# Remotely Controlled Magnetic Loop Antenna

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# Project Goals

- Smallest possible visual footprint
- Good noise rejection for city use
- Covers the 15M and 20M bands (at minimum)
- Handle at least 100 watts of transmit power
- Minimal outdoor wiring: Single 12VDC power supply plus feedline
- Modular for easy disassembly and repair
- Wind resistant
- Waterproof to “Seattle standards” for year round use

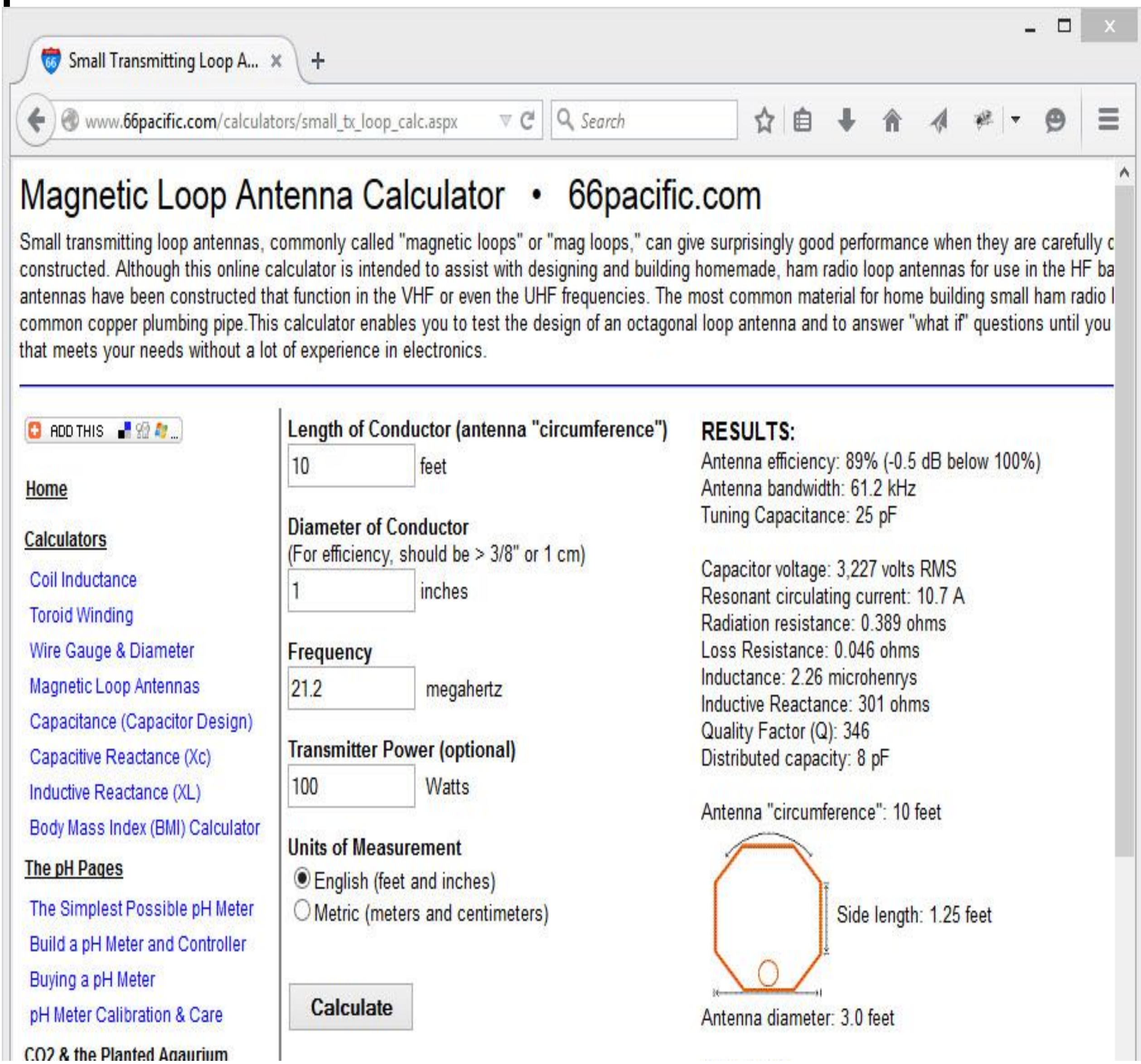
# Why a magnetic loop?

- Very small for a given wave length. 0.1 wave length or smaller.
- Quiet – not affected by electrical interference
- It's sturdy and wind resistant
- Can be mounted close to the ground (1-2 diameters)

# Why not a magnetic loop?

- Extremely narrow bandwidth means tuning is required for nearly all frequency changes
- Requires high voltage and expensive high current variable capacitors
- Great care must be taken to minimize loss resistance
- Not a gain antenna

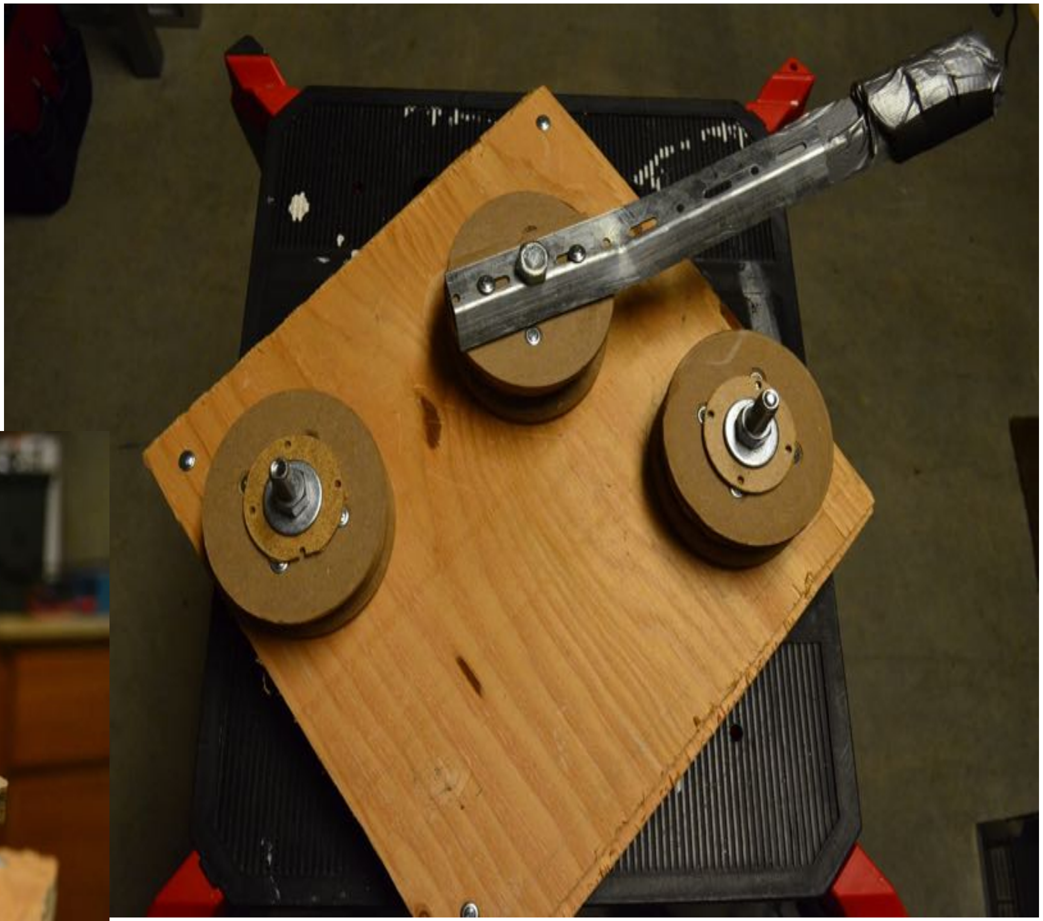
# Loop Calculations



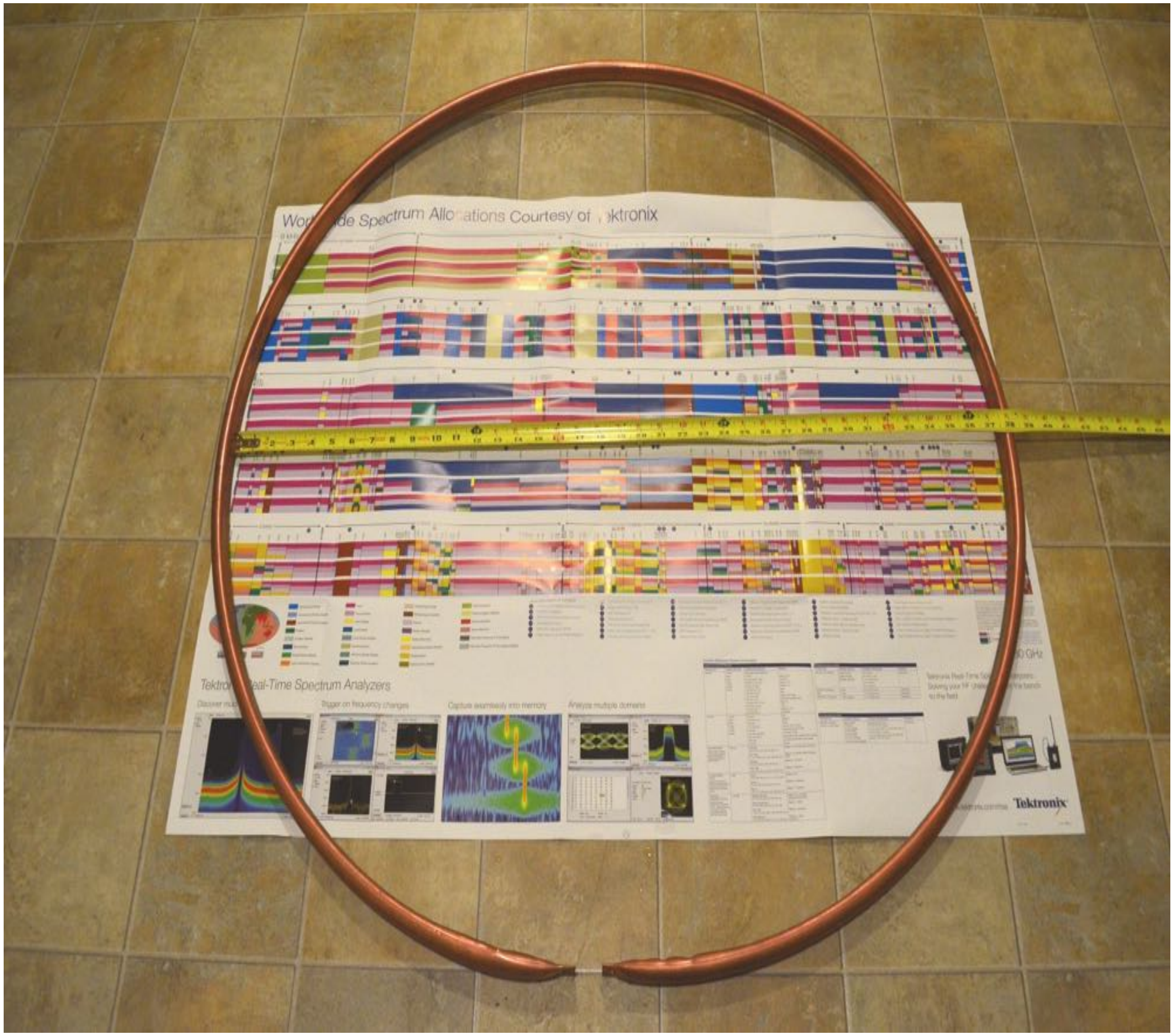
# Fabrication – Copper loop

- Loop is constructed from 10 feet of 1” diameter copper plumbing pipe. (Approx. $15 at Home Depot)
- In order to get the desired bend a bending jig was constructed
- The copper loop took about three passes through the bending jig (with increasing bend angles) to get to the desired radius

# Bending jig



# Finished Copper loop



# Fabrication – Electronics Housing

- Electronics housing was constructed from large diameter PVC pipe
- Brass hardware for loop electrical connections
- Waterproof DC connectors for power and N-connectors for feedline
- Stainless screw caps with ½" spacing for mounting on PVC stand pipe with egg-shaped holes

# Electronics Housing

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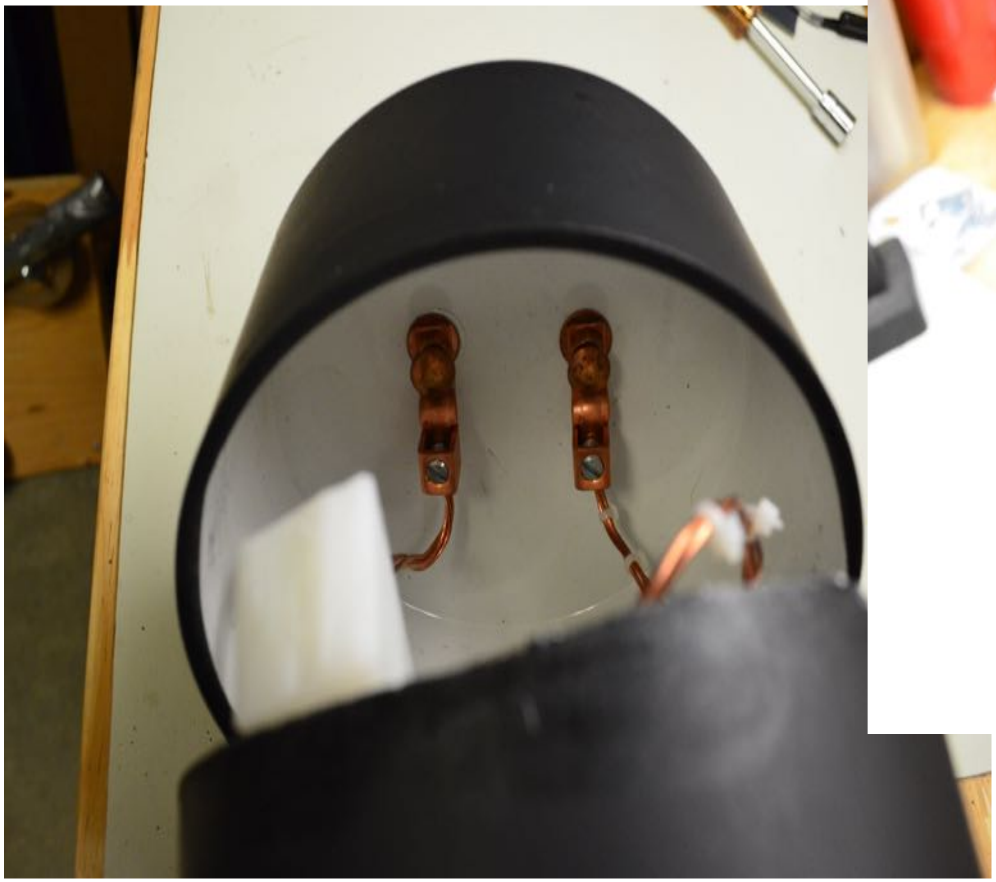


# Electronics Housing

# Fabrication – Electronics Platform

- All electronics (tuning capacitor, stepper motor and control system) were attached to a single HDPE sheet so that they could be managed as a module.
- High-density Polyethylene (HDPE) is chemical resistant, works well with HV and can be worked using standard woodworking tools.

- Important: HDPE will also hold a screw tap.
- Also important: Nothing sticks to HDPE. Glue won't work

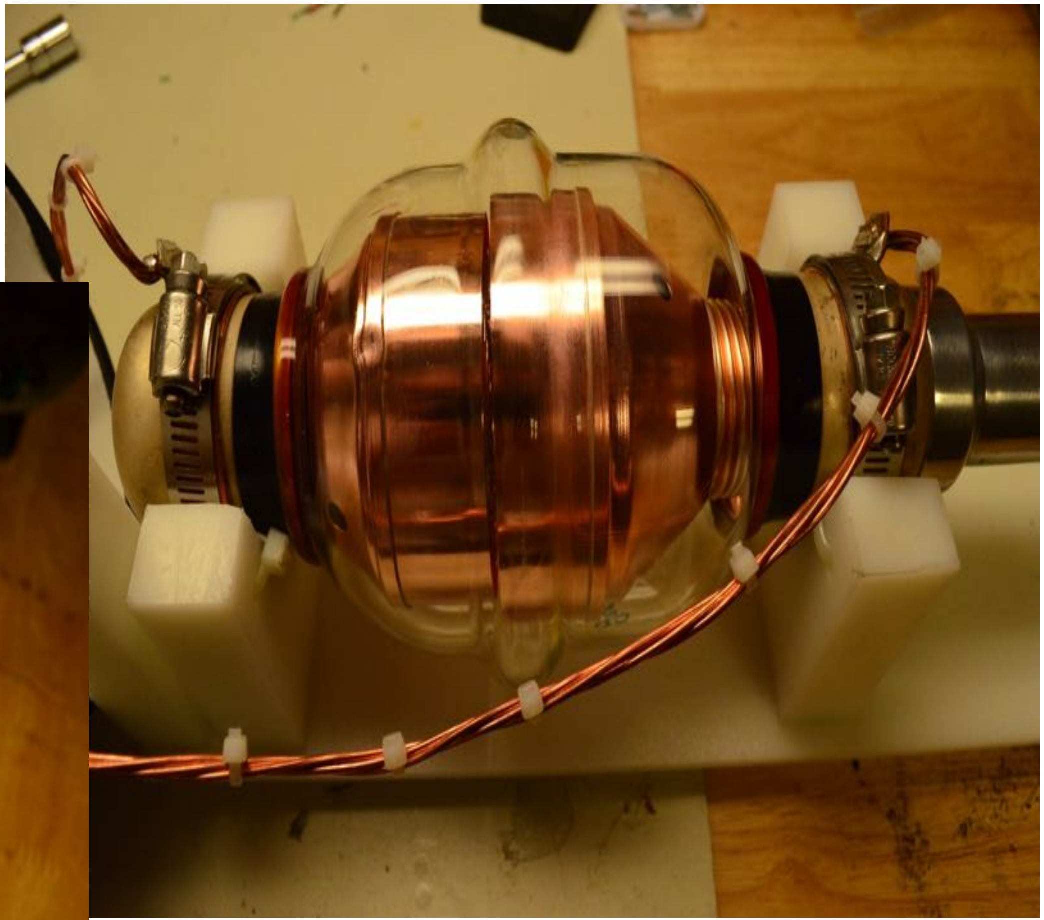
# Electronics Platform

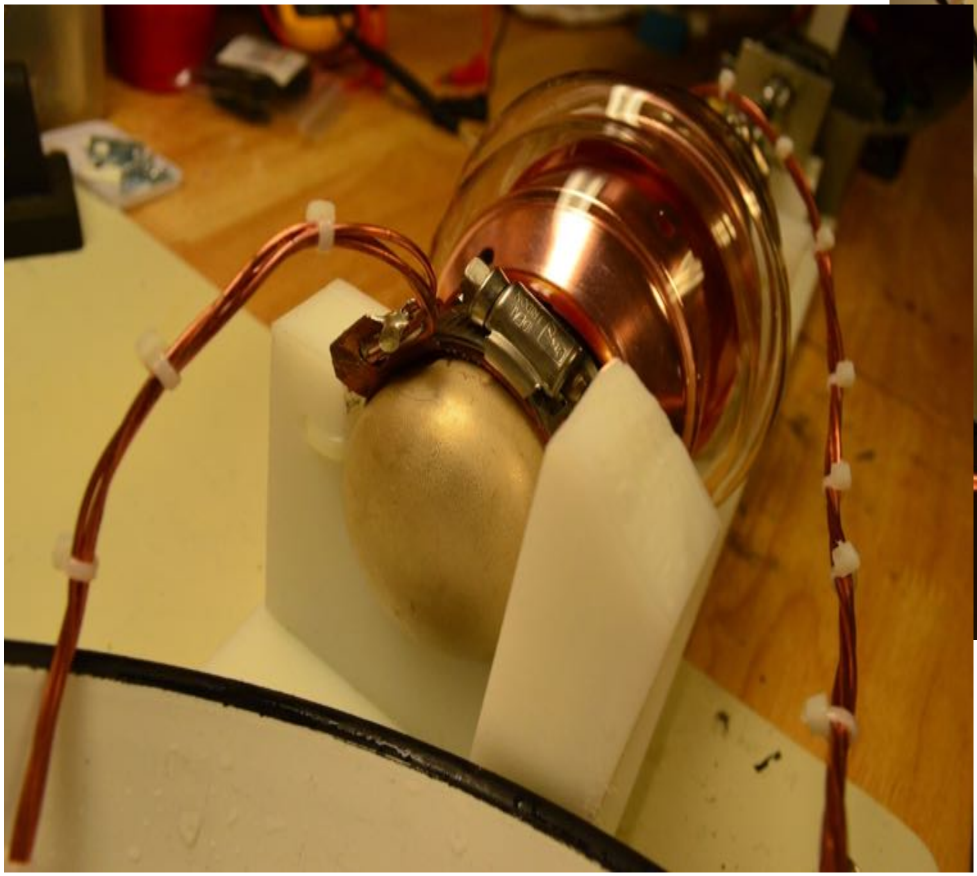
# Vacuum Variable Capacitor

- Jennings 10-75 MMFD (45KV rating) vacuum variable capacitor purchased on Ebay
- Internal copper is still shiny and seals look good
- Combined with a 10ft circumference loop, this capacitance range should theoretically allow tuning of 10M, 12M, 15M, 17M and 20M
- In practice, I can actually only tune 15M, 17M and 20M. This is likely a limitation due to the loop diameter being too large to be optimal for these frequencies.

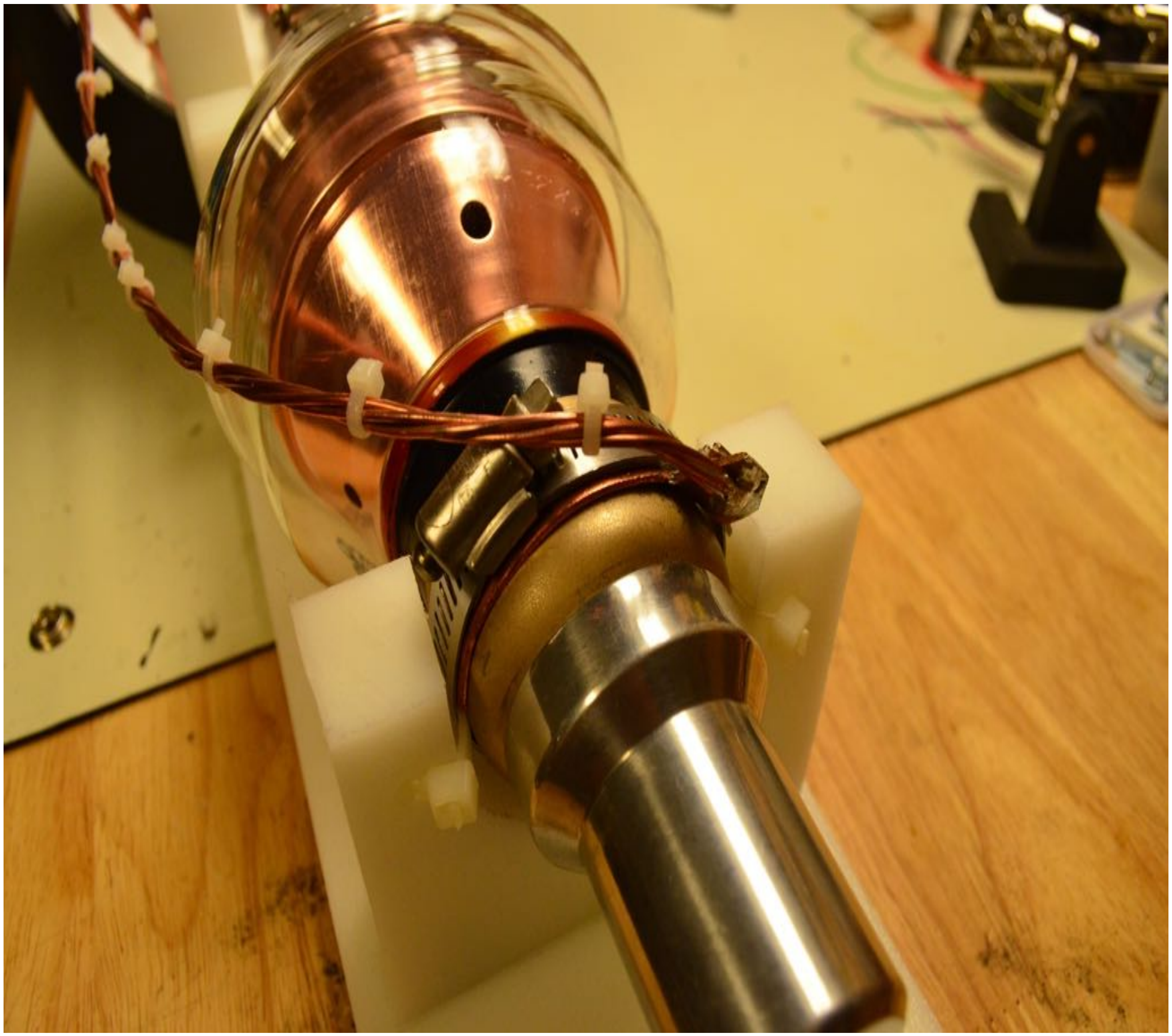
- Note capacitor terminals connected with homebrew copper pads wrapped with hose clamps

# Vacuum Variable Capacitor



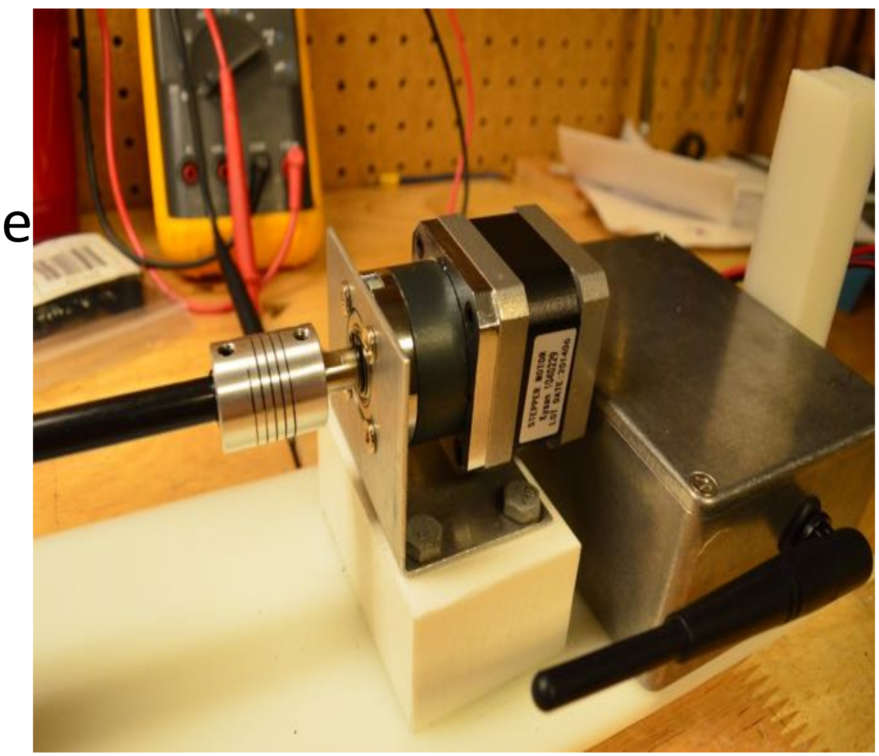


# Vacuum Variable Capacitor

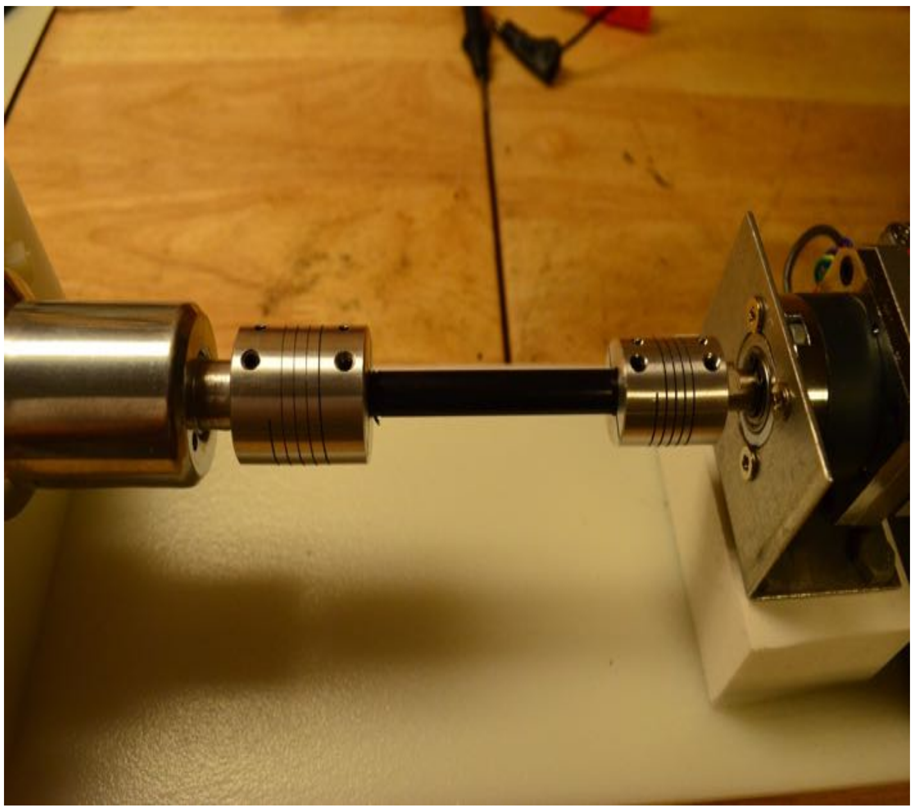


# Stepper Motor

- Kysan NEMA 17 stepper motor purchased on eBay
- This motor has a 5.18:1 planetary reduction gear
  - Gives the motor added torque (the vacuum variable is difficult to turn)
  - Improves capacitor tuning precision
  - Resists backlash when the motor is powered off



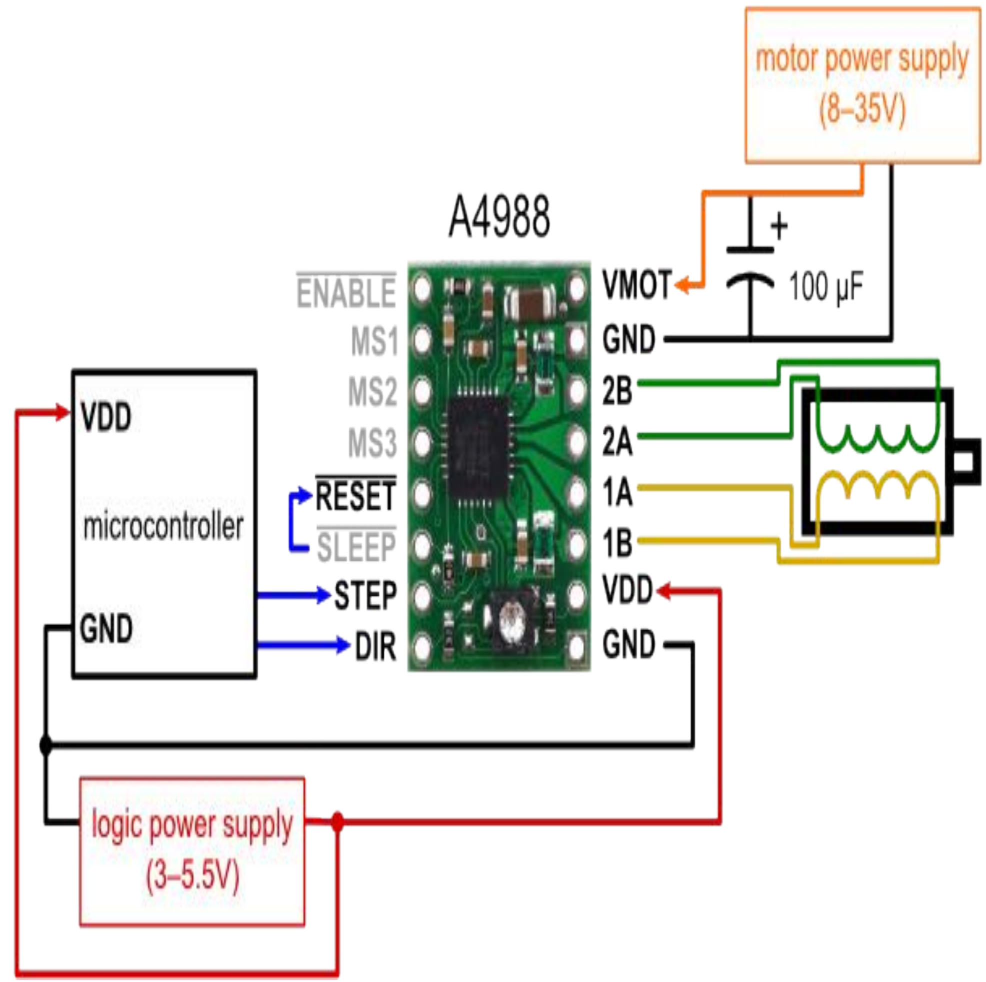
# Capacitor Drive Shaft



- Drive shaft must be non-conductive as the turning end of the capacitor will be at high voltage (~ 10K volts)
- Drive shaft is 8mm Polyoxymethylene (Acetal POM) thermoplastic (eBay)
- Acetal POM provides high stiffness and dimensional stability
- Aluminum flex couplings are used to eliminate the need for precise alignment of capacitor and motor along the driveshaft

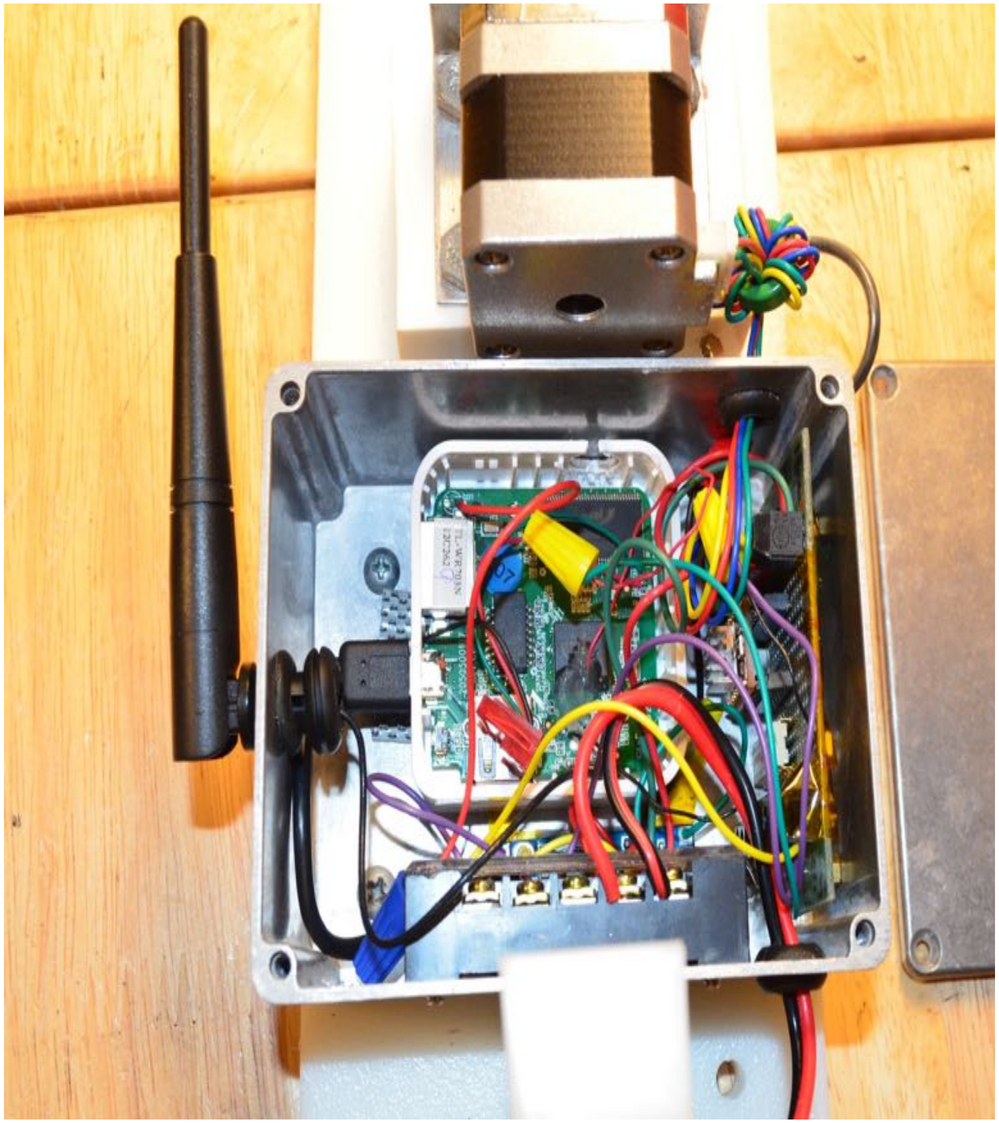
# Motor Control Driver

- A4988 “Polulu  compatible” stepper driver purchased on eBay ($2)
- Will accept a 12V input for motor power supply
- On-board current control trim capacitor
- This driver at a minimum requires two control inputs: step and direction
- Important!  Logic power supply needs to be 3.3V if using 3.3V control signals
- Also: Don’t skip the capacitor!

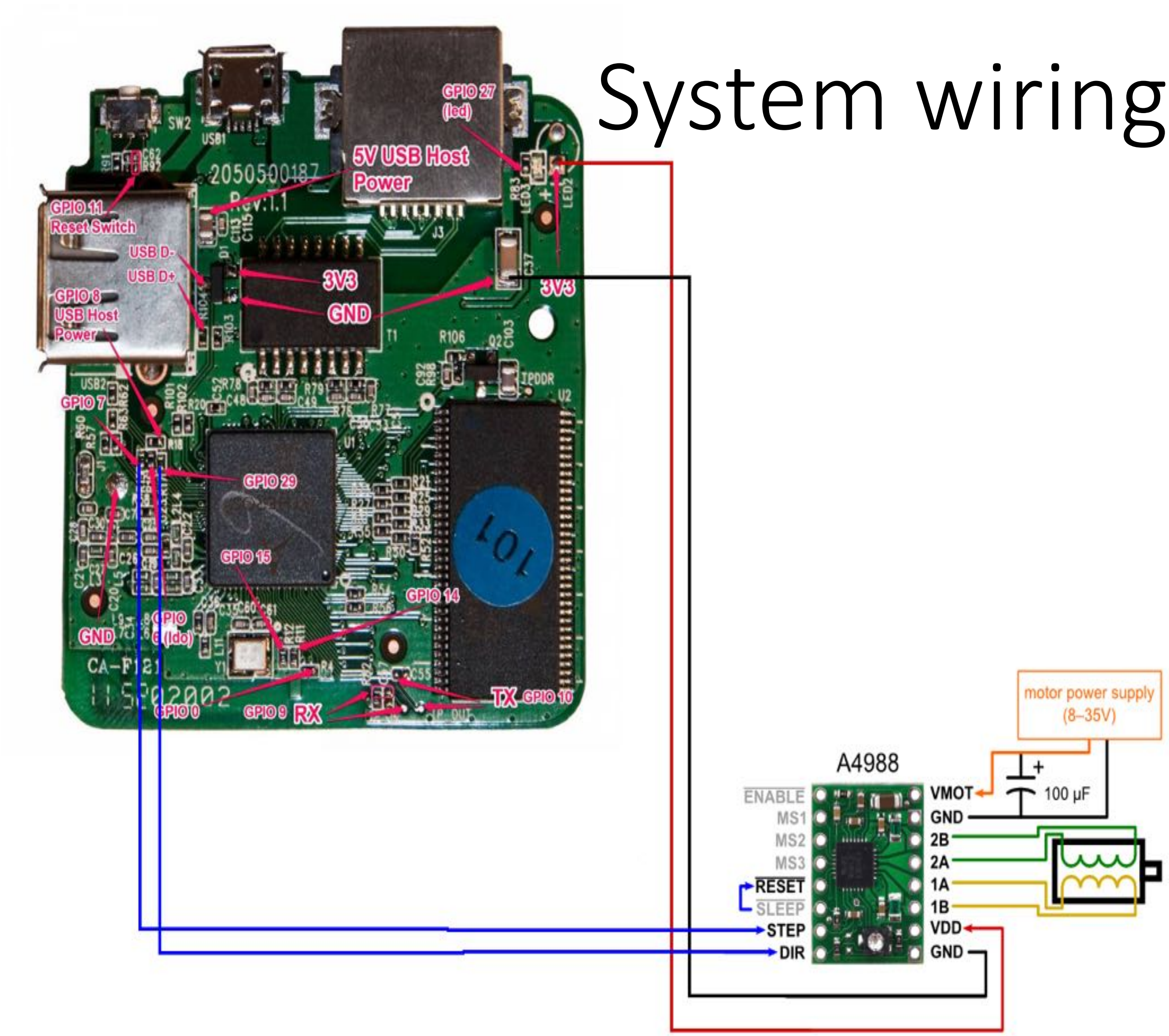


# Motor Control Microcontroller

- TP-Link TL-WR703N mini portable wireless router running OpenWRT in Client Mode
- TL-WR703N modified with:
  - External antenna
  - Wires soldered to GPIOs 7 & 29
  - Wires soldered to GND and +3.3V
- OpenWRT provides
  - ssh access
  - LUA scripting
  - Easy access to GPIO ports
- +5VDC for TL-WR703N provided by DC-DC buck converter (also in case)
- Built into an aluminum Hammond case for shielding



# System wiring diagram



# Motor Control Software

```
require ("gpio")
require ("socket")

MOTOR_DIRECTION_GPIO=29
MOTOR_PULSE_GPIO=7
MOTOR_PULSE_ON_TIME_SECS=0.00001
MOTOR_PULSE_OFF_TIME_SECS=0.0001
TEST_PULSES=10000
LOCKFILE="/tmp/motor.lockfile"
POSITIONFILE="/root/motor.position"
INVALID_POSITION=-99999999

function setMotorDirection(dir)
  writeGPIO(MOTOR_DIRECTION_GPIO,dir)
end

function pulseMotor(numPulses)
  for i=0,numPulses do
    writeGPIO(MOTOR_PULSE_GPIO,1)
    socket.sleep(MOTOR_PULSE_ON_TIME_SECS)
    writeGPIO(MOTOR_PULSE_GPIO,0)
    socket.sleep(MOTOR_PULSE_OFF_TIME_SECS)
  end
end
```

```
function resetGPIO()
  writeGPIO(MOTOR_PULSE_GPIO,1)
  writeGPIO(MOTOR_DIRECTION_GPIO,1)
end

function init()
  configureOutGPIO(MOTOR_DIRECTION_GPIO)
  configureOutGPIO(MOTOR_PULSE_GPIO)
  resetGPIO()
End

function unlock()
  os.execute("rmdir " .. LOCKFILE)
end

function getMotorPosition()
  local position
  local file = io.open(POSITIONFILE, "r" )

…..
```

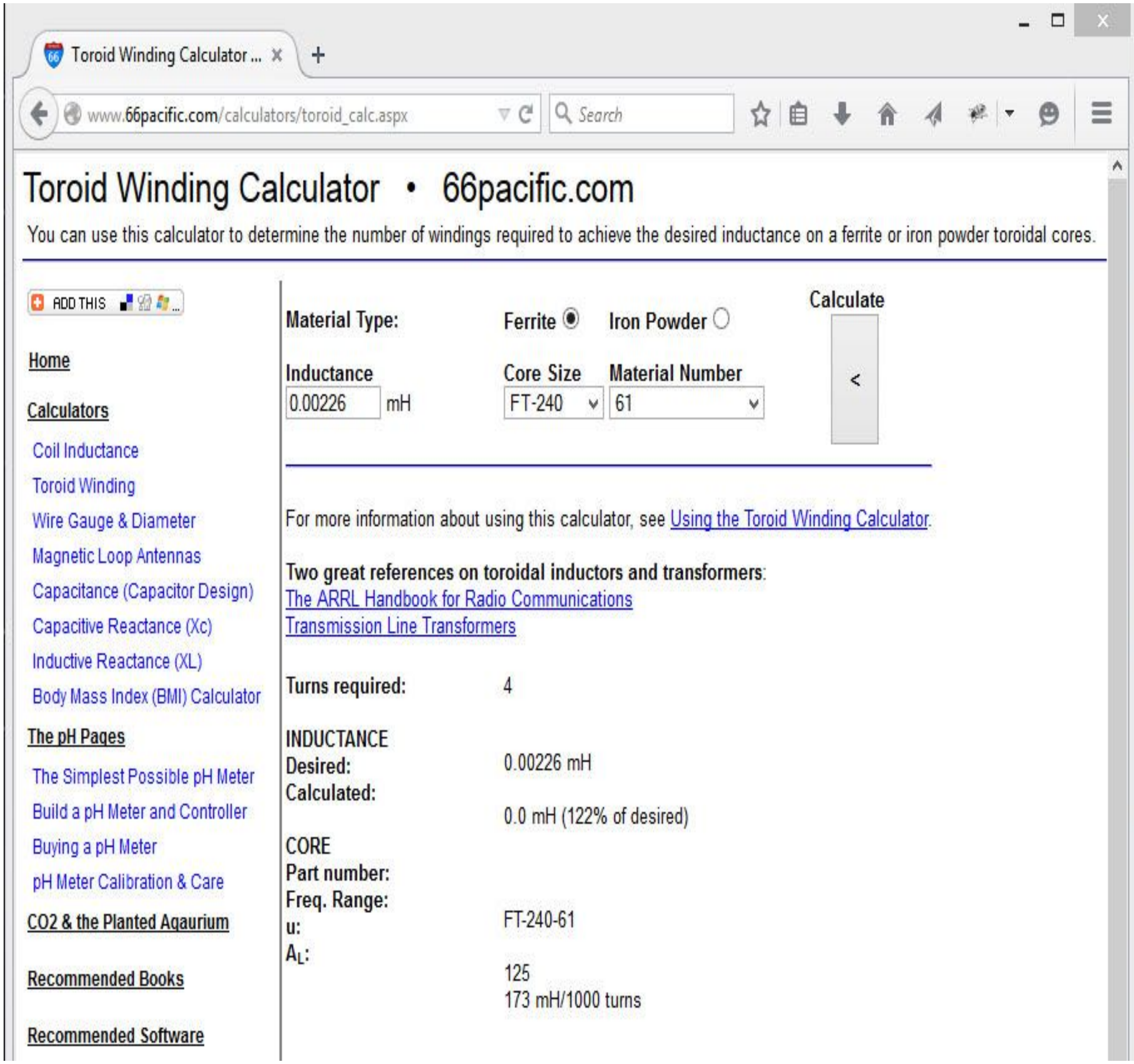
# Magnetic Loop Feedline Coupling Methods

- Unshielded coupling loop
- Shielded coupling loop “faraday loop”
- Gamma match
- Ferrite coupling transformer

Ferrite coupling doesn’t require tuning!

See also: http://www.nonstopsystems.com/radio/frank_radio_antenna_magloop.htm

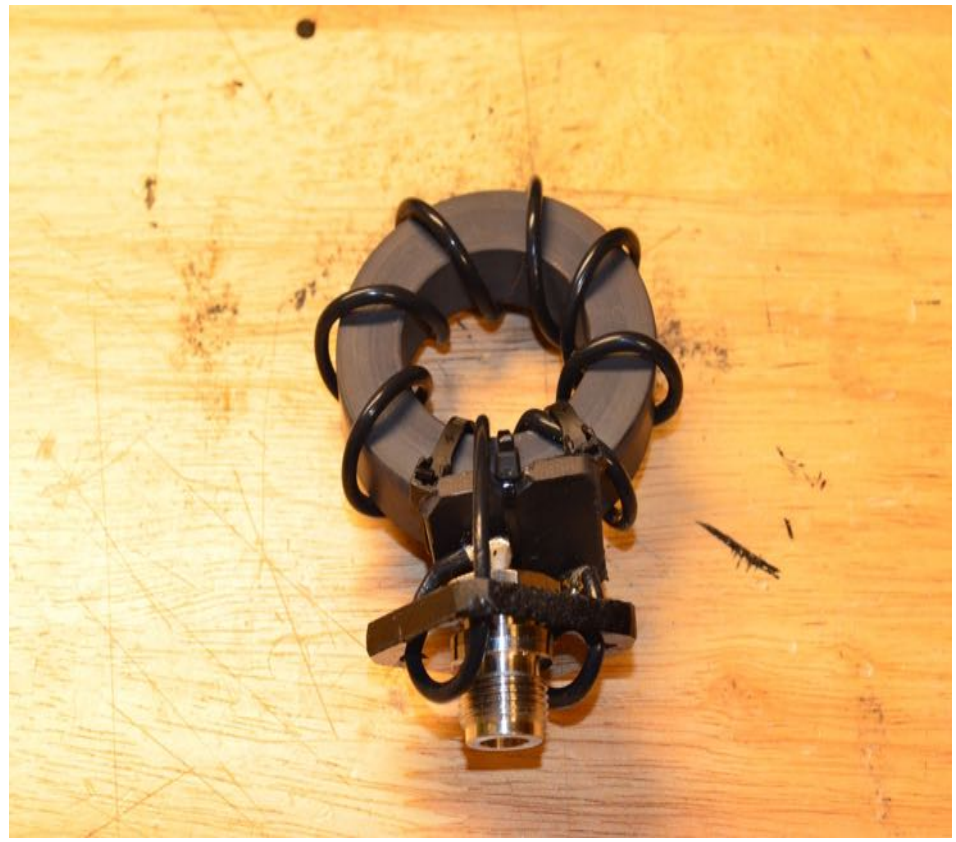
# Ferrite Coupling Calculations



# Ferrite Coupling Fabrication

- Amidon FT-240-61 core
- Wrapped with 12AWG Black Silver Plated Teflon-coated aircraft wire
- Terminated with bulkhead N connector with plastic strain relief

- The version in this image exhibited poor SWR. Final version has three windings total!

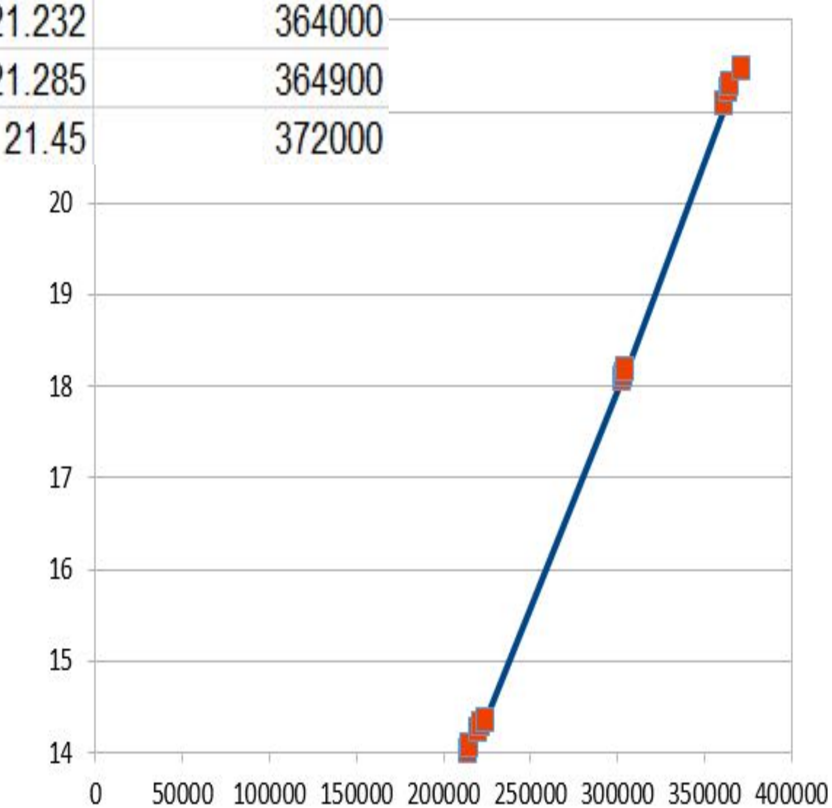


# Calibration

- Calibration was done using an SWR meter
- Motor steps were recorded for different frequency configurations
- The software allows a specific motor step number to be input as a “goto” target for the motor

- Result is that capacitor settings are highly repeatable!

| Frequency | Stepper Position |
|---|---|
| 14 | 214400 |
| 14.07 | 215500 |
| 14.23 | 220000 |
| 14.3 | 222000 |
| 14.35 | 224500 |
| 18.068 | 303000 |
| 18.1 | 303700 |
| 18.168 | 304900 |
| 21.07 | 362000 |
| 21.232 | 364000 |
| 21.285 | 364900 |
| 21.45 | 372000 |



# The Loop Antenna in Practice

1. A coax switch is used in the shack to switch between SWR analyzer and the radio
2. When starting a session I first validate that the SWR is as expected for the current capacitor position. Sometimes this changes slightly (likely due to weather conditions) and has to be adjusted by changing the values in the stepper position file.
3. I then log into the WR-703N using ssh and execute LUA scripts to move the capacitor to the position associated with the frequency I am interested in.
4. I have created separate LUA scripts “presets” which allow me to quickly go to frequencies I typically like to work

# Does it work?

Yes!

First contact with Ohio with 30 watts MFSK on 20 meters. 599 report.

More recently made an SSB voice mode contact with Puerto Rico with 100 watts. 59's reported

Performance has been very steady. Recalibration is generally not required before use.

# Future Work

- Using the table of capacitor steps to frequency, curve fit a formula (looks linear) to compute capacitor steps for any frequency input. Change the LUA script to use the formula for tuning.
- Connect CIV output from Icom 7000 to another WR-703N in the shack. Read out the current frequency and automatically signal the Motor Controller to tune the capacitor accordingly
- Create a web gui (hosted on the Motor Controller WR-703N) that allows easy access to LUA script execution and displays capacitor position in real time
- Measure motor-capacitor backlash. Look into backlash compensation for stepper motor direction changes on the stepper motor
- Map out the effect of exterior weather conditions (wet vs. dry) on SWR and determine if this can also be automatically compensated for

# Questions?