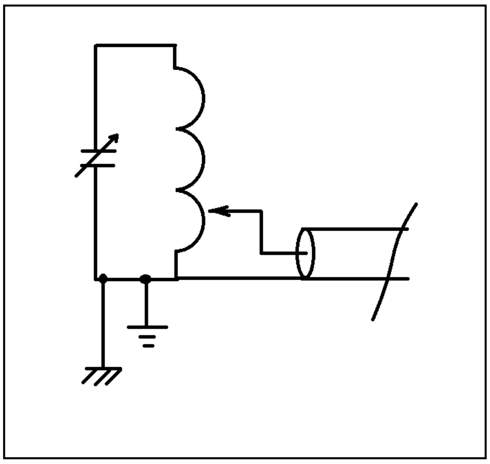
80m loop Antenna

Michael Harvey VK2JMJ December 2021

Specifications

- Not to copy any other design.
- Cover the 80m band only.
- Driven by a stepper motor controlled via a microcontroller.
- Interface to Wifi to a smart phone.
- Compact size as space in the back yard is limited.
- Tidy and compact so the neighbour does not freak out about COVID and 5G.
- Able to be mounted on a single pole mast to gain height.
- Able to fit into the back of a VW caddy van. (4 metre circumference)



Theory

Antennas are basically a resonant element in the sky. That resonance can be obtained by a natural RF length or wavelength of wire. That length can be physically shortened or made to look longer at RF by adding inductance in that length. A combination of inductance and capacitance makes the element resonate. This design has a fixed inductance and a variable capacitance. The start of the inductor is physically grounded to the coax shield and mast ground and physical ground. The other end of the inductor is connected to the hot side of a variable capacitor. The cold side of the capacitor is tied firmly to the start of the inductor and therefore is also grounded. The equivalent circuit is a grounded LC tank, out there in the sky.

The inductance

I chose to use aluminium rod, 12mm solid in 4m lengths. Once around and relying on parasitic capacitance, it produced a dip at about 20mhz. Adding capacitance dragged the resonance down to 7mhz. So I went around twice. The natural resonance reduced to about 7mhz. Adding capacitance dragged the resonance down to 2mhz. So that will do. Twice around using 4m lengths of 12mm solid aluminium. I used rural electric fence insulators to hold the inductor away from ground and provide mechanical strength to hold the loop up-right. The insulators were also used around the loop to hold the inductance value steady. The rod lengths are welded in length to avoid noisy joints.


The capacitance

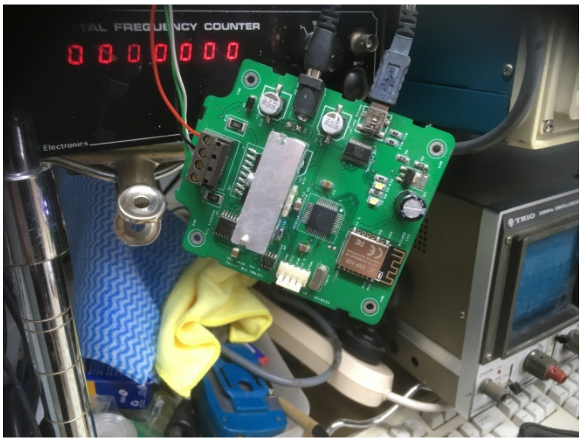
I am not going to spend big bucks on a evacuated variable like everyone else does. I will make my own HV capacitor. The capacitor design went through an evolution process including the need to increase the air gap to avoid flashing over. The air gap has about 5mm between the plates and this gap is wide enough for my 100W drive. Some first designs used nylon spacers, but alas, the spacers became conductive under power (ie voltage stress).
I used porcelain electric fence insulator bobbins with a bearing inserted into the bobbins. Bunnings sell a small U-bolt that exactly fits the centre of the bobbins and a 10mm threaded rod fits though the bobbin hole. The hot side assembly swings freely on the bearings. The cold side is mechanically connected to the mast mounting. A stepper motor is mounted on the grounded (cold) side with a stainless steel threaded length as a screw drive and a 12mm stainless steel bar running a linear bearing. The stepper motor directly drives the screw thread parallel to the linear bearing and shaft. The linear shaft swings the stepper motor drive mounting to maintain a constant angle as the plates move apart. The capacitor plates are not shaped to produce a linear result and do not take much movement to vary the resonant point of the aerial. The useable SWR range of the resonant dip is 10 khz wide. The capacitor gives a range of 30pf to 160 pf. The design of the software fixes any need to make the capacitor linear.

The impedance Match

I will not be using an ATU in the shack. I don't believe in them and I don't have one.
I believe the coax should be a transmission line and not be part of the tuner. Coax length then becomes un-important and irrelevant (expect for in length losses).

The transceiver presents 50 Ohms resistive to the coax and the coax presents 50 Ohm resistive to the aerial. The antenna must present 50 Ohm resistive to the coax. Consider the grounded end of the inductor that is connected to coax shield (connected to mast ground). This will be the ZERO Ohm point and the ZERO volts point. Consider the other end of the inductor. This can be considered as the INFINITY Ohms point and maximum voltage point. Somewhere around the loop and close to the grounded end will be a match to the required 50 Ohms. Another short rod transports the centre of the coax around the loop to the (unknown) 50 Ohm point.

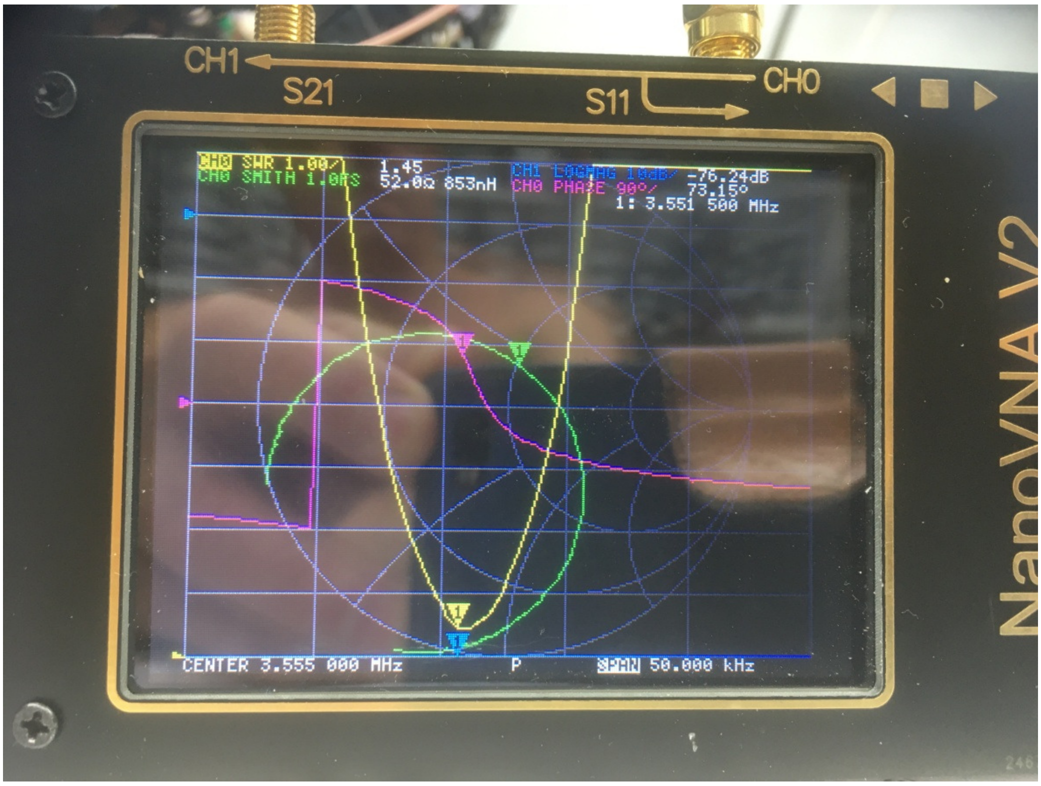
The gamma match leaves a small amount of inductance on the Smith Chart at the 50 Ohm match. Cleaning this small amount away is not important to me, but I am open to suggestions for future modifications. Using a gamma match restricts the frequency range that a good match can be obtained, but my design specification is to cover the single 80M band only so a gamma match will suffice. The equilivant circuit is now as shown.



Microcontroller

- Microchip 32bit 40 pin QTFP microcontroller. PIC32MX270F256D.
- I2C EEPROM chip.
- I2C IO chip to driver the stepper driver IC.
- ESP12S wifi module to connect a smart phone.
- USB to serial chip for a debug serial interface into a Windows 10 serial program.

The first prototype used a smart stepper driver IC with a PWM current control on chip. When this stepper chip came alive, the PWM noise fully saturated the receiver with noise. A much cheaper and dumb DC H Bridge stepper driver IC was used and it produced much less noise. The schematic and PCB design was completed in RS Design Spark PCB. JLC PCB manufactured the board. (You may use PCBWAY as an alternative). I manually populated the board with SMD and through components. Microchip MPLABX was used to program in C with the ICD3 programmer to transport the code into the microcontroller. I wrote the I2C and serial and stepper driver routines and the HTML for the smart phone interface. You may ask "why all this trouble"? Amateur radio is not just about picking up a microphone and talking to some dude.



The program flow

The EEPROM remembers the stepper position as a number steps away from a mechanical home. The last position of the motor is always known, even with no power. A look up table inside the EEPROM makes the link from a requested frequency to the number of steps to move, forward or backward, as steps away from home. The design of the capacitor will determine an unknown number of steps from 3.500mhz to 3.995mhz. A software utility is used move the motor between the two extremes to determine the unknown number of steps required. The capacitor design shown required over 3,000 steps between the extremes. When ready, the EEPROM is formatted with calculated divisions as 'steps away from home' and calculated to 5khz divisions over the range.

When selecting "Go to a Frequency", the lookup table is used to move the motor a number of steps. A "Fine Tune" utility is used to add or subtract steps at that frequency. The fine tune utility may be used at any other frequency when selected. This has removed any need to worry about the action of the variable capacitor being non linear.

How to use

Connect the Wifi of the phone to the ESP12S wifi module. Browse to the gateway IP provided and contest a login. From a menu drop down, select the frequency. The motor runs the number of steps from the last position to the new position.

Adjusting the GAMMA MATCH

I used the Nano VNA directly at the aerial connector. This ensures the aerial is presenting 50 ohms to the coax. Avoid trying to set the matching bar with the VNA at the shack end of the coax. Inductance and capacitance of the coax will confuse the result. Clean the aluminium rod and the matching bar with sand paper to ensure clean contact. Move the matching bar to obtain a good SWR dip at a frequency in the centre of the band. Apply final adjustments to the bar. Remember your body near the loop changes inductance and capacitance.

Power test

Prove the capacitor does not flash over under full power peaks.

(1) view at night. Look for a blue light at the edges of the capacitor plates.
(2) watch the return VSWR under full power peaks. A pulse in the return power will indicate a flash over.
(3) use another receiver and listen for splatters away from the transmitting frequency and also out of the band.

Joints test

Use the VNA to display a sweep and wack the mast and aerial with a hammer. Any bad joints with show up as noise on the VNA. You may consider oils and grease to seal away joints.

When does development stop

I stop development when "that will do, pig".

(1) future builds could use a frequency counter connected to the VFO of the transceiver. The VFO count result would then move the capacitor the steps required to chase the VFO.
(2) a touch screen interface rather than "I can't join the 80m net because I can't find my phone".
(3) an old school LED 8 segment with a jog toggle knob to make a cluster of radio gear look for the shack.
(4) drink Merlot, start next project.
    - He who dies with the most stuff wins.
    - He who has the most unfinished stuff never dies.
    - The more you learn, the more you realise what you don't know.
    - If you stop learning, you must be dead.
    - Keep learning.

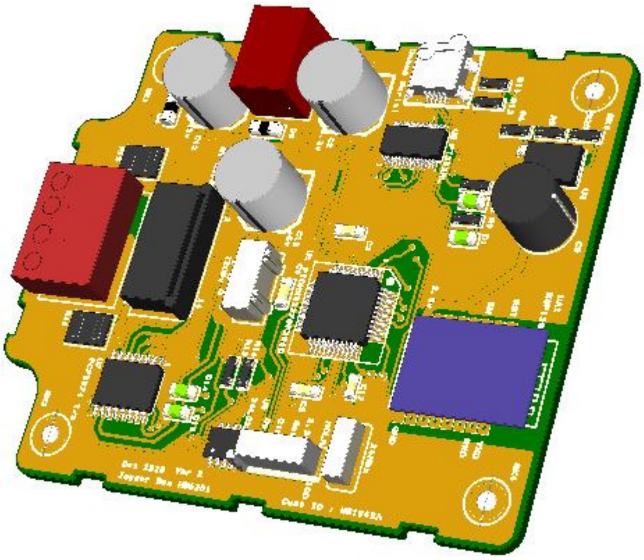
Construction hints

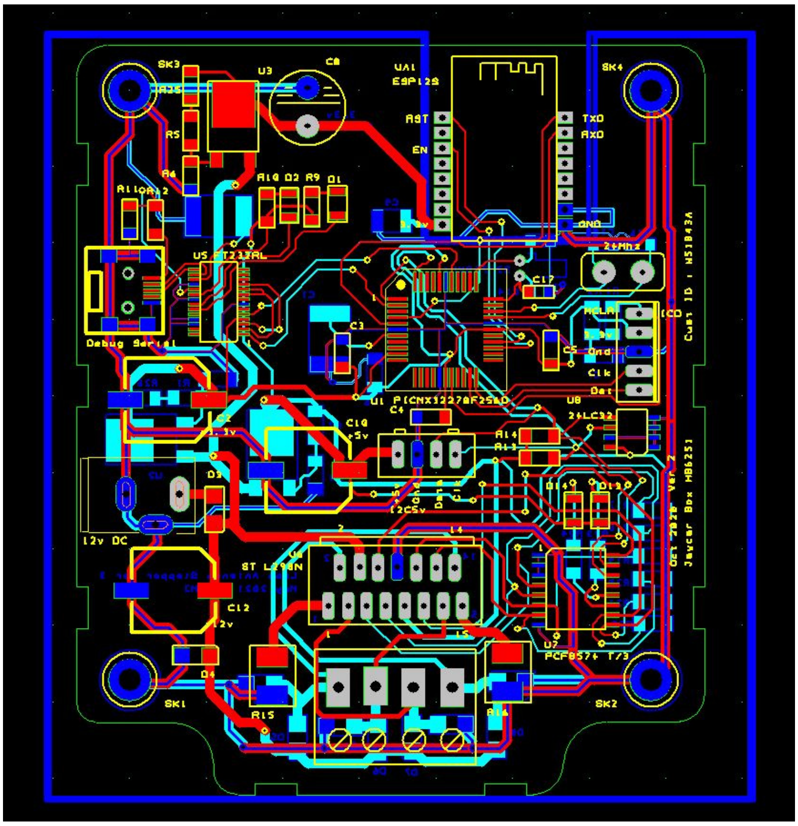
Aluminium to aluminium joints	Welded
Aluminium to zinc bolts and washers	OK
Aluminium to Cu copper wire	Avoid

Avoid any chance for corrosion and creating metal salts.
Make connections as aluminium to aluminium. Compression is suitable, welding is best.
The only other metal to contact the aluminium is zinc (zinc coated nuts, bolts, washers)
Where a Cu wire (ie, the centre of the coax) is needed, solder a zinc coated tab to the Cu and then compress that tab between zinc washers and use zinc coated nut and bolts to the aluminium.

I have built a rain shade to keep water off the plates. Water droplets change the capacitance value. Bugs and spiders between the plates are of no concern. A quick blast of RF quickly dispatches them in a puff of smoke.

VK2JMJ Albury




SK3
U3
C8
UA1
ESP12S
SK4
RST
TxD
RxD
EN
R5
R4
R10
D2
R9
D1
R11
R12
GND
24Mhz
Cust ID : WS1843A
U5 FT231XL
C17
Debug Serial
MCLR
Gnd
Clk
Dat
C3
C5
U8
24LC32
C10
+5v
R14
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U7
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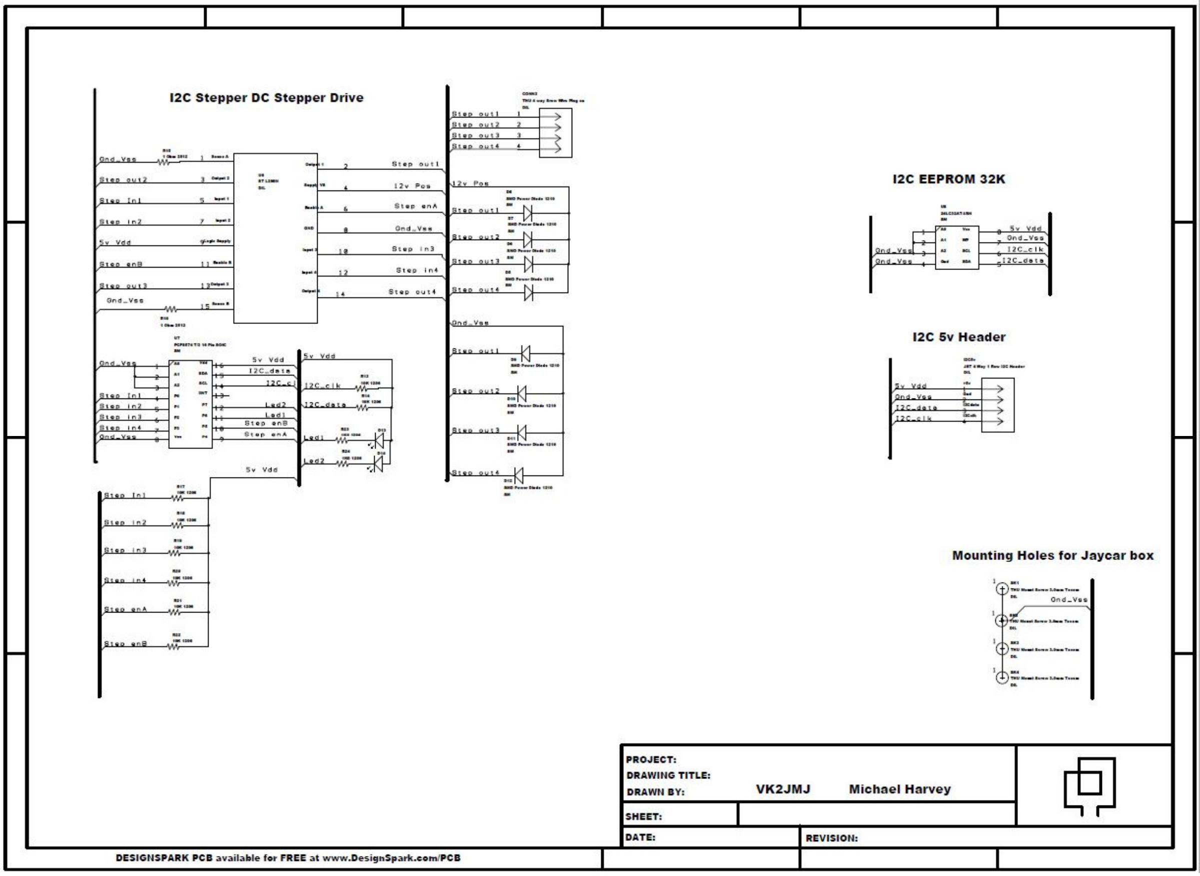
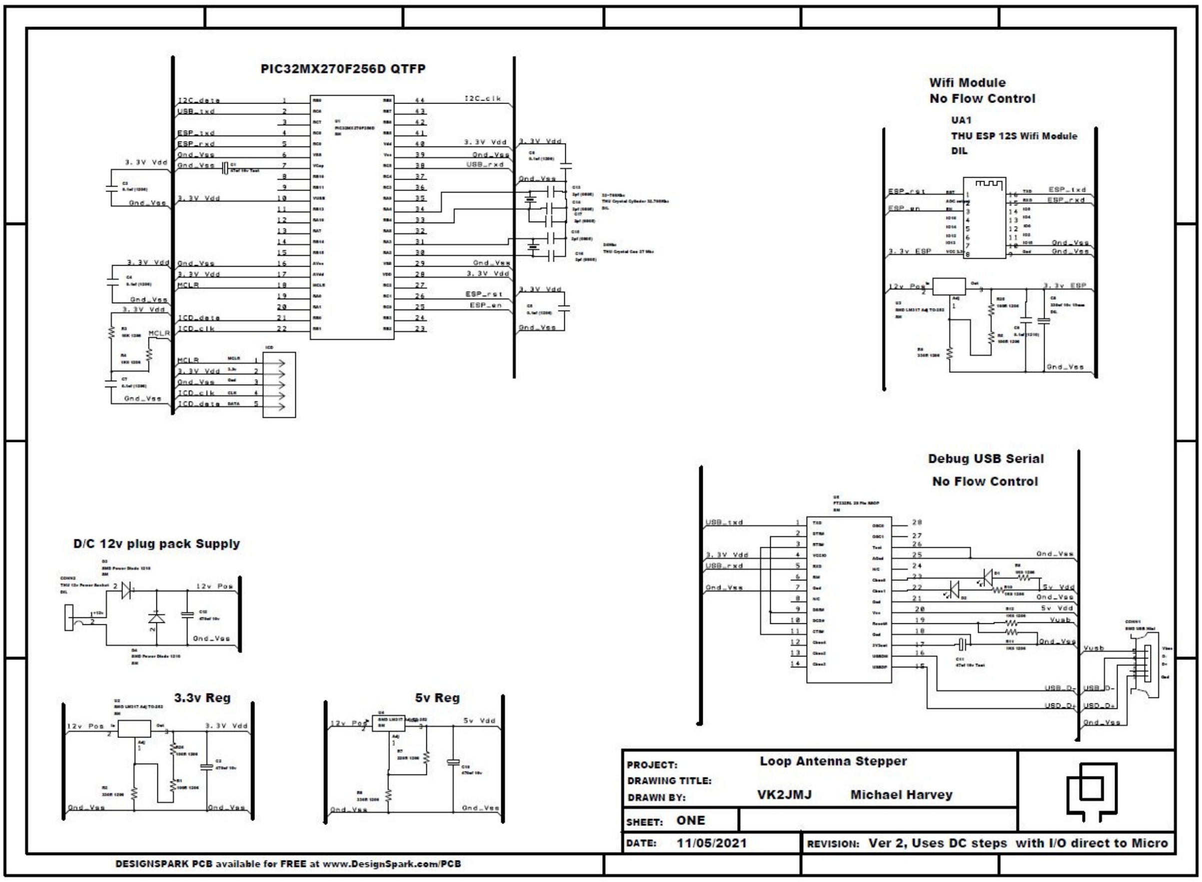
SK2
D4
R15
R16


I2C Stepper DC Stepper Drive
I2C EEPROM 32K
I2C 5v Header
Mounting Holes for Jaycar box
PROJECT:
DRAWING TITLE:
DRAWN BY: VK2JMJ Michael Harvey
SHEET:
DATE:
REVISION:
DESIGNSPARK PCB available for FREE at www.DesignSpark.com/PCB


PIC32MX270F256D QTFP
Wifi Module
No Flow Control
UA1
THU ESP 12S Wifi Module
DIL
Debug USB Serial
No Flow Control
D/C 12v plug pack Supply
3.3v Reg
5v Reg
PROJECT: Loop Antenna Stepper
DRAWING TITLE:
DRAWN BY: VK2JMJ Michael Harvey
SHEET: ONE
DATE: 11/05/2021
REVISION: Ver 2, Uses DC steps with I/O direct to Micro
DESIGNSPARK PCB available for FREE at www.DesignSpark.com/PCB