LOOKING AT LOOPS.

A Visual Survey of Loop Antennas.

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INTRODUCTION.

This Presentation is intended to be a Visual Demonstration of some Basic Properties of Loop Antennas.
A Loop Antenna has an enclosed area. It has a closed-circuit path with two adjecent ends for connecting.

I will not cover the various Traveling Wave Antennas, Flags, Pennants, Ferrite Rods, and Aperiodic Arrays that are often used to improve reception in the noisy Spectrum below 10-MHZ. Some of these depend upon conductive ground for their operation. These Antennas deserve an entire text-book.

The Demonstration uses a few Watts of transmitted power at 432-MHz, which is received on various nearby Antennas. Small Lamps serve as Detectors to indicate relative signal-strength.

Why 432-MHz ? This Ultra-High Frequency (UHF) has a Wave-Length of 0.694 meters, or 69.4 centimeters, which is about 27.4 inches. Many Antennas for this Wave-Length can be easily transported, and set up within a room. Try doing that for Wave-Lengths of several tens of meters! Miniature Antennas can be cheaply made from house-wire and sticks of wood. Going to a much higher Frequency (shorter Wave-Length) results in critical tolerances and measurement uncertainties.

SOME ADVICE.

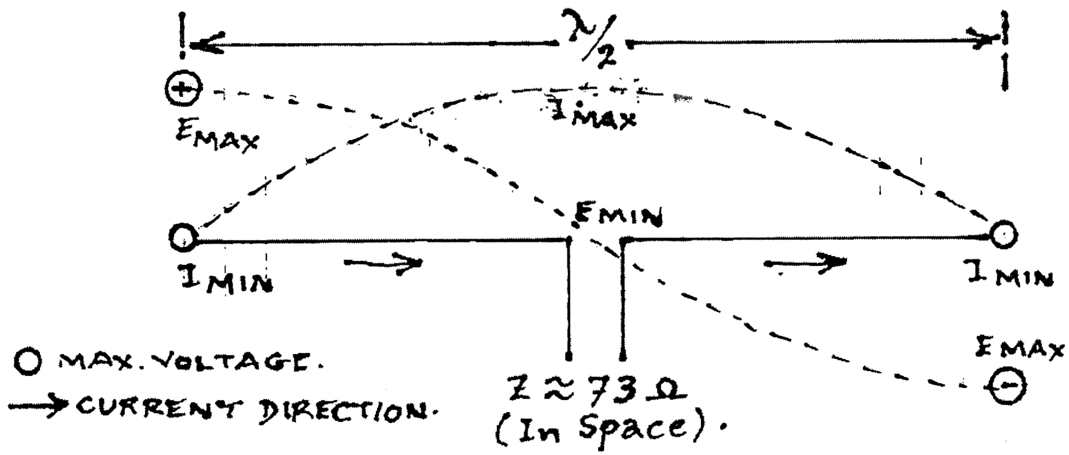
A key to understanding Antennas is to think in terms of Wave-Length. Try to imagine one of my 432-MHZ models as a bigger version for your favorite "1Ø-Meter" Frequency, let's say 28.4 MHZ. My Wave-Length (λ) is 3ØØ / f(MHZ) = 3ØØ/432 = Ø.694 meters. Your Wave-Length (λ) is 3ØØ / f(MHZ) = 3ØØ/28.4 = 1Ø.56 meters. Your dream Antenna will be bigger (in all Dimensions) by a Factor of 1Ø.56/Ø.694, or 15.2. I can hold my little Antenna 5ft. off the ground, and you will have to raise yours 76-ft. high to get the same results. Can you imagine building an Antenna for our new Low-Frequency of 136-KHZ (Ø.136 MHZ), where λ = 22ØØ meters? That's over a mile! At the other extreme, some of our Microwave Bands have Wave-Lengths in the millimeter range. You would need a microscope and a lot of dexterity to scale one of my Antennas for this.

LARGE vs. SMALL LOOPS.

I will define a LARGE LOOP as one having a Perimeter greater than ½λ, and a SMALL LOOP as one having a Perimeter less than ½λ. The two Categories behave very differently, as you will see.
A LARGE LOOP for 1296-MHZ may appear to be ridiculously tiny, while even a SMALL LOOP for 136-KHZ may be too big for many of us to install on an average house lot.

HALF-WAVE LOOPS.

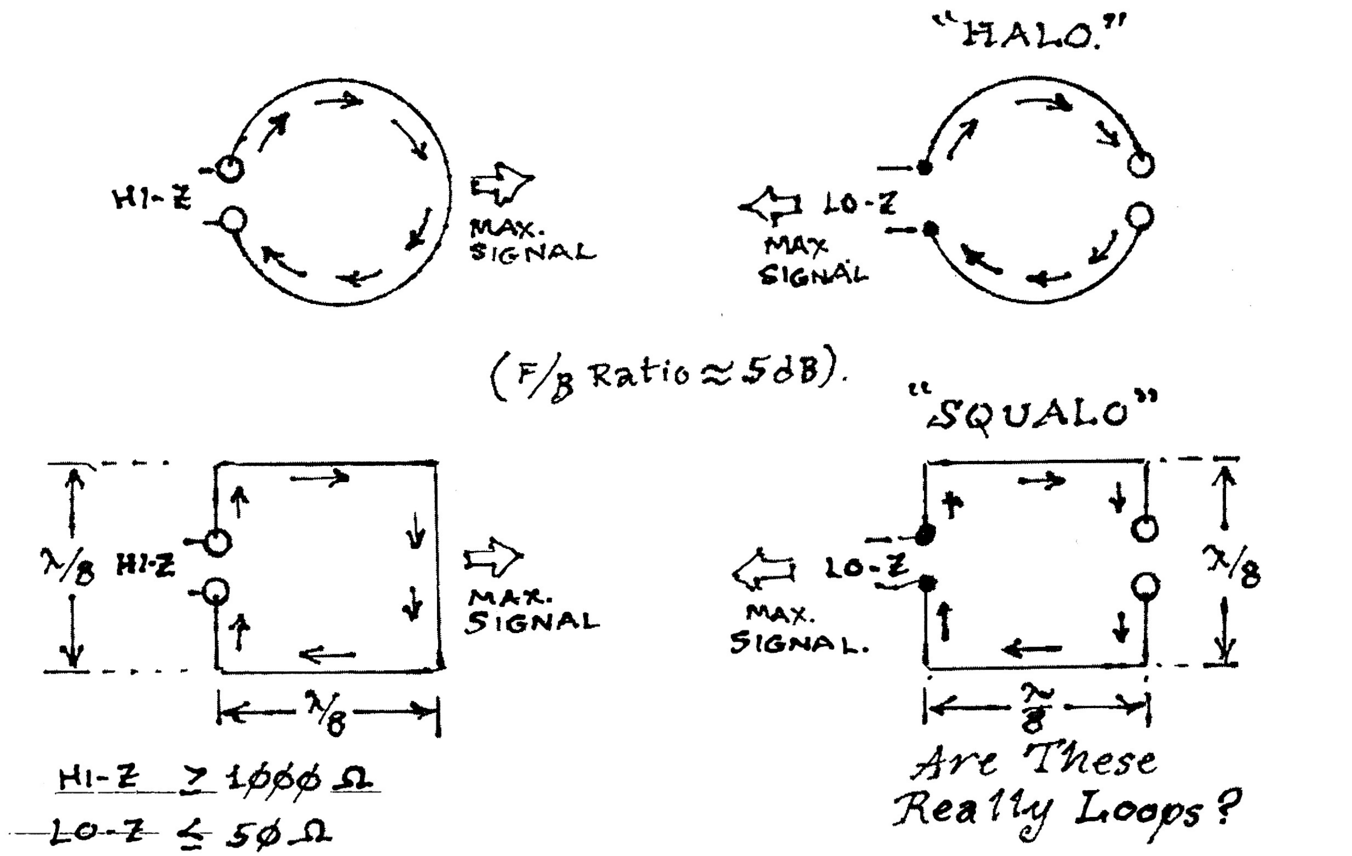
Consider the Voltage and Current along a Resonant ½-Wave-Length Dipole.



Bend the Straight Dipole into a Loop, so that the Ends nearly Touch each other. Consider the Radiation Pattern. Hint: Maximum Radiation occurs Perpendicular to Maximum Current Direction.

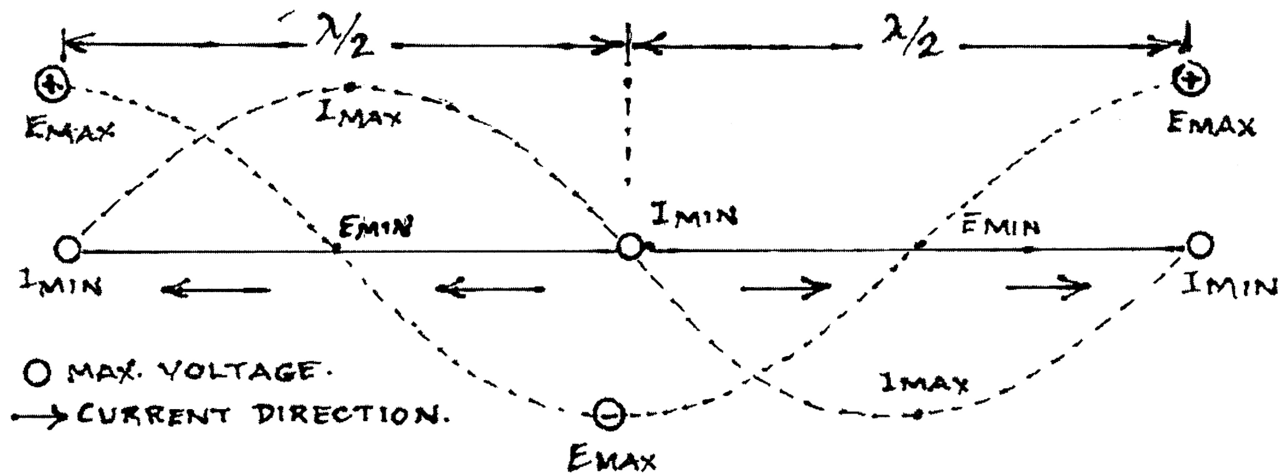
HALF-WAVE LOOPS.

○ MAX. VOLTAGE.
→ CURRENT DIRECTION.



FULL-WAVE LOOPS.

Consider the Voltage and Current along a Resonant 1-Wave-Length Wire.

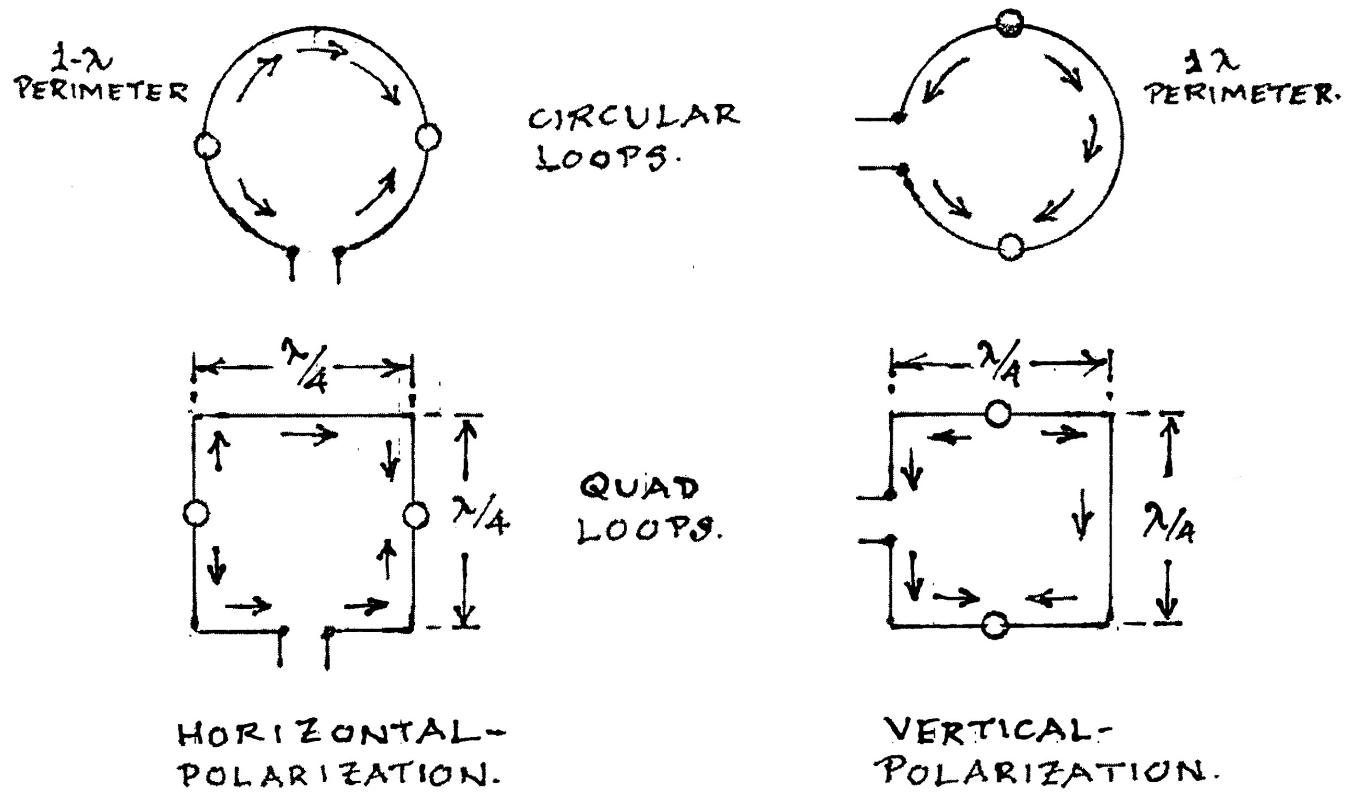


Bend the Straight Wire into a Loop, so that the Ends nearly Touch each other. Consider the Radiation Pattern. Note the Current Reversal at the Mid-Point, ½-λ from each End.

FULL-WAVE LOOPS.

Feed-Point Impedance ≈ 120-Ω.

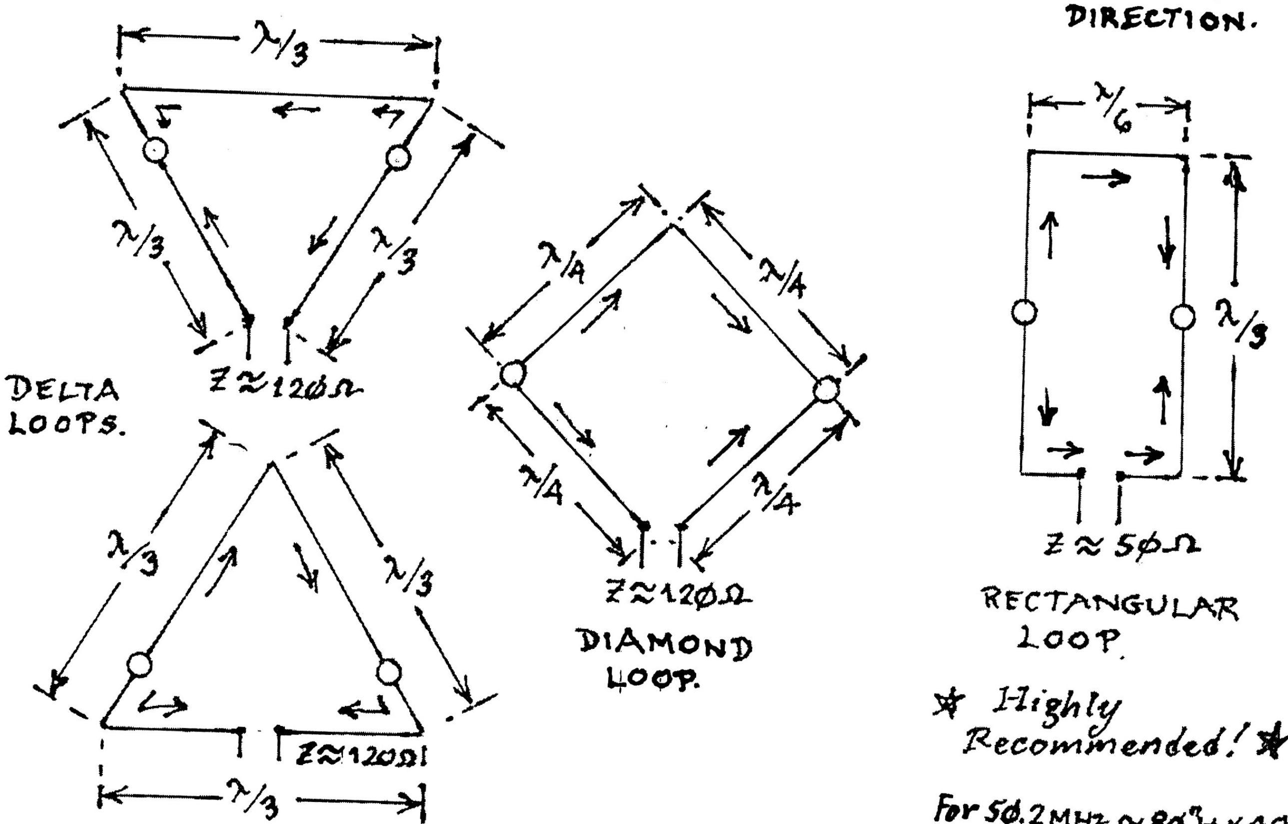
O MAX. VOLTAGE.
→ CURRENT DIRECTION.



Maximum Radiation Perpendicular to Plane of Loops.

MORE FULL-WAVE LOOPS.

O MAX. VOLTAGE.
→ CURRENT DIRECTION.



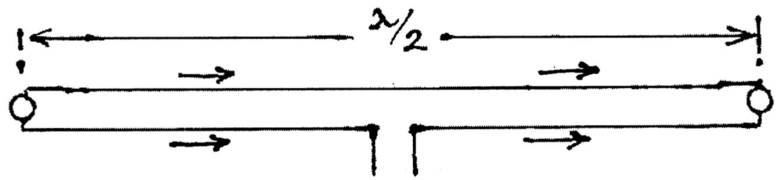
☆ *Highly Recommended!* ☆

For 50.2 MHz ~ 80" H. x 40" W.
For 432 MHz ~ 9.2" H x 4.6" W

Maximum Radiation Perpendicular to Plane of Loops.

FULL-WAVE LOOPS.

These Limits are Reached when the Shape of a 1·λ Loop is adjusted for an Area approaching Zero:

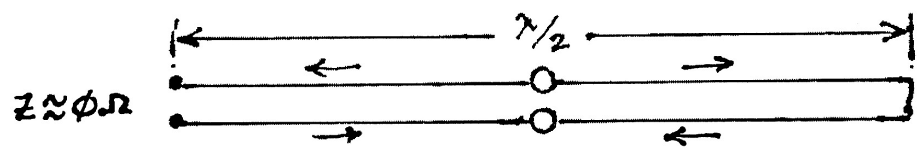


Z ≈ 288 Ω

FOLDED DIPOLE.

○ MAX. VOLTAGE

→ CURRENT DIRECTION.

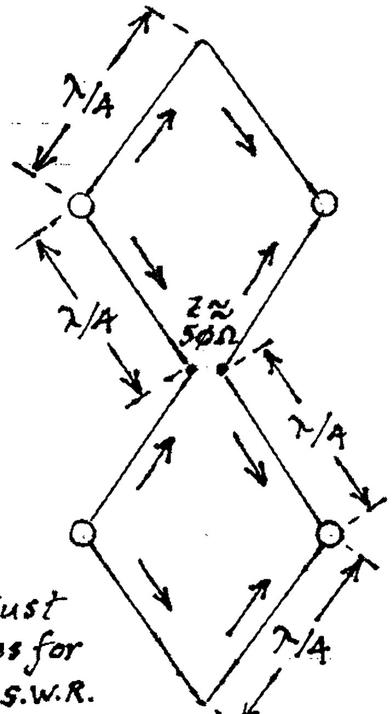


SHORTED TRANSMISSION LINE.

This does not Radiate!

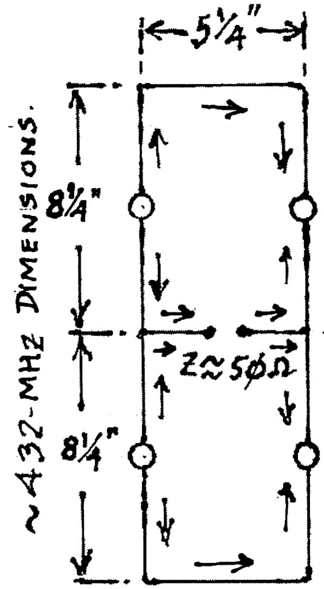
COMBINATION FULL-WAVE LOOPS.

O MAX. VOLTAGE.
→ CURRENT DIRECTION.



Adjust Angles for Best S.W.R.

DOUBLE-DIAMOND.



DOUBLE-QUAD.

The shared Middle-Branch has Twice the Current of the Top or Bottom.

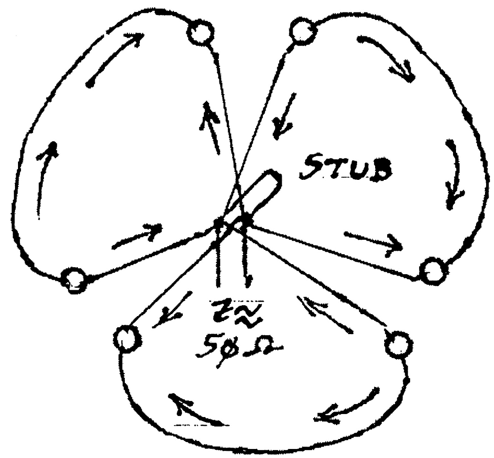
The QUAGI (N6NB) combines Loop Reflector and Driven Elements with Linear Yagi Directors. It is easy to Build for 144, 222, 432, 9Ø2, or 1296 MHz.

The LOOP YAGI (G3JVL) uses flat Circular Loop Elements as Parasitic Directors and Reflectors. It is Popular for 9Ø2, 23Ø4, 1296, and 34ØØ MHz.

COMBINATION

FULL-WAVE LOOPS.
THE "BIG WHEEL"
(W1FVY & W1IJD).

O MAX. VOLTAGE.
⟶ CURRENT DIRECTION.



- ★ Omni-Directional.
- ★ Maximum Gain in Plane of Loops.
- ★ Broad Band-Width.
- ★ Requires Inductive Stub and Shortening of Loops for 50-Ω Match.
- ★ Three 1-λ Loops in Parallel.

MEASURED VALUES:

432-MHZ S.W.R. = 1.02
(R = 50 Ω; X = 0 Ω)

2.0 S.W.R. @ 423 & 442 MHZ.
(B.W. = 19 MHZ).

1.5 S.W.R. @ 427 & 438 MHZ.
(B.W. = 11 MHZ.

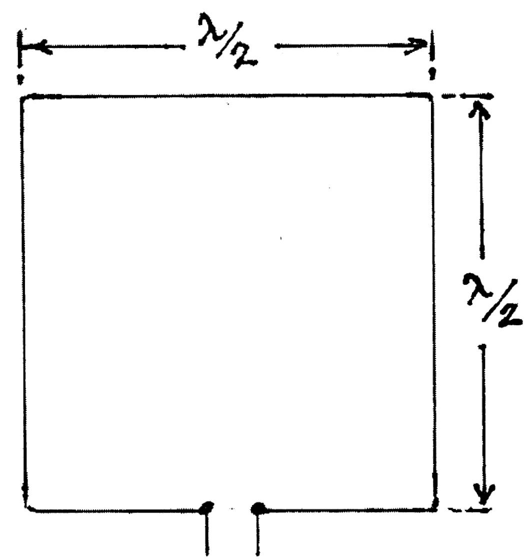
432-MHZ MODEL:

- ★ Each Loop 26" Total Length #12 Romex Insulated Solid-Copper Wire, with ½" Insulation Removed from Each End.
- ★ Soldered Wires 120° Apart to 2 Printed-Circuit Board Triangles (1/16" Thick, 2½" per side). BNC Jack on 1 Triangle.
- ★ 3 Stubs each 1½" #12 Bare Copper wire, Soldered 120° Apart to Triangles.

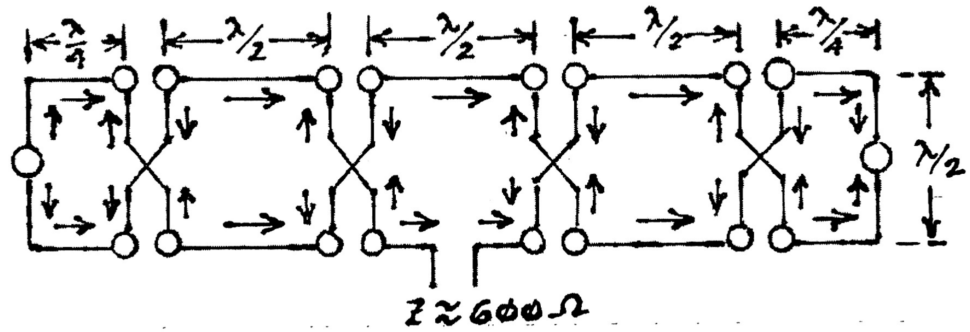
3/8" C-C
7/8"

A TWO-WAVE LOOP

Can You Predict the Behavior of this Antenna?



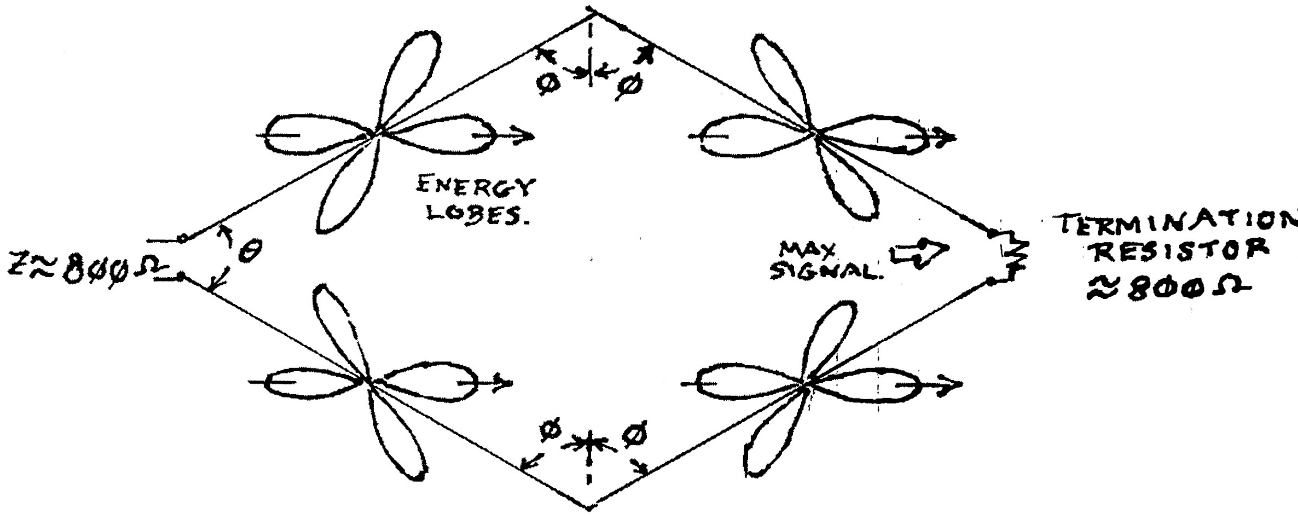
ANOTHER LARGE LOOP ARRAY.
THE STERBA CURTAIN.



This is an 8-Element Example (The two ¼ λ Ends are considered to be 1 Element).
More Elements may be added to Expand the Array both Horizontally and Vertically.
Horizontal Polarization is shown here.
Maximum Radiation is Perpendicular to the Plane of the Array.

A REALLY LARGE LOOP.

THE TERMINATED RHOMBIC.



Four Equal Sides are Each > 1λ (>2λ Preferred).
Select Angles θ and ϕ so that Major Lobes from Each Leg Re-Inforce Each Other.
Eliminating the Non-Inductive Termination Resistor makes the Rhombic Bi-Directional. Also, it will no Longer be a Loop!

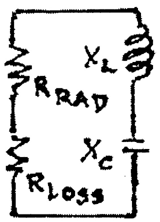
SMALL LOOPS.

These have been around for over a century, but are especially popular now because of the desire for physically small portable Antennas for Frequencies below 3Ø-MHz, where Wave-Lengths are greater than 1Ø meters. A Small Loop has a Perimeter of less than $\lambda/2$. If the Perimeter is much less than this, perhaps Ø.1λ or so (some texts say Ø.Ø8λ), then the Current in the Conductor will be nearly constant in Amplitude and Phase. The Loop Inductance must be resonated (tuned) with a series Capacitor. At the Resonant Frequency f_{RES}, $X_L = X_C$. Since $X_L = 2\pi f L$ and $X_C = \frac{1}{2\pi f C}$; combining these two Equations and solving for f yields $f_{RES} = \frac{1}{2\pi\sqrt{LC}}$. For a given physical size Loop (constant Inductance), halving the Resonant Frequency f_R requires quadrupling the Capacitor value in pF or nF. Most of today's popular Transmitting Loops have one-turn Inductors, but for Low Frequencies (below a few MHz), and for Receiving applications, they may have multiple turns.

Constant Current around the Perimeter results in maximum Radiation (and Reception) in the Plane of the Loop, and a deep Null perpendicular to this Plane. This is the Opposite of the Full-Wave Loops shown Earlier! The Null may be used for rejecting unwanted Signals, or for Direction Finding.

SMALL LOOPS CONTINUED.

Does all this come at a Price? Of Course! Otherwise, we would all be using Small Loops. The Radiation Resistance R_{RAD} is very Low for such a Loop. This is the Effective Load in which the Radiated Energy is dissipated (It can't be measured directly).



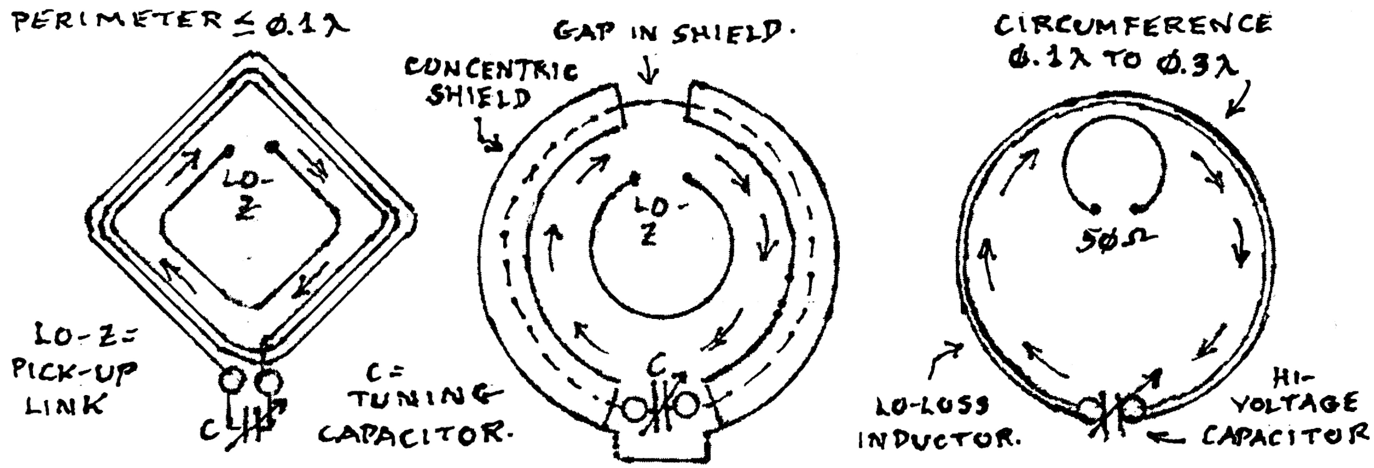
Suppose I have a 0.1λ Perimeter Circular Loop for 10 MHz, where $\lambda = 30$ m. Diameter is $3\text{m}/\pi$, or 0.955m, and Area is πr^2, or $0.716\ \text{m}^2$. $R_{RAD} = 320\pi^4 A^2/\lambda^2$, which simplifies to $R_{RAD} = 3.12 \times 10^4 A^2/\lambda^4$, where A is in square meters, λ is in meters. $R_{RAD} = 0.01974\,\Omega = 19.7$ milliohms! The Loss Resistance R_{LOSS} due to wire, dielectric, ground, and nearby objects is likely to be much greater than this. How depressing!

Doubling the Frequency to 20 MHz, where $\lambda = 15$m, gives $R_{RAD} = 0.316\,\Omega$, an increase of 16 Times. Tripling the Frequency to 30 MHz, where $\lambda = 10$ m, gives $R_{RAD} = 1.60\,\Omega$, or 81 Times the 10-MHz Value! But now the Perimeter is 0.3λ, and the Loop will have a distorted pattern.

EFFICIENCY $= R_{RAD}/R_{RAD}+R_{LOSS} \times 100\%$. Increase R_{RAD} by increasing Area, and reduce R_{LOSS} by choosing Components and Design (A circle uses a shorter conductor than a square). When a Small Loop is used for Transmitting, a tremendous amount of circulating Current will flow, (maybe tens of Amps.), and huge Voltages will appear accross the Capacitor. This partly explains why Small Loops rated to 1500 watts are expensive. Efficient Loops have a narrow Frequency BandWidth (high-Q). But they can be made to be amazing performers.

A FEW SMALL LOOPS.

O MAX. VOLTAGE.
→ CURRENT DIRECTION.

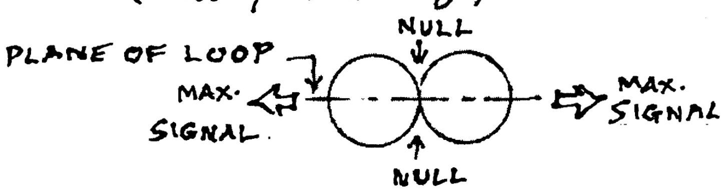


MULTI-TURN LOOP.

SHIELDED LOOP.

"MAGNETIC" LOOP.

These have Narrow-Band-Width (Sharp Tuning).

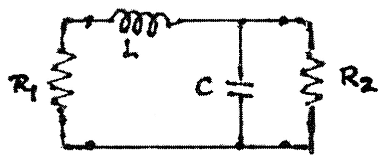


Used for Transmitting.

Low-Loss Construction is Important.

Small Pickup-Loop. ~ 1/5 - 1/4 Dia. of Main Loop.

MATCHING NETWORKS.

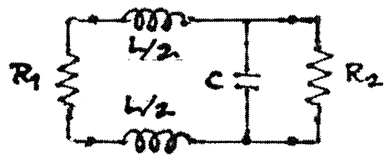


UNBALANCED-L

$R_2 > R_1$

$X_L = \sqrt{R_1 R_2 - R_1^2}$

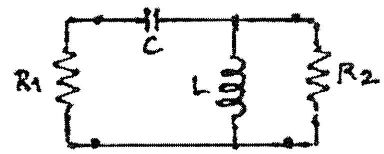
$X_C = \dfrac{R_1 R_2}{X_L}$



BALANCED-L

$L = \dfrac{X_L}{2\pi f}$

$C = \dfrac{1}{2\pi f X_C}$

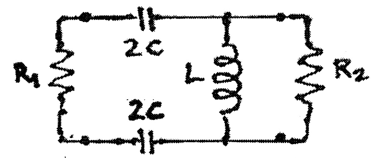


UNBALANCED-L

$R_2 > R_1$

$X_L = R_2 \sqrt{\dfrac{R_1}{R_2 - R_1}}$

$X_C = \dfrac{R_1 R_2}{X_L}$

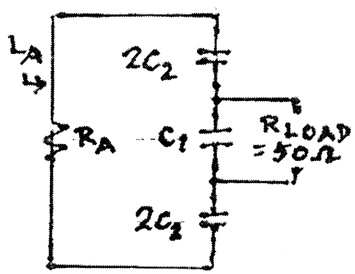


BALANCED-L

$L = \dfrac{X_L}{2\pi f}$

$C = \dfrac{1}{2\pi f X_C}$

FOR SMALL LOOPS.



$R_A = R_{RAD} + R_{LOSS}$

L_A = ANT INDUCTANCE

$C_1 = \dfrac{\sqrt{\dfrac{50 - R_A}{R_A}}}{2\pi f (50)}$

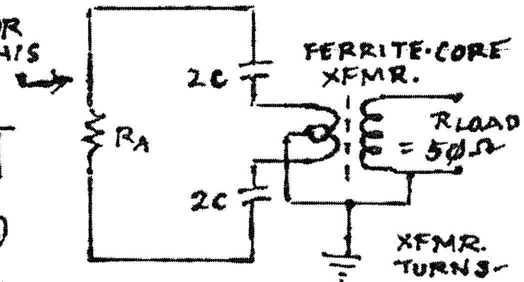
$C_2 = \dfrac{1}{2\pi f \left[2\pi f L_A - \sqrt{R_A (50 - R_A)} \right]}$

L_A: ANT INDUCTANCE

$L_A \approx 2 \times 10^{-7} p \cdot \log_e \left(\dfrac{3440 A}{d P} \right)$

Where P = Loop Perimeter (m).
d: Conductor Diameter (mm).
A: Loop Area (m2).
Log e = Natural Logarithm.

OR THIS



$C = \dfrac{1}{2\pi f \sqrt{L_A}}$

XFMR. TURNS-RATIO = $\sqrt{\dfrac{50}{R_A}}$

R, X_L, X_C IN OHMS. / L IN HENRYS / C IN FARADS.

See "LF Today", By G3XDV (R.S.G.B.)