High Power Transmit Mag Loop Build Project

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The Q_c of the resonating capacitor also contributes to losses in the form of parallel resistance across the capacitor, so that the net loaded Q_L of the antenna is,

$$Q_L = \frac{0.5}{\dfrac{1}{Q_C} + \dfrac{\mathrm{Re}\{Z_{loop}\} + R_{loss}}{\mathrm{Im}\{Z_{loop}\}}} \qquad (14)$$

from which we can determine the loop current amplitude term I_0 for a given transmitter-supplied RF power P,

$$I_0 = \sqrt{\left(\frac{P}{R_{rad}}\right)\left(\frac{Q_L}{Q_{rad}}\right)} \qquad (15)$$

The efficiency *eff* of the loop antenna follows,

$$eff = \frac{I_0^2 R_{rad}}{P} = \frac{Q_L}{Q_{rad}} \qquad (16)$$

The value of Q_L can be obtained from Eqn. (14) or from direct measurements.

3 — The Secondary Feeding Loop

The secondary feeding loop has two main effects on the system. First, the total loop inductance increases by the mutual coupling inductance, M_{12}, between the primary loop and the secondary feeding loop. The result is that less capacitance is needed to resonate the antenna than if just the primary loop inductance were considered. Second, the relative diameters of the secondary feeding loop and the primary loop step up the primary loop resonant radiation plus loss resistance to the feed point value needed to match the feeding coax cable.

We used the Jordan and Balmain[10] high frequency extension to the Neumann formula, specialized to circular loops with constant current, to find the mutual coupling M_{12} between the primary loop and the secondary feeding loop.

$$M_{12} = \int_0^{2\pi}\int_0^{2\pi} \frac{b_2 b D_{12} \exp(-jkR_g)}{R_g} d\theta_1 d\theta_2 \qquad (17)$$

and D_{12} and R_g are function of θ_1 and θ_2, the angles around the circumferences of the two loops,

$$D_{12} = \cos(\theta_1)\cos(\theta_2) + \sin(\theta_1)\sin(\theta_2) \qquad (18)$$

and R_g further depends on the relative displacements of the two loops,

$$R_g = \sqrt{\begin{matrix}[b_2 \sin\theta_2 - b\sin\theta_1 + X]^2 + \cdots \\ + [b_2 \cos\theta_2 - b\cos\theta_1 + Z]^2 + Y^2\end{matrix}} \qquad (19)$$

where X, Y, and Z are the center-to-center displacement distances of the two loops that are in the zx plane. We solved Eqn. (17) using direct numerical integration in *Mathcad* software and include that solution on the **/qex-files** web page. For our loop dimensions, $(L_{self}+M_{12})/L_{self}$ is 1.02. M_{11} is the self-inductance of the primary loop. M_{12} is 57.3 nH for our example, and the loop centers are displace in the loop plane by 0.343 m.

Eqn. (17) can also be used to compute the complex self inductance L_{self} of the primary loop. Then, $j\omega L_{self}$ provides another way to compute the primary loop radiation impedance and reactance for a constant loop current.

4 — Fields at the Loop Center and in the Far Field Null

The electric field perpendicular to the surface of the wire is proportional to the rate of change (differentiation) of the current in the circumferential ϕ direction around the loop. Since we've included a loop term that varies with $\cos(\phi)$, thus survives differentiation in ϕ, we can derive a expression for the electric field in the center of the loop plane. Likewise, we can analyze the far field of the loop in the far-field null direction. In both cases the solution originates with the $2(C_\lambda)^2\cos(\phi)$ term of the loop current.

4.1— Fields at the Loop Center

The electric field at the center of the loop in the zx plane is found from the derivative with respect to ϕ of the loop current. Stated at the loop center $(x, y, z) = (0, 0, 0)$,

$$E_\phi(0,0,0) = -j\frac{\eta_0 k I_0}{2} \qquad (20)$$

and the magnetic field can be approximated from the single-turn solenoid equation,

$$H_z(0,0,0) = \frac{I_0}{2b}\,. \qquad (21)$$

The electric field depends on wavelength (via k) but does not depend on any loop dimension. The magnetic field, however, depends on the loop radius b. The wave impedance Z_W at the loop center is a measure of how well the loop discriminates between the electric and magnetic fields. That wave impedance is,

$$Z_W = \frac{E_\phi}{H_z} = -j\eta_0 kb = -j\eta_0 C_\lambda \qquad (22)$$

clearly revealing the dependence of Z_W on the loop circumference. Also, because the electric field at (0, 0, 0) depends on the *variation* in the loop current, we would not be able to formulate an expression for the wave impedance from just a constant current term.

4.2— The Far-field Null

We evaluated the fields very far from the antenna using the exact analytical expressions in *Mathcad* to determine the loop peak-to-null ratio, and validated the results by NEC simulations. The far-field peak-to-null ratio depends on the current variation term in a simple manner for $C_\lambda < 0.3$. Stated in decibels the peak-to-null ratio of the small loop is,

$$N_{dB} = -20\log(2C_\lambda) \qquad (23)$$

Table 2 shows the null depth across the 7 to 30 MHz operating range of our example loop. We compared the null depth using the simple [illegible] Eqn. (23), a detailed loop near-field calculation in *Mathcad*, and the null calculated from the 4*nec*2 model. The null becomes monotonically and smoothly shallower as the frequency increases for a fixed-size loop. This is normal and expected; recall that at $C_\lambda = 1$ we have the popular full-wavelength loop that exhibits gain of about +4 dBi in the broadside direction. Omitting the current variation term results in an erroneous prediction of an infinitely deep null.

The formula and analysis rely on the first term of the current variation, while the NEC result calculates the exact loop current. The single additional Fourier term loop current approximation becomes less reliable as frequency increases, but is still viable up to 30 MHz. As a result, we estimate that our loop current including a single variation term is reasonably accurate up to at least $C_\lambda = 0.3$.

5 — Loop Coupling to the Coax Feed Line

The secondary loop is fed directly with unbalanced coaxial cable, so there is opportunity to generate common mode currents on the coax feed line. We modeled the primary loop, secondary loop and coax outer shield in 4*nec*2, as rendered in Figure 1. We then varied the length of the

A Few Transmit Magnetic Loop Facts

- Magnetic Loops primarily couple to the H (magnetic) field at a right angle from the E (electric) field
  - Minimizes reception of electrical noise
- Magnetic Loops are small relative to larger dipoles
- Magnetic Loops have a small resonant frequency (or Q), requiring re-tuning even when moving within a band
- Magnetic Loops do not need to be elevated, they work well around 6 feet above ground
- Magnetic Loops contain kilovolts and 10's of amps (current is highest at feedpoint, voltage highest 180° away)

A Few Transmit Magnetic Loop Facts

- In comparison, dipole antenna couple to earth ground
  - Not unusual to have 50% or less efficiency
- Magnetic Loop Coupling
  - Mag loops trade earth ground for a coupling loop and capacitor (typically easier to control)
  - However, a <u>transmit</u> loop should be at least 2 loop diameters above ground to minimize earth coupling

Basic Transmit Mag Loop Components

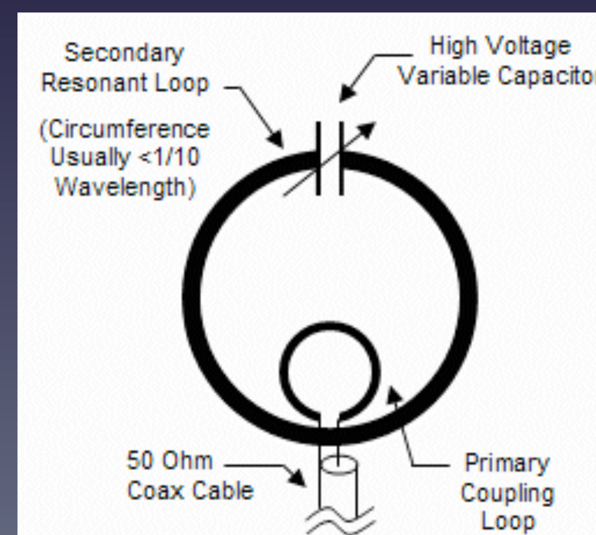
Choke stopping common mode current on feedline

Coupling loop, close but not connected to the main loop. 1/5 size of main loop. Fed with coax from the radio

Main loop

Coax feedline to the radio (connected across the coupling loop ends

Box holding a capacitor (connected across the main loop ends)



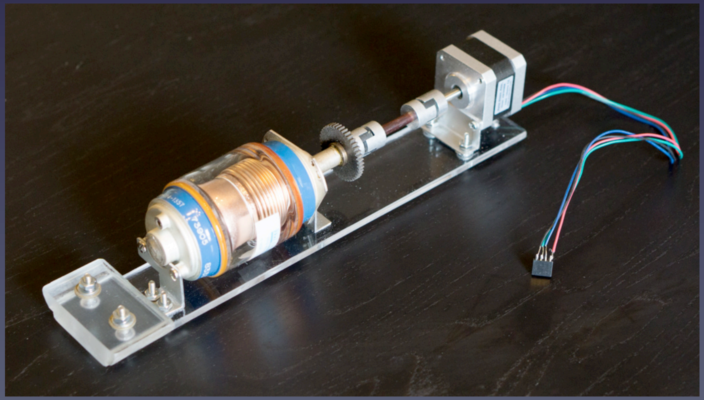
Project Decisions

- You must first decide on the power handling capability of the loop, and on the capacitor type to be used
- Then building the coupling and main loops are simply a mechanical assembly process
- If the antenna will be remotely tuned then a motor assembly and an electronic remote tuner must also be built

Tuning Capacitors and Power Considerations

- Split Stator and Butterfly capacitors
  - Generally usable only up to 10W power
  - Inexpensive (a few dollars)
  - Generally a reduction gear is suggested for precision tuning

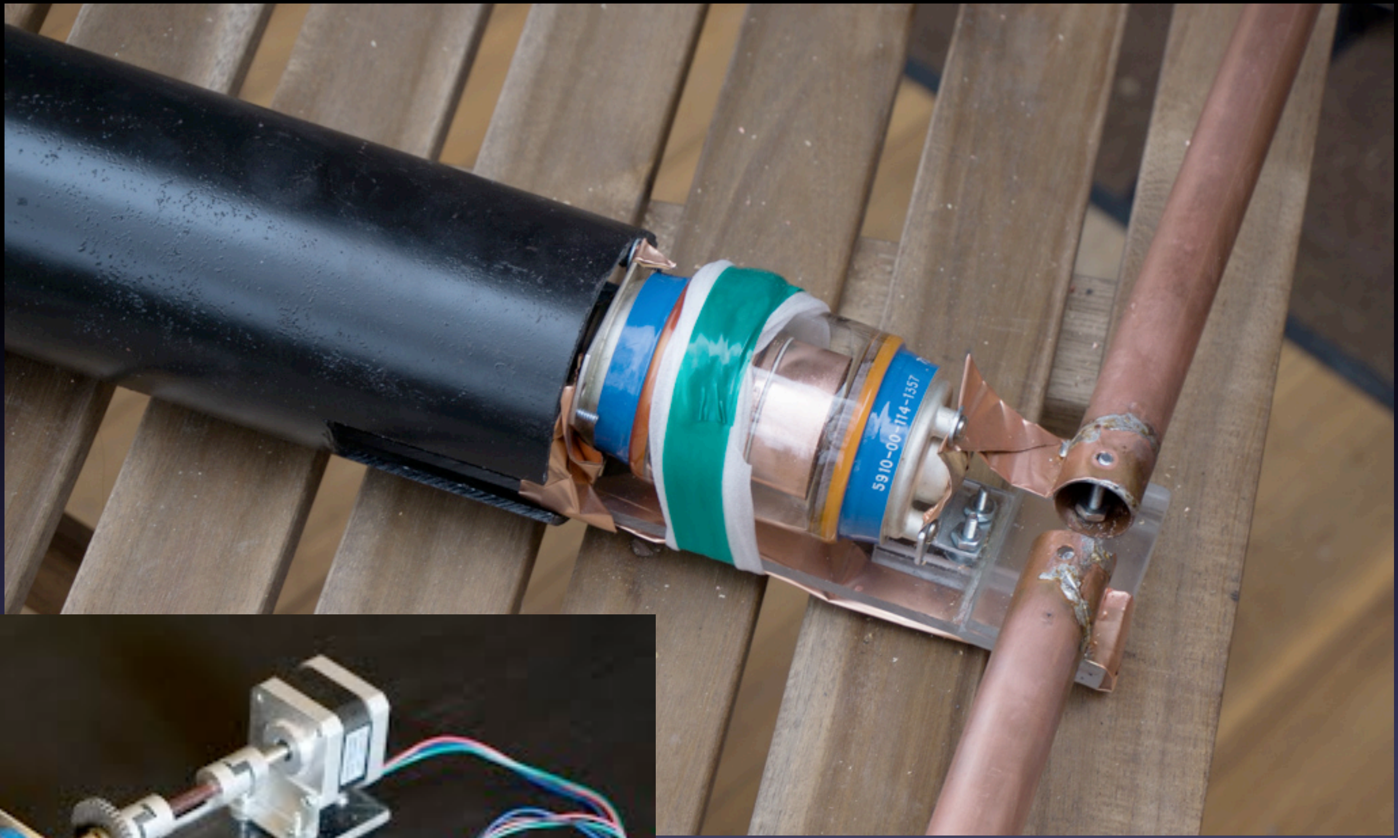
- Vacuum Variable capacitor
  - Can handle 100's of watts of power
  - Contained within a vacuum container
  - Can handle over 15KV and over 50A
  - Reduction gear is included in the sealed unit
  - Expensive (over $100 used, over $400 new)

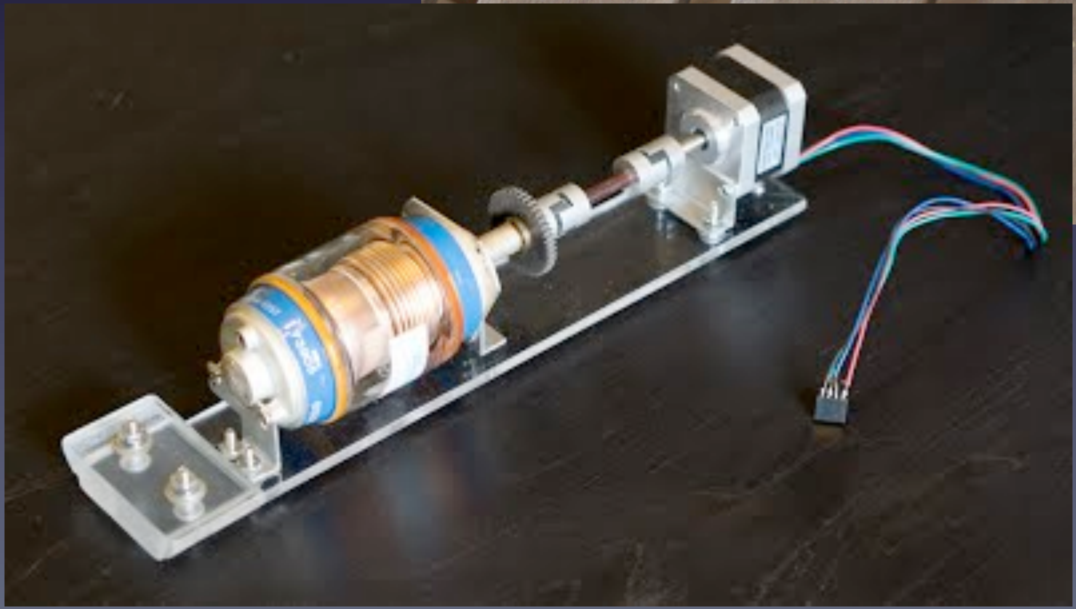


My Planned Loop Antenna Build

Let’s take the best of all the previous attempts…

Vacuum Capacitor Installation





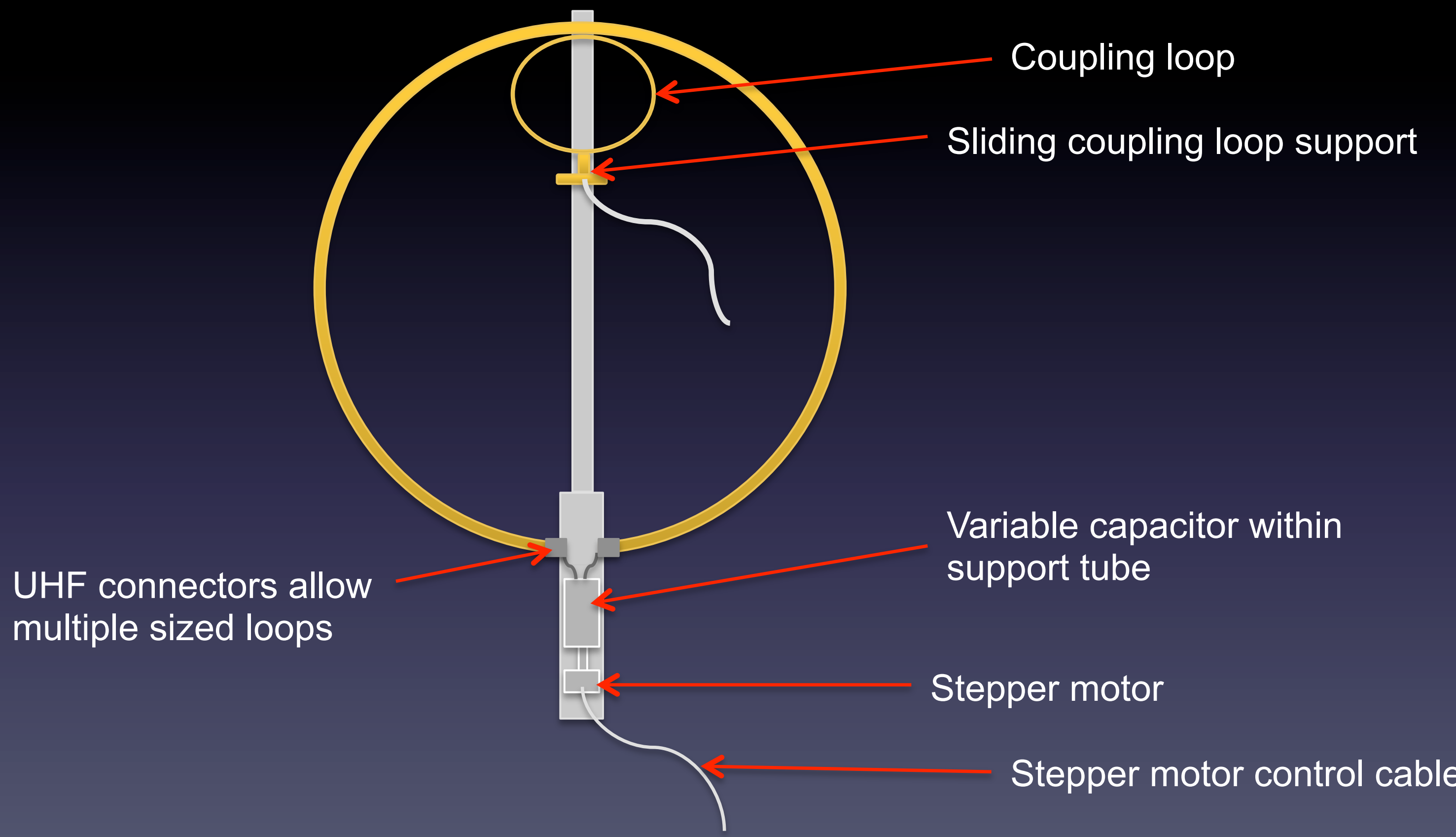
Vacuum capacitor and motor drive is contained within the mast for weatherproofing

Can handle close to 500W depending on capacitor and connections

Coupling Loop

PVC Pipe with endcaps and UHF connector slides and rotates for SWR adjustment

Completed Antenna



Technical Loop Considerations

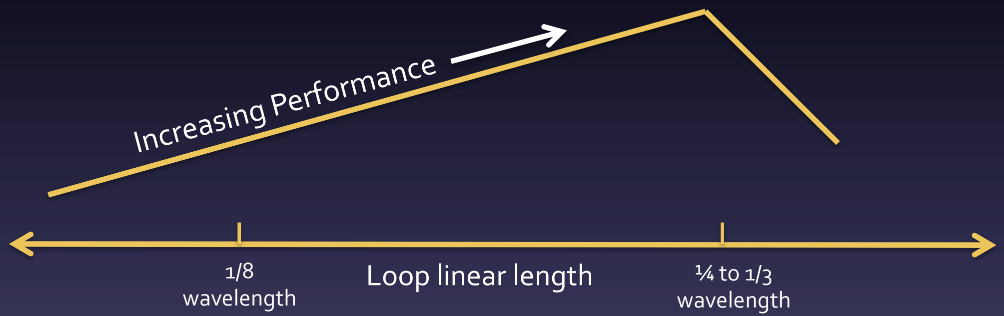
Determining the Loop Size

- Increasing loop size improves both efficiency and resonant bandwidth (GOOD)
- Example: 20M (14MHz) Loop with 1" conductor
  - 9 ft (2.9 diameter) 59% efficiency, 13KHz bandwidth
  - 13.3 ft (4.2 diameter) 82% efficiency, 28KHz bandwidth
  - 17 ft (5.4 diameter) 91% efficiency. 49KHz bandwidth

So why not simply make the largest possible size loop?

Optimizing the Loop Size

- For highest loop efficiency
  - The loop circumference should be > 1/8 wavelength
  - BUT, to avoid self-resonance the loop length should be < ¼ wavelength



- There is no 'perfect' loop size unless you use only a single frequency
  - The variable capacitor adjusts the antenna tuned circuit for near perfect resonance within the parameters above

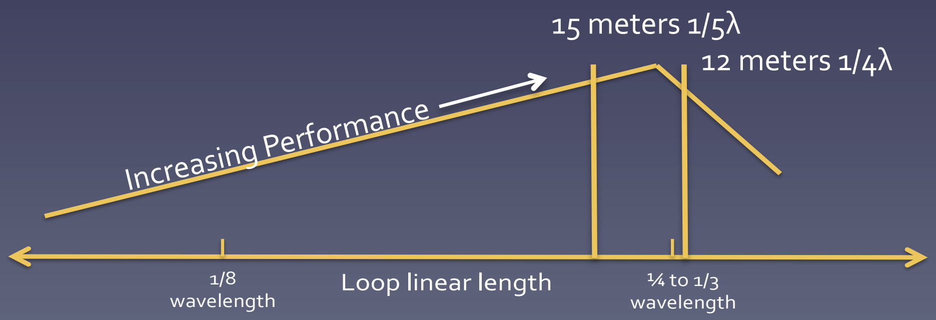
Optimizing the Loop Size

- We had a conversation with Sebastian a few months ago regarding a decrease in efficiency on the Pixel antenna in higher frequencies…

- I hypothesized the preamp did not perform well at higher frequencies…

Optimizing the Loop Size

- We had a conversation with Sebastian a few months ago regarding a decrease in efficiency on the Pixel antenna in higher frequencies…
- I hypothesized the preamp did not perform well at higher frequencies…
- ACTUAL CAUSE
  - The Pixel antenna is 10 ft circumference (or about 3 meters long)
  - Which is about ¼ of 12 meters (the limit of expected performance)
- Observations match that the antenna performs well through 21 MHz (15M), but not well above that



Further Optimizing the Loop

But there’s more, its not as simple as simply choosing a loop size

Loop Conductor Diameter

- Changing the loop conductor diameter also affects efficiency and bandwidth
- *Example: 20M (14MHz) loop at any length*
  - *Moving from 0.4" to 1" conductor, efficiency increases 10% but BW decreases 45%,*
  - *Moving from 1" to 2" conductor, efficiency increases 5% but BW decreases 20%*
  - ***NOTE**: Increasing conductor diameter has decreasing effect with size*

Increasing the loop conductor diameter IMPROVES efficiency (GOOD) and DECREASES resonant bandwidth (BAD)

Notes on Loop Efficiency

- How can a loop antenna have a 1:1 SWR and be 5% efficient?
  - Loop conductor and connection electrical resistance lowers efficiency. Lower is better (in the milliohms)
  - Anything creating a non-uniform electric field (length over ¼ wavelength, bent elements…)
  - Objects in the near-field (within a few loop diameters); metal, your body…
  - Antenna coupling to the ground (closer than approx one loop diameter)
  - Common mode current on the feedline
- NOTE: 20% efficiency loss represents only -1 dB (1/3 S-Unit)

Electrical Resistance MUST be Minimized

- Conductor electrical resistance has a dramatic impact on the performance of the loop
- 100 milliohms (1/10 of a ohm)
  - At 28 MHz (10M) 8% decrease in efficiency, and a 9% increase in bandwidth
  - At 14 MHz (20M) 50% decrease in efficiency, and a 100% increase in bandwidth
  - At 7 MHz (40M) 80% decrease in efficiency, and a 430% increase in bandwidth

Choosing the Loop Conductor

- If power is 10W or less use simple coax
- If power is greater than 10W use Copper or aluminum tube
  - Aluminum is lighter in weight and is less expensive
  - Copper has slightly less resistance and is more expensive
- Standard thickness of copper tubes
  - K Thickest
  - L Thinner
  - M Even Thinner
  - DWV Thinest

Loop Antenna Calculator

Home

Check out the recommended reading list

Calculators

- Small Transmitting Loop Antennas
- Full-Wave Loop Antennas
- Quarter-Wave Vertical Antennas
- Coil-Shortened Vertical Antennas
- Dipole Antenna Length
- Coil-Shortened Dipole Antenna
- Coil Inductance
- Toroid Coil Winding
- Wire Gauge & Diameter
- Capacitance (Capacitor Design)
- Capacitive Reactance (Xc)
- Inductive Reactance (XL)
- Body Mass Index (BMI) Calculator

The pH Pages

- The Simplest Possible pH Meter
- Build a pH Meter and Controller
- Buying a pH Meter
- pH Meter Calibration & Care
- pH Probes
- pH Meter Calibration Buffers
- pH Buffering
- pH Test Kits

CO2 & the Planted Aqaurium

Recommended (free) Software

Computers

- Create a Database Table from a Spreadsheet
- Export a Database Table to a Spreadsheet

Small Transmitting Loop Antenna Calculator

Small transmitting loop antennas, commonly called "magnetic loops" or "mag loops," can give surprisingly good performance when they are carefully designed and constructed. Although this online calculator is intended to assist with designing and building homemade, ham radio loop antennas for use in the HF bands, magnetic antennas have been constructed that function in the VHF or even the UHF frequencies. The most common material for home building small ham radio loop antennas is common copper plumbing pipe.This calculator enables you to test the design of an octagonal loop antenna and to answer "what if" questions until you arrive at a design that meets your needs without a lot of experience in electronics.

Length of Conductor (antenna "circumference")

9 feet

Diameter of Conductor
(For efficiency, should be > 3/8" or 1 cm)

.9 inches

Frequency

14 megahertz

Transmitter Power (optional)

100 Watts

Units of Measurement

- (●) **English (feet and inches)**
- ( ) **Metric (meters and centimeters)**

CALCULATE

Antenna efficiency:
Antenna bandwidth:
Tuning capacitance:

Capacitor voltage:
Resonant circulating current:
Radiation resistance:
Loss resistance:

MAG LOOP SIZING MODEL (Model does not include efficiency losses due to connection resistance or near field objects)

Freq (mHz)	Sugg Length **	Length (ft)	Loop Dia (ft)	Wire Dia	Bandwidth (kHz)	Efficiency	Cap (pf)
7	17 - 34 ft	9 ft	2.87	0.4	13	**5**	351
7	17 - 34 ft	9 (x2=18 ft)	2.87	0.4	14	**29**	139
7	17 - 34 ft	13 ft	4.14	0.4	13	**13**	214
7	17 - 34 ft	13 (x2=26 ft)	4.14	0.4	20	**55**	87
7	17 - 34 ft	16 (x2=32 ft)	5.10	0.4	29	**70**	67
7	17 - 34 ft	16 (x2=32 ft)	5.10	1	19	**85**	54
7	17 - 34 ft	16 (x2=32 ft)	5.10	2	15	**92**	48
14	8.5 - 17 ft	9	2.87	0.4	29	**37**	88
14	8.5 - 17 ft	13	4.14	0.4	44	**64**	53
14	8.5 - 17 ft	16	5.10	0.4	63	**76**	41
14	8.5 - 17 ft	9	2.87	1	13	**59**	65
14	8.5 - 17 ft	13	4.14	1	26	**81**	41
14	8.5 - 17 ft	16	5.10	1	43	**89**	32
14	8.5 - 17 ft	9	2.87	2	8	**75**	55
14	8.5 - 17 ft	13	4.14	2	20	**90**	35
14	8.5 - 17 ft	16	5.10	2	35	**94**	27
18	6.6 - 13.3 ft	7	2.23	0.4	37	**40**	43
18	6.6 - 13.3 ft	10	3.18	0.4	57	**66**	46
18	6.6 - 13.3 ft	13	4.14	0.4	94	**81**	32
18	6.6 - 13.3 ft	7	2.23	1	17	**62**	55
18	6.6 - 13.3 ft	10	3.18	1	34	**83**	35
18	6.6 - 13.3 ft	13	4.14	1	64	**91**	25
18	6.6 - 13.3 ft	7	2.23	2	12	**77**	45
18	6.6 - 13.3 ft	10	3.18	2	26	**91**	29
18	6.6 - 13.3 ft	13	4.14	2	52	**95**	21
21	5.7 - 11.4 ft	6	1.91	0.4	44	**41**	69
21	5.7 - 11.4 ft	8.5	2.71	0.4	68	**67**	42
21	5.7 - 11.4 ft	11	3.50	0.4	111	**81**	30
21	5.7 - 11.4 ft	6	1.91	1	20	**64**	49
21	5.7 - 11.4 ft	8.5	2.71	1	41	**83**	31
21	5.7 - 11.4 ft	11	3.50	1	74	**92**	23
21	5.7 - 11.4 ft	6	1.91	2	14	**78**	40
21	5.7 - 11.4 ft	8.5	2.71	2	31	**91**	26
21	5.7 - 11.4 ft	11	3.50	2	60	**96**	19
28	4.3 - 8.5 ft	5	1.59	0.4	69	**53**	50
28	4.3 - 8.5 ft	6	1.91	0.4	88	**66**	39
28	4.3 - 8.5 ft	8.5	2.71	0.4	170	**85**	26
28	4.3 - 8.5 ft	5	1.59	1	35	**74**	35
28	4.3 - 8.5 ft	6	1.91	1	50	**83**	28
28	4.3 - 8.5 ft	8.5	2.71	1	115	**93**	18
28	4.3 - 8.5 ft	5	1.59	2	25	**85**	29
28	4.3 - 8.5 ft	6	1.91	2	38	**91**	23
28	4.3 - 8.5 ft	8.5	2.71	2	93	**96**	15

13 ft (.4" conductor x2)	Bandwidth 20kHz, Efficiency 55%
16 ft (.4" conductor x2)	Bandwidth 29kHz, Efficiency 70%
16 ft (1" conductor x2)	Bandwidth 19kHz, Efficiency 85%
16 ft (2" conductor x2)	Bandwidth 15kHz, Efficiency 92%
16 ft (.4" conductor)	Bandwidth 63kHz, Efficiency 76%
13 ft (.4" conductor)	Bandwidth 44kHz, Efficiency 64%
13 ft (.4" conductor)	Bandwidth 94kHz, Efficiency 81%
8.5 ft (1" conductor)	Bandwidth 41kHz, Efficiency 83%
8.5 ft (1" conductor)	Bandwidth 170kHz, Efficiency 85%

NOTE: Variable capacitor range from about 20pf to 90pf
NOTE: Going from 0.4" to 1.0" conductor decreases bandwidth abt 45%
NOTE: Going from 0.4" to 1.0" conductor increases efficiency abt 10%
NOTE: Going from 1.0" to 2.0" conductor increases efficiency abt 5%

FYI: 80% transmit efficiency represents -1db or 1/3 S-Unit loss
FYI: SWR 2.0 = 89% forward power, SWR 4.0 = 64% forward power

**** For highest efficiency, the length should be greater than 1/8 wavelength**
**** To avoid self-resonance, the length should be less than 1/4 wavelength (BAD)**

Summary Design Criteria

- Increasing antenna size (up to a limit)
  - Increases efficiency, increases bandwidth
- Increasing conductor diameter
  - Increases efficiency, decreases bandwidth
- Increasing electrical resistance
  - Decreases efficiency, increases bandwidth

Loop Boundry Calculations

- 8 ft loop 15M – 10M (2.54 ft diameter)
  - .75" loop 28 MHz (10M) 21pf 100W 2700 V, 500W 6000V
  - .75" loop 21 MHz (15M) 37pf 100W 3300V, 500W 7300V
  - 1" loop 28 MHz (10M) 19 pf 100W 3000V, 500W 6600V **
  - 1" loop 21 MHz (15M) 34 pf 100W 3700V, 500W 8200V
- 10 ft loop 20M – 15M (3.18 ft diameter)
  - .75" loop 21 MHz (15M) 28 pf 100W 3000V, 500W 6600V
  - .75" loop 14 MHz (20M) 62 pf 100W 3700V, 500W 8300V
  - 1" loop 21 MHz (15M) 25 pf 100W 3300V, 500W 7300V
  - 1" loop 14 MHz (20M) 57 pf 100W 4300V, 500W 9500V

** 100W loop requires capacitor at 10-50 pf at 5KV rating
500W loop requires capacitor at 10-50 pf at 10KV rating

Loop Boundry Calculations

- 13 ft loop 17M – 7M (4.14 ft diameter)
  - .75" loop 18 MHz (17M) 27 pf 100W 2900V, 500W 6500V
  - .75" loop 7 MHz (40M) 177 pf 100W 3800V, 500W 8400V
  - 1" loop 18 MHz (17M) 25 pf 100W 3200V, 500W 7100V **
  - 1" loop 7 MHz (40M) 164 pf 100W 4500V, 500W 10,100V
- 17 ft loop 40M – 20M (5.41 ft diameter)
  - .75" loop 14 MHz (20M) 32 pf 100W 3100V, 500W 6800V
  - .75" loop 7 MHz (40M) 126 pf 100W 4100V, 500W 9100V
  - 1" loop 14 MHz (20M) 29 pf 100W 3400V, 500W 7400V
  - 1" loop 7 MHz (40M) 118 pf 100W 4800V, 500W 10,600V

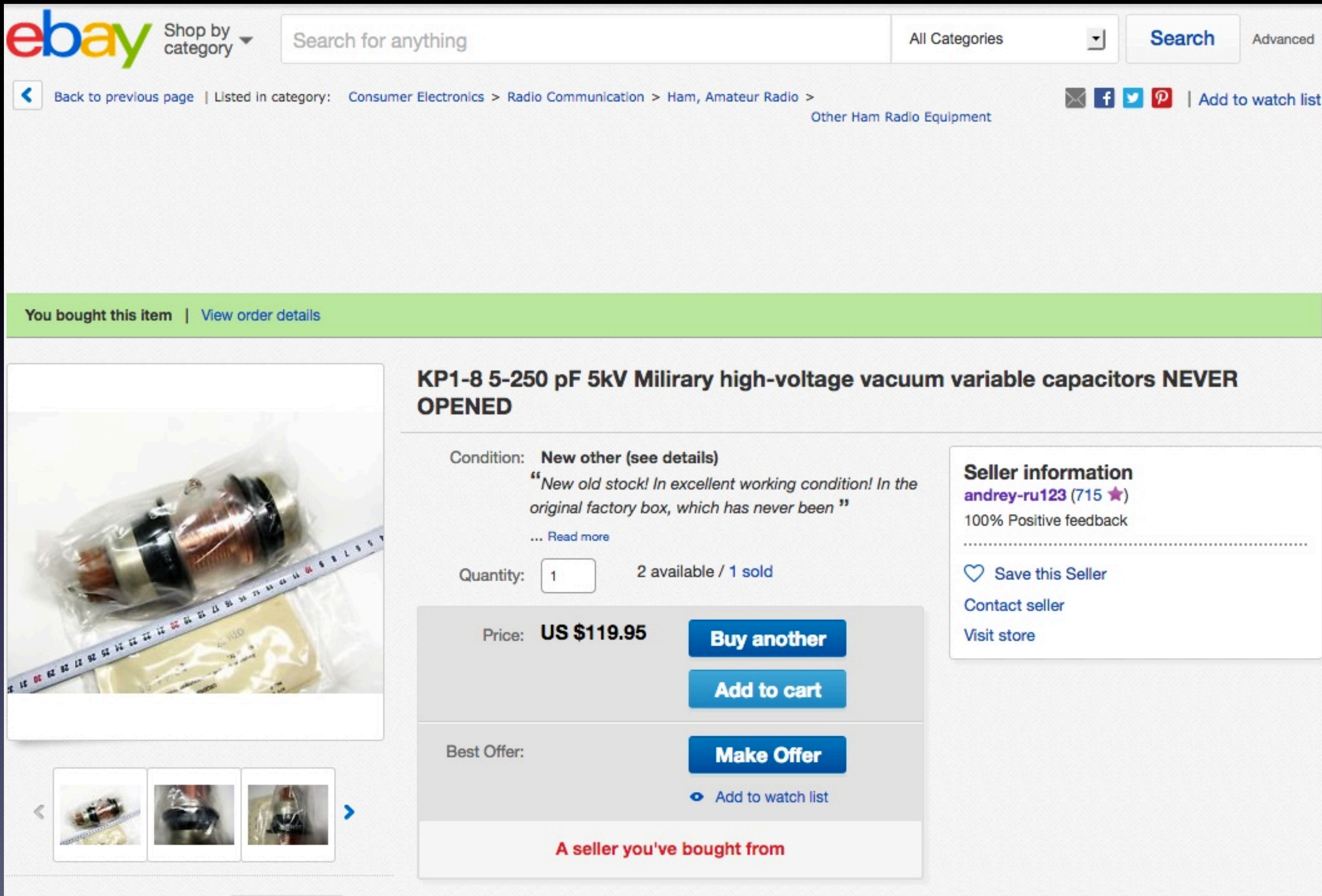
** 100W loop requires capacitor at 20-200pf at 5KV rating
500W loop requires capacitor at 20-200pf at 15KV rating

Consider a Removable Loop Option

- Attach removable loops using UHF connectors
  - Adds a little resistance but would allow 40M thru 10M

13 ft loop 40M (7 MHz) – 17M (18 MHz) 4.14 ft diameter
8 ft loop 15M (21Mhz) – 10M (28 MHz) 2.54 ft diameter

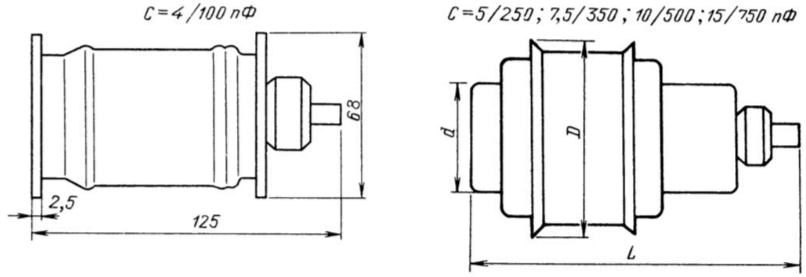
Purchased Vacuum Capacitor



100W loop requires capacitor at 10-200pf at 5KV rating

Purchased Vacuum Capacitor

КП1-8



Номинальная емкость, пФ		Номинальное напряжение, кВ	Размеры, мм			Масса, г, не более
мини-мальная	макси-мальная		D	L	d	
4	100	5	68	125	58	550
5	250		70	156	52	800
7,5	350		84	156	52	900
10	500		108	200	60	1900
15	750		108	200	60	2000

Тангенс угла потерь, не более .... $1 \cdot 10^{-4}$
Сопротивление изоляции в нормальных климатических условиях, не менее .... $1 \cdot 10^{7}$ МОм
Момент вращения .... До 0,47 Н·м
Число циклов перестройки емкости .... До 5000
Скорость перестройки .... До 5 цикл./мин

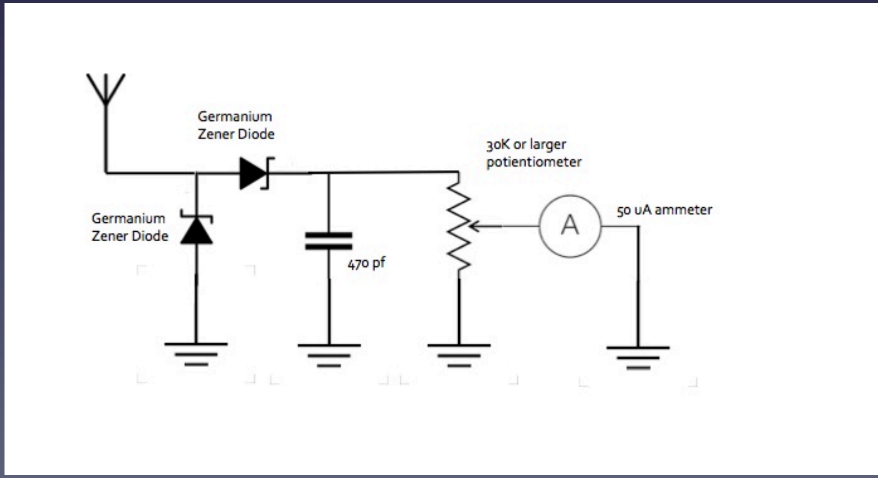
Предельные эксплуатационные данные

Рабочая частота .... До 30 МГц
Рабочий ток .... До 35 А
Температура окружающей среды .... От −60 до +125° С
Относительная влажность воздуха при температуре 35° С .... До 98%
Пониженное атмосферное давление .... До 533 гПа (400 мм рт. ст.)
Минимальная наработка .... 5000 ч
Срок сохраняемости .... 12 лет

Measuring Actual Loop Performance

Build an inexpensive RF field strength meter

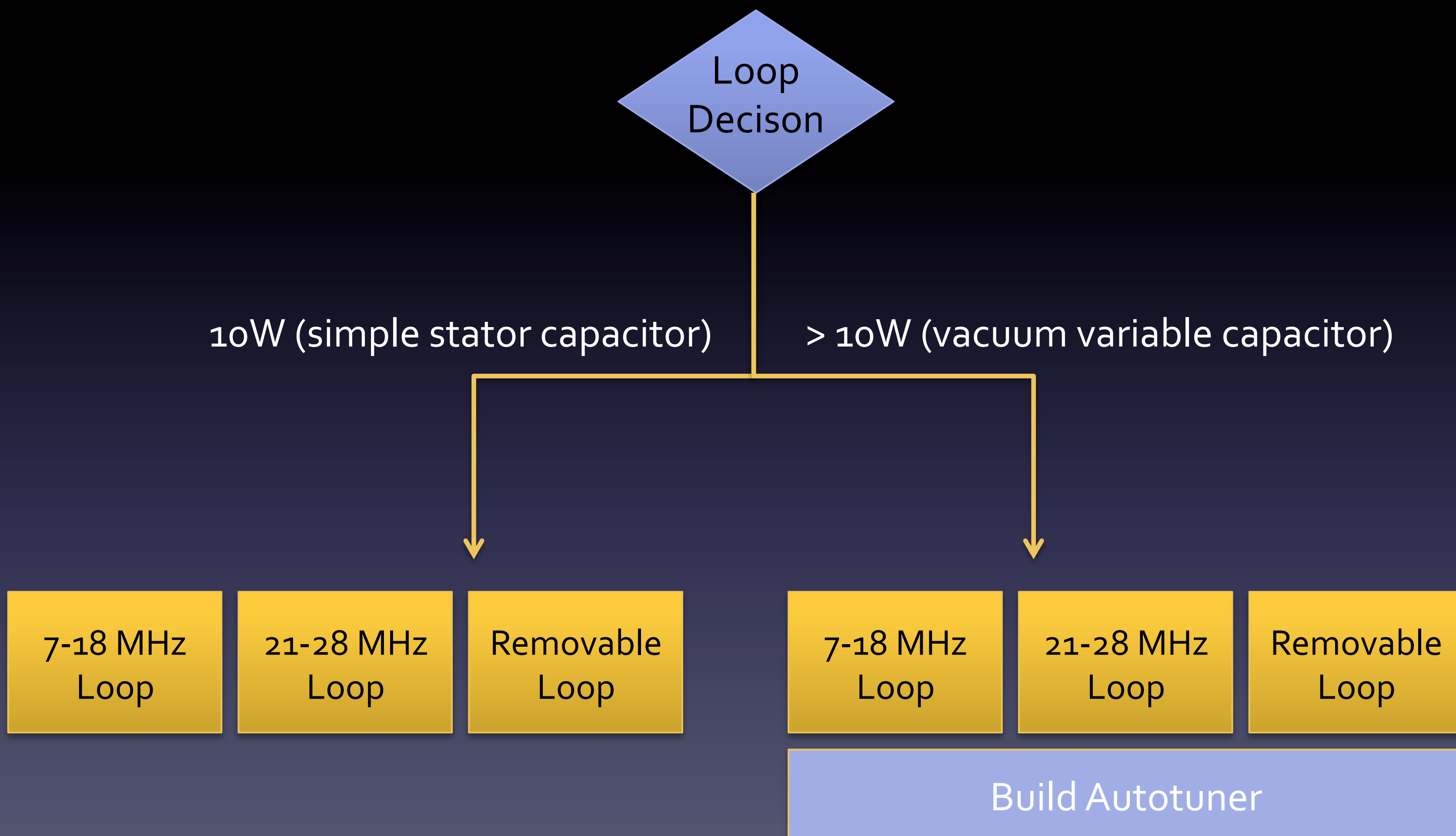
Indicates relative radiated power but not a calibrated measurement



Mag Loop Build Skills Requirements

- If the loop will <u>not handle over 10W</u>
  - General soldering and mechanical assembly skills
- If the loop <u>will handle over 10W</u> (up to several hundred watts)
  - Skills listed above PLUS
  - Mechanical design and assembly of vacuum capacitor and stepper motor assembly
  - HIGHLY RECOMMENDED: Skills to build the Autotuner (in subsequent section)

Final Loop Decision



Mag Loop Cost Estimate

- If the loop will not handle over 10W
  - Stator capacitor cost is less than $50
  - Coax can be used for the loop elements (minimal cost)
  - Connectors and material cost about $25 **(TOTAL COST <$100)**
- If the loop will handle over 10W (up to over 500 watts)
  - Vacuum capacitor cost is $100+ used, $400+ new
  - Aluminum or copper tube (cost $150 for aluminum, more for copper)
  - Connectors and materials cost about $75 **(TOTAL COST $350 - $650)**
  - An autotuner is highly recommended (along with a motor drive assembly for the capacitor). Estimated cost is $250 - $400

Mag Loop Build Final Notes

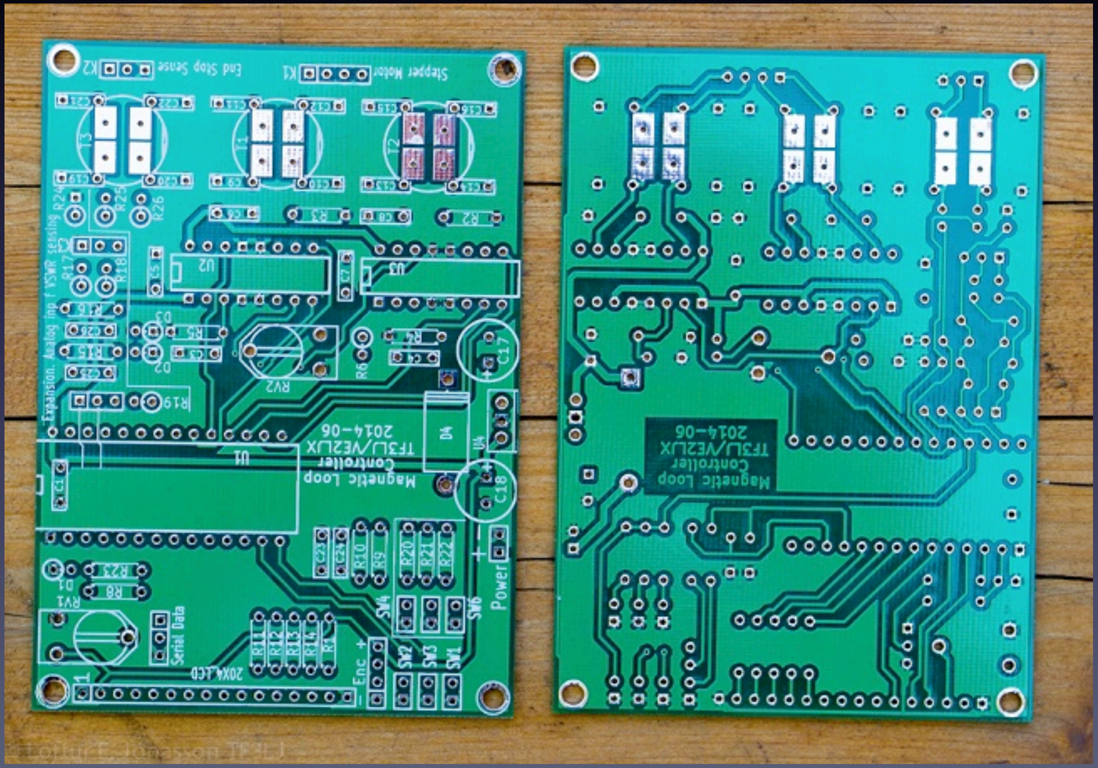
- *YOUR LOOP ANTENNA MAY BE UNIQUE, BASED UPON YOUR CHOICE OF MATERIALS AND DESIGN*
- *SOME MATERIAL MAY BE GROUP PURCHASED AS POSSIBLE*
- *YOU MUST SUPPLY ALL MATERIALS UNLESS OTHERWISE ARRANGED*


Auto-Tuner Build Project
Magnetic Loop Controller
PDØLEW
Radio: 7.083.000 Hz
Tuned: 7.073.877 Hz
StepP: 0.262 0.248
Range: 2 Motor: On
ICOM
HF/50MHz TRANSCEIVER IC-7300
POWER
TRANSMIT
TUNER
VOX/BK-IN
PHONES
MIC
NB
NR
NOTCH
AF RF/SQL
MULTI
RIT
SPLIT
TX/RX
AUTO TUNE
LSB
FIL1
VFO A 1
20:51
7.083.00
SPECTRUM SCOPE
< 1 >
EDGE
HOLD
CENT/FIX
EXPD/SET

Why Build an Autotuner for the Loop?

- The small resonant frequency range of the loop requires re-tuning even when changing frequency a few KHz
- Interaction with objects (your hand) in the loop antenna near-field makes tuning difficult
- High voltages on the antenna make manual tuning dangerous
- Memory tuning decreases the need to transmit with every tune (tuning ‘off frequency’ from a desired signal is often outside the resonant range)

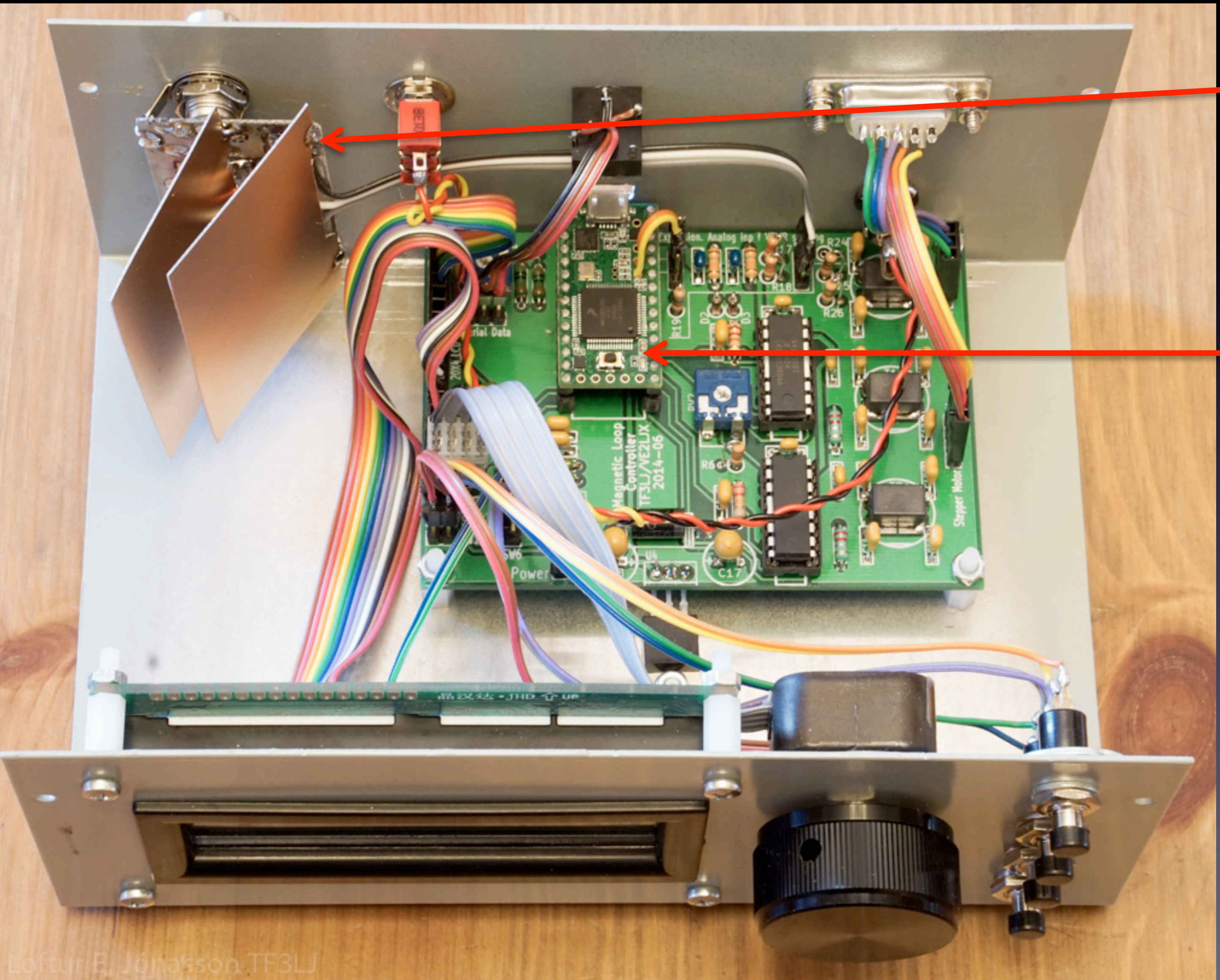
Available 2-Sided Printed Circuit Board



A 2-sided PCB makes construction easier

Over 500 boards have been provided to users from the designer

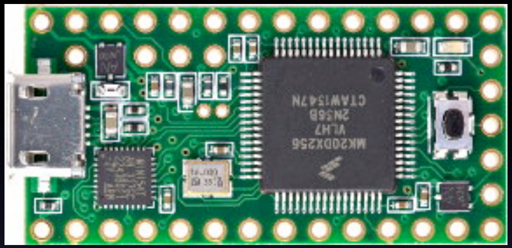
Typical Auto-Tuner Build



Tandem Match Coupler for SWR meter

Teensy 3.2 Arduino near-clone daughterboard

Microprocessor Details

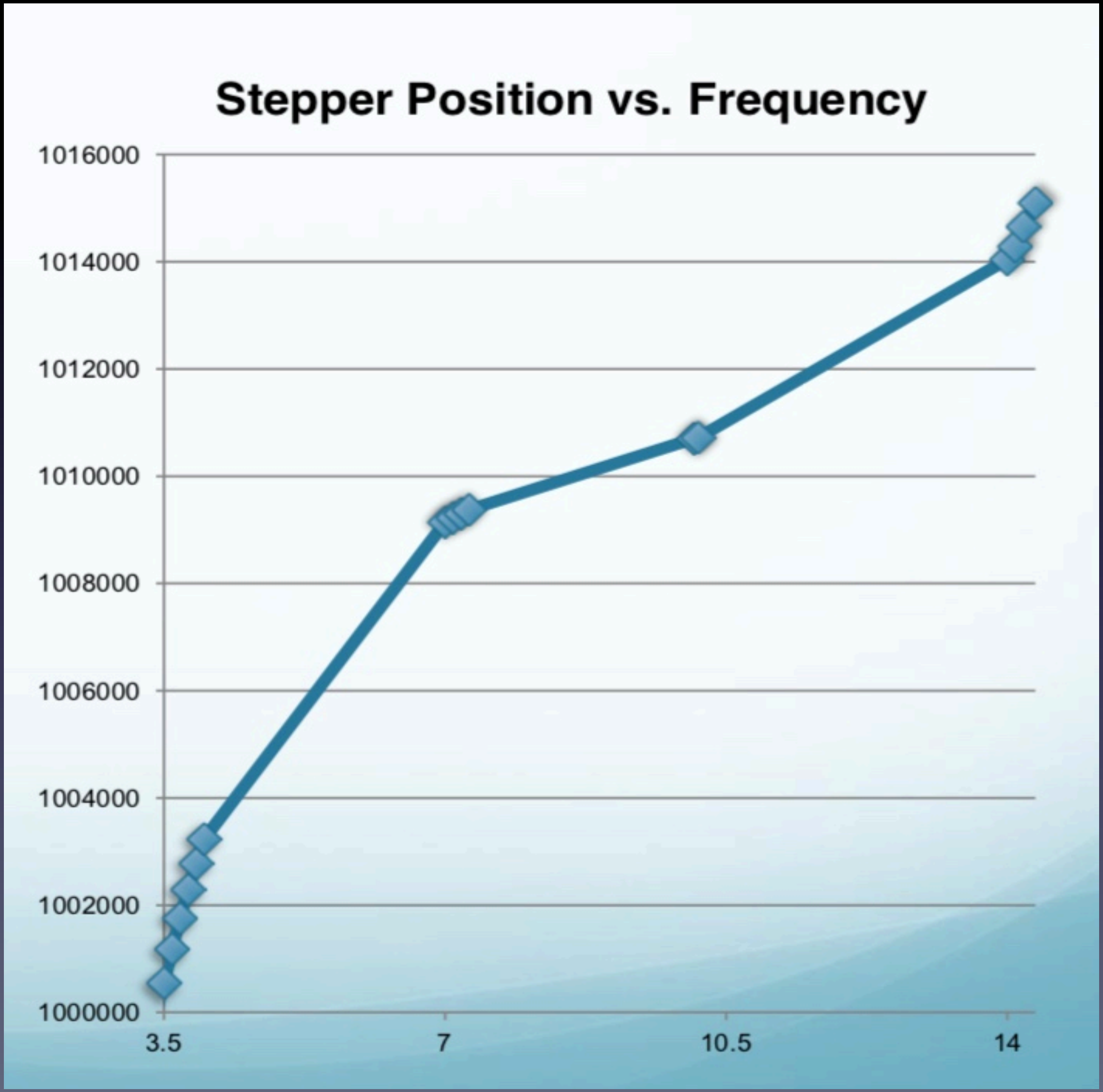


- Teensy 3.2 Controller
  - Cortex-M4 Processor 72MHz
  - Flash 256kbytes, RAM 64kbytes, EEPROM 2kbytes
  - USB (1), Serial (3)
  - 200 autotune memories
- Program code for the project is readily available

Autotune Architecture

- Many similar controller projects use SWR based auto tuning
  - Requires "Transmit to Tune" every time the frequency is changed
- This controller reads frequency from the transceiver and stores antenna matches in memory
  - Will re-tune the antenna automatically without needing to transmit
  - Can also do SWR tuning by transmitting power

Autotune Architecture



The controller automatically tunes in a linear fashion between any stored frequency/position pair

Up to 200 frequency/position pairs can be stored

Storing Frequency/Position Pairs

- Tune the Transceiver to a desired frequency, say 14.000 MHz. Turn the Encoder and tune the Antenna for maximum noise. Store position.
- Add up to 200 frequency/position memories, in any order.

AutoTune in Action

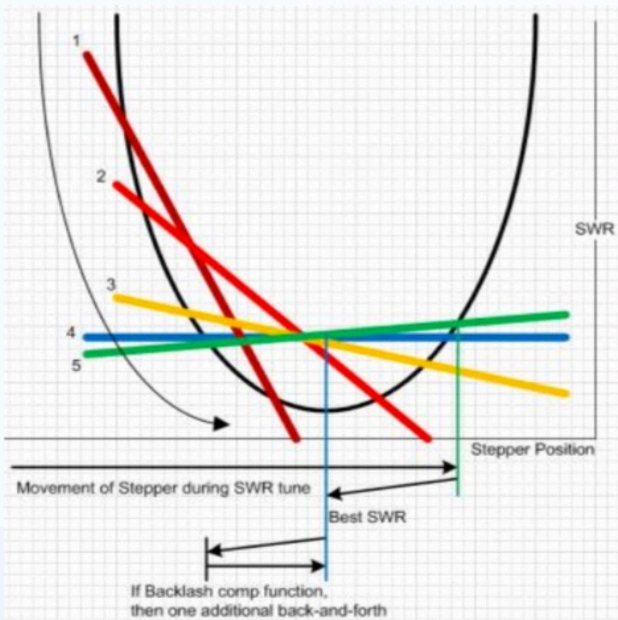
- Two tuning modes
  - Hunt mode: Hunts for an SWR dip within a range of a few hundred steps to each side of current position
  - Tune UP or DOWN: Tunes until endstop or SWR dip is found
- SWR Autotune Option
  - Automatically initiates Hunt Mode if SWR above acceptable level. Will give up if 3 consecutive failures

Backlash Correction

- When adjusting the capacitor with a sub-degree precision, any backlash or slop in the coupling mechanism will cause huge inaccuracies depending on whether the capacitor is being tuned in an upward or a downward direction. To battle this, an optional backlash compensation function can be enabled.
  - When the controller receives frequency information from the radio which is lower than the most recent previous frequency information, then it:
  - Tunes down to the new position
  - Tunes further down by a set angle and then finally tunes back up by the same angle.

Autotune Algorithm

SWR Auto Tune



While moving the stepper, a running sum is made of the square of each of the **32** last SWR measurements. As per diagram:

Average for 2 is lower than for 1

Average for 3 is lower than for 2

Average for 4 is lower than for 3

Average for 5 is **higher** than for 4 – We have passed the **best SWR** dip

If the SWR 17 steps earlier (midpoint: 32/2 +1 = 17) was better than minimum acceptable SWR – then we have found best SWR – Move back to midpoint.

If backlash comp, then an additional move back and forth

The tuning sequence only takes a couple of seconds ☺

Capacitor Tuning 'Soft' Endstops

- The stepper motor should be just powerful enough to turn the capacitor but not excessively more. The stepper current is adjustable (RV2).
- The Up/Down switches can be disabled beyond the lowest/highest stored frequency/position, the radio will not tune the capacitor beyond these positions.
- To go beyond an already "proven" range, one manually turns the capacitor by turning the encoder, then store the new frequency/position to extend the range.

Autotuner Build Skills Requirements

- Building the autotuner requires a range of ‘semi-advanced’ skills
  - PCB soldering (no surface mount)
  - Microprocessor program loading, and some Linux
  - Cabinet assembly, drilling, labelling, and wiring
  - Coax and control cable assembly
  - Electrical testing

Autotuner Cost Summary

• Stepping motor and drive components	$100
• PCB	$20
• Electrical components	$75
• Rotary Encoder	$50
• Cabinet (possible custom cabinet avail $$)	$25
• Teensy Processor	$25
• Tandem Match Coupler	$30
• Misc connectors, wire…	$50
• **TOTAL**	**$375**

Helpful Links

http://www.66pacific.com/calculators/small-transmitting-loop-antenna-calculator.aspx

https://sites.google.com/site/lofturj/to-automatically-tune-a-magnetic-loop-antenna

https://www.youtube.com/watch?v=r3BIlnZ68R4 Video of the Autotuner

https://groups.yahoo.com/neo/groups/loopController/info Yahoo Group on the Autotuner

http://www.ur4ll.net/#caps3_1 Source for various Russian parts (no guarantee…)

https://www.facebook.com/MagLoop/ Builder of high-end custom mag loops

Comparison to Amplified Receive Loop

(Is a separate receive loop still desirable?)

- Tests performed on WWV 5 MHz between Pixel non-resonant mobius receive amplified loop and Alpha transmit loop

	Background	WWV Carrier		
PRO-1B with preamp	-105 dBm*	-83 dBm	←	22 dBm signal
Alpha resonant/no preamp	-120 dBm	-118 dBm	←	2 dBm signal
Alpha resonant/with preamp	-70 dBm*	-52 dBm	←	18 dBm signal

** Pixel background noise S3 vs Alpha (resonant) S9*

Comparison to Amplified Receive Loop
(Is a separate receive loop still desirable?)

- Summary Findings at 5MHz
  - The transmit loop is deaf when <u>non-resonant</u>
  - When the Alpha was <u>resonant</u> both signal and noise increased 20 dBm
  - The Alpha transmit loop w/preamp performance roughly equaled the Pixel when it was resonant
  - The Alpha transmit loop had a significantly higher noise floor than the Pixel when it was resonant (6 s-units)

Yes, a separate receive loop is desirable if wideband reception is desired

MAGNETIC LOOP AND AUTOTUNER BUILD PROJECT SIGNUP LIST

Name	10W Loop Y/N	>10W Loop Y/N	Alum Tube Y/N	Autotuner Y/N	email	phone

Project (you need to build all projects, they are not completed products)	**Expected Cost**
13 ft Loop antenna up to 10W using coax	$25 to $100
13 ft Loop antenna up to 10W using alum tube ($150)	$175 to $250
13 ft Loop antenna greater than 10W using coax	$200 and up (depends on the variable capacitor)
13 ft Loop antenna greater than 10W using alum tube ($150)	$350 and up (depends on the variable capacitor)
Autotuner (includes all components, you need to build)	$400
Autotuner (includes all components, you need to build) with custom cabinet	$400 plus cost of cabinet (TBD)

Who’s interested in having some fun building these projects?