CHAPTER 11

630M TRANSMIT ANTENNA SYSTEMS: CONCEPTS, MODELING AND MEASURING

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3/18/16 CAN A HIGH-LOSS 630M ANTENNA SYSTEM EVER BE A GOOD THING?

Generally, I take for granted that antenna system efficiency should be as high as possible. By antenna system I mean the whole outdoor system of antenna, top hat conductors, radials and earth grounding.

"Warming earthworms" seems like a poor use of RF power that could be radio waves going skyward. After all we love radio. That means *radiating* those 630m radio waves, doesn't it?

Today, let's suspend the usual assumptions nevertheless and see what advantages a *low efficiency* antenna system might provide. Send in your experiences or words of wisdom to level-set and blog this topic better!

Advantages of a *Low Efficiency* 630m Antenna System

Simpler Installation: A lower efficiency antenna system is likely to have less vertical height so it's easier to put up. A lower efficiency antenna system, even one that's full height, quite likely has higher ground resistance, higher antenna conductor resistance to RF, and higher top hat resistance to RF. These things generally happen when less expense and work are invested. You use shorter, smaller diameter, lighter weight conductors, fewer ground rods and radials, and make less ground clutter for family members to be mindful.

Reuse of HF Antenna System Components: The grounding system you use for HF and perhaps some HF antenna system you already have can be repurposed or switchably coupled and tuned to make a 630m or 2200m TX antenna system.

Acceptable transmitter cost: Some operators may be ready and willing to incur some extra *indoor* work and expense of a higher power 630m transmitter to sufficiently drive an inefficient LF/MF antenna system that's easier to put in place outdoors.

Moving from your property: It's easy to think we're going to be vigorous indefinitely, or that a job we have will last. People move more now than they used to, for all sorts of reasons. Suppose you have a lot of buried radials and ground rods. Isn't it easier to take down a wire antenna and top hat before you move than to rip up a yard to get an extensive system of buried radials and ground rods out?

Ham rules may differ from Part 5: When a ham would reach 1-2 watts total radiated power on 630m, it bumps the ceiling of a 5 watt EIRP legal limit. At that point, hams probably care less than Part 5 ops about reducing losses and ditto about transmit antenna gain.

Lower Q, Less Retuning: More losses mean lower Q. That reduces the need for retuning an antenna coupler box outdoors when you change frequency. (Feb. 9, this blog.) Ability to swiftly change frequency allows operators to change modes and quickly take advantage of propagation opportunities when WSPR SNRs reach favorable levels for those other modes. As the LF/MF station population increases after an anticipated FCC allocation of 630/2200m in the USA, more QSO opportunities will arise. QSOs call for mode and frequency adjustments to enjoy different parts of band-planned 630/2200m bands.

Easier Matching: With more ohms, ohmic antenna system resistance more nearly matches to 50Ω transmitters and coax. That means less impedance transformation is needed and can make the antenna coupler box simpler.

Lightning Safety: Lightning safety precautions will remain just as important as they already are at HF. (March 12-14, this blog.)

Antenna voltage KV: Lower Q means less voltage multiplication at MF/LF bands, but higher transmit power may offset this voltage reduction. (Jan. 16, this blog.) Safety precautions at ground level and advisable spacing from other antennas and towers at points high above the ground still require attention.

Shorter Paths: If regional communication rather than full continental coverage is your main goal anyway, a low efficiency LF/MF antenna may be all you need.

4/2/16 MF/LF ANTENNA DEGREE-AMPERES

Have you ever wondered what antenna degree-amperes are for? Here's my take.

RF current along the length of a vertical generates the oscillating magnetic field to launch your RF signal. Degree-amperes numerically express a quantity that when squared **$(\text{degree-amps})^2$** relates to total radiated power TRP. The idea is to multiply an *average* value of RF current (as if it were uniform over the whole vertical antenna height) times the electrical length in degrees of the vertical height of the antenna system. More height and more average current jointly make more TRP. A quarter-wave vertical would stand roughly 90° tall. Degree-amps capsulize an area-under-the-curve of nonuniform current distribution along vertical height.

But on 630m, verticals are electrically short. A vertical 20m tall occupies 11.4° on the 630m band. Most Part 5 and non-USA ham 630m verticals are electrically 5° to 10° tall. On 2200m the same verticals are 1.5° to 3° tall. If you run 1.5A RF averaged over height, that's 7.5-15 degree-amps on 630m and 2.25-4.5 degree-amps on 2200m.

Using electrical degrees instead of multiplying by the length itself recognizes that the same vertical height of antenna, when driven with the same RF current, radiates less TRP at lower frequencies, longer wavelengths. If you read somewhere about ampere-radians, just remember that 1 radian = 57.3° and it's the same thing in concept as degree-amperes.

Field strength as measured by field strength meters *is directly proportional to degree-amperes.* The next web site says 1 degree-amp gives 1.04 mV/meter at 1 kilometer. Nice! http://www.vias.org/radioanteng/radio_antenna_engineering_01_06_01.html , citing E. Laport.

I hope to talk more about RF field strength in a blogpost some future day. In the meantime, let's get better acquainted with degree-amperes today and critique top hats tomorrow.

A vertical without a top hat has no current at its tip, meaning most of the upper part of a hatless short vertical is inefficiently used. Average RF current along the hatless vertical's height becomes half what the RF ammeter shows. If there *were* current at the hatless tip, the antenna would be undesirably sparking and going nonlinear!

Talking about RF base current and estimated radiation resistance $R_{radiation}$ just gives you an different way of picturing the same thing as degree-amperes. You may see a radiation resistance formula that's proportional to the square of the fraction that the antenna vertical height bears to the wavelength. $\mathbf{R_{radiation} = a^2 (h/\lambda)^2}$. The fudge factor $\mathbf{a^2}$ depends on the amount of top hat and gets you to ohms. On the above web site you you see a log-log graph to straighten out the squared quantity $\mathbf{(h/\lambda)^2}$. It includes various graphical straight lines for different top hats--different values of the constant **a.**

The antenna design jargon of degree-amps and radiation resistance $R_{radiation}$ flow from one same idea—power equals I^2R. Total radiated power is TRP:

$$\mathbf{TRP = I_{base}^2\ R_{radiation}}.$$

The degree-amps approach recognizes that the fudge vector $\mathbf{a^2}$ depends on the amount of top hat because that affects the RF current distribution:

$$\mathbf{TRP = I_{base}^2\ R_{radiation} = I_{base}^2\ a^2\ (h/\lambda)^2}.$$

When you massage the equation you see that constant **a** takes you from antenna base RF current to the *average* current along the whole vertical height of the antenna system. What's inside the brackets is proportional to degree-amperes.

$$\mathbf{TRP = [a\ I_{base}\ h/\lambda]^2}$$

TRP is proportional to the square of field strength at 1 kilometer, and field strength itself is proportional to degree-amperes. One could get really technical about the math, but this is enough for now. Remember that EIRP is *triple* the TRP of a short vertical!

For more background on the subject of degree-amps see your favorite antenna textbook, or see pp. 16-7 and 16-8 in this additional web site:
http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwjks977u-vLAhXIMyYKHcy1C5sQFggiMAE&url=http%3A%2F%2Fwww.qrz.ru%2Fschemes%2Fcontribute%2Farrl%2Fchap16.pdf&usg=AFQjCNEBblgaRaN6sca4IbD9xc9IqB8Mcw
http://rudys.typepad.com/files/comments-on-laport.pdf

4/3/16 MF/LF TOP HATS AND DEGREE-AMPS

Today, let's talk about the advantages and disadvantages that MF/LF top hats can deliver.

Top Hat Advantages:

Higher EIRP comes from a more nearly uniform current distribution all the way up a TX vertical. https://en.wikipedia.org/wiki/T-antenna . But remember that adding top hat doesn't help you if your license is subject to a legal limit EIRP that's reached by your station already.

A vertical without a top hat has no current at its tip, meaning the upper part of a hatless vertical is inefficiently used. Average RF current for a hatless short vertical is only half what an RF ammeter shows at the antenna base. Top hat lets a *shorter vertical* antenna yield same total radiated power TRP by increasing its **degree-amperes**, as discussed March 31, this blog.

2 amperes of 630m RF base current in a 10° tall hatless short vertical can give 10 degree-amps (2 x ½ x 10°) and yield *15 degree-amps* with an ample top hat. A top hat can increase average RF current by about a quarter to half, which could as much as double the TRP.

Top hat increases antenna system capacitance. You get more flexible QSY by decreasing the system Q. SWR increases rapidly as your frequency departs from antenna system resonance, see graph Feb. 10, this blog. With lower system Q the SWR doesn't increase so rapidly. Then you can QSY temporarily a little way without retuning or by just retuning a little in the shack instead of outdoors at the ATU.

Decreased Q somewhat lowers antenna voltage KV from antenna base to top hat. On 630m $\mathbf{Q = (2\pi\ 475)L/R}$ by definition and $\mathbf{V_{antenna} = 1.4\ Q\ \ P\ /\ I\ <\ V_{breakdown}}$. See Jan. 16, this blog.

Top hat wires can be symmetrically or asymmetrically positioned to give approximately similar capacitance whichever way. I've not modeled the effect of a top hat on the azimuth and elevation antenna patterns of an electrically short vertical. I don't think the effect is very significant. But if you know a link or some better information about this, let us know.

If your radials have extended way beyond the extent of a small top hat high above, then providing longer top hat conductors above the radials can more efficiently utilize the radials. If the radials mostly go in one or two directions, then for highest antenna system capacitance the hat wires should extend in those directions to couple best with the radials. Your experience may suggest this last is not too important, especially if you have a perimeter conductor and/or several ground rods and your soil has favorable conductance.

Another top hat advantage is that top hat conductors are compatible with structural support and stabilization for the very top of an MF/LF vertical antenna. You get added degree-amperes--and steadying at the top to boot.

If the top hat slants upward, its system capacitance contribution is somewhat decreased compared to a top hat of same length horizontally, but the vertical slant contributes radiated power. Depending on the arrangement of antenna and trees on some properties, using a shorter vertical with an upwardly slanting asymmetrical top hat may make the antenna system both easier to guy and less obvious to neighbors.

Putting in a top hat or improving a top hat increases the degree-amperes of a short vertical mainly by distributing the same RF amperes more uniformly. Adding more radials and longer radials decreases the antenna system resistance and increases the degree-amperes of a short vertical mainly by increasing the RF amperes of antenna current itself.

Top Hat Disadvantages:

A top hat obviously requires outdoor work to construct or revise it. You may be able to simply increase your transmitter power TPO more conveniently than to do the outdoor work.

A top hat needs to extend more or less horizontally from the *top* of the vertical, although the angle is not too critical within +/-45°. Distant supports for the top hat at that top level may be unavailable or expensive and inconvenient to provide. If the top hat were attached to the vertical *below* the top of the vertical, the otherwise radiation-beneficial top segment of the vertical becomes mostly unused.

If the top hat slants quite steeply downward, its effect on system capacitance may be a wash-- more capacitance by closer approach to the ground and less capacitance because same length top hat conductor extends less outward over the ground below. That defeats a reason for putting up a top hat in the first place.

Moreover, if the top hat slants steeply downward, then vertically downward RF current in the top hat cancels part of the radiation from the vertical antenna and at least partially defeats the improvement in vertical antenna current uniformity that the top hat is intended to confer.

A long top hat may not fit on the available real estate. Even if it fits, it may add to visibility as far as difficult neighbors are concerned.

Adding a top hat means you need to retune the ATU after the addition. But so does improving the radials or just about anything else you do.

Top hat conductors add more weight on a vertical than lighter-weight guying does. The weight of the top hat likely adds to the support demanded of the antenna base. If you put downward-slanting top hat conductors under tension at their far ends to keep them from drooping in the middle, then a lot of that tension will be imposed on the vertical too. That can produce a buckling force on the vertical which may call for additional guying halfway up the vertical.

Top hat conductors convey a declining but substantial RF current along their length. That involves I^2R losses in the skin effect resistance of the top hat conductors. However, if your earth resistance is high or your radial/grounding system is not very elaborate, some loss in the top hat probably does not decrease the RF amperes of antenna base current very much at a given TPO compared to the improvement in radiation TRP that the top hat gives you.

If skin effect resistance losses in the top hat are significant compared other losses in the system, reducing top hat losses generally means more conductors or heavier conductors in the top hat. That translates to more weight for the whole system to support.

A top hat translates KV of antenna top voltage to its ends. If the top hat extends all the way to leaf cover of trees or shrubs, unexpected sparks might jump to them in quiet weather, or in windy weather, or sometime when such trees or shrubs grow nearer to the top hat end(s).

Generally top hat advantages outweigh their disadvantages so long as you plan intelligently.

4/4/16 ESTIMATE DEGREE-AMPERES FOR YOUR ANTENNA SYSTEM

Recall from April 2, this blog, that degree-amperes are closely related to field strength in mV/meter at 1 kilometer. Total radiated power TRP is proportional to the *square* of degree amperes. That's nice, but if you don't know the RF antenna current averaged all way up the height of the antenna, then how can you estimate the degree-amperes?

Today let's address that question for LF/MF using insights from a 2200m web site: http://www.strobbe.eu/on7yd/136ant/ . Scroll down to section 2.3. There you see some interesting capacitance formulas.

In a capacitance picture of the short vertical antenna and horizontal top hat conductor surfaces, numerous small capacitors with their susceptances (2πf C; 1.0/reactance) are distributed over the height of the vertical and along the length of the top hat. RF current gets diverted into these reactances and consequently diminishes as it progresses up the short vertical and out onto the top hat.

If you think of the vertical as having one overall average capacitance C_{vert} and the top hat having another capacitance C_{hat}, then the RF current fraction I_{hat} that reaches the top hat is the same fraction that the susceptance $2\pi f\, C_{hat}$ of the top hat bears to the susceptance of the whole antenna system $2\pi f\,(C_{hat}+ C_{vert})$. To get an RF current average value over the vertical height, then add up the 100% of the RF current that enters the base of the antenna plus the current that enters the top hat, and then divide by two.

The result for *average* current along the vertical height is

$\mathbf{I_{avg}} = I_{base}\,[1 + 2\pi f\, C_{hat} /(2\pi f(C_{hat}+C_{vert}))]/2$, or $\mathbf{I_{base}(C_{hat}+ 0.5C_{vert})/ (C_{hat}+ C_{vert})}$.

Imagine a perfectly horizontal top hat and entire antenna system in the midst of a vast plain, use formulas for $\mathbf{C_{vert}}$ and $\mathbf{C_{hat}}$ from the web site:

$$\mathbf{C_{vert}/C_{hat} = h/L[\log(4.0\ h/d_{hat}) / \log(1.15\ h/d_{vert})]}$$

L is hat length, *h* is vertical system height, d_{hat} is hat wire diameter, d_{vert} is the vertical's average diameter for wire, tube or cage. Multiple L by number of Marconi-T conductors in that type antenna. If the hat slants up or down, then add half the hat's vertical rise to the vertical height h (or subtract half the hat's descent). Likewise if the hat slants, revise the hat length L to be the sum of all actual horizontally-outward extents of its conductors. Figure $\mathbf{C_{vert}/C_{hat}}$ and then calculate the average current $\mathbf{I_{avg.}}$

$$\mathbf{I_{avg} = I_{base}\ (1 + 0.5C_{vert}\ /C_{hat}\ )/\ (1+C_{vert}\ /C_{hat})}.$$

To get degree-amperes multiply the average current $\mathbf{I_{avg}}$ times the electrical height of the vertical in degrees:

$$\textbf{Degree-amperes} = \mathbf{I_{avg}\ (360° h/\lambda)}.$$

In the real world, you have an antenna farm and possibly a metal antenna tower, plus trees and nearby residences with their gutter systems and possibly even nearby buildings with steel structural support. You can still use the capacitance concept. You could just fudge numbers by hunch and experience.

Maybe you can even do better than that. Use an antenna analyzer or capacitance bridge or other measuring technique to measure the total capacitance C_{ANT} of the antenna system. Analyzer shows reactance $\mathbf{X_{ANT}}$, and from there you get

$$\mathbf{C_{ANT} = 1/(2\pi f\ X_{ANT}) = C_{hat} + C_{vert}.}$$

Using the capacitance formulas from the web site, estimate the capacitance $\mathbf{C_{vert}}$ or $\mathbf{C_{hat}}$ of whichever vertical or hat portion of the antenna system is farther from (and/or more nearly perpendicular to) nearby structures. Suppose the vertical is farther. Then:

$$\mathbf{I_{avg} = I_{base}\ (C_{ANT}\text{-}0.5C_{vert})/C_{ANT}.}$$

If the hat is farther from the structures and the vertical is closer, then see if you can adjust the capacitance $\mathbf{C_{vert}}$ from the web site by adding a capacitance calculated in light of the nearby geometry. If it's a grounded tower, then try a capacitance formula based on parallel conductors. If the nearby structures seem too difficult to estimate on, then estimate the hat capacitance from the web site formula and use:

$$\mathbf{I_{avg} = I_{base}\ 0.5\ (C_{ANT} + C_{hat})\ /C_{ANT}.}$$

If both the hat and vertical are nestled in a complicated environment and you can't figure out how to do the estimation, then tell us about it. We care about how things *really* work!

4/19/16

PART 1: DISPLACEMENT CURRENT AND YOUR 630M TRANSMITTING ANTENNA

Displacement current can seem a mysterious concept. Even if you're familiar with it, perhaps one more person's outlook can interact with your own perspective.

In a capacitor, when current flows some charge onto one conductor and out the other, no actual electric current flows between the oppositely charged conductors (unless it sparks over). Instead, the flow of current increases or decreases the strength of an *electric field* between the conductors. The field is pictured by lines of force. Electric field strength, roughly speaking, relates to the voltage V across the capacitor divided by the distance *d* between oppositely charged conductors.

In the 19^{th} century it was discovered that electric *current* makes a magnetic field **H** having a magnetic field strength proportional to the current. Later it was learned that the *rate* at which an *electric field* changes also creates a magnetic field having magnetic field strength proportional to it as well. So people continue to use the term **displacement current** instead of the clumsy phrase "equivalent current proportional to the rate at which an electric field changes." For some history, see https://en.wikipedia.org/wiki/Displacement_current

Excitation at frequency f=475 KHz makes the electric field change in the antenna capacitance of your 630m antenna. The displacement current represented by the changing electric field in the antenna capacitance is approximately $2\pi f$ 8.85 (pF/meter) V/d. Put another way, amount of displacement current comes from multiplying voltage by capacitive susceptance (i.e., dividing voltage by capacitive reactance).

At 630m, $2\pi f$ is about 3 million ($3\text{x}10^6$/sec). So displacement current *density* at 630m is about *26.6 uF/meter* times *V/d*. **For every 1 KV of voltage per meter at 630m, you get roughly 26 mA/sq-meter of displacement current density.** That's consistent unit-wise with uF/meter (microfarads/meter) times 1000 volts/meter = milliamperes per sq-meter. Just as antenna current scales with frequency, so also there's more displacement current density per KV at 160m and less displacement current density per KV at 2200m.

Now consider a 630m vertical antenna 20m tall, having 110 pF antenna capacitance, driven by a 630m transmitter and ATU to have 3A RF current and 13KV antenna voltage. (That was an example I blogged Jan. 15.) Let's do some back-of-envelope numbers. The electric lines of force from the 20m-high vertical antenna curve toward the ground a short distance from its base and a long distance from its top. From its middle, the lines of force traverse a medium distance, roughly an arclength let us say of 18m. That makes a rough medium displacement current density amount something like 26 uF/m x 13KV / 18m ~= **19 mA/sq-meter**. The displacement current density is greater near the base of the antenna and it's less at the top.

How much total displacement current does the antenna have? Exactly as much as its 3A RF current! (Because of the basic connection of both types of currents to magnetic field strength, physicists have arranged the definitions and the constant 8.85 pF/m to deliver this equality.)

Imagine partway up the height of the vertical that the displacement current showers radially outward from the vertical down through a horizontal imaginary circle say about 14m wide encompassing like a necklace most of the displacement current. Then multiply the average displacement current density by the area πr^2 of that imaginary circle. You get about 3A RF current: 19 mA/sq-meter x π (~7 meters)^2 ~= 3A.

Think of the currents in a 630 m vertical antenna like the water in a water sprinkler that makes a very fine spray. The water goes up inside the skin of a vertical tube. From the tube, the spray goes out in all directions and curves in a shower toward the ground from every point on the surface of the tube all along the way up the vertical tube. The water in the tube is the 3A of RF current that goes up. The *water in the spray is the displacement current* that arcs downward.

Suppose you imagine luminous water in the tube and you "look" at the antenna from a distance. Then the antenna looks like a brilliant vertical line of light in a veil of luminous spray. That's your 630m vertical antenna!

Now add a **top hat** to the picture. Displacement current spray still emanates from the vertical antenna section. Additionally, displacement current spray emanates sideways from the length of the top hat as well as off the end(s) of the top hat. A top hat makes the RF amperes of antenna current more uniform all the way up the vertical section (April 2, 3, 4, this blog). That way the antenna transmits more RF signal.

OK, but what difference does knowing about displacement current specifically make as we design and build our antennas and do our day-to-day LF/MF operations? Displacement current distribution means that antenna current and charge distributions aren't the whole story of the electrical and magnetic energy storage properties of your antennas. Stray capacitances and intended capacitances are more easily estimated, planned for, and adjusted with displacement current in mind. Displacement current helps you understand how mini-whips and other receiving antennas work. Considering displacement current distribution also aids our experienced common sense assessing effects of 630m transmit antenna placement relative to towers, wire antennas, gutters, metal sheds, etc.

Do you have some helpful analogies or tips to aid common sense understanding of antenna principles.

4/20/16 PART 2:DISPLACEMENT CURRENT IN YOUR RADIATED SIGNAL

Radio waves get too far from their launching antenna to have antenna electric current make their magnetic field directly. Indeed, somewhere the radio waves are still traveling even after you stop transmitting! Because of their *displacement* current that goes so far, the magnetic fields in the radio wave nevertheless do arise and the radio energy propagates. It's because the varying electric fields make varying magnetic fields and vice-versa.

From your transmitting antenna as its center, concentric layers of displacement current consecutively convey electromagnetic energy ever outward. Like layers of an onion, these layers of displacement current comprise a growing laminated shell that expands endlessly at the speed of light. https://en.wikipedia.org/wiki/Radio_wave (animation).

After launch from your antenna, each layer of displacement current is separated from its neighbor by *half a wavelength*—λ/2--315m at 630m, or about 1000 feet. Doesn't that seem remarkable considering the height of your antenna is probably less than one-thirty-secondth of a wavelength (λ/32)! The layers comprise alternating directions of displacement current: one layer of displacement current arches upward, the next layer of displacement arches downward, and so on.

Magnetic lines of force, for their part, are generated by the onion-layers of displacement current and fill the spaces between those layers of displacement current like magnetism inside a coil. Resembling latitude lines on the surface of a globe, horizontally circular magnetic field lines occupy the interlayer spaces in directions first one way and then the opposite way from space to space.

I invite us to remember one number by heart: 377Ω. If air or free space be compared to a transmission line, its characteristic impedance is 377Ω. 377Ω is the ohms you get by dividing amplitude of electric field strength E in microvolts-per-meter by magnetic field strength H in amperes-per-meter that the displacement current of a propagating wave generates. Instead of characteristic impedance, it's called intrinsic impedance, but it's essentially the same thing. Dividing (E/H) boils down to taking the square root of the ratio of the inductive and capacitive properties of free space:

377Ω = sqrt[(1.26uH/m)/ (8.85pF/m)].

The intrinsic impedance in ionospheric regions departs from 377Ω a little. When a radio wave encounters the ionosphere, it sees what amounts to a transmission line characteristic impedance *discontinuity*. As a result, some of the radio wave is reflected. Also, some of it is transmitted, meaning that part travels onward even if redirected somewhat. In reality, an ionospheric region may include dissipation that saps some of the radio wave energy as well. The D-layer, for instance, may dissipate strongly some days in the daytime but allow daytime propagation other days on 630m.

Speaking of radio wave energy--at any place along their travel the radio waves have *power density* in microwatts/sq-meter moving at the speed of light in the direction of propagation. The power density is **E x H** because microvolts-per-meter times amperes-per-meter is microwatts/sq-meter.

Just remember that the power we are talking about results from the electric field **E** being perpendicular to and *in phase* with **H** along the wavefront plane where **E** and **H** are maximum. Displacement current is situated a quarter-wavelength displaced from both electric field **E** and magnetic field **H**. That's because displacement current is our label for *rate of change* of electric field **E.**

The power density in your sky wave rapidly declines because the transmitter radiates a limited amount of power that spreads out over vast reaches of 630m paths in every direction. But it's *there*, even when deeply buried in the noise-- *indeed even when so faint the WSPR decoder can't decode it*.

For 630/2200m RX station operators, the challenge is to present as best as we can the elusive signal we know is there and dig it out of the noise. Can the limitations of WSPR2 and even WSPR15 ever be transcended without demanding even slower data rates? Like breaking the old 4-minute mile that once seemed impossible, who knows what improvements lie ahead!

4/21/16 PART 3: ENERGY IS COMMUTING BETWEEN YOUR ATU AND ANTENNA

The last couple of days I've talked about displacement current in your antenna capacitance and displacement current in your radiated signal. Recall that an MF/LF antenna system is like an RLC circuit that your transmitter drives. "C" is the antenna system capacitance. "L" is the loading inductance of the antenna tuning unit (ATU). "R" combines the ohmic resistances—earth ground and any radials, plus antenna conductors and a little MF/LF radiation resistance.

The ATU loading inductance forces its energy into the antenna capacitance. A quarter-cycle later the antenna capacitance returns the energy into the ATU loading inductance. Then the ATU forces its energy into the antenna capacitance again but with opposite voltage polarity, and in another quarter cycle the energy is forced back into the ATU, whereupon a new cycle begins.

It's like blowing up a balloon with one deep breath and then letting the balloon blow air back into you, and so on. Like your workday in miniature, the energy is shuttling or commuting back and forth from "home" in the ATU to its "workplace" in the antenna where something useful gets accomplished and then the energy returns "home" again!

Your transmitter initially energizes this repetitive process. In about 100 microseconds after transmission starts, the TX has "pumped up the LC swing," so to speak. Thereafter, your TPO is simply making up for the dissipative losses and radiated power emission implicit in the resistance "R" of RLC.

How *much* energy? How *much* power are we talking about? The peak energy in the 110 pF example of MF/LF antenna capacitance is half the square of its peak voltage times the capacitance. **Capacitive Energy= ½ CV^2**. In the MF/LF antenna example I used Jan. 15-16, this blog, the RLC antenna system resonated at 630m, consumed 200 watts TX power (TPO), stood 70' tall, and featured 20 ohms, 1mH, 110pF, 3 RF amperes rms, Q=150, 13KV antenna peak voltage.

Energy = 0.5 x 110 x 10^{-12} farads x (13 x 10^3 volts)^2 ~= **9 milliJoules**.

Every half-microsecond quarter-cycle at 475 KHz, about 9 mJ are "commuting" to the example antenna. A quarter-cycle after that, the 3A rms RF antenna current has turned around and "charged up" the magnetic energy inside the 1 mH loading inductance: half the square of its peak current times the inductance. **Inductive Energy = ½ L I ^{2}.** The 1 mH loading coil acquires a *nearly equal energy*:

½ x 1mH x (4.24A peak)^2 = **9 mJ**, minus some ohmic losses on the way.

In each quarter cycle that's an average rate of energy transfer over **17,000 watts**!

9 x10^{-3}J / 0.52 x10^{-6} sec. ~= 17000 watts.

Believe it or not, that's what the high antenna Q=150 entails in this example.

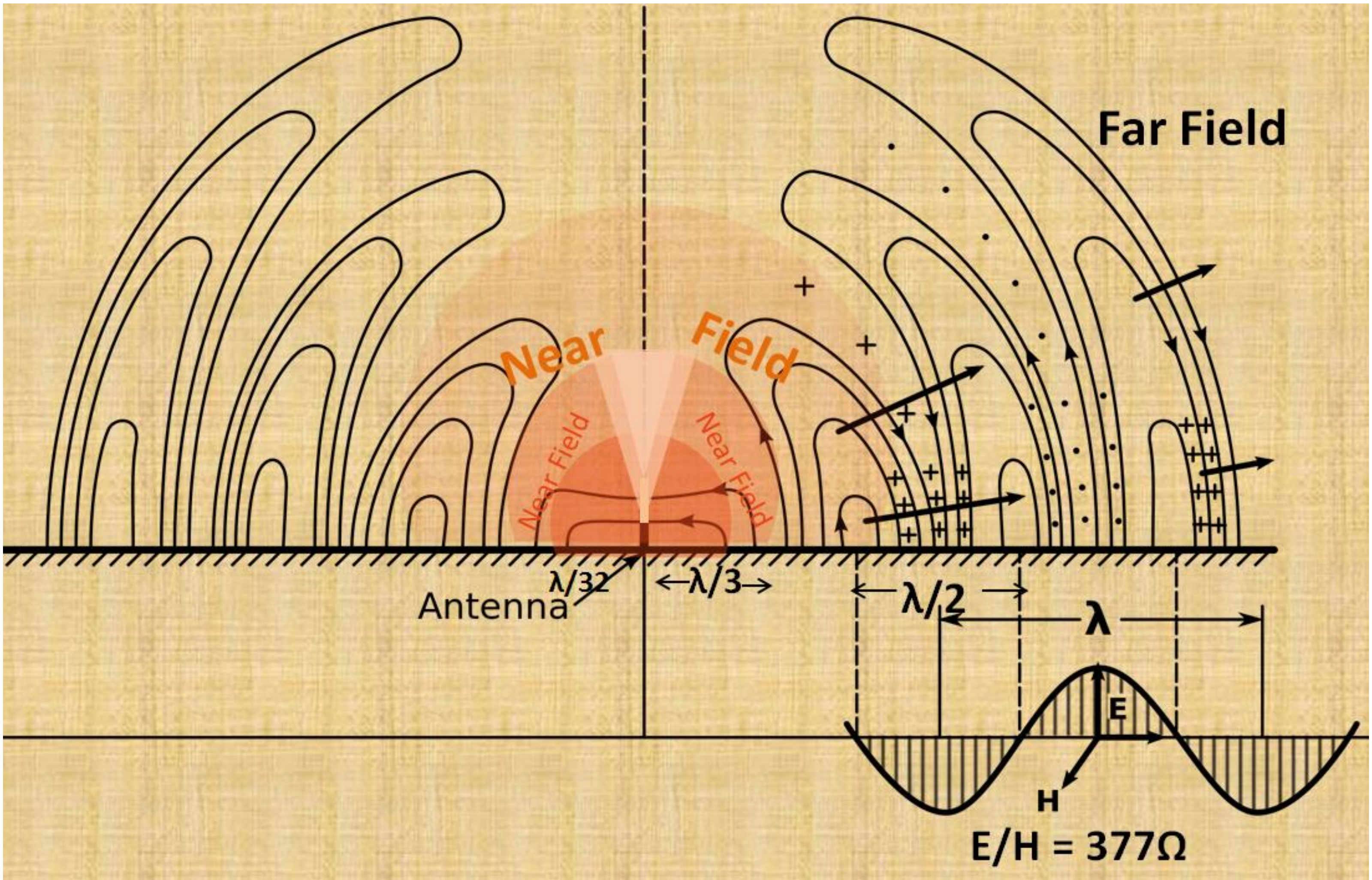
The shuttling of energy to and from the antenna capacitance is manifested in the changing electric field there. Current in the vertical antenna section is encircled in the inductive magnetic fields it makes. Displacement current corresponds to changing electric field as discussed April 19, this blog. Displacement current contributes a magnetic field too. There's a radio wave in embryo, somewhere.

Out to a fraction of a wavelength —I calculate out to roughly 100-200 meters at 630m--the mixture of electric fields and magnetic fields arising in their various ways constitutes what's called the *near field*. Meanwhile the antenna is radiating, which constitutes the *far field* more remotely.

The near field zone is a complex place that includes both non-radiative electric and magnetic fields as well as your RF signal power (TRP) getting launched. It's an interesting place--if only because your shack and your home are tenuously immersed in it! For the most part, these fields are like those associated with any inductor and capacitor as well as boomerang "wannabe" electromagnetic waves that never get launched. The unradiated fields in the near field nevertheless harbor the vast majority of the energy that "commutes" and enters the MF/LF antenna system each half-cycle from the ATU.

You could say a 630m TX antenna develops an energetically "hot" hemispheric ball of inductive and capacitive energy within about 200m of a 70' vertical, with or without top hat. This hemispheric, mostly-nonradiating ball of energy is close to the antenna because that's where the strongest electric and magnetic fields are found. The ball of energy has an indistinct, fuzzy boundary where some of the energy "evaporates" and steams outward so to speak. That's the RF signal radiation you constructed the antenna to send skyward. Only a few watts are radiated compared to the thousands of watts commuting to the antenna.

Since your antenna is probably electrically small, 70' or less, how do all those fields in the near field come to be? In other words, how do the propagating radio waves of your RF signal ever get made? Let's dig into the innards of the near field!



Adapted from https://en.wikipedia.org/wiki/Radio_wave

4/22/16

PART 4: HOW THE ANTENNA'S NEAR FIELD LAUNCHES YOUR RADIATED SIGNAL

Since your TX vertical antenna is probably electrically small, 20m (66') or less, how do those near fields get out to 200 meters away to launch RF? *How* are the propagating radio waves of your RF signal launched anyway? What's in this mysterious near field? This subject is a bit like when a child asks how babies happen. A child knows that babies get born and that at least Mommie has something to do with it. Beyond that, the conversation may trail off.

Here's one approach to an answer—on the topic of RF launch, that is. The antenna fields E and H need to match the 377Ω intrinsic impedance of free space. That's not a simple thing. Fortunately in the near field, the E and H fields at a given point are already perpendicular, which is a first requirement. Electric fields in an isolated vertical antenna lie in vertical planes passing through the vertical. The magnetic fields encircle the antenna horizontally.

Additionally, however, E and H fields have to be *in phase*, which is another way of saying that some of the displacement current has to act like a lamination of current a significant fraction of a wavelength nearer the antenna than at least some of the H field. That way, they will be able to regenerate each other farther out and propagate outward. On top of that, E and H need to be in the *right ratio* to match the 377Ω characteristic impedance of air and free space.

If E/H departs considerably from 377Ω, RF power simply boomerangs back to the antenna. Insofar as portions of electric field E and magnetic intensity H do get in the right ratio and in phase, those portions will continue to propagate and will get launched by your antenna.

Very close to the antenna, in a non-radiative portion of the near field, the strong magnetic field H is in phase with the vertical RF base current *I* that generates it. Meanwhile, the strong electric field E due to the capacitance of the antenna is 90° out of phase with that RF base current *I*. These close-in magnetic and electric fields are not in phase and lack significant spatial separation because they largely intersect. Consequently, they do not support radiation regardless of whether they have the right ratio of magnitudes.

Farther away, E/H approaches not only the in-phase condition but also the right ratio E/H =377Ω ohms in an outer part (Fresnel zone) of the near field and beyond.
https://en.wikipedia.org/wiki/Electromagnetic_radiation

Most energy in the electric and magnetic near fields of the antenna is poorly coupled to the 377Ω impedance of free space. That energy simply reflects back into the antenna and to the loading coil of the ATU.

With all that in mind, coupling to 377Ω *can* occur at a radius *r* from the MF/LF vertical antenna in a radiative zone. Not far into the radiative zone of distance, the match of the fields to 377Ω is about 6:1 "SWR" relative to free space, not very good. But the "SWR" gets more and more favorable with increasing distance *r*.

By the way, the term "SWR" is not generally used to describe the coupling of an antenna to free space, but SWR generally does have meaning to us experimenters and radio amateurs. In a radiative way of using "SWR" here, we are looking for distances out from the antenna that deliver in-phase E/H roughly in a range 75Ω to 377Ω without being very reactive. This "SWR" has nothing to do with the match to the ATU nor the ATU match to the coax from your shack.

I've been digging into antenna field equations and their near-field solutions. My calculations indicate that, relative to free space, an electrically-short vertical antenna at about one-ninth wavelength (λ/9, 70 meters or 220 feet out) looks like a very low impedance, very-high-"SWR" source with significant capacitive reactance. Almost all the real RF power in the fields there is incapable of coupling to free space 377Ω.

At one-sixth wavelength ($\lambda/6$, 105 meters or 350 feet out), however, about half the power in the RF fields there is coupled into free space as if "SWR" were considerable. Farther out, moreover, RF signal launch conditions become really favorable at and beyond one-third wavelength ($\lambda/3$, 210 meters or 700 feet out). There, the "SWR" referenced to free space falls to 1.5:1 or less, and the amount of power delivered into radiation out of the fields there rises above 95%. That's the good news. The bad news is only a small portion of the energy in the MF/LF antenna fields lies that far distant.

An amateur's HF quarter-wave vertical is already about $\lambda/4$ tall. Its radiation emerges from the surroundings right by it. By contrast, an electrically short MF/LF vertical is often no more than $\lambda/32$ and radiates from places that are 5-10 times as far away from the antenna as the antenna is tall. Close in, a big hemispheric ball of stored energy just shuttles in and out of the antenna between it and the ATU.

Structures like HF antennas, tower, metal shed and residential gutters mostly lie within the MF/LF antenna's non-radiative zone where most of the energy of the MF/LF antenna is stored. So those other structures mostly attract displacement currents that divert from the MF/LF system some of its vertical antenna current. Those structures may shift the physical distribution of the ball of reactive energy in the antenna fields somewhat as well.

In conclusion, I hasten to emphasize that I've quite informally pictured your 630/2200m vertical TX antenna and its near field. The equations supporting this blog post are available on request. If you have better wisdom or a better way of describing antenna subjects, or a link to some good website, or some outright correction, e-mail us so we can post to this blog!

*I presume similarity to dipole radiation of energy that "flowers" outward as illustrated at p. 230 in Brown, R.G., Sharpe, R.A., & W.L. Hughes. (1961). *Lines, Waves and Antennas*. New York: The Ronald Press Co. See also pp. 203-208 for magnetic vector potential method of derivation of **E** and **H** far fields, radiated power and radiation resistance for an electrically short antenna wire with constant current distribution.

The Poynting vector represents E x H power density and direction the power is traveling. (Click the color animation.) https://en.wikipedia.org/wiki/Poynting_vector#/media/File:DipoleRadiation.gif .

4/23/16 VIEWPOINT: DISPLACEMENT CURRENT ADDS 630M ANTENNA CREATIVITY

Visualizing antenna fields and displacement current can help you generate ideas for antenna geometries to analyze with antenna modeling and calculation programs. I was inspired to think about this topic by the post from Doug WH2XZO that he blogged April 10. (Any errors here are mine though.) I've illustrated a variation on the inverted-L antenna theme and discuss it later below.

The last few days, I've surveyed some fundamental ideas about MF/LF antennas. The antenna gets the RF ready to launch by putting perpendicular magnetic and electric fields *in phase* in a *ratio E/H* that somewhat matches to 377Ω impedance of free space. (This blog April 21.) "Launching RF" invites us to increase the radiation resistance and the antenna efficiency. Recall that displacement current phase is 90° from the phase of electric field E, because displacement current involves *rate of change* of electric field E.

Getting E and H fields in-phase therefore means positioning the antenna's displacement current to have a significant spatial separation from the magnetic field H. That separation presages the onion-layered geometry the displacement current and the magnetic field H will need to have to regenerate each other and thereby propagate outward on their way to the sky.

A hatless, short vertical antenna launches RF to some extent. You can increase its radiation resistance by including a horizontal top hat to distribute the displacement current somewhat farther away from the magnetic field-generating vertical conductor itself. That repositioning moves the displacement current incrementally nearer the quarter-wavelength separation from the H field that it needs to have inside the radio wave after launch. (April 20, this blog.) Thinking this way brings an additional perspective to top hats, which likewise improve degree-amperes in the vertical (April 4, this blog).

Moreover, considering the antenna fields and their phasing gets us thinking about the question of what parts of the antenna are really "pulling their weight" and what parts are mostly sitting there not doing much. If USA amateurs become allowed by FCC to use MF/LF, can we recommend any more efficient TX antenna than today's top-hatted vertical? What's the best economy and height, least real estate footprint, and easiest construction? Have we considered many alternatives and streamlined the ones we have?

For instance, are sections of the top hat closest to the vertical antenna top point doing much to position the displacement current there in a way that launching radiation? If not, doesn't that mean that the *ends of the top hat* invite us instead to pay attention to their design geometry?

Thinking about displacement current and fields brings a magnifying glass to the design of the grounding system and its radials too. Are sections of the radials closest to the vertical antenna base doing much to help launch radiation or are they shunting displacement current unnecessarily? Where indeed should most of the copper in the radials be located? If we redistribute or redesign the radial layout, can we launch more radiation than we forgo? After all, ground resistance might nevertheless worsen in an otherwise well-intentioned redesign.

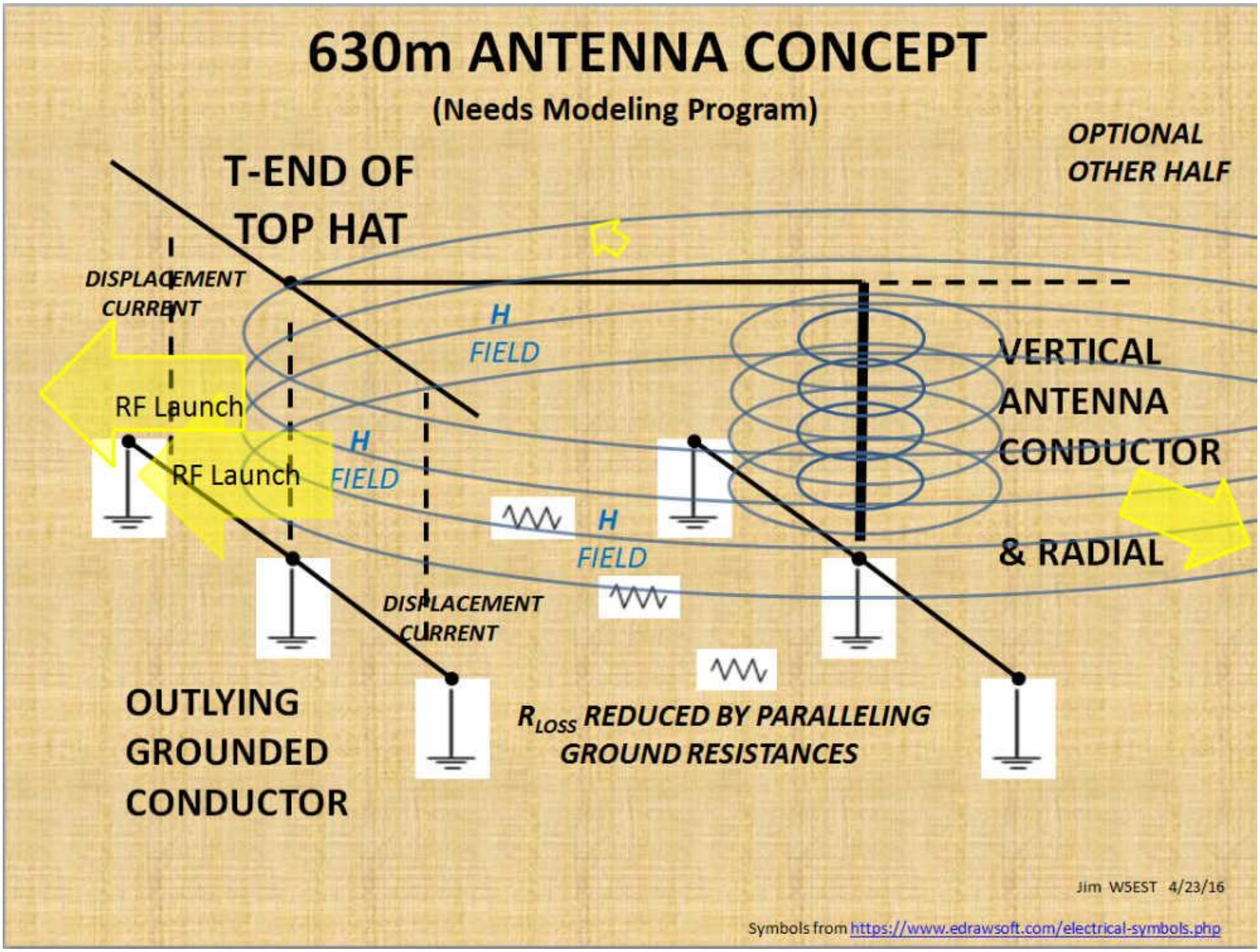
What about the vertical antenna conductor itself? Generally its magnetic **H** field lines are nearly circular in shape as if formed on concentric cylinders, see illustration. Would we be better off running two vertical wires upward and fanning them out perhaps three yards from each other to make the magnetic **H** lines more flatly oval? Would that beam out RF enough better to justify the inconvenience getting two verticals up.

Today's illustration shows one 630m antenna concept example. One well-grounded outlying conductor segment is ready to receive displacement current. A parallel central radial, likewise well grounded, parallelizes earth resistances between it and the outlying conductor segment. System ground resistance is likely substantial anyhow, so it needs to be offset by improvement in the antenna radiation resistance.

To increase radiation resistance, augment the top hat with a *T-shaped* end aligned overhead with the outlying conductor segment of the grounding system. This contributes a curtain of displacement current showering down vertically at some distance from the vertical antenna.

Does this antenna have directivity? If so, then plan for a desired direction of the top hat. If the antenna has increased directivity, then an amateur should be careful to stay within an applicable legal limit on EIRP. (FCC ham allocation of 630m is still pending in USA. Part 5 station licenses often allow a more generous power limit and may define it by ERP or by TRP instead of EIRP.)

Will the illustrated 630m antenna yield advantages over an ordinary inverted-L? Hopefully yes, but perhaps the more important point is that considering displacement current and antenna fields helps you deepen your antenna experience. If an antenna design doesn't work as well as you expected, *why* does it underperform? If another antenna design works really well, why *does* it work better? This interchange of practical antenna experience with mental pictures of displacement current and antenna fields helps you build a more realistic knowledge how both antennas and fields really work in practice.



5/3/16 ESTIMATING TPO USING MODELING dBi FOR GIVEN EIRP

The April 27 blog discussed modeling of an antenna over EZ-NEC Demo's "real ground" while omitting explicit ground system resistances that you might otherwise put into loads or L-networks. By omitting, you can get total radiated power TRP(dBw) from a desired EIRP level such as 7dBw. **To get TRP from the EIRP, subtract the antenna gain dBi vs isotropic** value EZ-NEC Demo displays with the antenna elevation pattern.

Some FAQs take the topic further.

Q1: How can you figure the transmitter power output TPO from the modeling results when all antenna and ground resistances are effectively in series?

A1: **TRP** = $\mathbf{I_{rms}^2 R_{radiation}}$. In simpler models all the antenna and ground resistances in the antenna system are effectively in series. So add them all up and call their total "R":

TPO = TRP x R / $R_{radiation}$.
To get TPO with series resistances, just multiply the TRP times the sum of all the resistances in the system divided by the radiation resistance.

Q2: Can you calculate TPO the same way if you specify an estimated ground resistance allocable to hat and a separate ground resistance allocable to vertical?

A2: You can enter separate ground resistance values into an EZ-NEC Demo L-network at the base and into an RLC load in the top hat. Remarkably, we saw in the April 28 blog that ground resistance under an extended top hat doesn't just add arithmetically to ground resistance near the vertical. These combine in a more complicated way because of the multiple paths the displacement current traverses at various places in the system.

Fortunately, you can execute a model on EZ-NEC Demo by entering your estimated allocable ground resistances separately there. From them, let the software calculate the weirdly-combined antenna impedance seen by a specified Source connected directly to the base of the antenna. (The vertical wire number for the antenna is specified in EZ-NEC button "Wires" section.) Do this calculation before you subsequently specify ATU inductance(s) and capacitance(s) in L-networks.

TPO = TRP x R / $R_{radiation}$.

TPO = {10^ [(7dBw$_{EIRP}$ –dBi$_{RealGnd,Rgnd=0}$)/10]} x R / $R_{radiation}$.

The "R" is found in the resistance part of the combined impedance R+jX that shows in the "SWR" display window. It signifies overall system resistance now seen by the Source instead.

Q3: Isn't there some easier way? And, what if the SWR isn't 1:1 because you match the TX in the shack to some resistive impedance like 75Ω from the ATU instead of 50Ω from it—how do you estimate TPO then?

A3: Run EZ-NEC with allocable vertical and hat ground resistances entered from your estimates. Click SWR, and then FFPlot. The FFPlot elevation pattern windows reports dBi including both antenna gain minus ground loss. Get TPO in dBw and convert to watts using FFPlot window dBi as follows:

TPO = 10^[(EIRP(dBw) –dBi$_{RealGnd,Rgnd=YourEstimates}$)/10] watts.

You get the same TPO estimate regardless of which method A2 or A3 you use. This one doesn't require you to know anything but the dBi the FFPlot window reports for your specified model. Use it, it's simpler! No separate calculation of radiation resistance is needed to estimate TPO. The *appended TABLE* illustrates an example how it works either way you do the calculation.

Q4: How can you figure the RF current at the antenna base from the modeling results such as dBi with ground system resistance?

A4: From answer A3, get TPO.

$I_{Base(rms)}$ =sqrt(TPO/ R).

The combined system resistance R is displayed in the R+jX values in the SWR window of EZ-NEC Demo. **$I_{Base(rms)}$** here gives the ATU *output* rms current amperes to the antenna base. If you want the ATU *input* current required to get that EIRP, then for a lossless ATU:

$I_{ATUinput(rms)}$ =sqrt(TPO/ 50Ω).

(For a discussion of lossy ATUs, see this blog March 29-31.)

REMARKS ON DOUBLE-LOADING OF 630M ANTENNA "F"

It turned out the double-inductance loaded 630m antenna "F" described yesterday improves the radiation resistance but not the antenna efficiency. Increased loading inductances are disproportionately increasing the ground current and increasingly coupling some of the transmit power into ground loss beneath the arrow end of the top hat.

Murphy's Law prevents the greatly improved radiation resistance of loaded antenna "F" from benefitting you! Nevertheless, the main conclusions blogged yesterday (May 2) remain.

If various *real structures* like HF tower and home AC ground wiring cage could destroy the 630m antenna performance, you can design around them and move the displacement current where you want it. You do this by inductively *loading* antenna "F" even if you can't outperform the model results of an *unloaded* antenna "F" that assumed no interfering structures. Moreover, you can null out the usual kilovolts on the antenna base at ground level.

TABLE: MODELING TPO FOR DOUBLE-LOADED ARROW-HAT 50' ANTENNA "F"

Loads (uH)	R_{ANT}	Gain (dBi)/TPO	Effic.	TPO	$R_{radiation}$	dBi (R_{gnd} = 0,0)
2x400	76.7Ω	-13.91/123.3w	1.72%	123.7w	1.32Ω	+3.72
2x300	54.4Ω	-13.26/106.2w	2.03%	106.8w	1.11Ω	+3.64
2x200	43.9Ω	-12.95/ 98.9w	2.23%	98.8w	0.98Ω	+3.57
2x 0	35.3Ω	-12.89/ 97.5w	2.30%	98.0w	0.81Ω	+3.47

*NOTE: TPO is RF *forward power minus the reflected power* from the ATU input. If your SWR departs from 1.0 : 1, then the transmitter RF output power will need to be more than the TPO just calculated. EZNEC demo gives you reflection loss report in the "SWR" display window as if you feed a non-50Ω antenna with a 50Ω transmitter. Adjust the TPO estimate higher by that reflection loss if you drive an imperfectly matched antenna with a 50Ω transmitter. Better yet, match the non-50Ω antenna perfectly by using a TX autotuner or a shack tuner. Then for TPO calculations you can ignore the reflection loss in the SWR display window.

For another article on antenna power, see: http://www.amateurradio.com/the-joys-of-erp/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+amateurradiocom+%28AmateurRadio.com%29

6/16/16 POLARIZATION DIVERSITY: COULD IT BENEFIT 630M RECEPTION?

Today's **Appendix and illustration** lay out the reasons that I think either Faraday rotation of polarization or multipath self-interference are responsible on 630m for a lot of the SNR variability we see even on a favorable quiet reception night during the best of the 630m season. I'm not sure we can do much about 630m multipath, if that's the culprit. But if Faraday rotation is a significant contributor to SNR variability, then we'd want to get very shrewd about the subject of polarization.

What does this mean for hams and other experimenters? I think it means that we may well consider whether an experimental receiving antenna system at someone's 630m station could be arranged to adequately receive 630m horizontal polarization as well as vertical polarization. A horizontal loop or dipole positioned as high up as possible over imperfect ground could be a candidate antenna.

The SNR would probably be significantly different for the horizontal vs. vertical polarization. We could discern whether the SNR *variations* of the two polarizations are correlated or not, however. If the SNR of horizontal polarization increases when the SNR of vertical polarization decreases, that would be a clear sign of predominant Faraday rotation as distinguished from multipath.

A **horizontal loop would be omnidirectional** at all headings, while a vertical loop is bidirectional with nulls. For a given signal, its SNR would probably be less in the horizontal loop. Stray capacitance to ground would contribute vertically polarized pickup mostly to the common mode and could be mostly rejected by careful construction.

A **receiving dipole, by contrast**, would receive zenith noise like a vertical loop does, and has a bidirectional azimuthal pattern like a vertical loop. A 630m horizontal reception dipole might be constructed like two E-probes back to back. If such a horizontal dipole and its preamp were oriented perpendicular to the plane of a vertical loop and situated high and far enough away from the loop to avoid interaction and detuning, it could be rotated in tandem with the vertical loop.

The $64 question is whether a double E-probe 630m reception dipole would deliver a bidirectional azimuthal pattern for the horizontal polarization (subject to some horizontally polarized zenith noise pickup in both the dipole and the vertical loop antenna). I suspect the stray capacitances to ground from the dipole ends would make it act like a low-sensitivity vertical loop instead and would receive mostly vertically polarized noise and overwhelm horizontally polarized signal from the desired direction.

If the double E-probe dipole arrangement were effective, then would noise cancellation would be effective as between the two antennas to reduce zenith noise? Relative to zenith noises they would be perpendicularly polarized, which means such cancellation opportunity would probably be modest at most, I think.

What do you think? Neither antenna would work? Already tried? Better wisdom? Worth a shot?

APPENDIX: **Middle 50% of decodes, SIQ (SNR Interquartile Difference)**:

A first picture imagines that nighttime 630m SNR variability arises from Faraday rotation causing the polarization arriving at the 630m RX antenna to vary. Faraday rotation of an RF signal can occur when the signal wave encounters a magnetic field in a plasma like the geomagnetic field (GMF) in some layer or region of the ionosphere offers. Faraday rotation of a vertically polarized signal as originated from a TX vertical probably delivers any and all polarizations to the RX antenna sooner or later in a reception night. But how to recover the energy from both polarizations and employ them for improved reception?

If the receiving antenna receives only vertically polarized 630m waves, then the received electric field amplitude in the vertical direction is proportional to sinA, where A is the angle of rotation of the field relative to the horizon around the heading of the arriving signal as its axis.

Suppose all polarization angles are equally likely, which means the middle 50% of signals occupy a 45°-wide range of angles A centered on A=45°. That range extends from 22.5° to 67.5°. The dB calculation involves $10\log_{10}$ of power, and power is proportional to the square of the electric field strength that varies as sinA. So the middle 50% of signals occupy a dB range

$$\mathbf{SIQ_{polzn} = 10\log_{10}[(\sin 67.5°/\sin 22.5°)^2] = 7.655\ dB}$$

This theoretical 7.655dB value falls **squarely in the middle of observed variabilities** of single hop paths across the USA November, 2015. See **illustration shown at Ham-Com**.

If, instead, the polarization were unchanging, and wave amplitudes from 0.0 minimum to 1.0 maximum are instead all equally likely due to granularity in the ionosphere, then the middle 50% of amplitudes would range from 0.25 to 0.75 and

$\mathbf{SIQ_{granul} = 10\log_{10}[(0.75/0.25)^2] = 9.542\ dB}$ (high end of observed variabilities Nov. 2015.)

If, in a third picture, the amplitude variations are due to multipath self-interference, then I would picture a mixture of amplitude and phase variations due to varying amplitudes and phases on two or more paths perhaps involving reflections/refractions at points only a few wavelengths apart. The resulting **$\mathbf{SIQ_{multipath}}$ would probably be at least the above 7.655dB** and probably considerably more.

A fourth picture would include rise of SNR during the evening and fall of SNR before sunrise due to changes in absorption. This undoubtedly contributes somewhat to the observed overnight SIQs. However, deep nighttime SNR variations are substantial enough to require additional explanation as above.

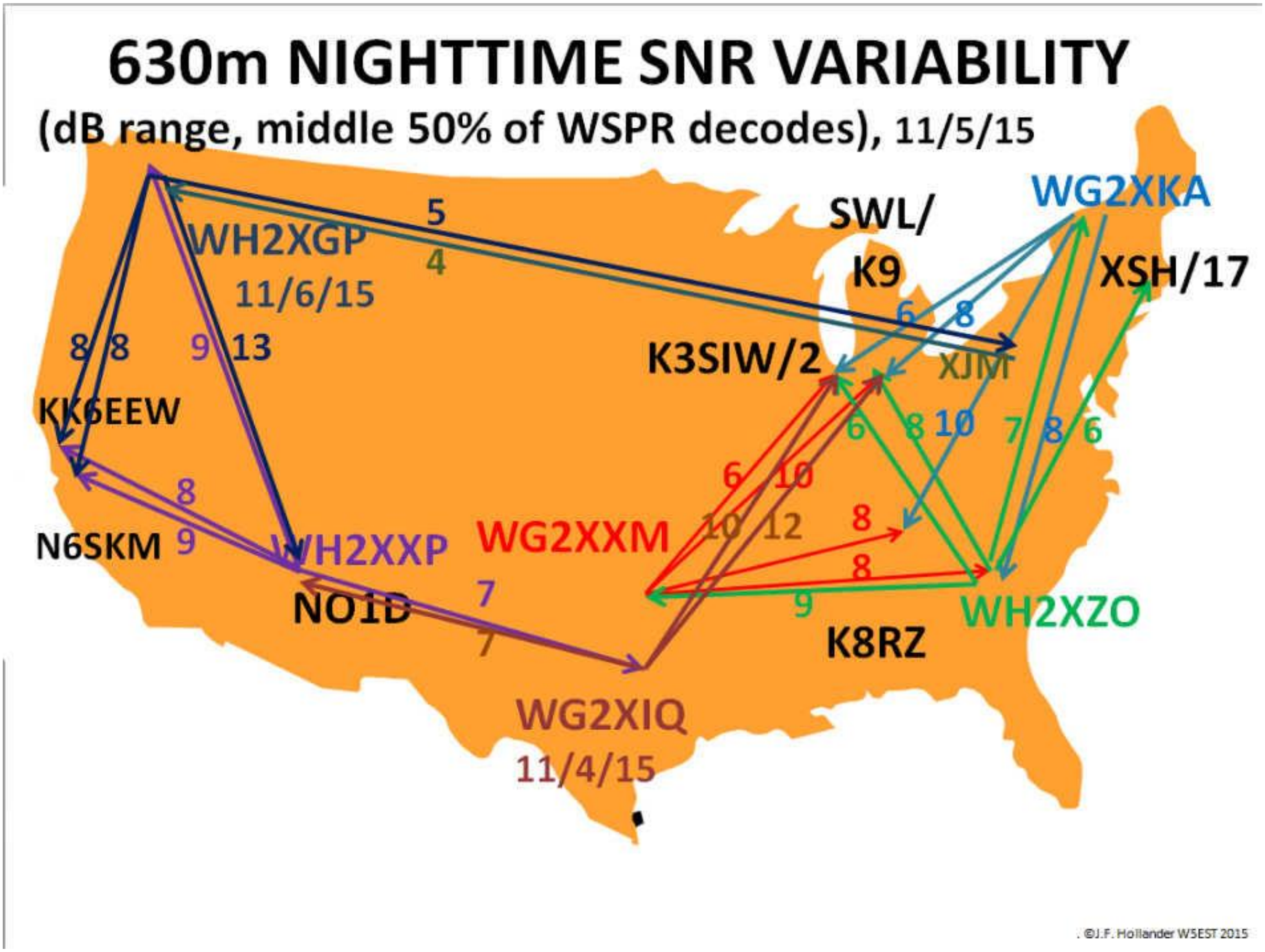
Fifth, I have omitted to discuss band noise variations that surely contribute to SNR variations. The nights in question were mostly storm free quiet nights and the dB contribution from band noise variation was probably small.

I conclude that one of these sources of signal variation predominated in early Nov. 2015 because the observed variability SIQ was 6-8dB, no more than any one of the first three main source possibilities would predict. If these sources of variation were equal contributors and at least somewhat uncorrelated, then the variability SIQ would be larger than any of the estimated values, which is inconsistent with observed variabilities Nov. 2015.

(The sources probably are indeed uncorrelated because I picture ionospheric spatial granularity to arise from local mass flows in their larger geophysical context, while Faraday rotation would vary signal polarization mostly by timewise changes in geomagnetic field strength and electron concentration. Multipath would depend on features of the path in multiple places at altitude as well as the separation distance(s) between those multiple places--which likewise does not correlate fully with the other proposed sources of variation. In these cases I focus only on the place (or places) in the ionosphere where the signal wave is reflected/refracted. In the middle of the night on single-hop, such place or places would most likely be near the path midpoint at altitude.)

So, what sources of variation are predominant? I speculate that the deep nighttime 630m-relevant ionosphere is probably relatively stable physically because there's not much to disturb it. The terminator is far away. The earth shields it from solar wind, so whatever disturbance may reach it would be indirect. So it's probably relatively free from turbulence and resulting granularity. I ignore TIDs (temporary ionospheric disturbances, deep subsonic acoustic waves).

Instead, electron mobility means ionospheric currents can affect GMF intensity locally at altitude. Also, multipath would easily occur due to slight variations in electron density contours. Consequently, I surmise that **either Faraday rotation or multipath or both are the important contributors on the short time scales** over which SNR variability plainly occurs on 630m.



6/23/16 SUSPICIOUS MF ANTENNA EVENTS: BEWARE!

John WG2XIQ reports: I don't typically operate my station during the daytime in the Summer unless I am testing something. Yesterday was one of those days and it triggered a number of events as I tried to diagnose a potential system problem. I was observing what looked like an AMing of the current waveform on the scope match. It wasn't fast but would change on an irregular schedule during a long transmit carrier. This was observed during the midday. A reduced base current was also observed during this time frame but I suspect that was the result of the temperatures which were even higher in the ATU. I suspected a large Mica transmitting capacitor and I found that one had been leaking so I replaced it but the problem continued. After checking the system into a dummy load where no problems were observed, my concern turned to a potential problem with the top loading wires. If I had to take this system down I have my doubts that I could get it back up in the air without a helicopter or crane. I also considered the possibility that the coil was changing shape slightly on the ATU in spite of being lightly coated in shellac due to the high temperatures. This seems to be the most likely situation as the system settled down in the late afternoon and base current returned to normal levels.

There may be another scenario in play that was also observed about 15 years ago: When I began operating QRO 160-meters from this location I would observe periodic changes in antenna impedance that I could never isolate to the actual antenna. Through dumb luck I found that the metal liner in my chimney and fireplace was rectifying between junctions and arcing which changed the resonance of the entire antenna structure in the near field. I could literally hear “pop pop pop” when listening in the fire place. The problem cleared up on its own but I had plans to skirt the chimney’s metal core to “tune it out” with a capacitor. It was warm enough this Winter that I did not use the fire place so its possible that the structure is once again “in flux”. I will continue to make observations but I think everything is fine with respect to the antenna system and should be OK for Field Day. Last night appears to have been “situation normal”.

6/29/16 Last week I reported an intermittent problem at my station related to the antenna and ATU. The problem seemed to resolve itself over the weekend and was stable for the field day demonstration but I began observing the behavior again during the day on Tuesday. I found that a few errant **strands of braid were intermittently contacting the center conductor of the coax** at the feed point which is consistent with the impedance variations that I was observing. Replacing the coax at the feed location solved the problem and through the overnight session and morning CW sked there were no additional impedance excursions.