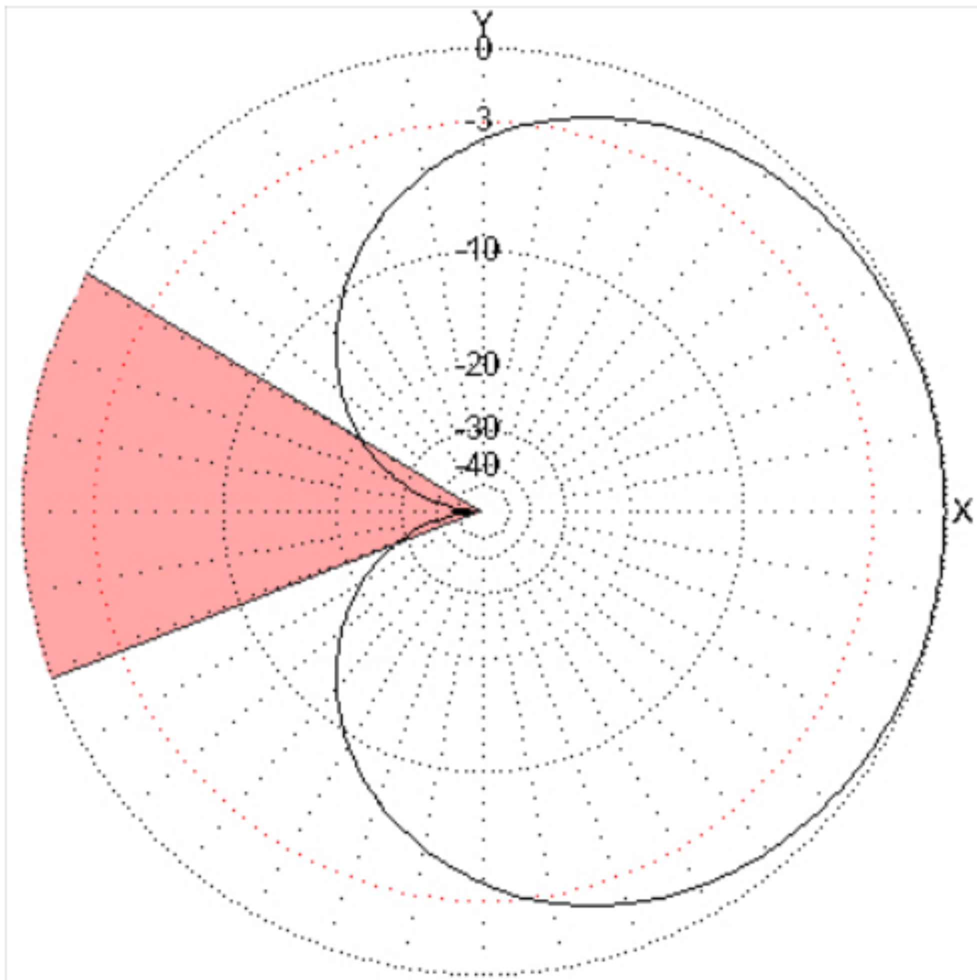




- **Understand behavior of noise**
  - **Far-field propagated noise (atmospheric)** is randomly polarized. Same ratio of electric and magnetic fields as "signal". Culmination of thousands of point sources. Can use antenna pattern to mitigate.
  - **Far-field groundwave noise** is vertically polarized 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

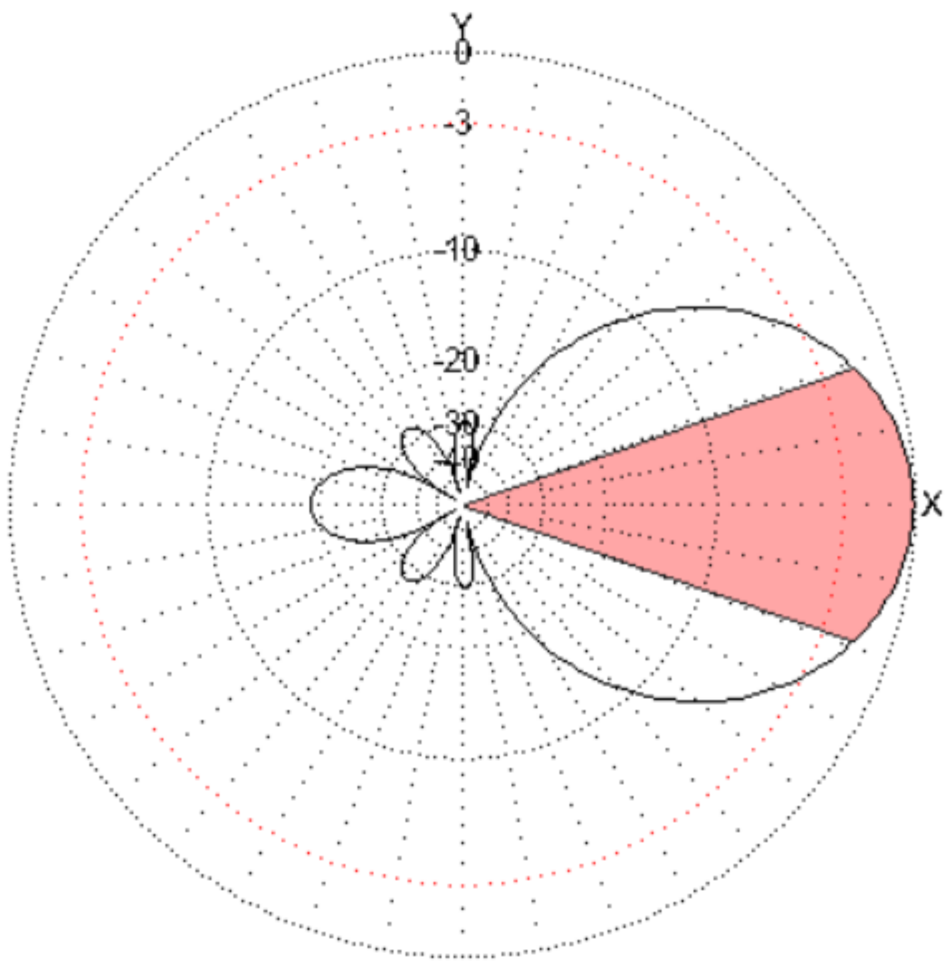
… *how do we improve SNR?, cont.*

- **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)***



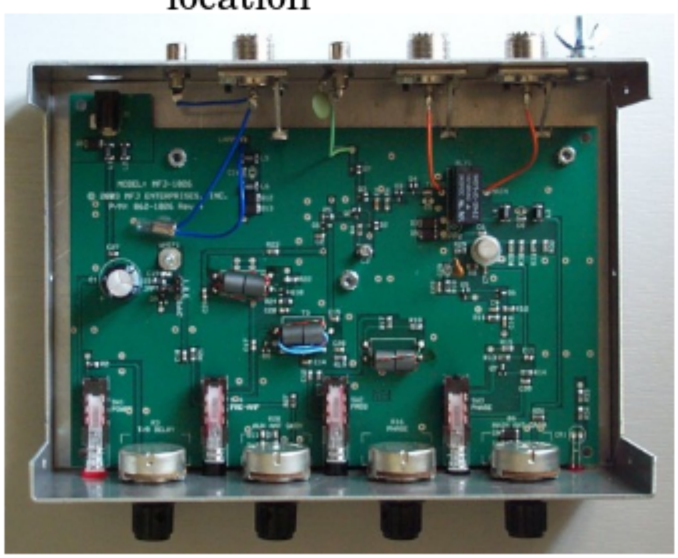
… *how do we* *improve SNR?*, *cont.*

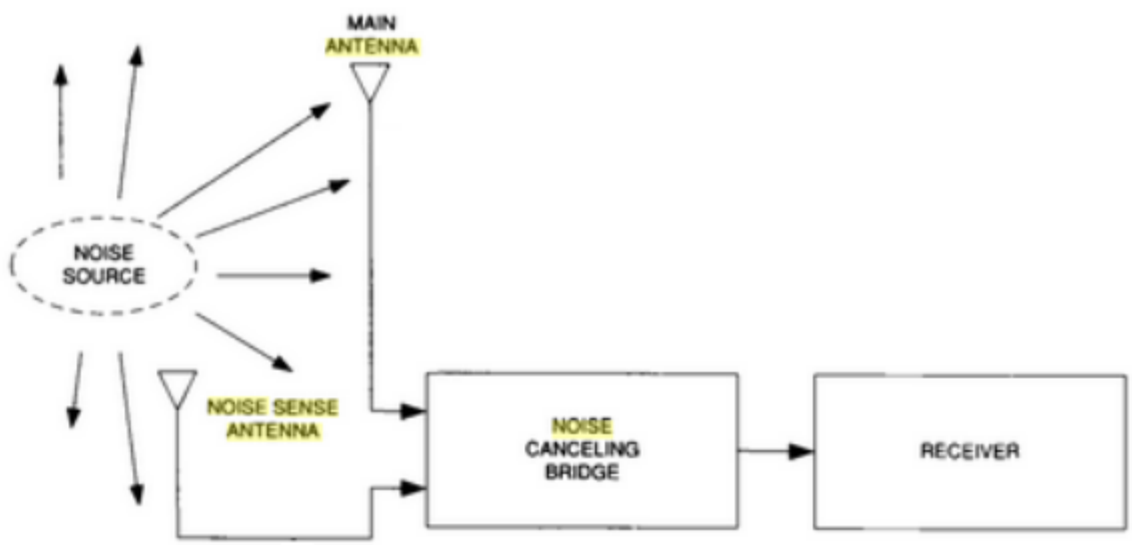
- **Antenna Radiation Pattern Characteristics**
  - **Directivity**
    - Lobes (increased sensitivity) in the antenna's pattern
    - Useful for discriminating against **evenly distributed, propagated** noise in the far field not in the direction of the main lobe
    - Quantified using RDF (Receive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



… how do we *improve SNR?*, *cont.*

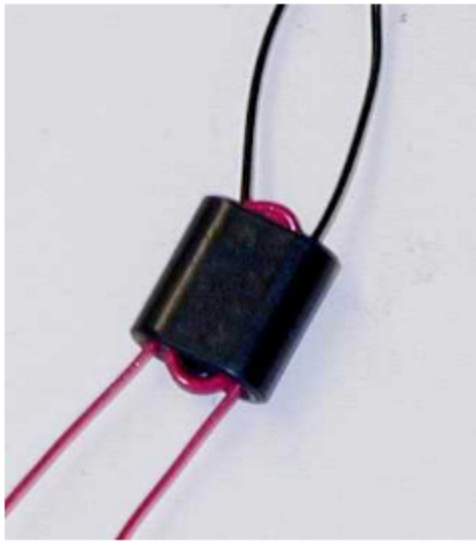
- **Noise cancellation**
  - Effective for local, man-made point sources (RFI) from a ***specific azimuthal region in the near field*** (before antenna pattern is fully formed)
    - Common issue in urban and many sub-urban environments
  - **PRIMARY INTENTION NOT TO MITIGATE PROPAGATED NOISE** (could 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



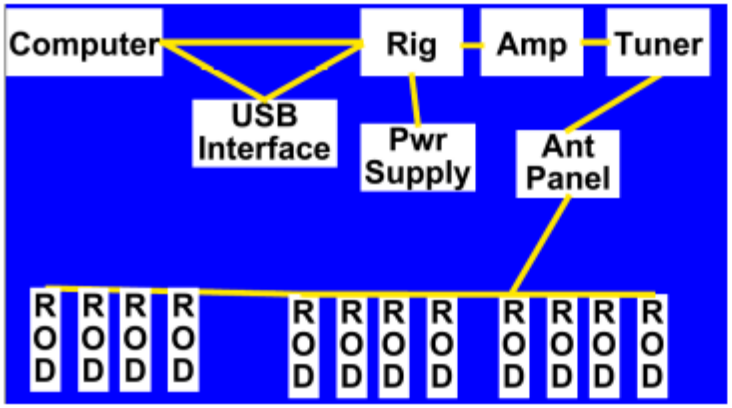


… how do we *avoid SNR degradation?*

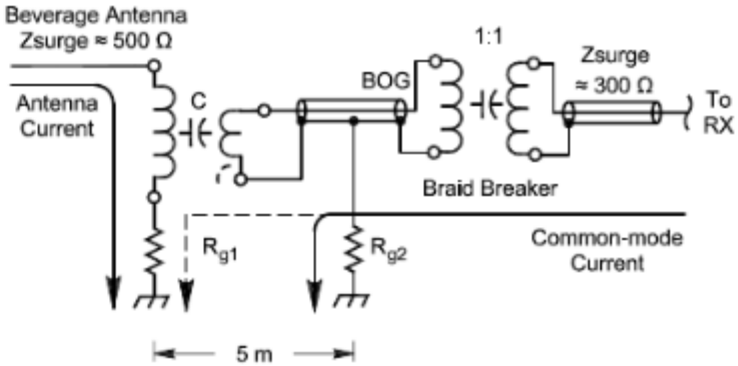
- **Common-mode noise suppression**
  - Feedline isolation and choking
    - Isolated Pri:Sec
    - Stacked (end-to-end) BN73-202 cores to increase choking impedance for LF/MF
    - Type #75, J, #31 cores
  - Feedline grounding (rods, earth proximity decoupling)
- **Station Bonding**
  - Reduce differential voltages between equipment, power mains, etc.
  - Excellent tutorials by **K9YC**: *http://audiosystemsgroup.com/publish.htm*



W8JI



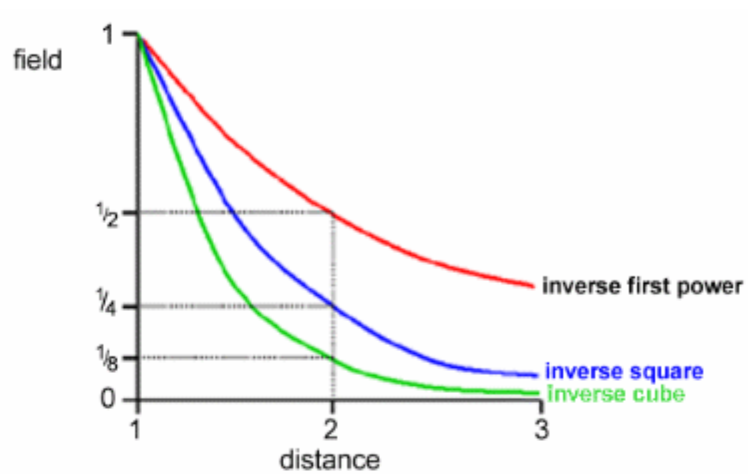
K9YC



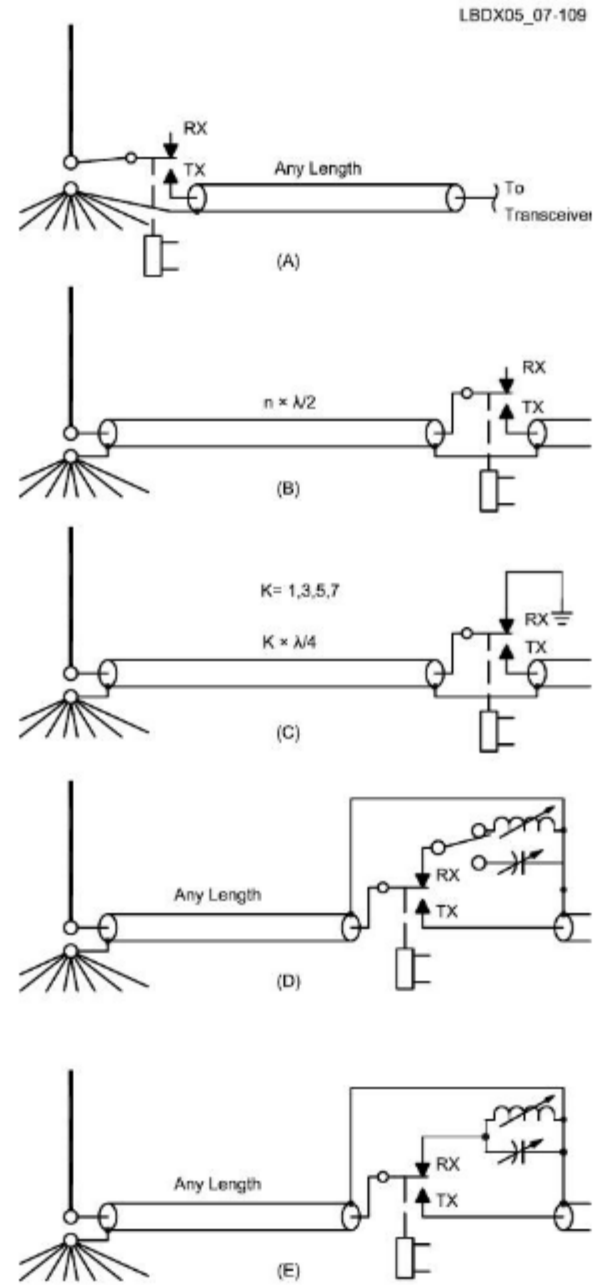
ON4UN

… how do we avoid SNR degradation?, cont.

- **Antenna Location**
  - Separation from local noise sources (near field)
    - H-field (magnetic) strength **1 / d^3**
    - E-field (electric) strength **1 / d^2**
    - 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

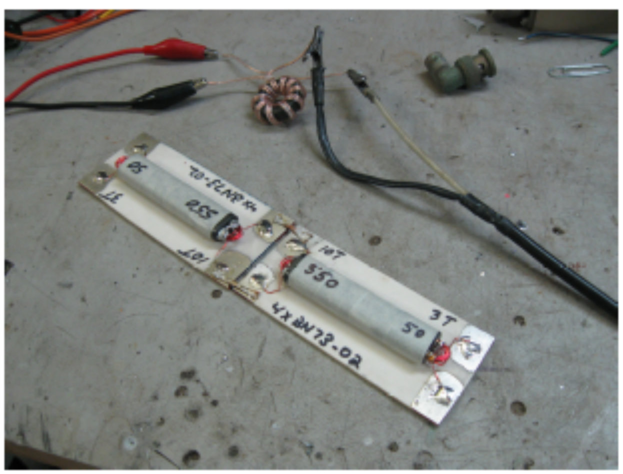
… how do *receive antennas for 630M compare to 160M?*

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

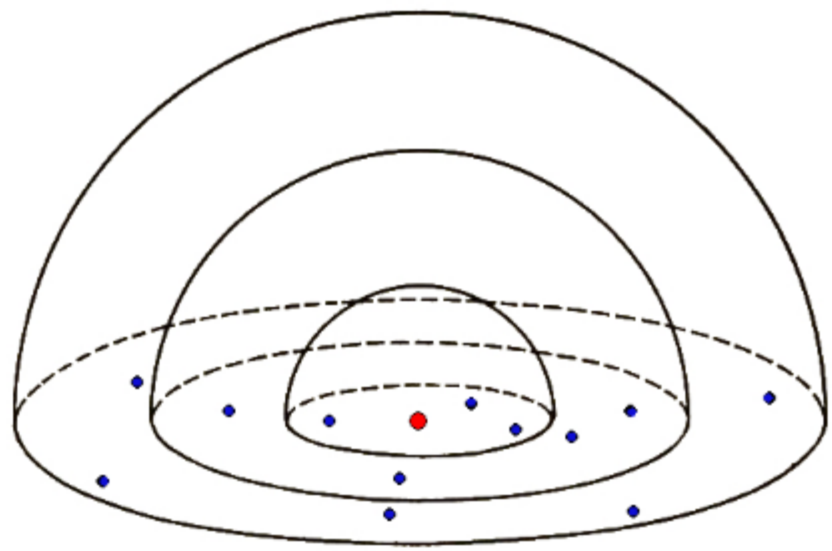
- **Generally physically larger to maintain comparable directivity (far-field)**
  - eg. beverages (*length*), phased arrays (*spacing*)
  - *Exceptions: terminated loops, verticals, "magnetic" loops where pattern is generally maintained but with lower gain*

- **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

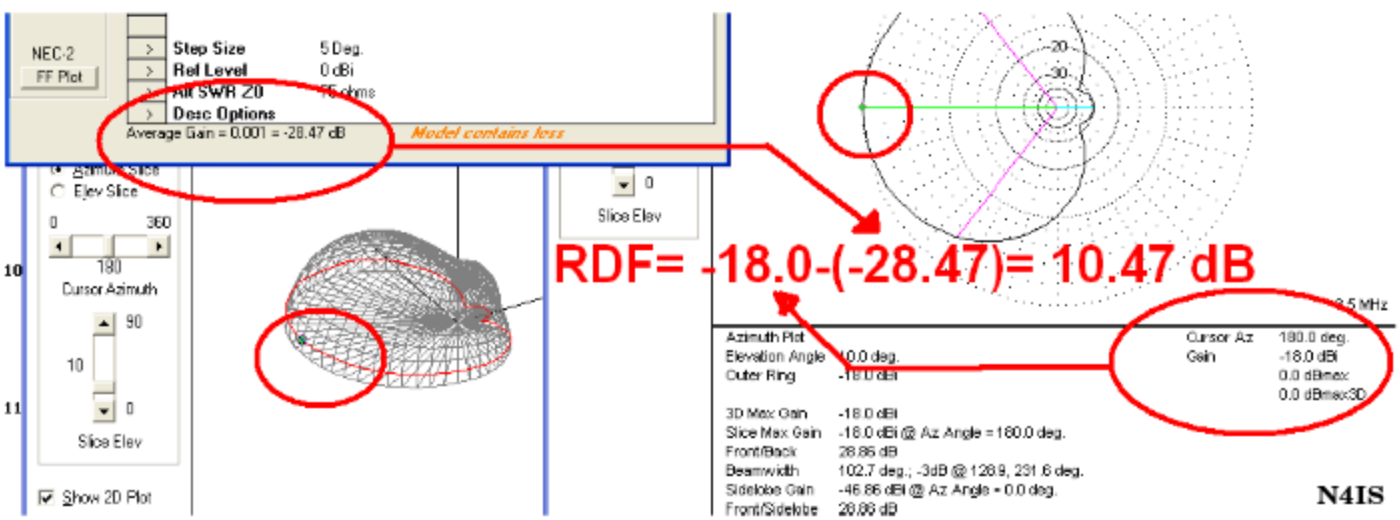


WA3TTS



… 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*

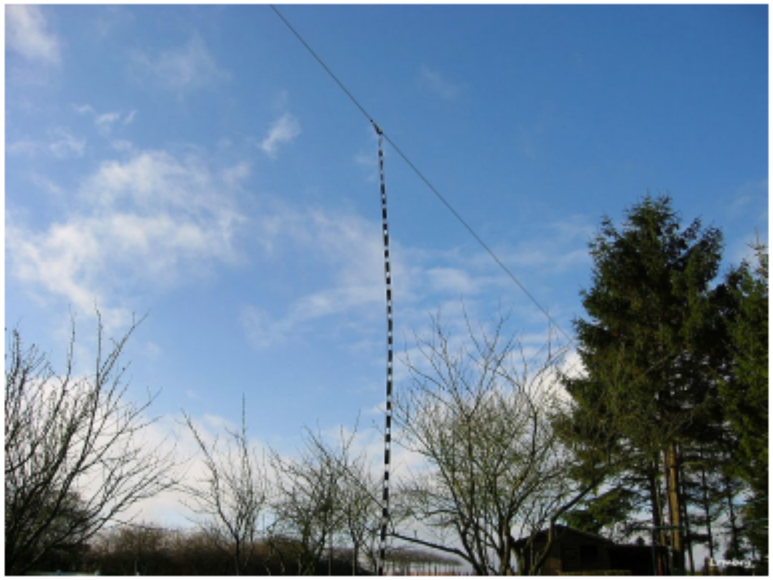
RDF (dB)	Antenna	Notes
??	Ferrite-rod / coil	
5.05	Verticals, E-probes	
5.0 – 6.0	Small Loop	
6.0 - 6.5	1/2λ Beverage	
7.4 – 7.7	EWE / Pennant / Flag / K9AY	Terminated Loops
8.0	Shared Apex Loop Array	30x30-ft or 50x50-ft footprint
9.2 - 10.0	2-el End-Fire Phased verticals	1/16λ, 1/8λ, 1/4λ spacing
9.0 - 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*

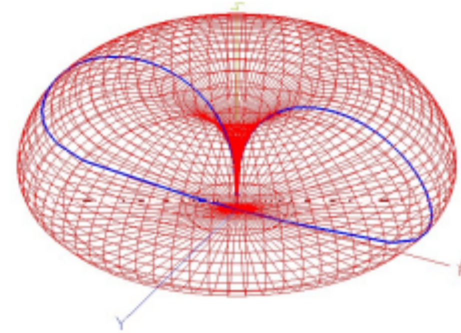


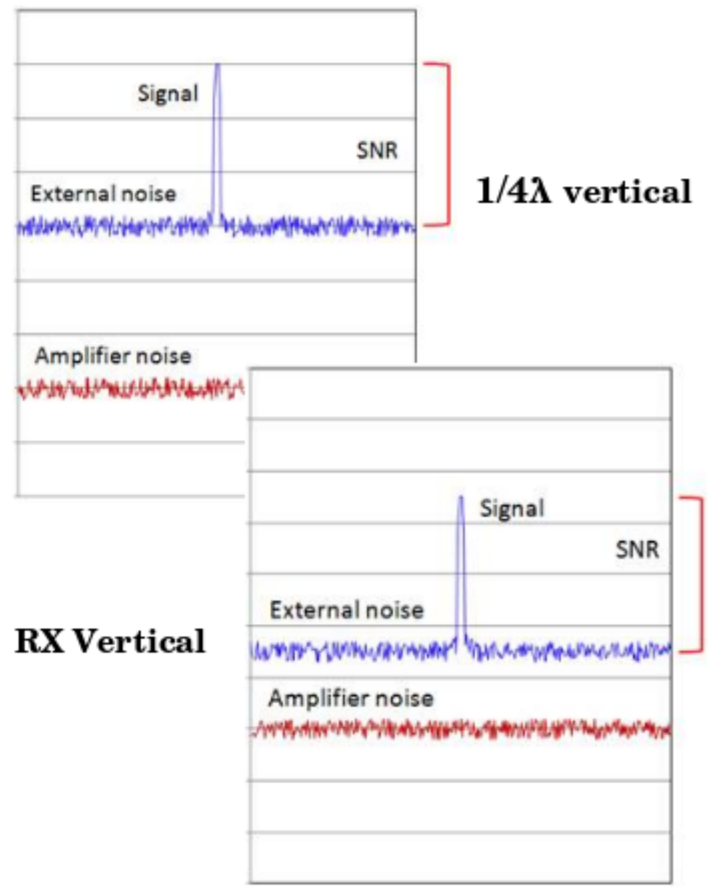
… *Vertical and E-Probe Receive Antennas*

- **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.)





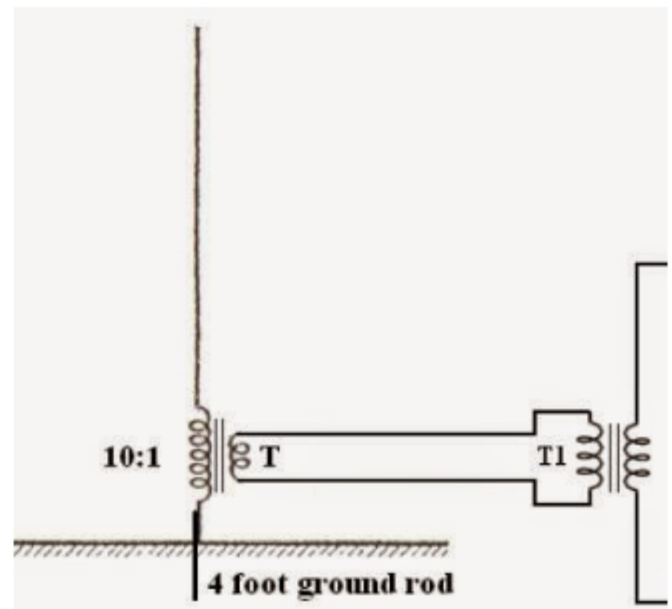
DL1DBC

… *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

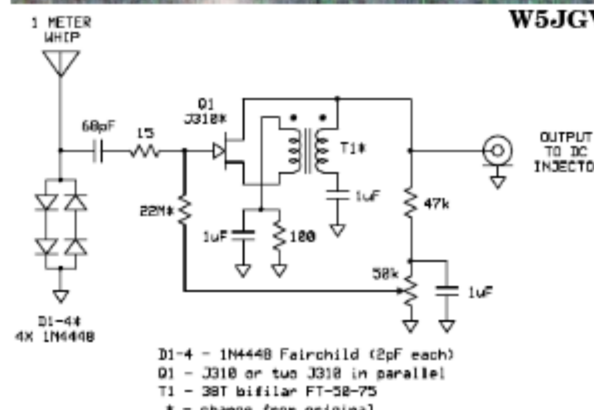


VE7SL

… *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

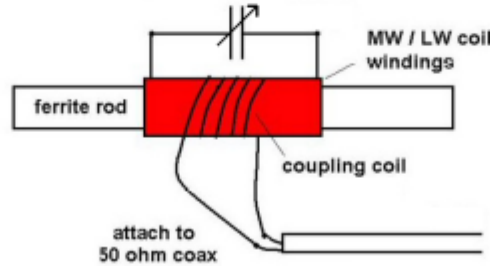
W5JGV

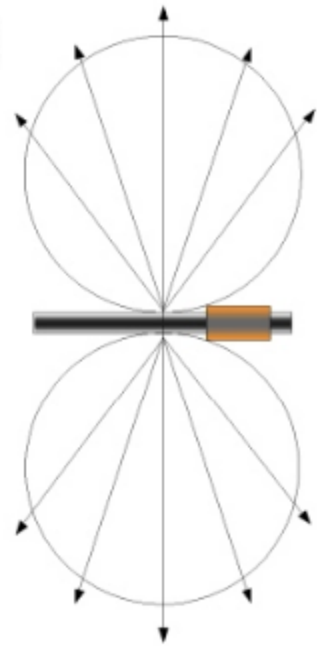


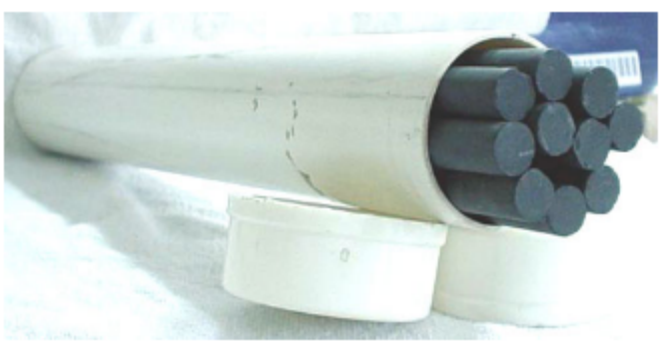
W1VD

… *Ferrite Rod Receive Antennas*

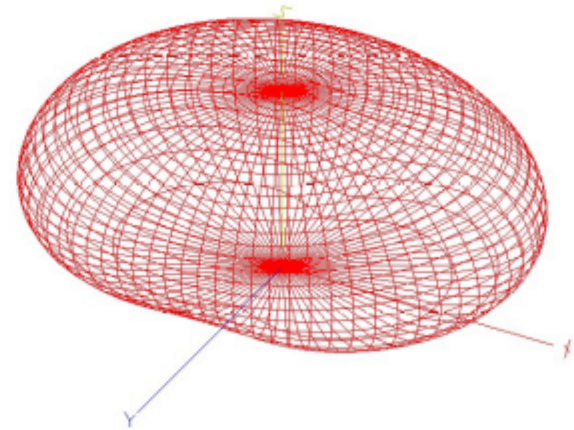
- **Popular antenna in LF/MF portable receivers**
- **Bi-directional far-field pattern**
  - *Similar to dipole*
  - *Nulls off the ends of rod, perpendicular to coil axis*
- **Hi-Q tuned circuit**
- **Low output**
  - *Generally inductively coupled via link coil*
  - *Hi-impedance input amplifier, light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







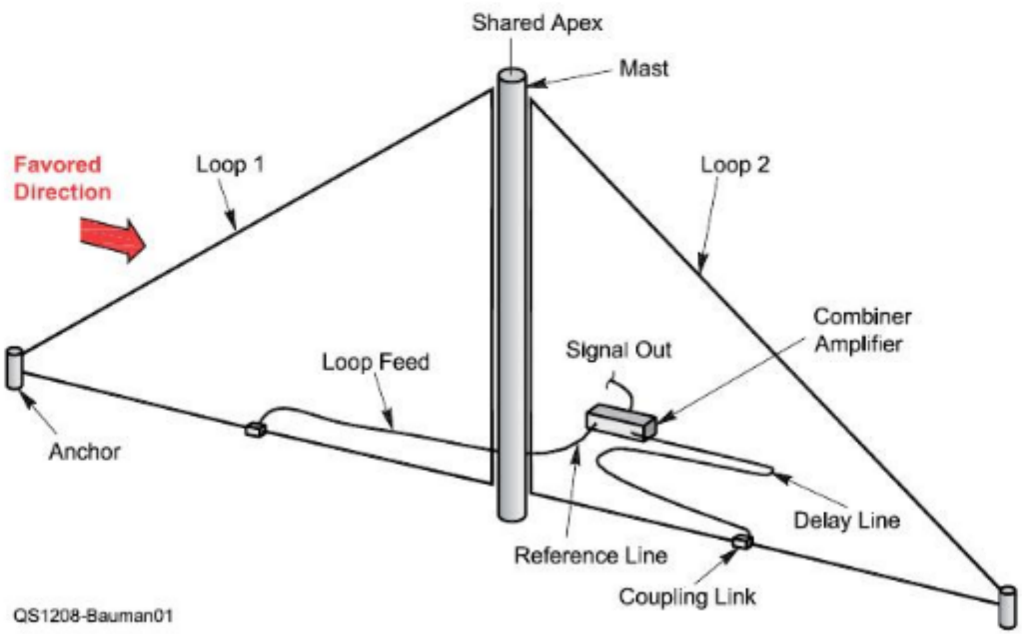
- **Various geometric configurations**
  - *circle, square/diamond, hexagon, octagon, etc.*
- **Different electrical configurations**
  - *Shielded / Unsheilded*
  - *Single or multi-turn (increased sensitivity, NOT directivity)*
  - *Directly connected or inductively coupled output*
- **Resonant, tuned circuit**
- **Low output,** *requires LNA (preamplifier)*
- **Figure-8 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 ($\lambda/2\pi = 0.159\lambda$) 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**



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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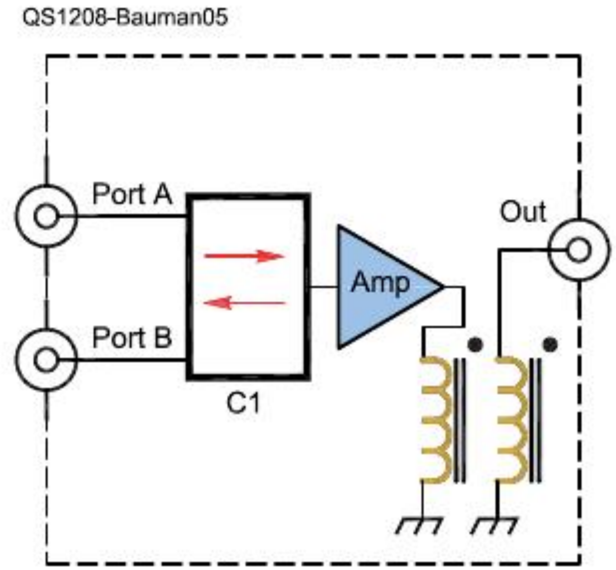

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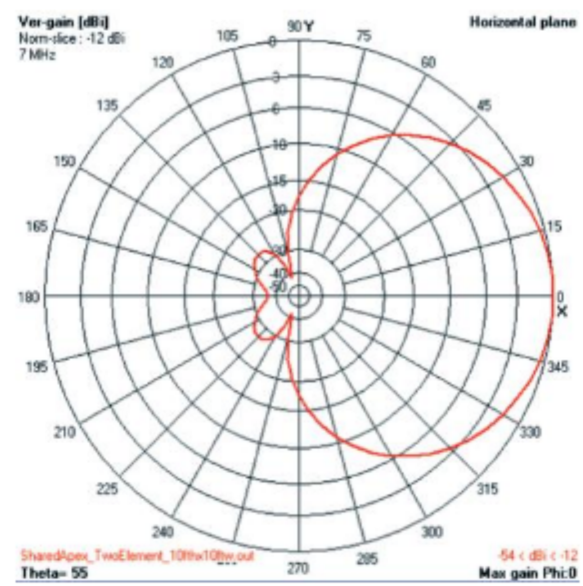
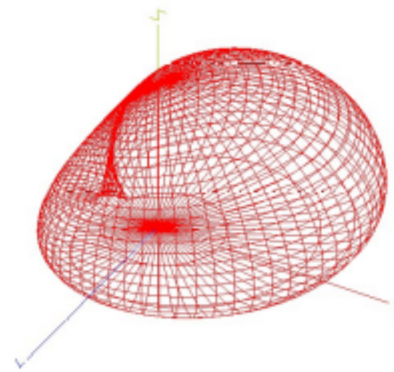
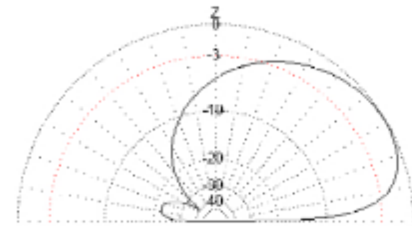
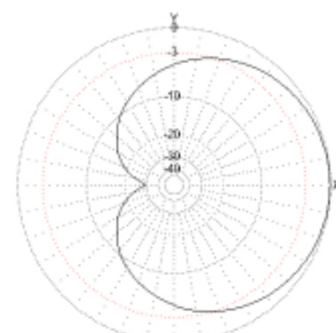


QST Oct 2012

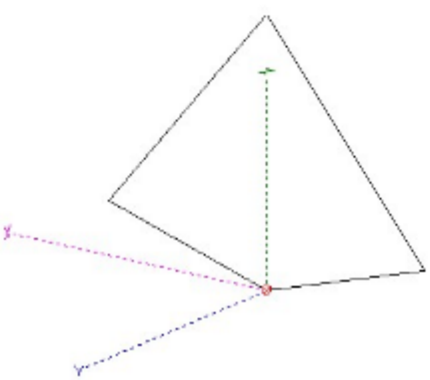
… *Terminated Loop Receive Antennas*

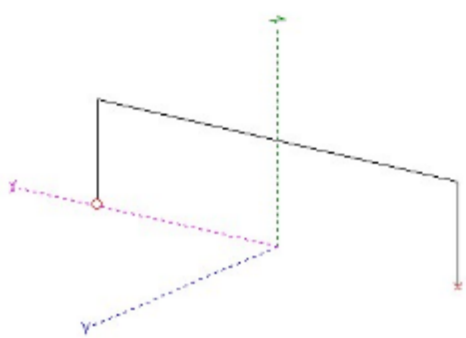


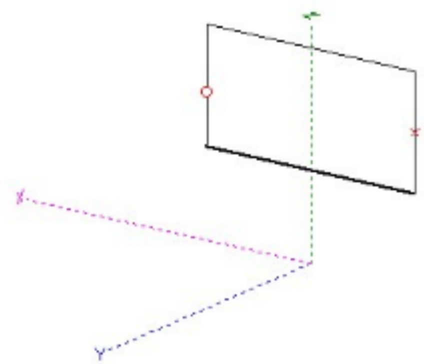


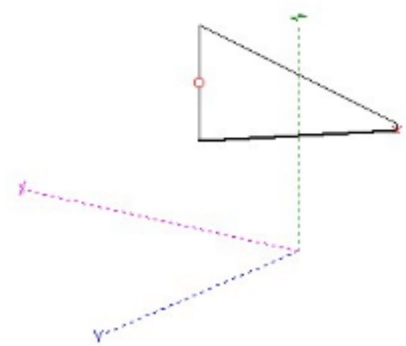


- **Cardioid pattern similar to 1/2λ beverage**
- **RDF 7.4 – 7.7 dB (2.4 – 2.7 dB over a vertical)**
- **Forward lobe from end opposite the termination**
- **Low gain**
  - *Requires LNA (preamplifier)*
  - *Can be scaled to larger dimensions to increase gain*
- **Termination optimized for best F/B (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**

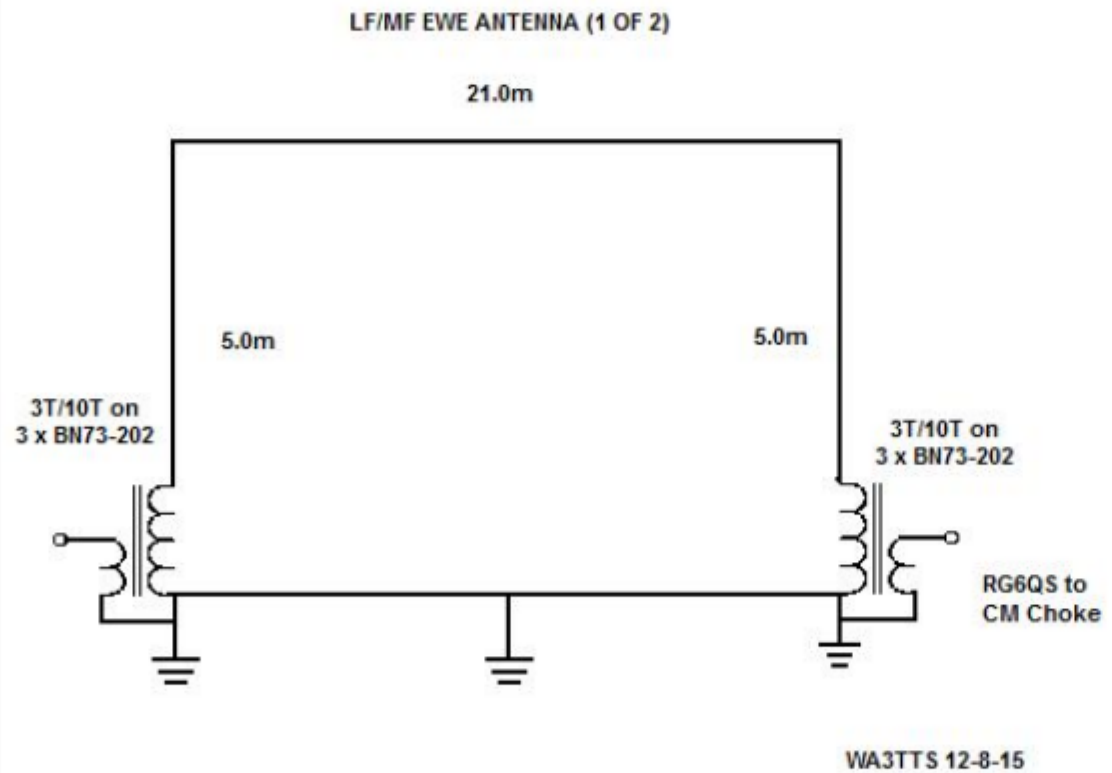




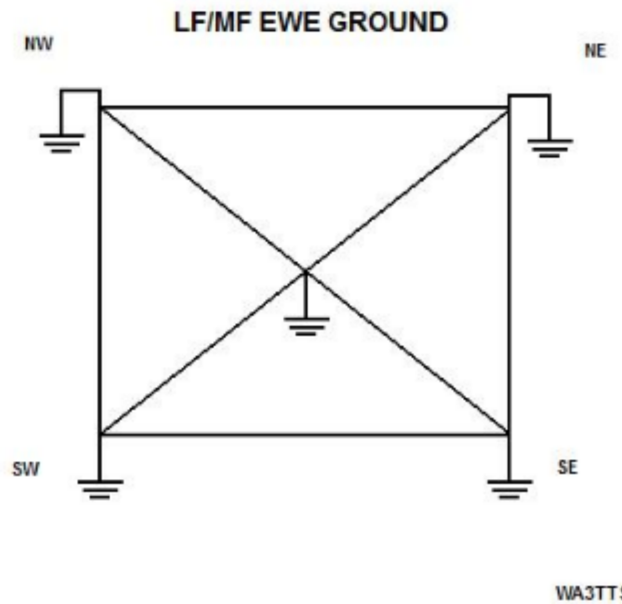




- **WA3TTS EWE**



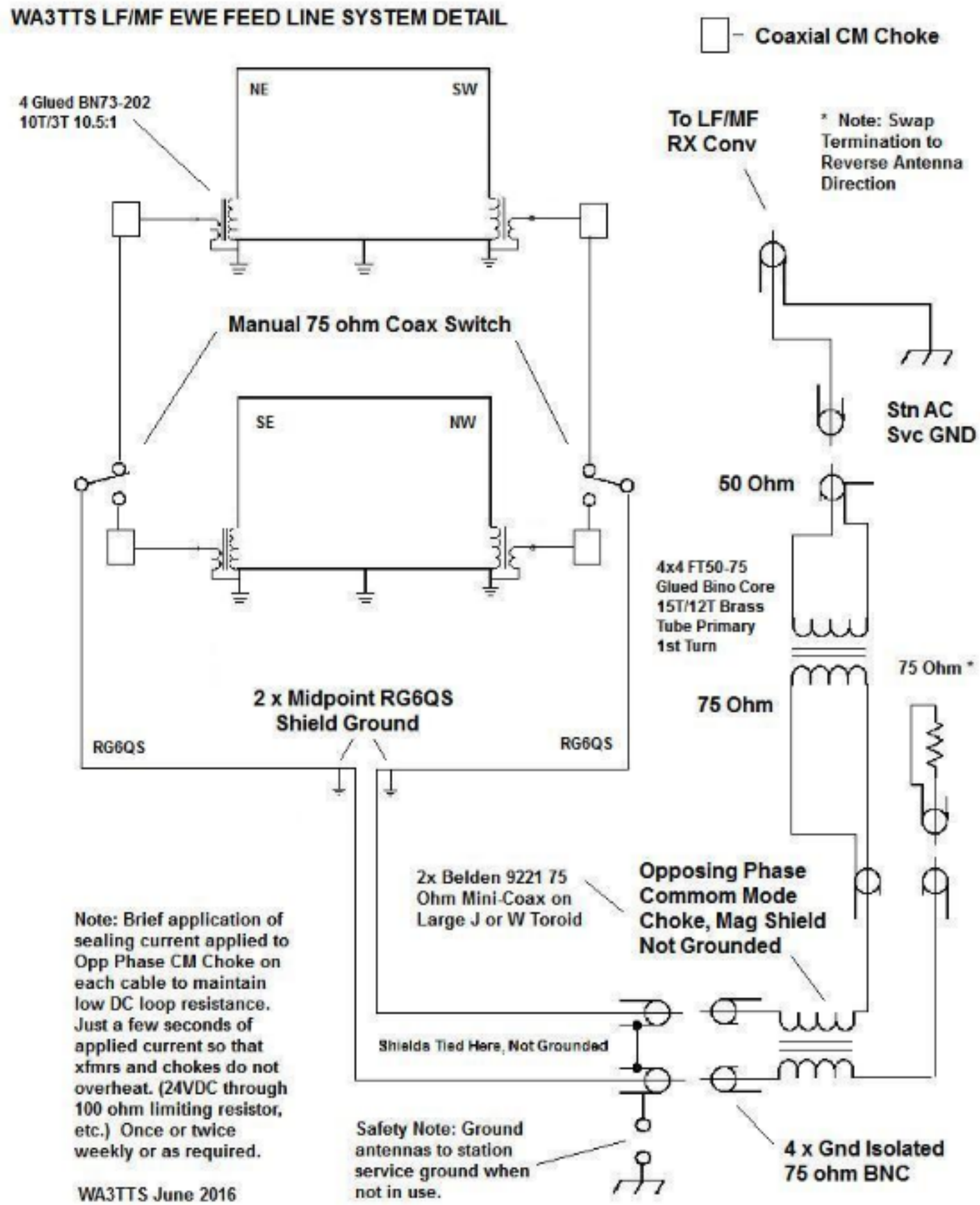
- *Slightly scaled up from standard 160/80M dimensions*
- *Ground return wires between all rods to minimize performance changes due to ground characteristic changes (EA3VY)*



- *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*

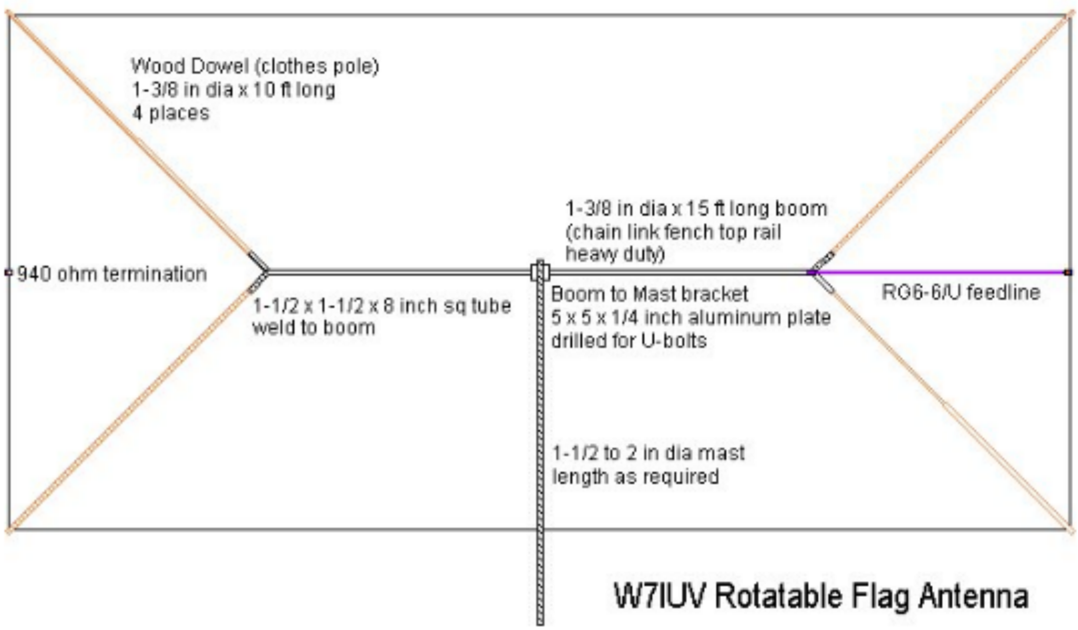
… *Terminated Loop Receive Antennas,* cont.

- **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*

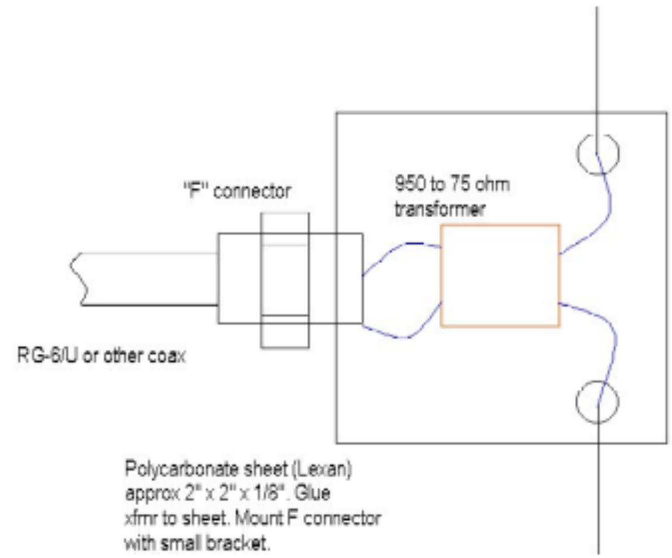


… *Terminated Loop Receive Antennas, cont.*

- **W7IUV Rotatable Flag**



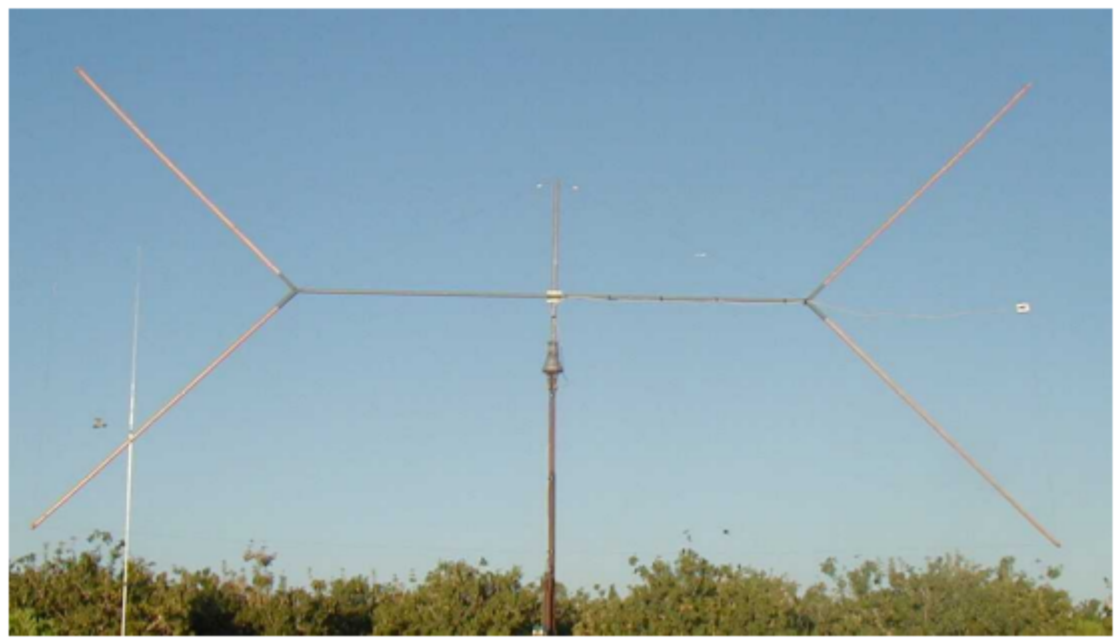
W7IUV Rotatable Flag Antenna



W7IUV

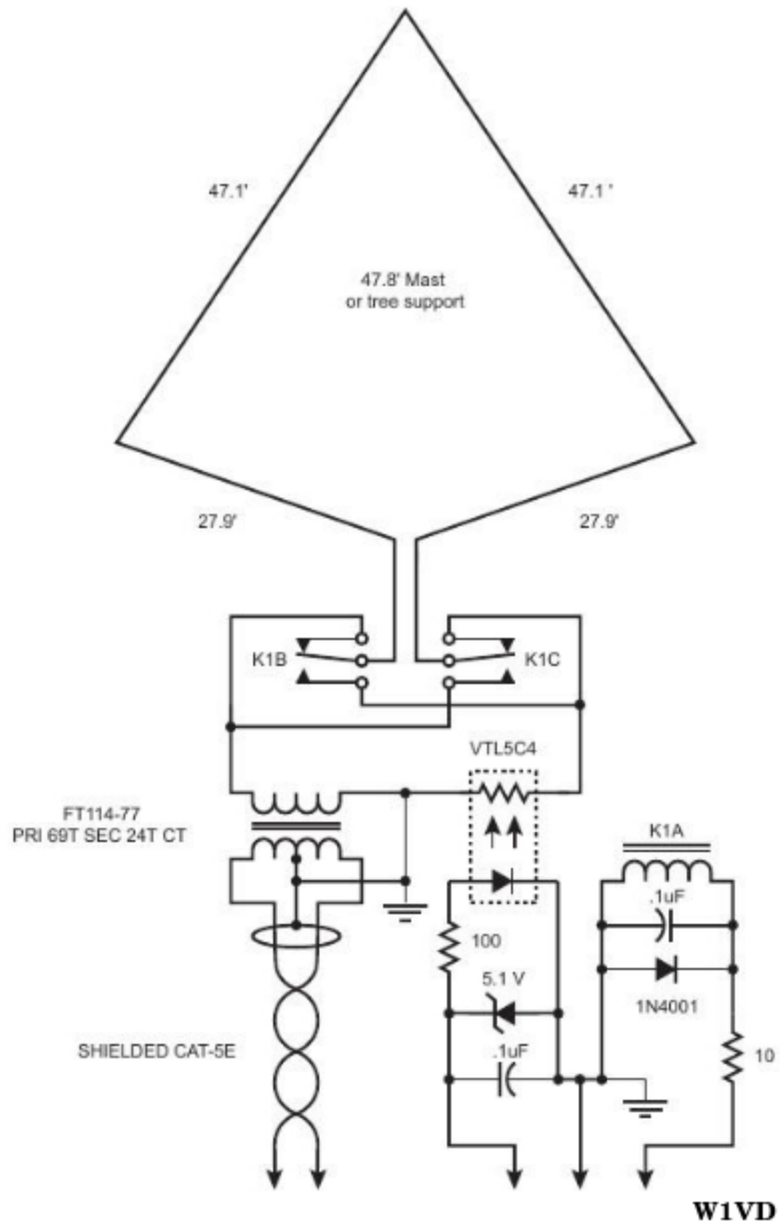
- *Based on standard K6SE optimized dimensions*
- *W7IUV reports good directivity and F/B on 630M*

W7IUV

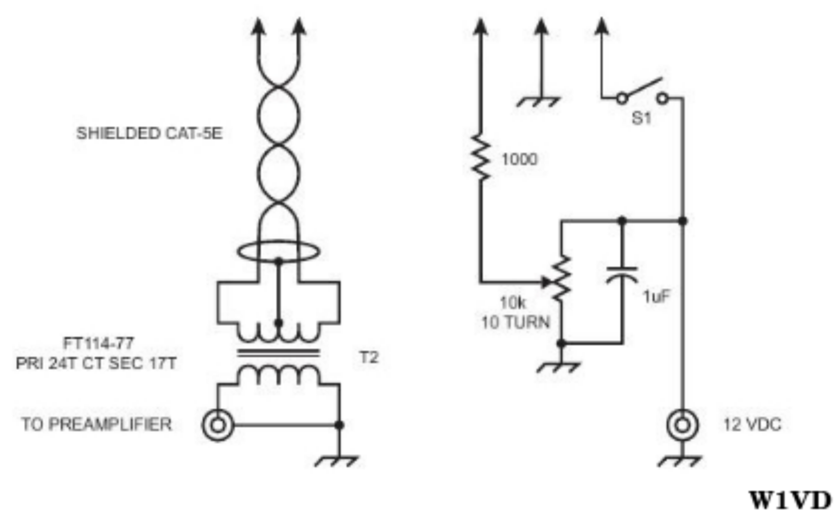


… Terminated Loop Receive Antennas, cont.

- **K9AY modified by W1VD**

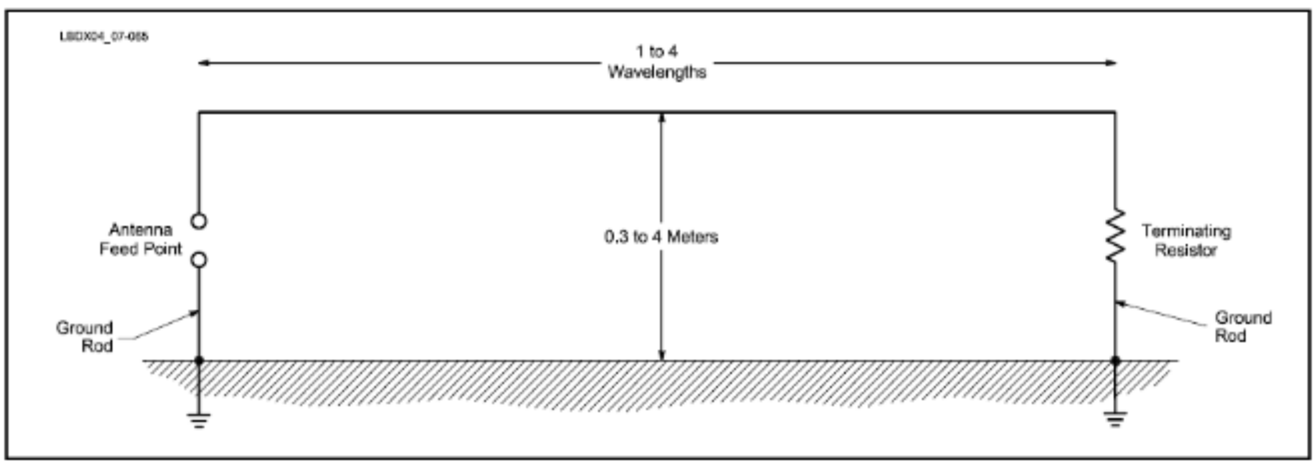


- *Scaled up version for LF/MF*
- *Twisted pair feedline with grounded shield*
  - *Shielded CAT-5E*
  - *110Ω braided shield digital audio cable (Belden / Gepco) [**K9YC**]*
- *Remotely controlled variable termination resistance (F/B, null optimization)*
- *W1VD reports excellent results on 2200M and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



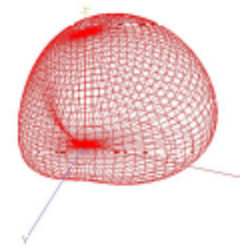
… *Beverage Receive Antennas*

- **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

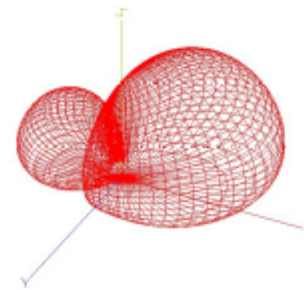


ON4UN

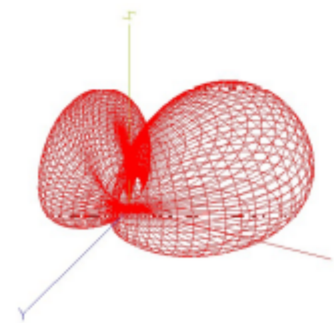
1/2λ



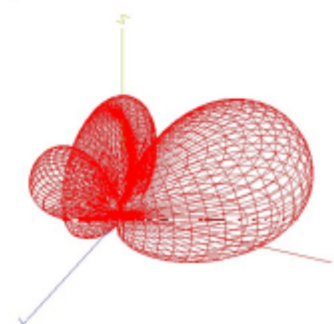
3/4λ



1λ

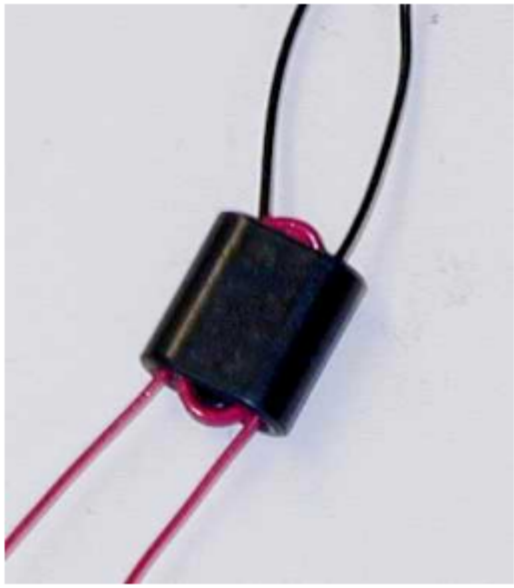


1-1/4λ



... Beverage Receive Antennas, *cont.*

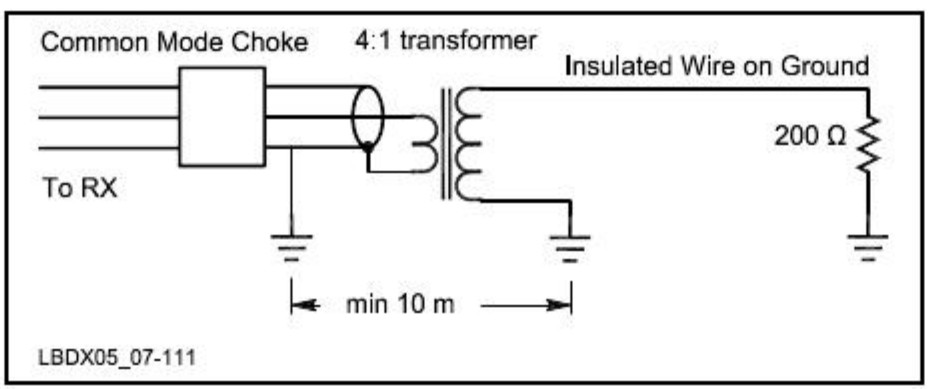
- **Classic Beverage**
  - Recommended feedpoint uses split winding transformer (*eg. BN73-202 binocular*)
    - *50Ω system: 9:1 imped. ratio*
    - *75Ω system: 6:1 imped. Ratio*
  - Non-inductive, high surge current termination resistor
  - **PRACTICAL?**
    - Even on large lots, lengths will generally 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***
    - 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)***



W8JI

… *Beverage 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)*

- **Realistic 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)*

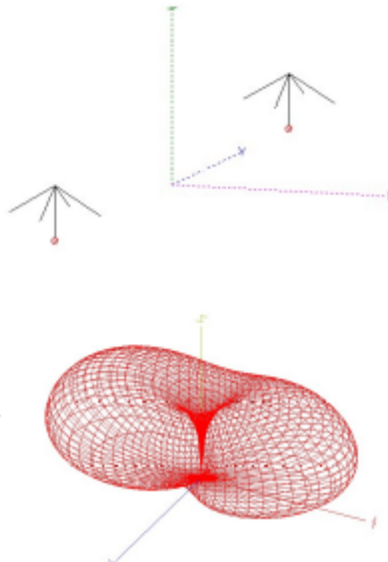
AC0C

K7TJR

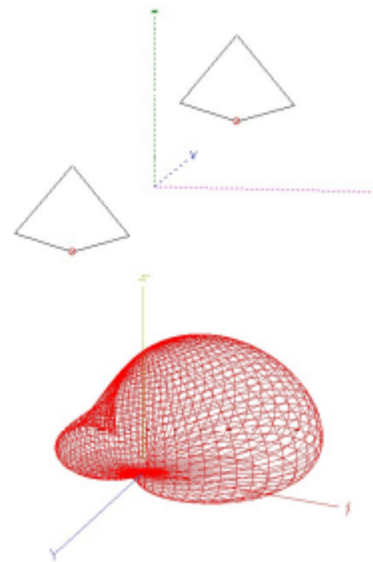
… *Phased Array Receive Antennas*

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

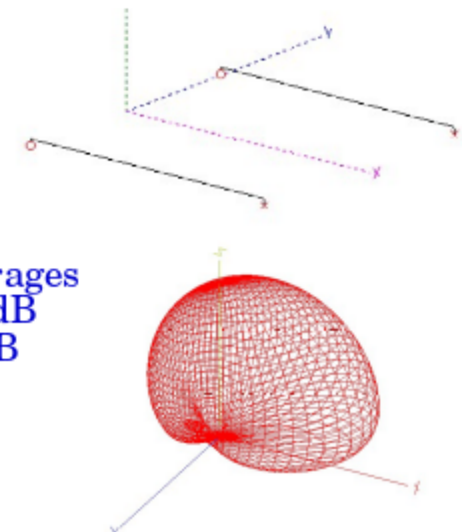
Verticals
RDF 8.3 dB
60-deg -3dB
Bi-directional



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

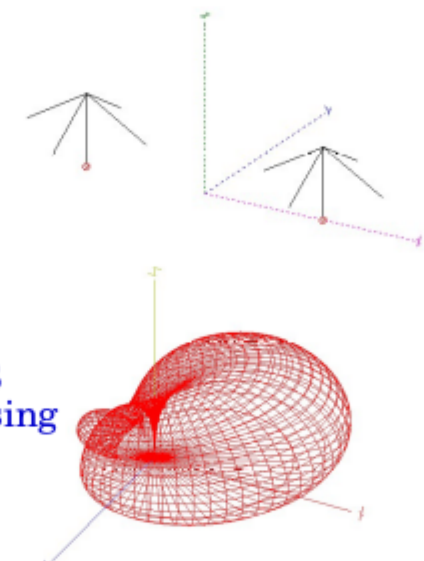


1/2λ Beverages
RDF 8.11 dB
50-deg -3dB

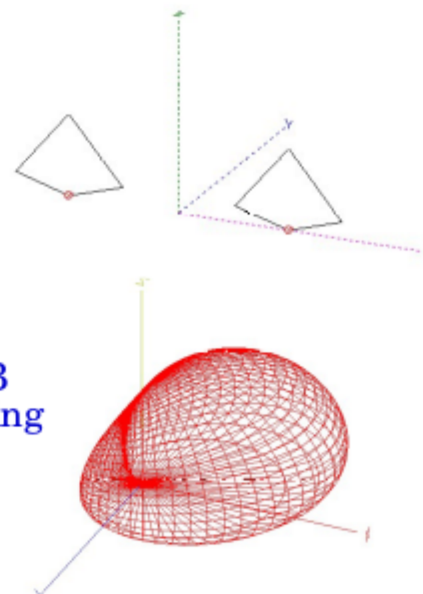


- **End-fire examples** (*1/8λ end-fire spacing; note: 1/16λ may be feasible on 2200M, 450-ft)*

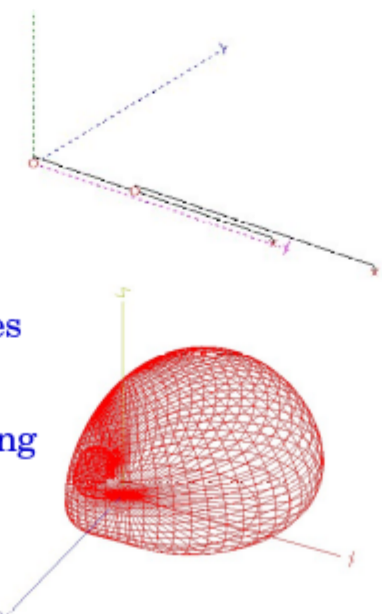
Verticals
RDF 8.9 dB
140-deg -3dB
135-deg phasing



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



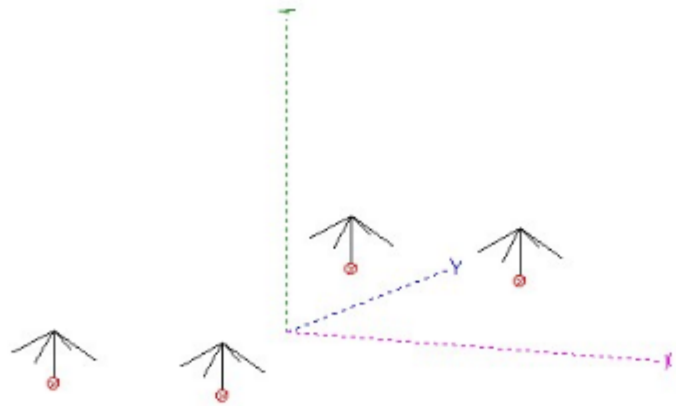
1/2λ Beverages
~*1/6λ* stagger
10 ft spacing
135-deg phasing
RDF 9.28 dB
75-deg -3dB

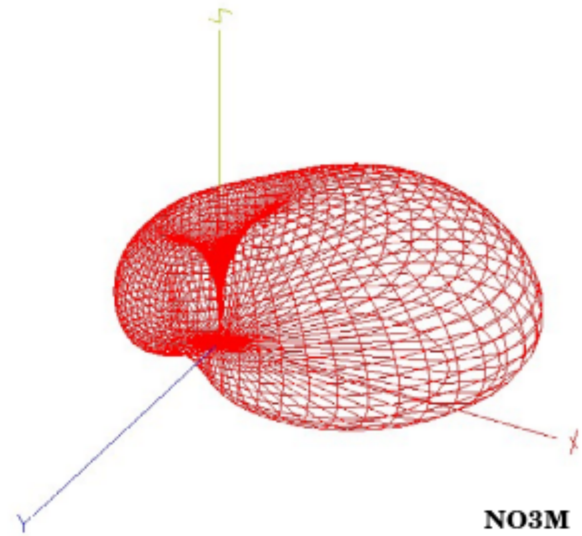


… *Phased Array Receive Antennas*

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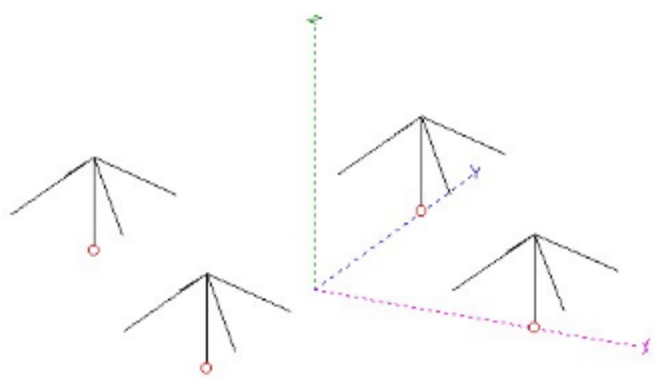
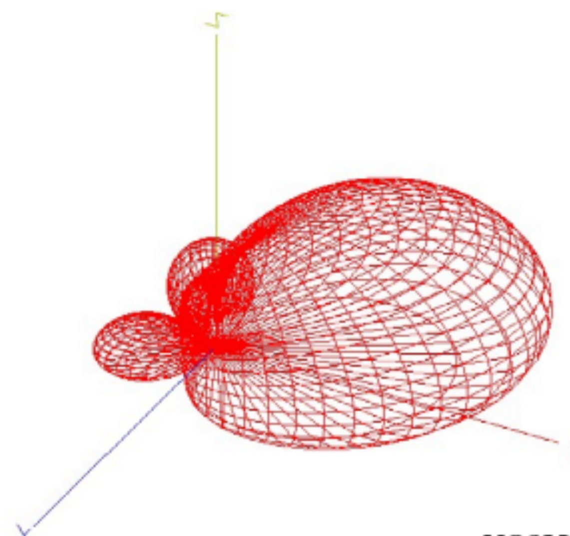
- **Four Square example (verticals), 630M and 2200M** *(1/16λ feasible)*

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





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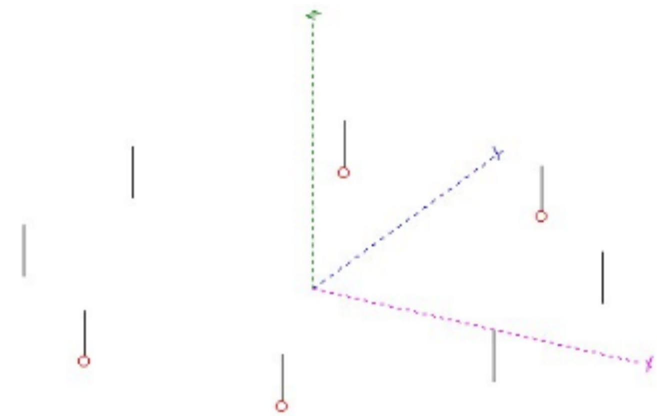
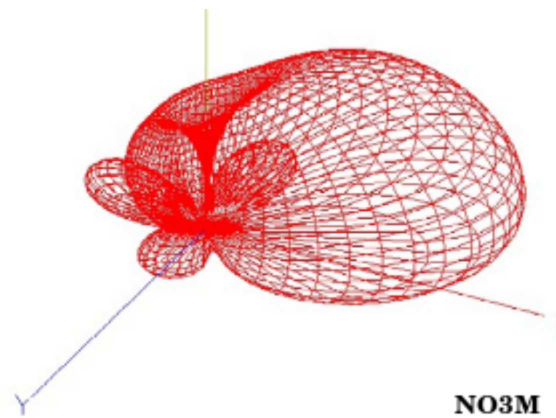
… *Phased Array Receive Antennas*

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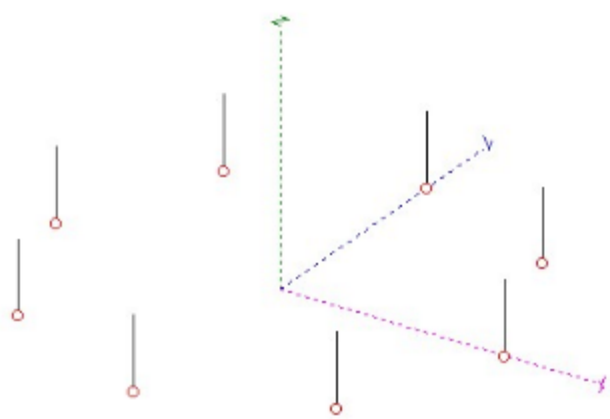
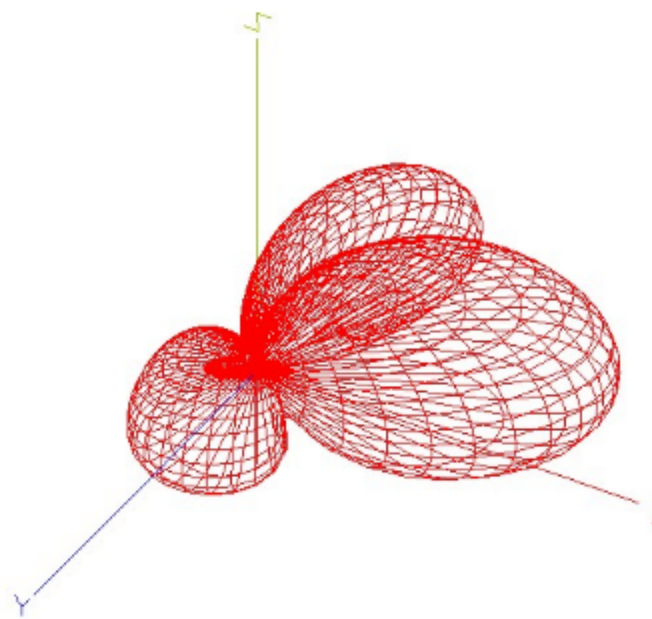
  - ***Hi-Z™ phased 8-circle (all elements active), 630M***

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





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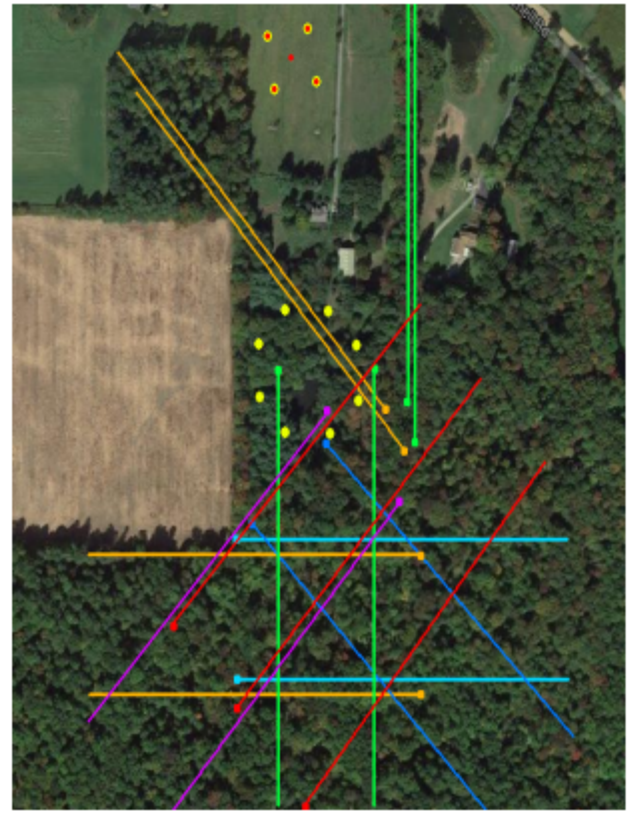
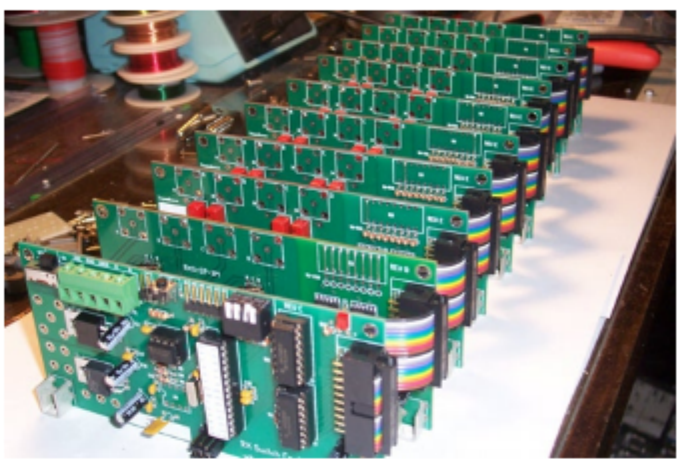
… NO3M 630M receive antennas

- **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

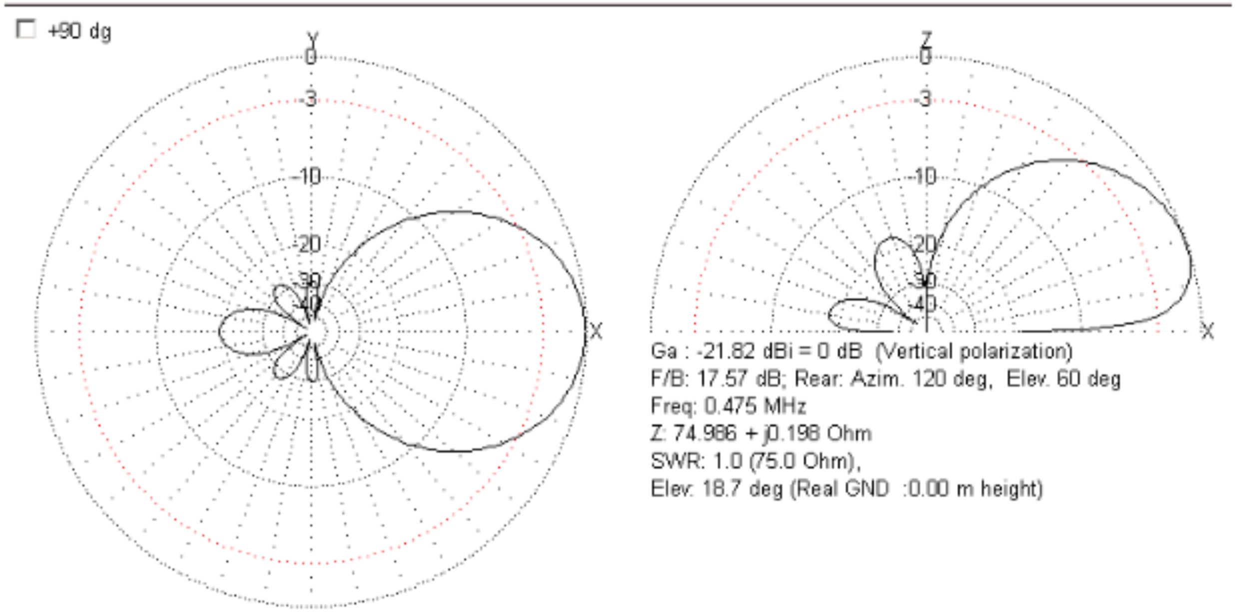


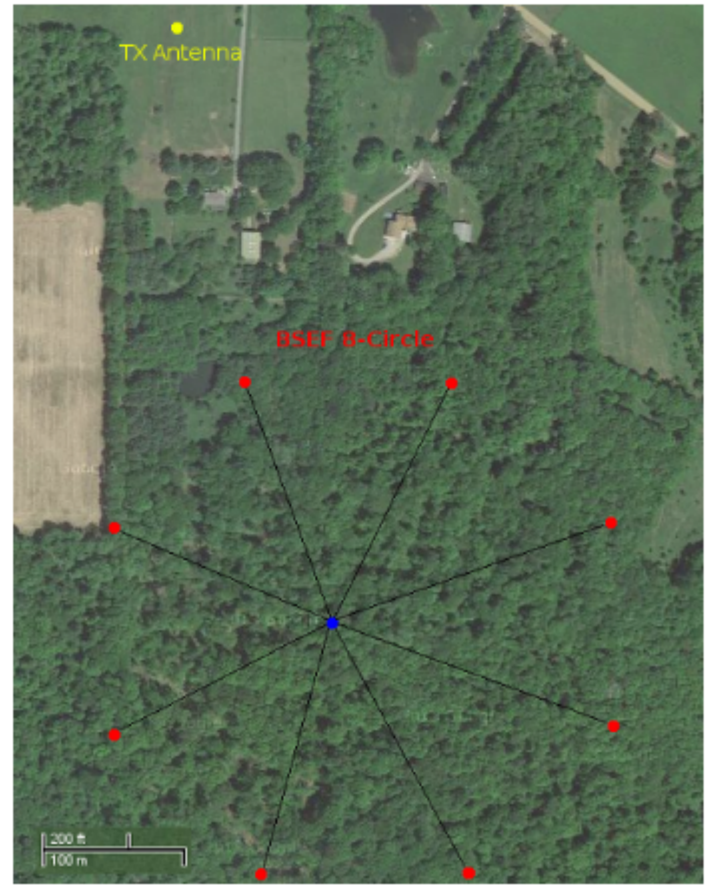
- **Antenna routing**
  - Custom remote switching matrix
  - 24 antennas (expandable) to 4 receivers
  - Desktop controllers connect via RS-485
  - Main switching hub located 600-ft from shack



… *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)**
- **Bulk Materials**
    - RG6 phasing lines + delay cable: 5912 ft (1802m)
    - 1 in. alum. tubing; elements: 192 ft (58.5m)

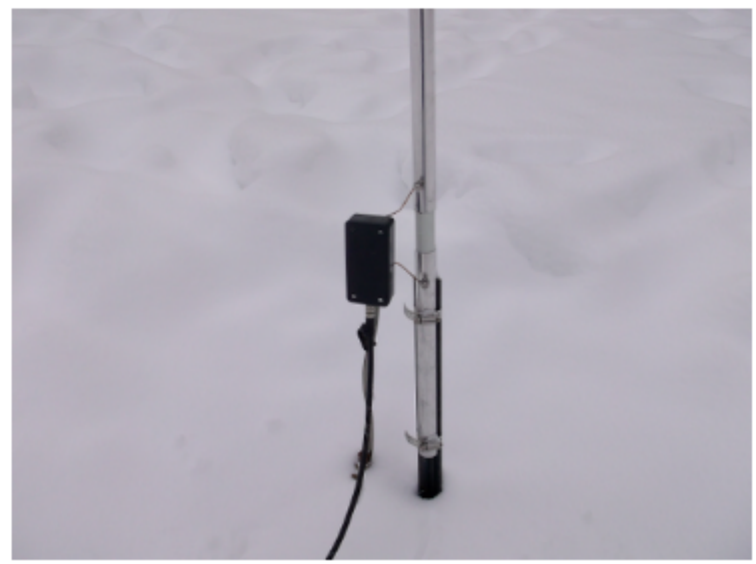




- **RDF 12.5**
- -3 dB beamwidth is 55 degrees
- **F/B 25 dB**

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

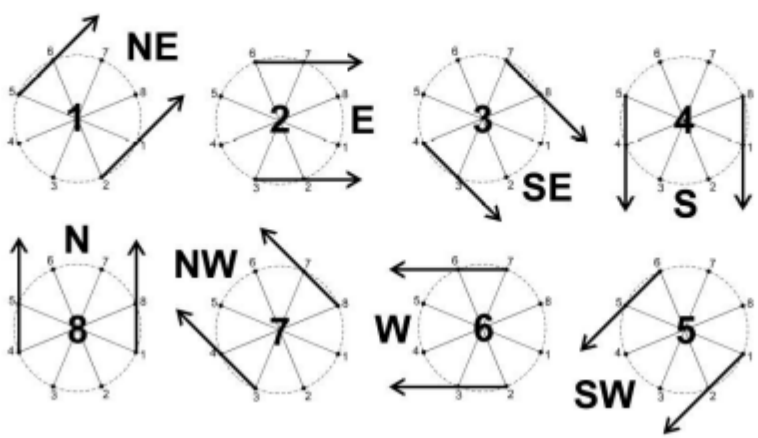
- **Elements**
  - Four (4) 6-ft sections of 1 inch dia. aluminum tubing (24 ft height)
  - Four (4) 30-ft wires for toploading
  - Top wires are tied off with fishing line
  - 0.875 inch fiberglass rod insulator between element and 12 inch piece of 1 inch tubing
  - Bottom 1 ft tubing section is clamped 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

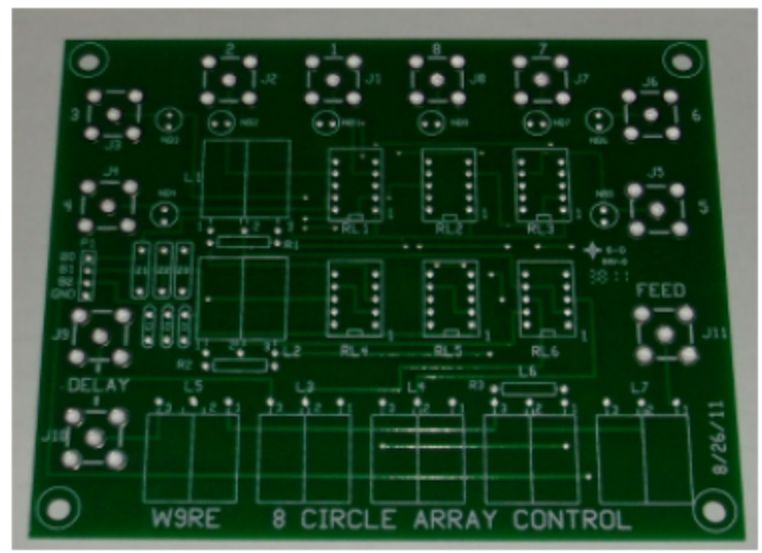


… *about the NO3M 630M passive BSEF 8-circle array, cont.*

- **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

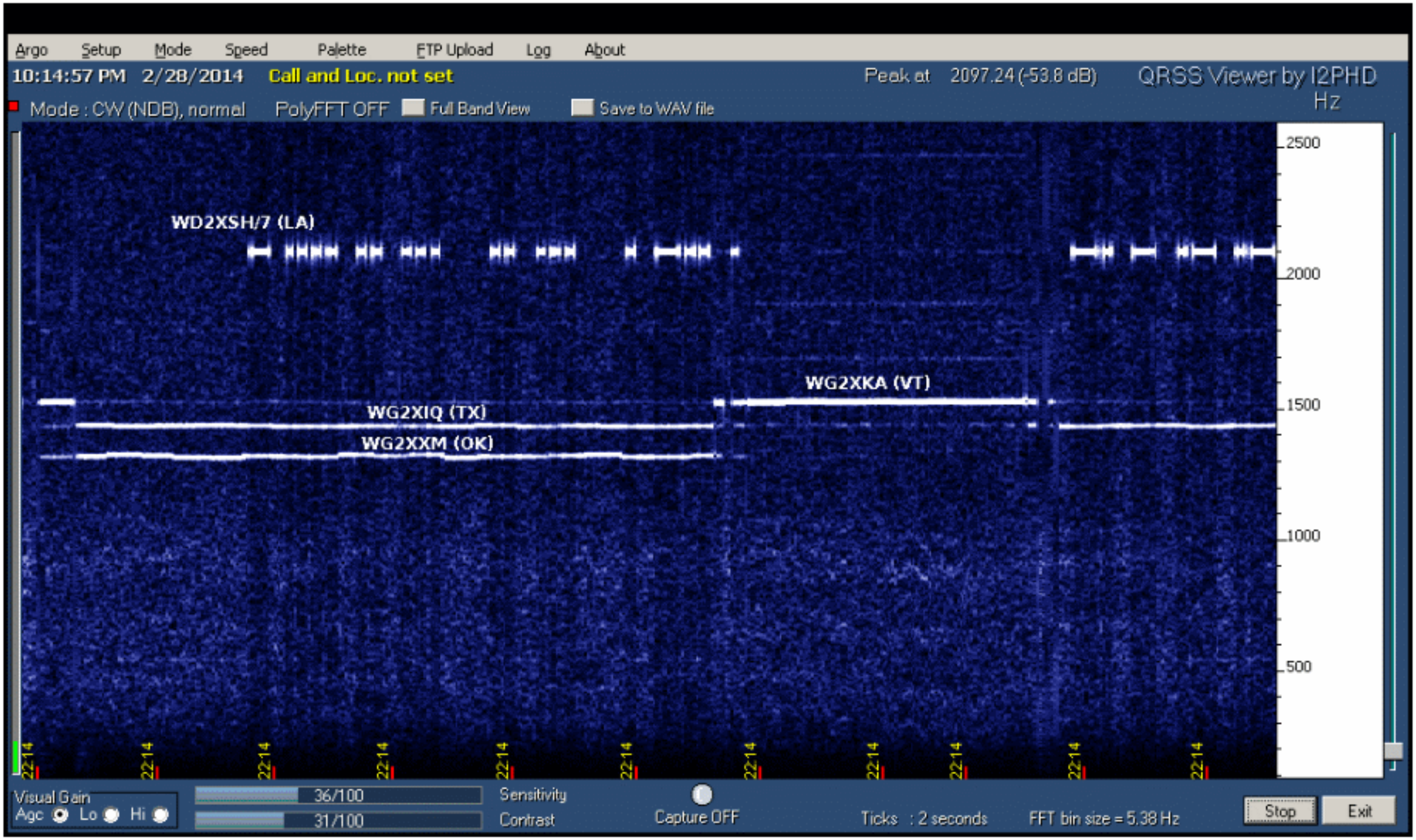
- **Switching / Phasing controller**
  - W9RE BS-EF PCB
  - 180 degree transformer and delay cable
  - Delay cable cut for 65 degrees at 475 kHz (approx 318 ft)
  - Phase shift of 115 degrees between front and back elements
  - Feedlines from each element approximately 700-710 ft long





… 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



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

- **Future Improvements**

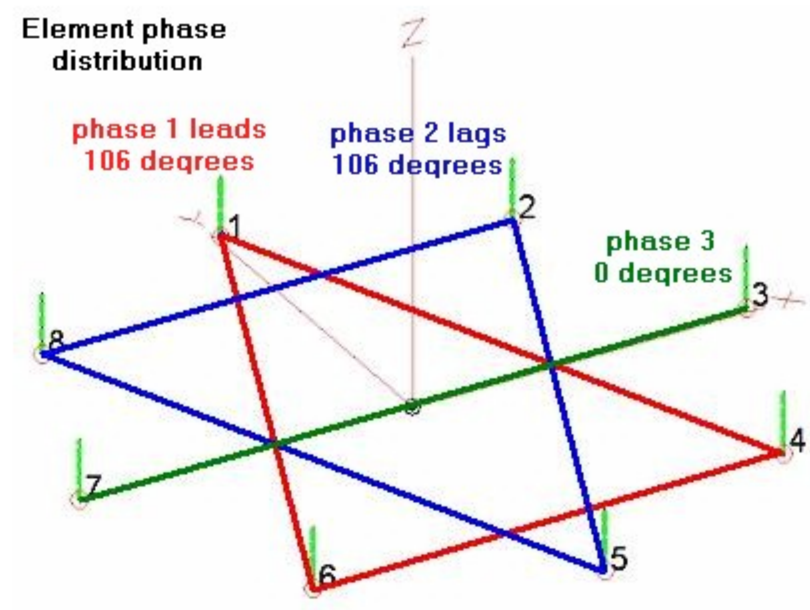
  - Replace passive elements with active elements (YCCC amplifier)

    - *improve operating bandwidth*
    - *Further reduce phasing errors with unconditionally stable 75 ohm feed*
    - *Less maintenance without radials or top loading wires*

    - **THIS CHANGE WAS IMPLEMENTED IN 2017**
      - *Amps powered through coax*
      - *W9RE phasing board modified for voltage over coax*
      - *Bias-Tees added to both ends of main feedline*

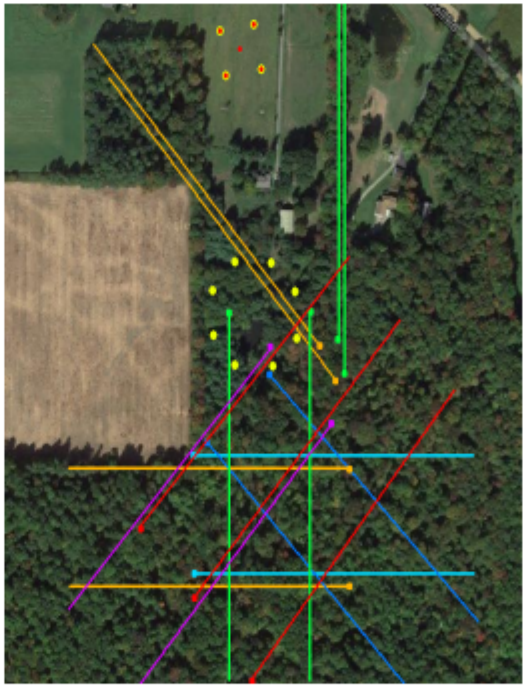
  - Use all-active, 0, -106, +106 deg (Hi-Z™) phasing

    - *Smaller diameter "circle" (800ft)*
    - *Increased RDF*



… *NO3M's receive antenna picks*

- **630m receive antennas based on lot dimensions**
  - **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



Array Sol.

K9XD

73 de NO3M

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Special thanks to KB5NJD, K9YC, WA3TTS, N6LF, and W3LPL

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