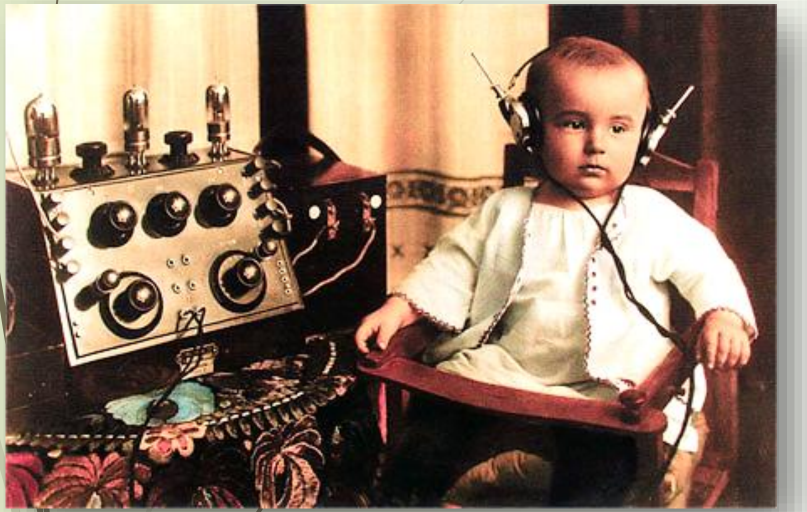
Small Magnetic Loops: A Beginner's Guide

"WOW! This is a very different antenna!"

Dave Wickert, AE7TD
Lake Washington Ham Club November 2018 Meeting
10-Nov-2018

Dayton Hamvention 2017

History



Balkan's War in 1942

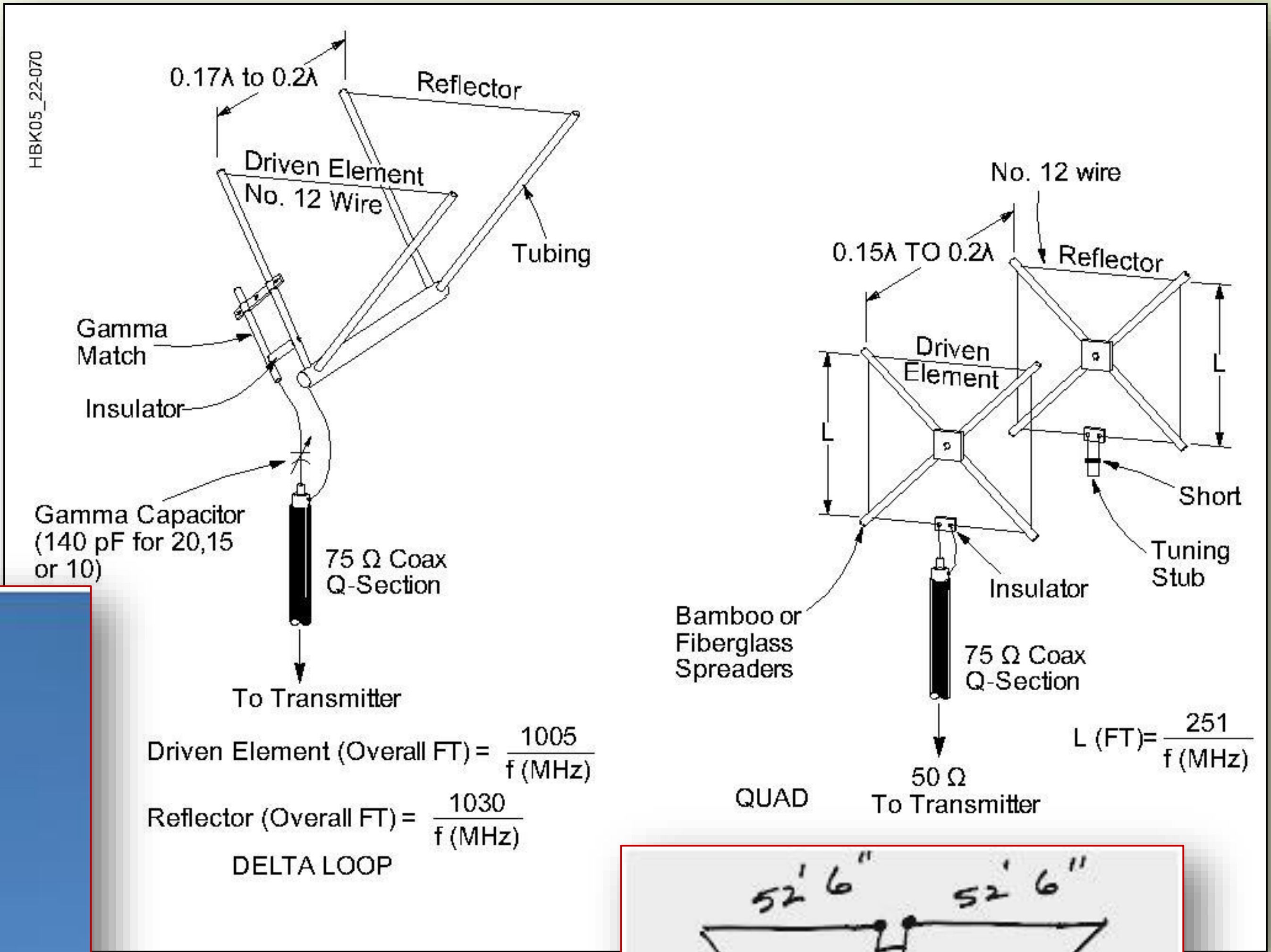
Portable Army Radio Tested

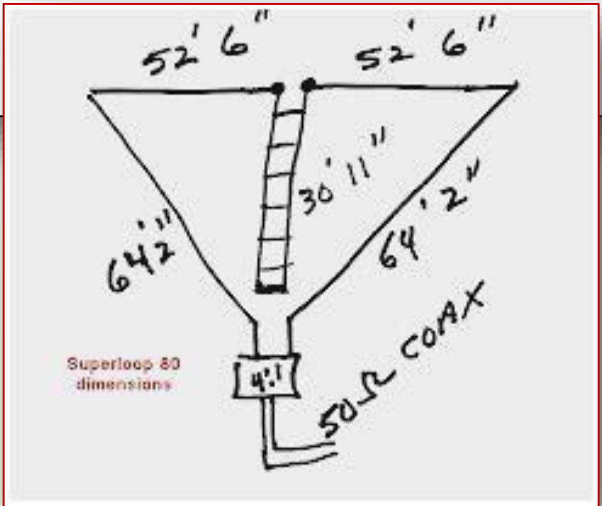
The Princess Royal expresses interest in a new portable field radio transmitting and receiving set that was demonstrated by the Royal Corps of Signals at Aldershot, England.

A PORTABLE field radio transmitting and receiving set that operates while strapped to a soldier's back was satisfactorily tested by the Royal Corps of Signals at Aldershot, England. The device features a special loop-type antenna, standard earphones and a hand microphone. The power supply unit is self-contained.

Alder-shot England, November 1937

Full Size Loops





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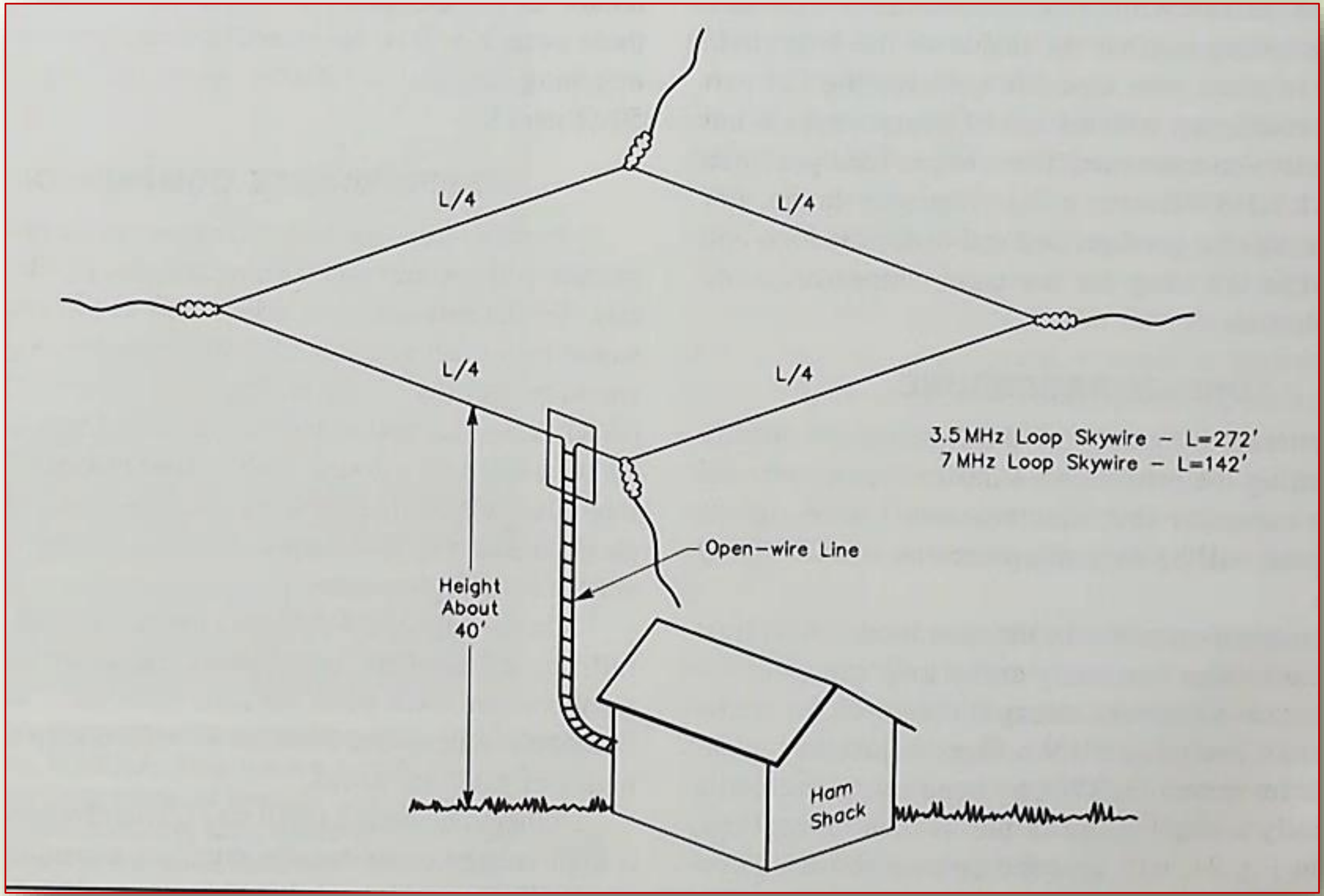
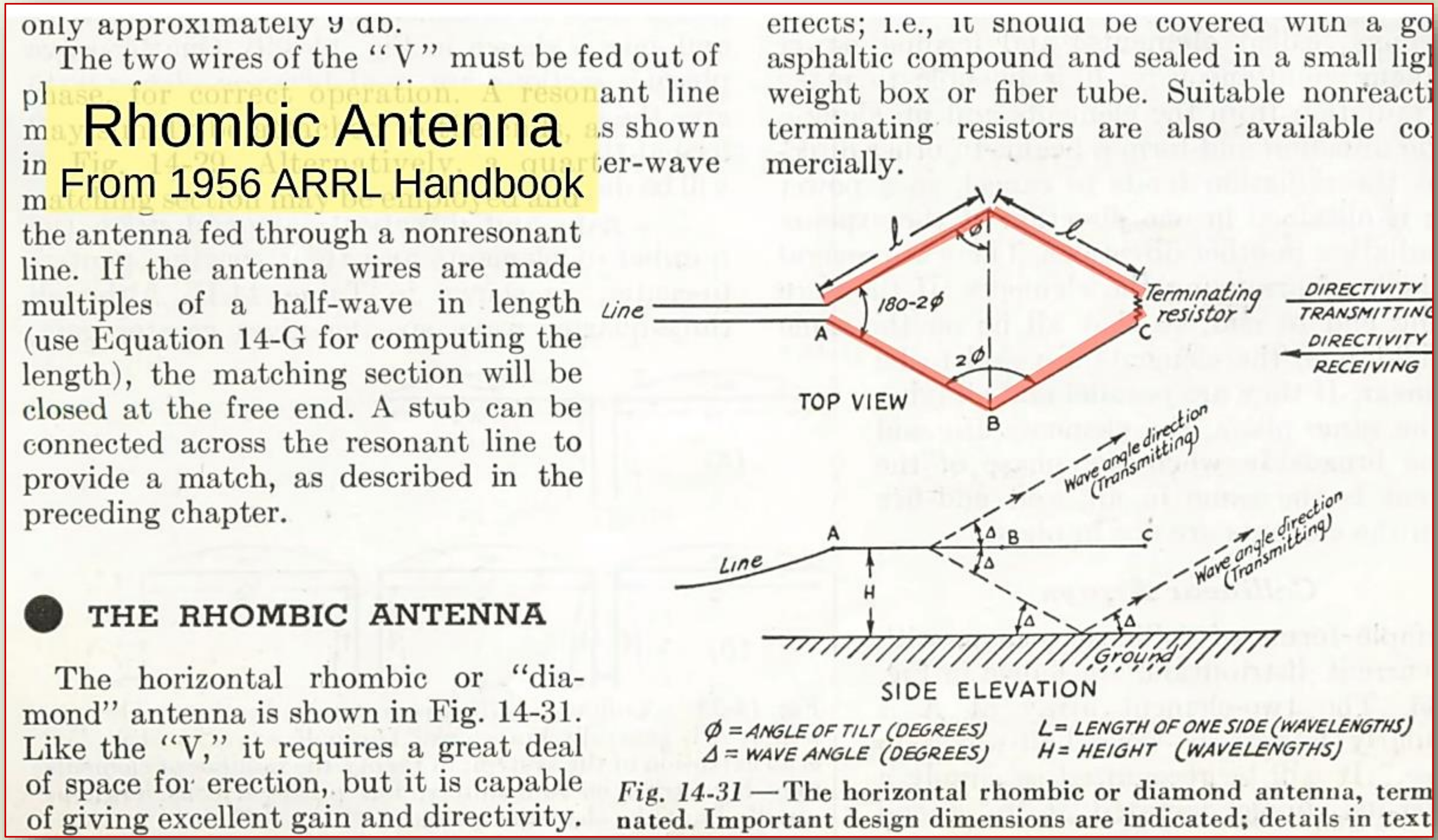


Nor the Mighty Rhombic Antenna



Rhombic Antenna
From 1956 ARRL Handbook

only approximately 9 db.

The two wires of the "V" must be fed out of phase for correct operation. A resonant line may ... as shown in Fig. 14-29. Alternatively, a quarter-wave matching section may be employed and the antenna fed through a nonresonant line. If the antenna wires are made multiples of a half-wave in length (use Equation 14-G for computing the length), the matching section will be closed at the free end. A stub can be connected across the resonant line to provide a match, as described in the preceding chapter.

THE RHOMBIC ANTENNA

The horizontal rhombic or "diamond" antenna is shown in Fig. 14-31. Like the "V," it requires a great deal of space for erection, but it is capable of giving excellent gain and directivity.

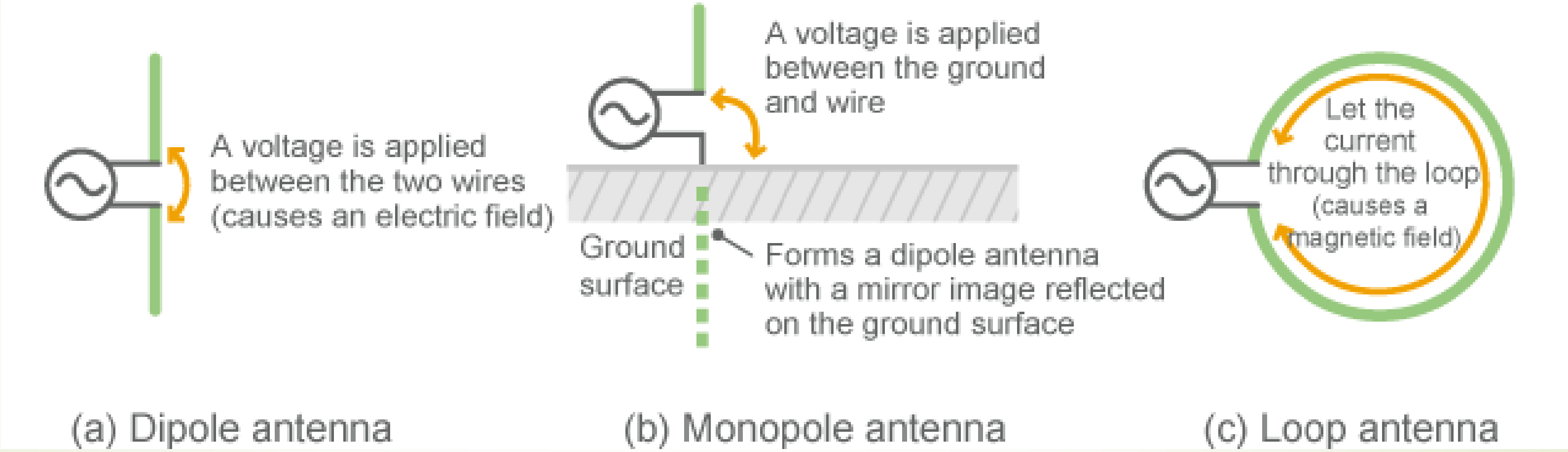
effects; i.e., it should be covered with a go asphaltic compound and sealed in a small ligh weight box or fiber tube. Suitable nonreacti terminating resistors are also available co mercially.

Fig. 14-31 —The horizontal rhombic or diamond antenna, term nated. Important design dimensions are indicated; details in text

Small Loop Antennas

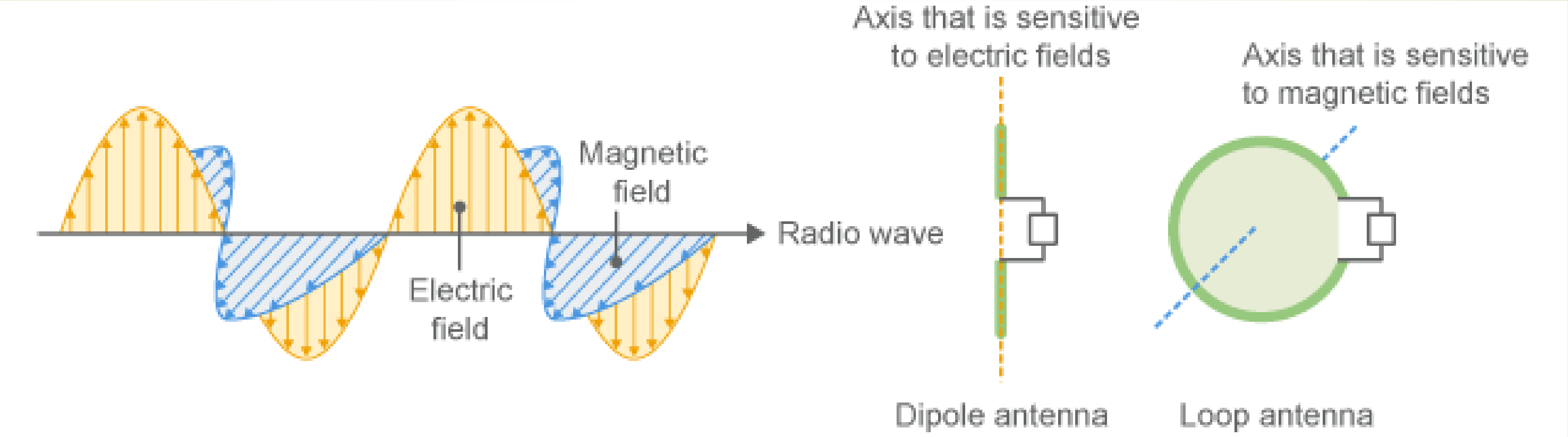
- Known as a "magnetic loop" due to the fact that they work with the magnetic near-fields of the antenna (more on that in a bit)
- Small  in comparison to the wavelength
  - Circumference less than λ/10
  - If multi-band, then the highest band drives size of the loop
- Smaller relative to wavelength means efficiency suffers

Electromagnetic Waves
(caused by either an alternating electric or magnetic field)



https://www.murata.com/en-eu/products/emc/emifil/knowhow/basic/chapter04-p2

Electromagnetic Waves
(emitted by either an alternating electric or an magnetic field)



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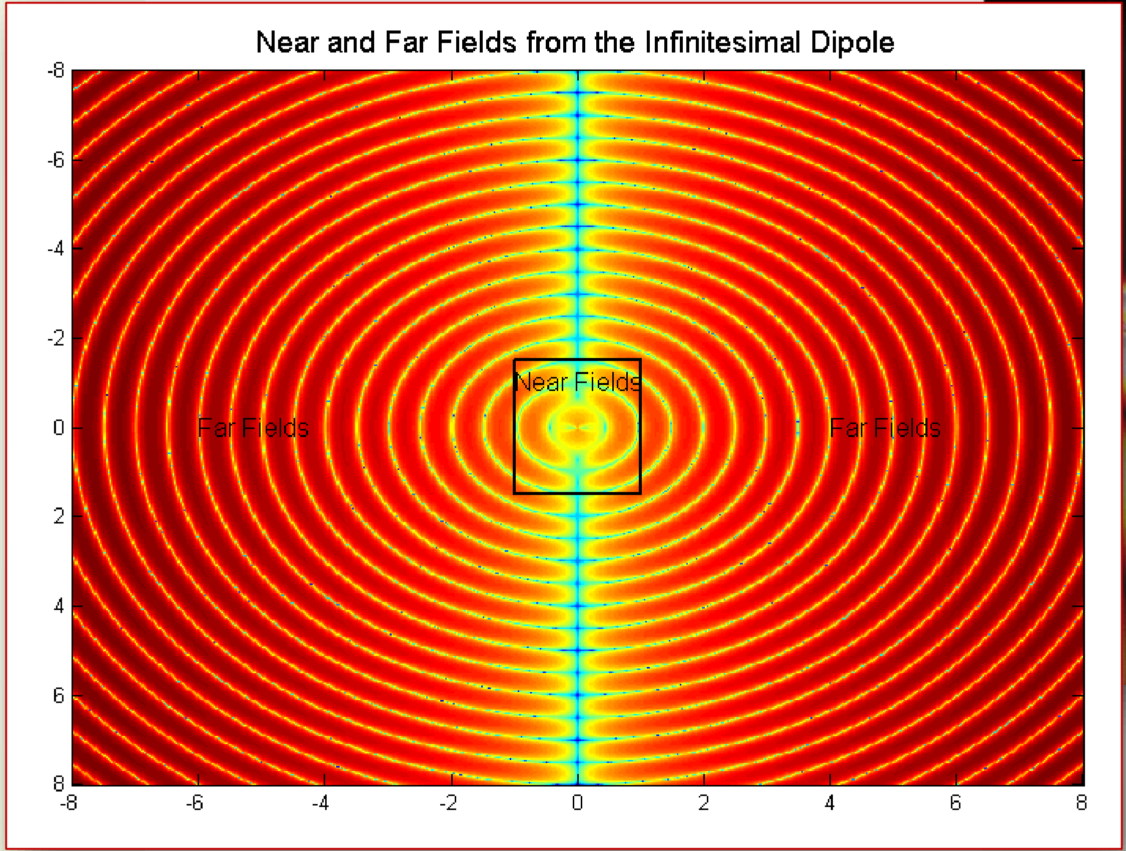
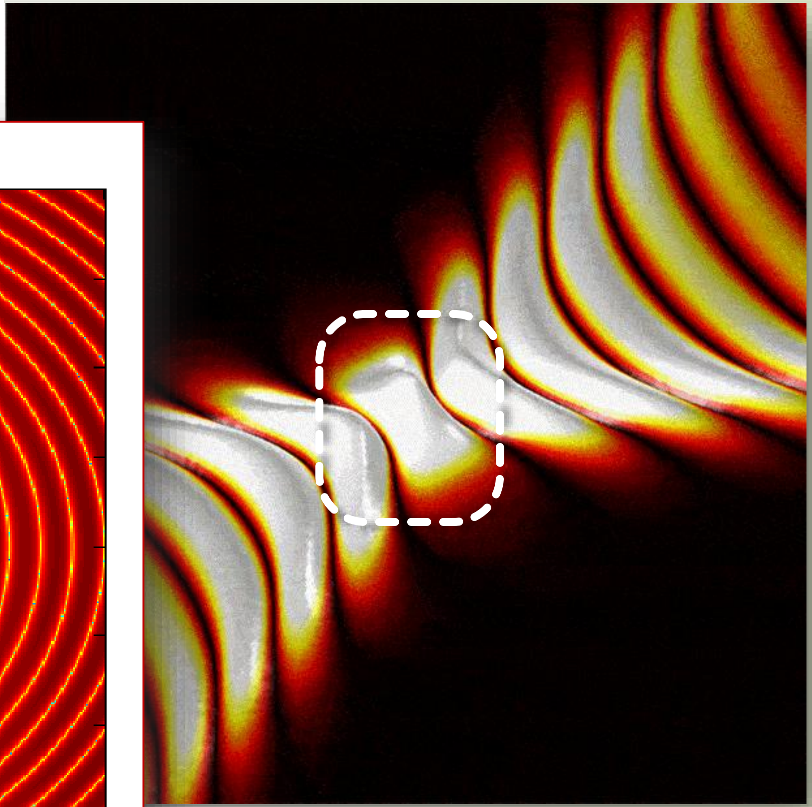
What the heck is “near-field”?





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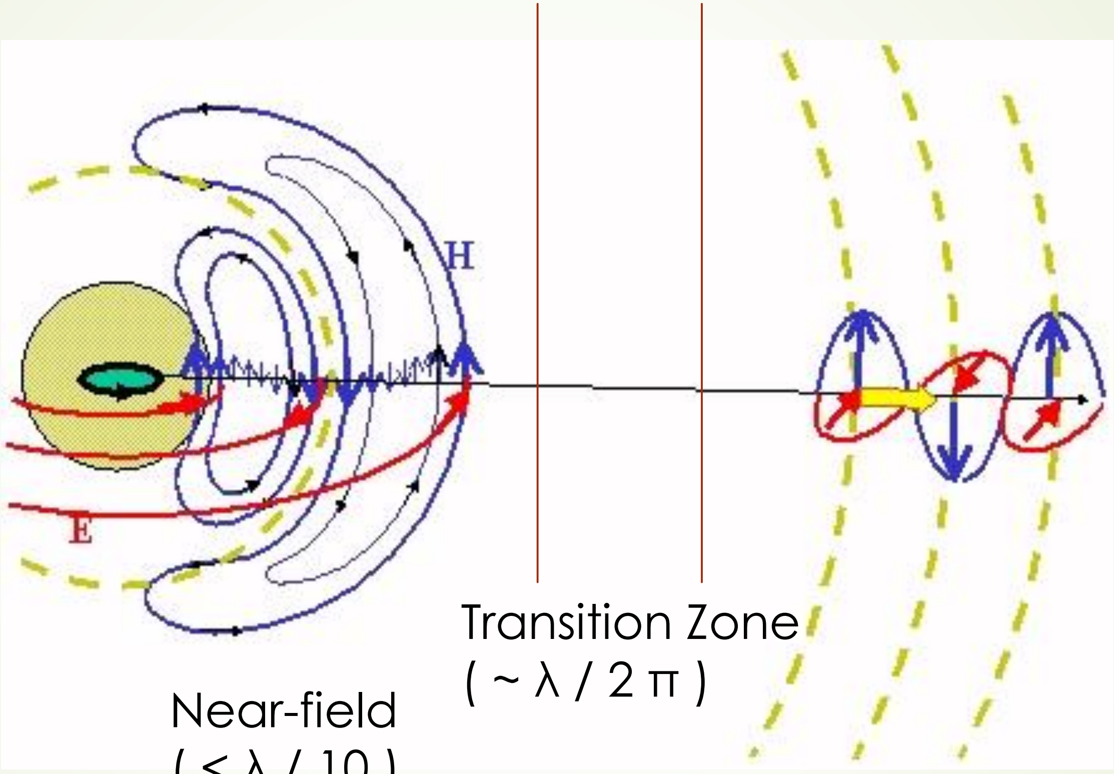

<u>The trick is that within the near-field:</u>
Electric (E-) field drops off with the <u>cubic</u> of the distance
Magnetic (H-) field drops off with the <u>square</u> of the distance
Therefore, within the near-field the magnetic field tends to dominate . . .

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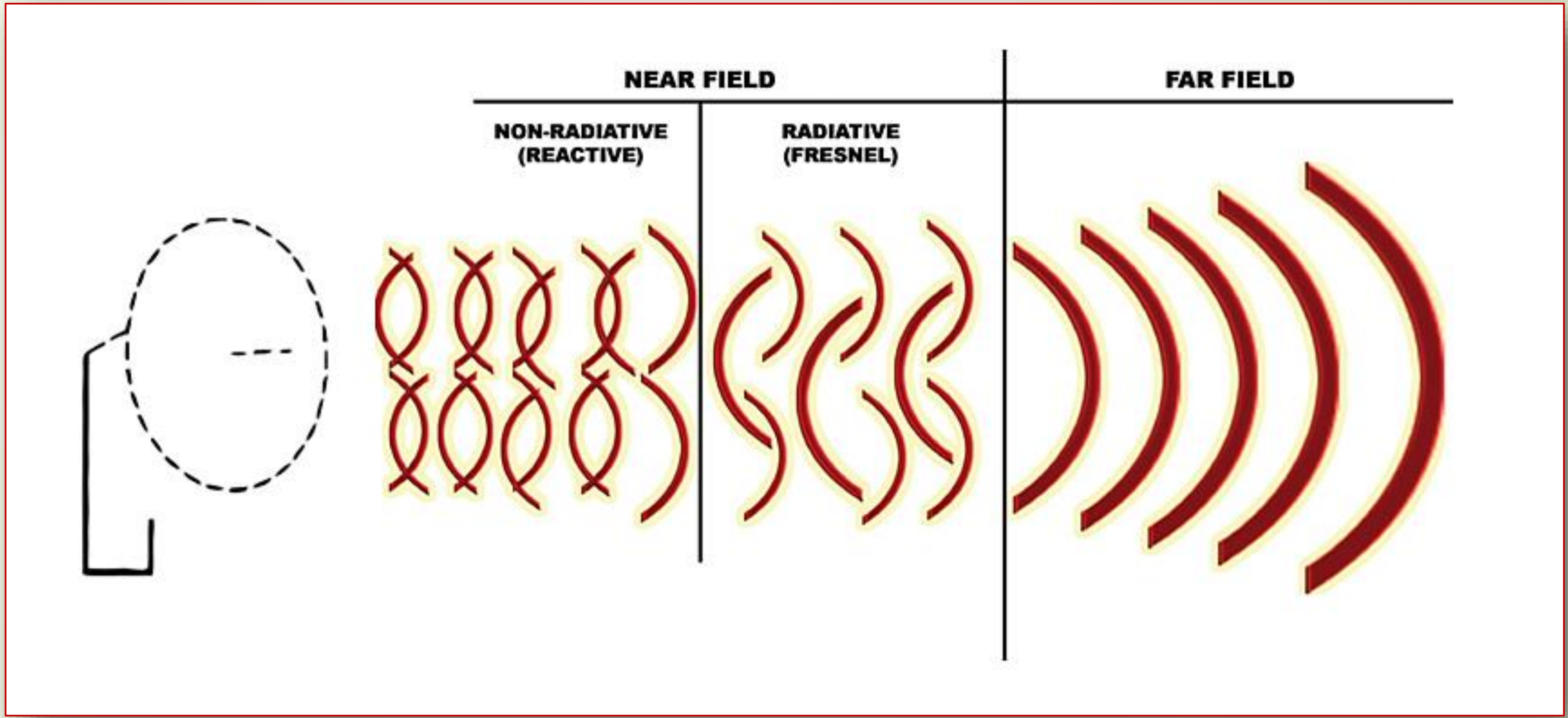
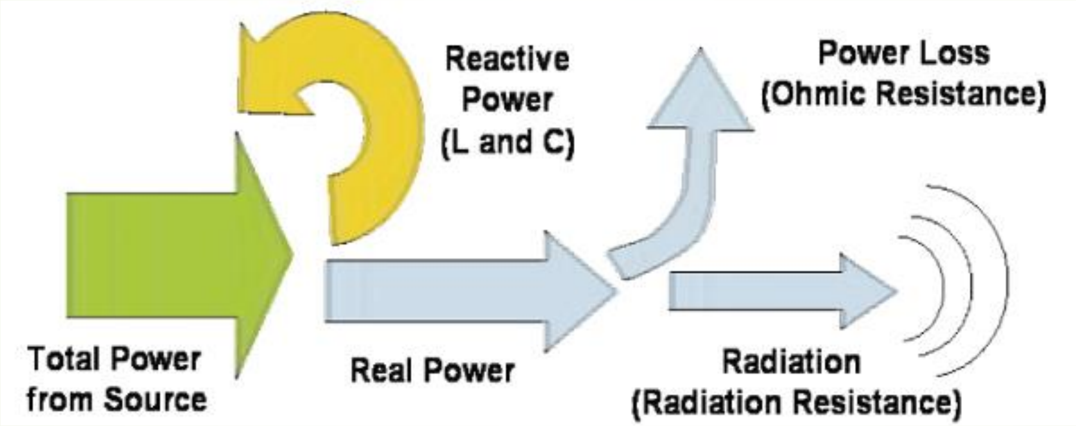


What the heck is "near-field"?

Near-field through the collapsing electric and magnetic fields

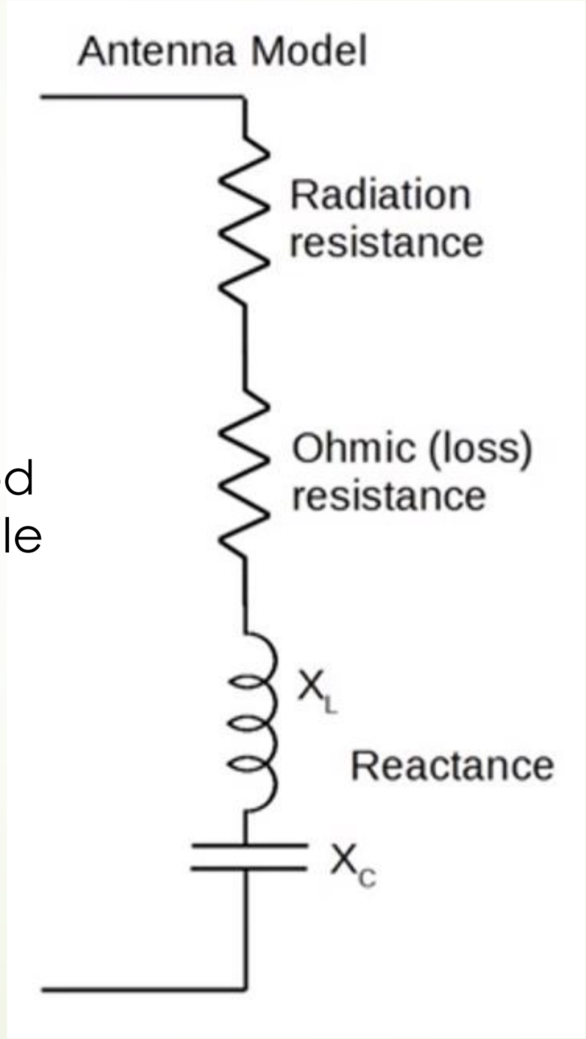


Far-field through heat loss and the propagating EM wave

General Antenna Model

$$\text{Efficiency} = \frac{R_{\text{Radiation}}}{R_{\text{Ohmic}} + R_{\text{Radiation}}}$$

(a well-tuned and engineered dipole has an efficiency in the high 90%; while a good base-loaded, bumper-mounted 8-ft mobile antenna on 80M might be 10-20%)

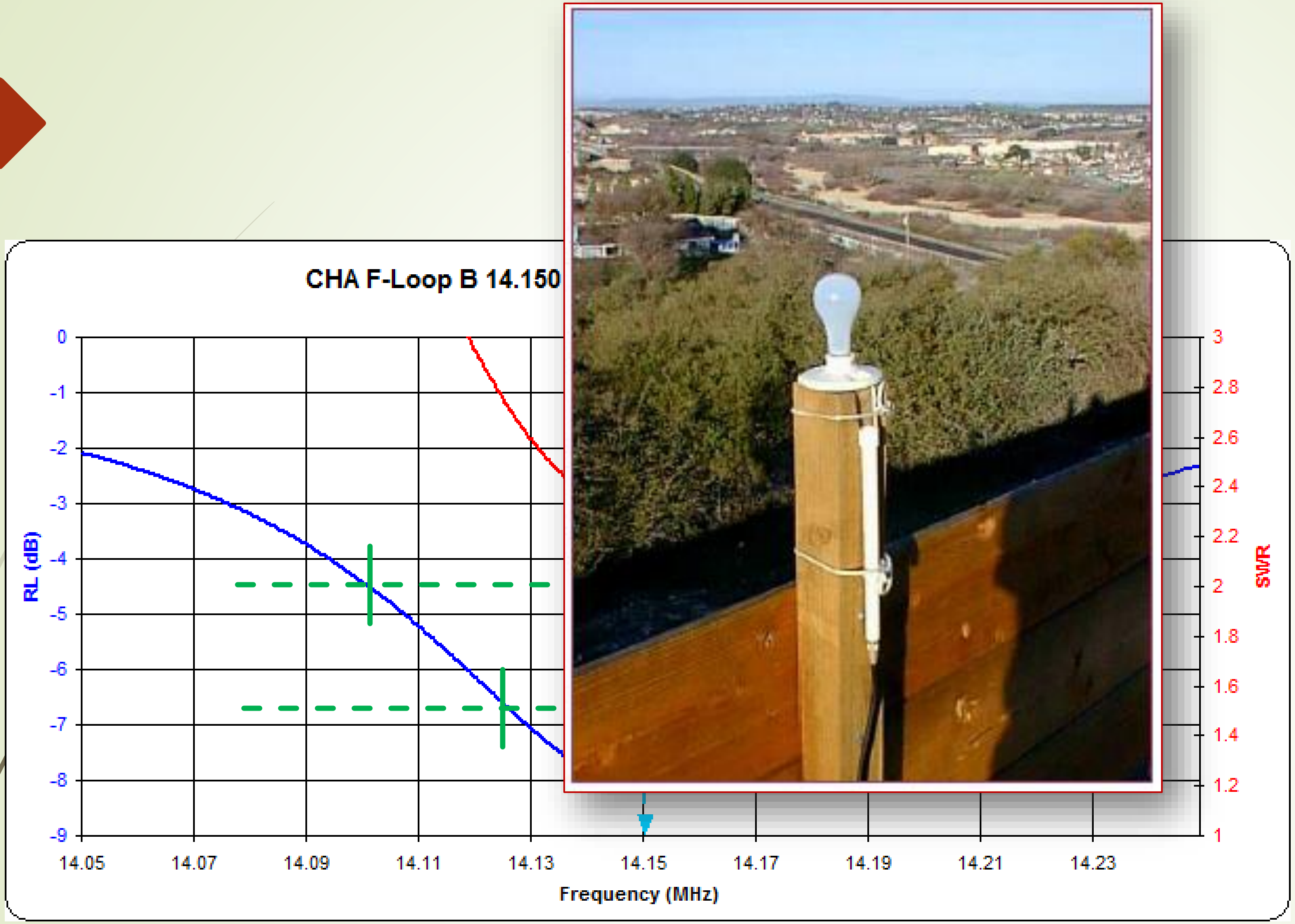


Trade Offs

- Pick two: small, efficient, or broadband
  - Small = < λ / 10
  - Broad bandwidth = low Q
  - Low Q implies more resistive losses
- Transmitting small loops
  - Small + Efficient

Where we are at . . .

- Receive-only small loops
  - Small + Broadband
- Full-wave loops
  - Efficient + Broadband



SWR: 2:1
14.200 – 14.100
(or about 100 kHz)
20M full band is:
14.000 to 14.350 MHz

SWR: 1.5:1
14.175 – 14.125
(or about 50 kHz)

The test antenna was the Chameleon CHA F-Loop, at 0.74 m (2.44 feet) diameter
https://www.qsl.net/kp4md/chafloop.htm

Parts

- Resonant Loop
  - Coax (uses shield and center typically connected together
  - Metal tubes (larger diameter improves efficiency)
  - Minimizes resistive losses (radiation resistance is small, but large compared to lose resistance)
  - Circle is more area possible for given perimeter (but can be other shapes, e.g. octagon is common to ease formation of the metal tube)
- Coupling Method
  - Required as the impedance of the resonant loop is typically 2 to 10 ohms
    - Max impendence, max current, lowest voltage at coupling point
    - Lowest impedance, lowest current, max voltage is 180° away at the other side of the loop
  - Techniques: coupling loop (what we will show today), gamma match capacitive, ferrite

Parts (cont.)

- Tuning capacitor
  - Air variable, trombone, vacuum variable
  - Voltage breakdown point is a big selection factor (arc across and resulting pitting) ← this is typically what drives the power limitations
  - Better implementations have reduction gearing to help with fine tuning
- Coupling point and the capacitor placed on opposite sides of the resonant loop

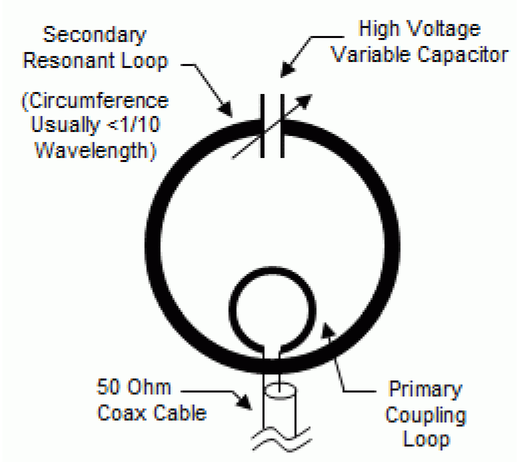
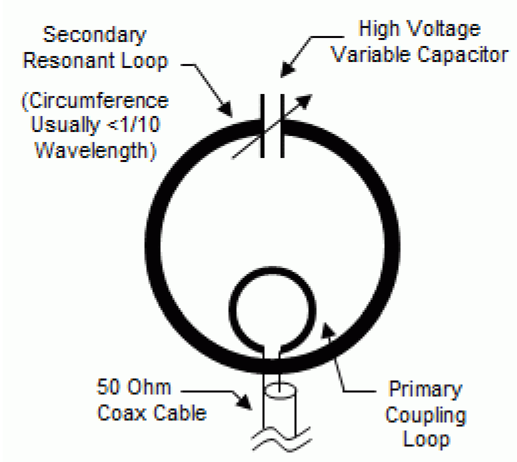


Diagram of a Small Loop Antenna

To get as strong coupling as possible, you typically bend the loops together

http://aa5tb.com/loop.html



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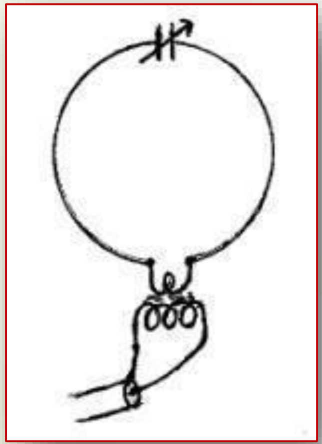

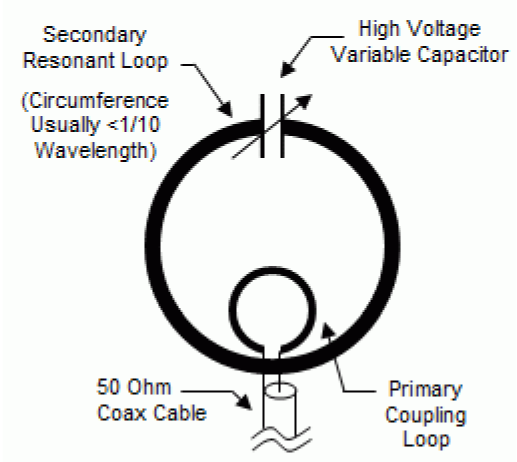

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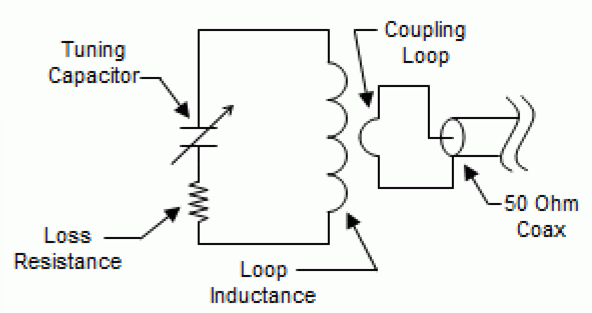
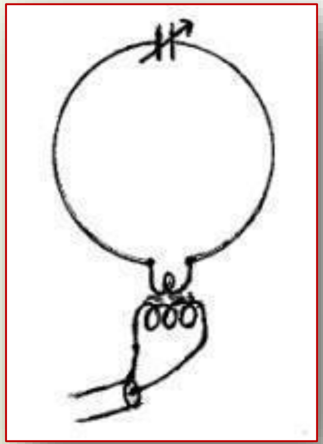
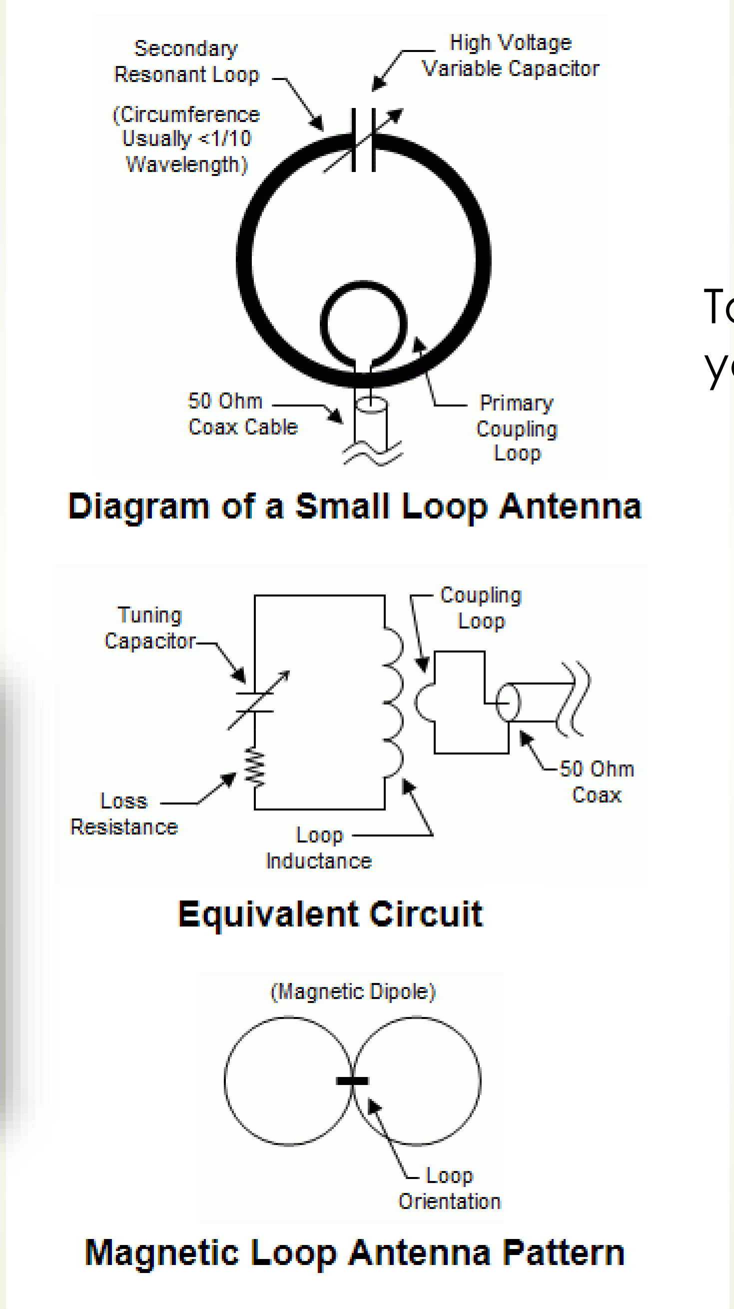


Equivalent Circuit

http://aa5tb.com/loop.html





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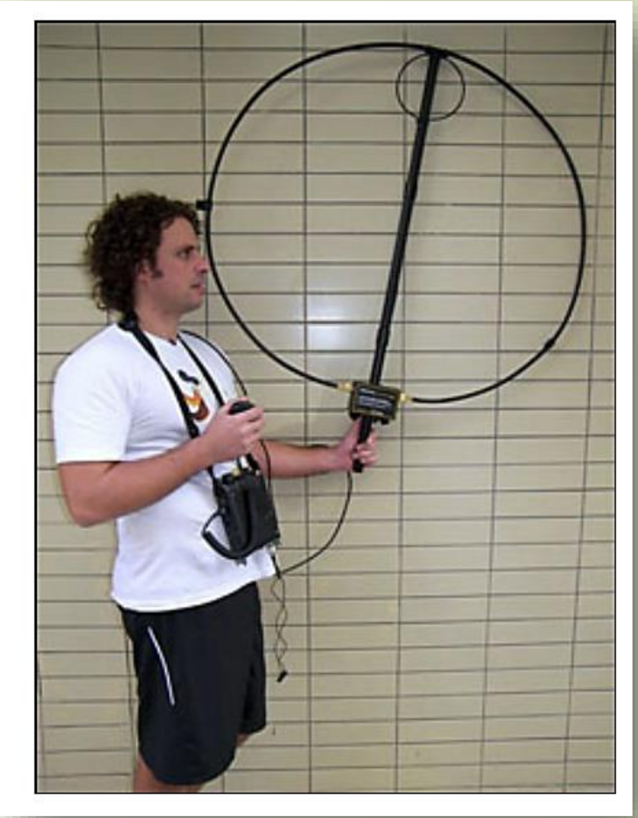
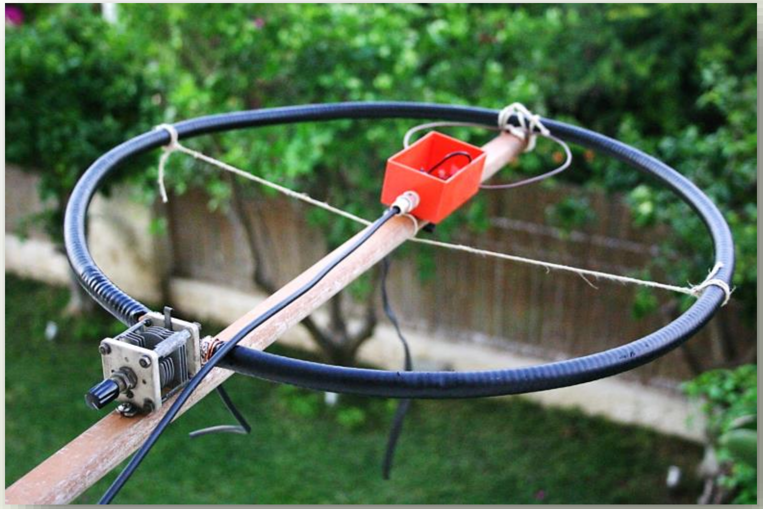
http://aa5tb.com/loop.html

Polarization

- Vertical (stand it up) – most common; does not need a ground plane; should be at least one diameter of the loop from the physical ground
- Horizonal (lay down) – can be done, but requires same above ground guidelines as a dipole, i.e. above ¼ λ





Samples

- Thick piping (good efficiency)
- Gamma match at bottom for coupling
- Mechanical tuning capacitor at top
- Mount it on a mast
- Warning: Nulls come off the broadside of the antenna, so either be careful where it is positioned, or have a rotator to spin it to null out signals

Samples

- Double loop to give more electrical circumstance (better efficiency and lower frequencies, e.g. 40M, or 80M)
- Coupling loop hidden inside casing
- Horizonal polarization and omnidirectional
- Must be mounted high (> λ / 4)

Lots of turns possible!

Samples

- Mechanical adjustment of capacitor (top)
- High quality copper for good efficiency
- Remote tuning to capacitor mounted on back of mount

Pros and Cons

- Fast setup – no trees, tall masts, or radials needed
- Needs to be reachable for tuning, rotation (or use remote controlled motors)
- Low height OK
  - 1-2+ diameter above ground for vertical orientation
  - Horizontal orientation needs same height as dipole (> $\lambda/4$)
- Magnetic near-field means humans don't mess with tuning as much
  - But works better away from large metal objects
  - Do not position the tuning knob so you have to reach into the loop to tune
(at least one commercial vendor does this)

Tuning

- Do not blindly use antenna tuners – need to move the resonance point
- Listen to the noise floor, look at the S-meter, tune for maximum noise
- Using a pan adapters lets you tune visually – put the noise peak in the middle as the "wave" comes into your freq range
- Some vendors are starting to make products to assist, e.g. Alex Tune
- Follow-up with fine adjustments to SWR in radio tune mode
  - This is where having reduction gears on the capacitor helps a bunch, e.g. the P-Loop has a 6:1 gear reduction within its box

Summary: Why use a small mag loop?

- Excellent portability and efficiency
- It is a good DX antenna
  - Nulls are very sharp – broadside off the mag loop
  - In-line with the loop you get maximum propagation, and a good takeoff angle
- Use the high-Q (and the nulls) to:
  - Eliminate local QRM
  - Eliminate adjacent strong stations (particularly with SSB)
- Difficult to tune – not a good fit for "Search and Pounce"
- Great for fixed frequency uses, e.g. "Running", SOTA, and for many digital modes, e.g. FT8, JBCALL, etc.

Commercial Offerings

- Alex loop – focus on portability $400
  http://www.alexloop.com/ also at:
  https://www.gigaparts.com/ph1ahd-alexloop-walkham.html
- Precise RF Loop – remote tuning and operation + portability $300-$450
  http://preciserf.com/
- Chameleon Antenna's P-Loop (portable, coax) and F-Loop (semi-portable)
  https://www.dxengineering.com/parts/cha-floop-plus20
  $400-$500 depending on options
- Ciro Mazzoni Automatic Magnetic Loop Antennas
  https://www.dxengineering.com/parts/mzz-baby ($2K and up ☺)
- MFJ 1788 (fixed location) (see Dave Casler's review and fixes) -- $500
  http://www.mfjenterprises.com/Product.php?productid=MFJ-1788
  they also offer a $250 receive-only mag loop as well

References

- Presentation by Bob Fleck, W4RAX
  https://www.youtube.com/watch?v=yYbKrw8l6JU
  (used as the basis for this presentation)
- Several interesting presentations by Dave Casler, KEØOG
  https://www.youtube.com/watch?v=Klg-_vQYbfw
  https://www.youtube.com/watch?v=CgKzvyeM8lw
  https://www.youtube.com/watch?v=pZkKfHvyOjo
- Tuning a homebrew mag loop using a toroidal match
  https://www.youtube.com/watch?v=CpgwXNwCmm4
- Interesting visualizations of voltage and current flow in a mag loop
  https://www.youtube.com/watch?v=SUYl81dkEMA

Additional backup slides

Feeding your small mag loop

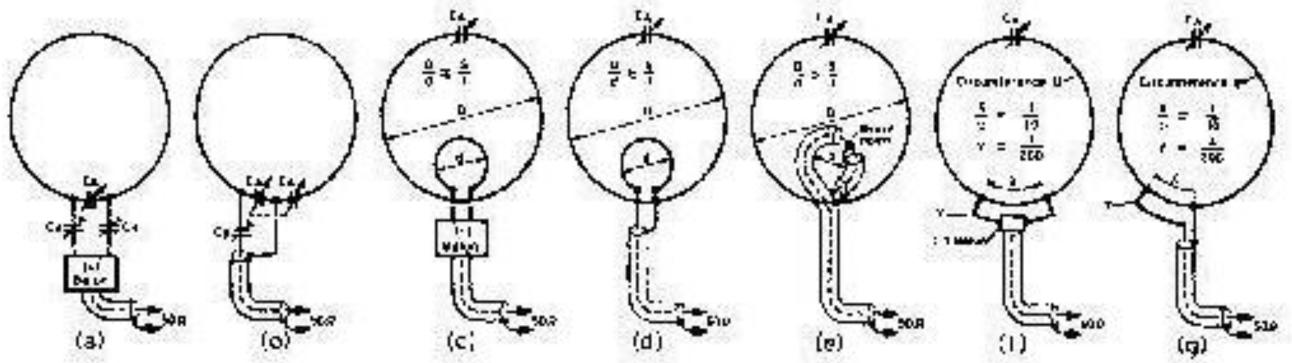
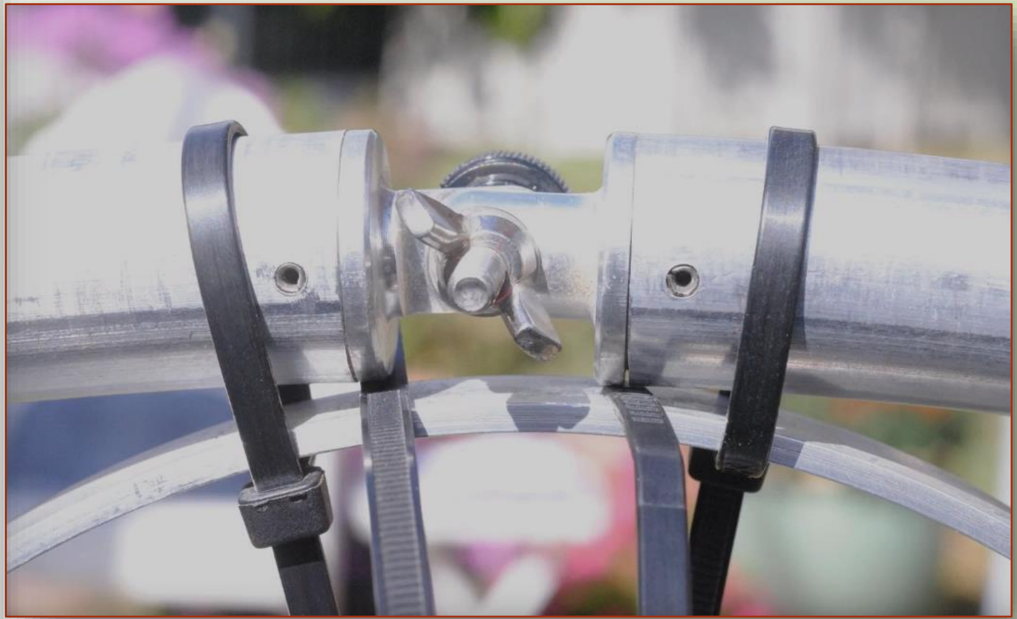


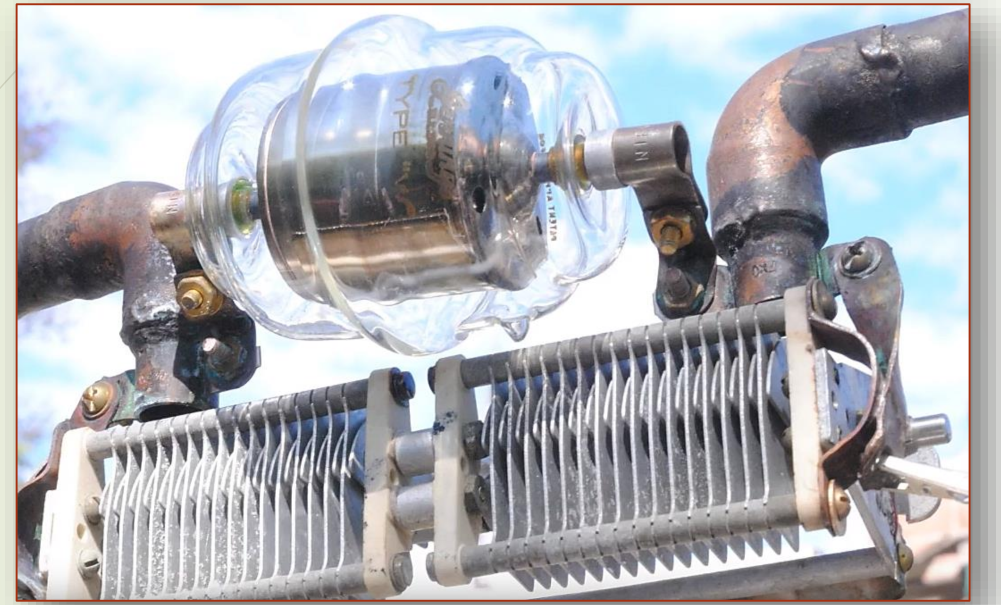
Fig 3. Matching a loop transmitting or receiving antenna to 50Ω cable as described in 1983 by DL2FA. The Faraday-loop coupling coil made from coaxial cable in (e) is considered optimum. (g) is the arrangement used by W5QJR

706 RADIO COMMUNICATION October 1985





Add-on fixed capacitor physically snap'ed in for 40M coverage in parallel with the variable one



Coupling Loop at the bottom