Low Band Receiving Loops

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Design optimization and applications, including SO2R on the same band

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www.n6rk.com/loopantennas/pacificon.pdf

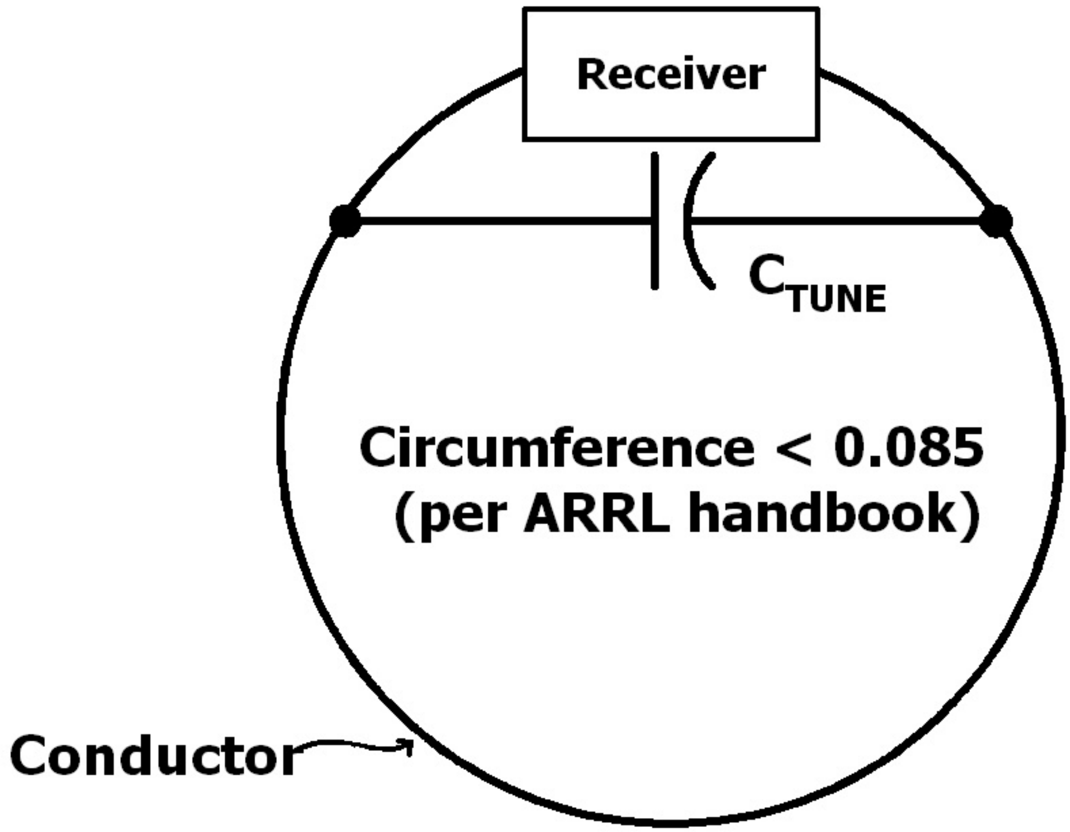
Topics

- Small, square so-called “shielded” receiving loops for 160m and 80m.
- Theory
- Design and optimization
- Applications
- NOT: Transmit loops, delta loops, “skywire” loops, ferrite loopsticks, non-ham freq., mechanical construction

Why this presentation is necessary

- Available literature on loop antennas is unsatisfactory for various reasons
- Misleading/confusing
- Incomplete
- Not applicable to ham radio
- Folklore
- Just plain wrong (even Terman is wrong)
- Even stuff published in Connecticut

The classic loop antenna



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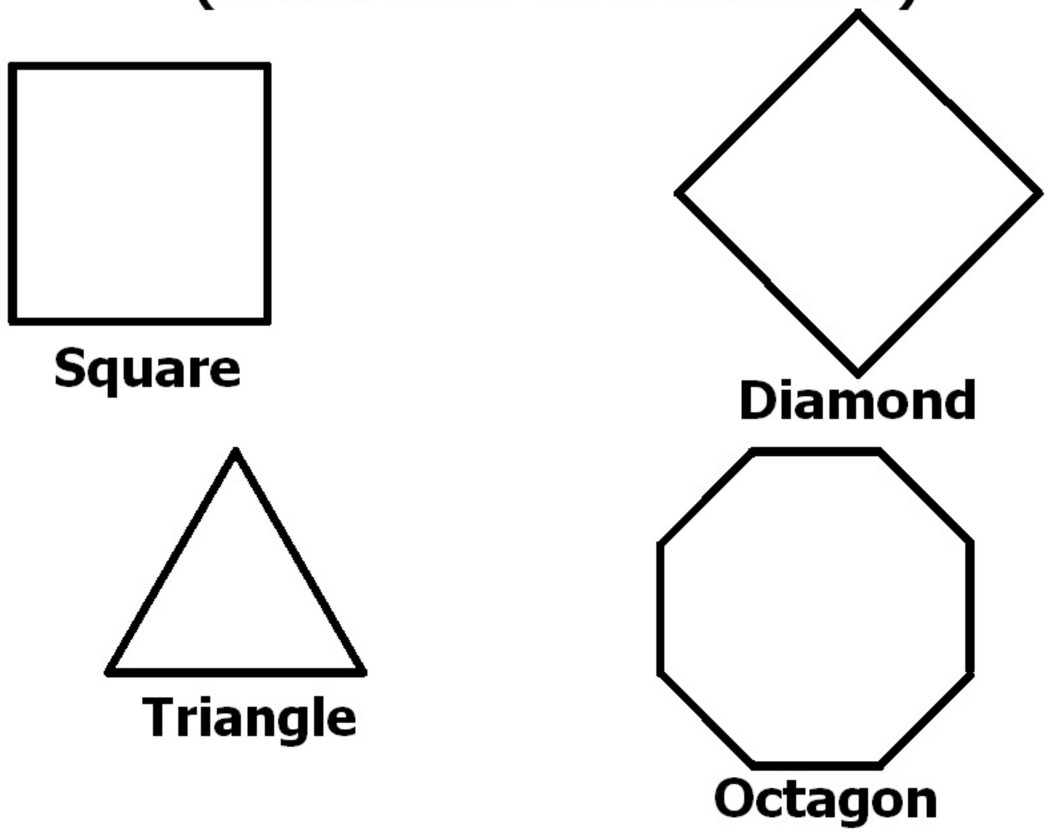
Any symmetrical shape OK

I will discuss square loops because they are the simplest mechanically (in the form on a diamond)



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Loop antenna characteristics

- Same free space pattern as a short dipole
- Directivity factor 1.5 = 1.76 dB
- Sharp nulls (40 to 80 dB) broadside
- Much less affected by ground and nearby objects than dipole or vertical
- Low efficiency (~0.1 to 1%), about the same as a modest mobile whip
- Portable (no ground radials needed)

Why to use a receiving loop

- Can null interference (QRM or QRNN)
- Direction finding to locate QRNN
- Remote receiving antennas
- SO2R on the same band (160 meter contests, field day, SOSB, DXpeditions
- Although vertically polarized, may be quieter than a vertical

Design equations: size, inductance

- Maximum size side = 0.02125 wavelength
- 10 ft at 2 MHz; 5 ft at 4 MHz
- ARRL Antenna Book inductance is wrong
- $L=0.047\ s \log(1.18s/d)$
- $L=\mu H$; s = side(in); d = conductor dia(in)
- Reactance of max size loop = 226Ω for s/d = 1000, independent of frequency
- Only weakly dependent on s/d

Conductor loss resistance

- We will assume copper conductor
- Conductor loss depends only on s/d
- Conductor loss at 2 MHz = 0.00047 s/d
- If s/d=1000, conductor resistance = .47Ω
- Conductor loss at 4 MHz max size loop= 0.00066 s/d
- If s/d=1000, conductor resistance = .66Ω

Radiation resistance

- Radiation resistance = $(F_{MHZ}s/888)^4$
- For max size loop, R_r = 0.0064 ohms, independent of frequency
- At 2 MHz, $R_r = (s/444)^4$
- At 4 MHz, $R_r = (s/222)^4$
- Radiation resistance is negligible compared to conductor loss

Loaded Q; efficiency

- For maximum size loop, s/d = 1000, theoretical Q_L = 240 @ 2 MHz, 171 @ 4 MHz
- Theoretical efficiency η = 1.4% (-18.5 dB) @ 2 MHz; 0.97% (-20.1 dB) at 4 MHz
- Gain will be higher by 1.76 dB directivity factor
- Doubling s increases efficiency 9 dB
- Doubling d increases efficiency 3 dB

Maximum circumference

- No definitive explanation of where this number comes from is published AFAIK
- In a “small” loop, current is uniform everywhere in loop
- As loop size increases, current phase becomes non uniform
- For large loops current magnitude is also non uniform

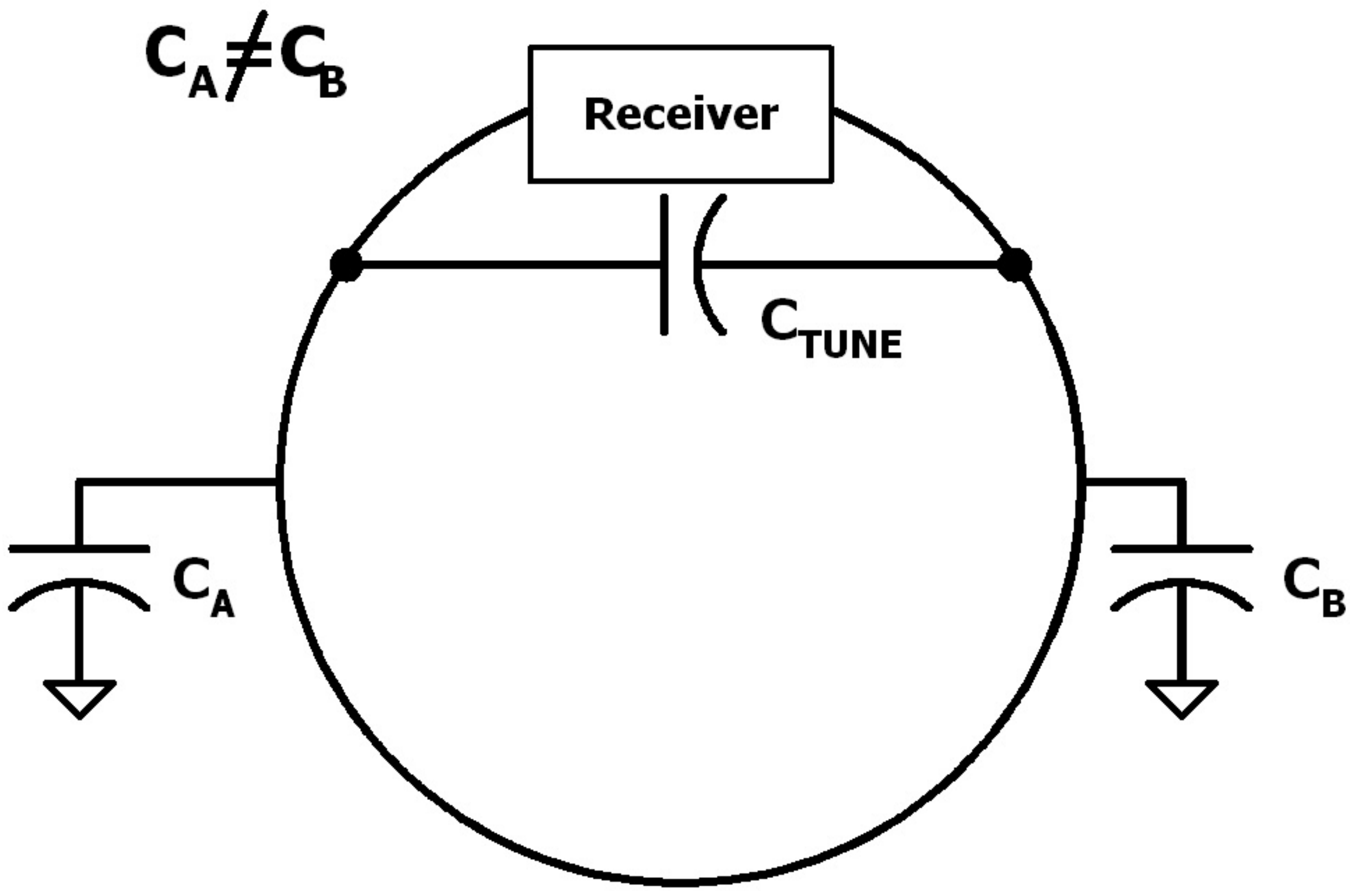
Effects of “large” loop

- Supposedly, a too-large loop will have poor nulls, but is this really true?
- For vertically polarized waves, there is a broadside null for any size, even a 1 wavelength “quad” driven element
- For horizontally polarized waves, there is an end fire null for any size
- Topic for further study
- I will use ARRL limit of 0.085 wavelengths

Multiturn loops

- Maximum perimeter rule applies to total length of wire, not circumference of bundle
- To the extent that max perimeter rule applies, multiturn configuration greatly limits loop size
- Multiple turns are a circuit design convenience, they do not increase loop sensitivity
- Multiple turns in parallel make more sense
- We will assume single turn from now on

Imbalance due to stray C



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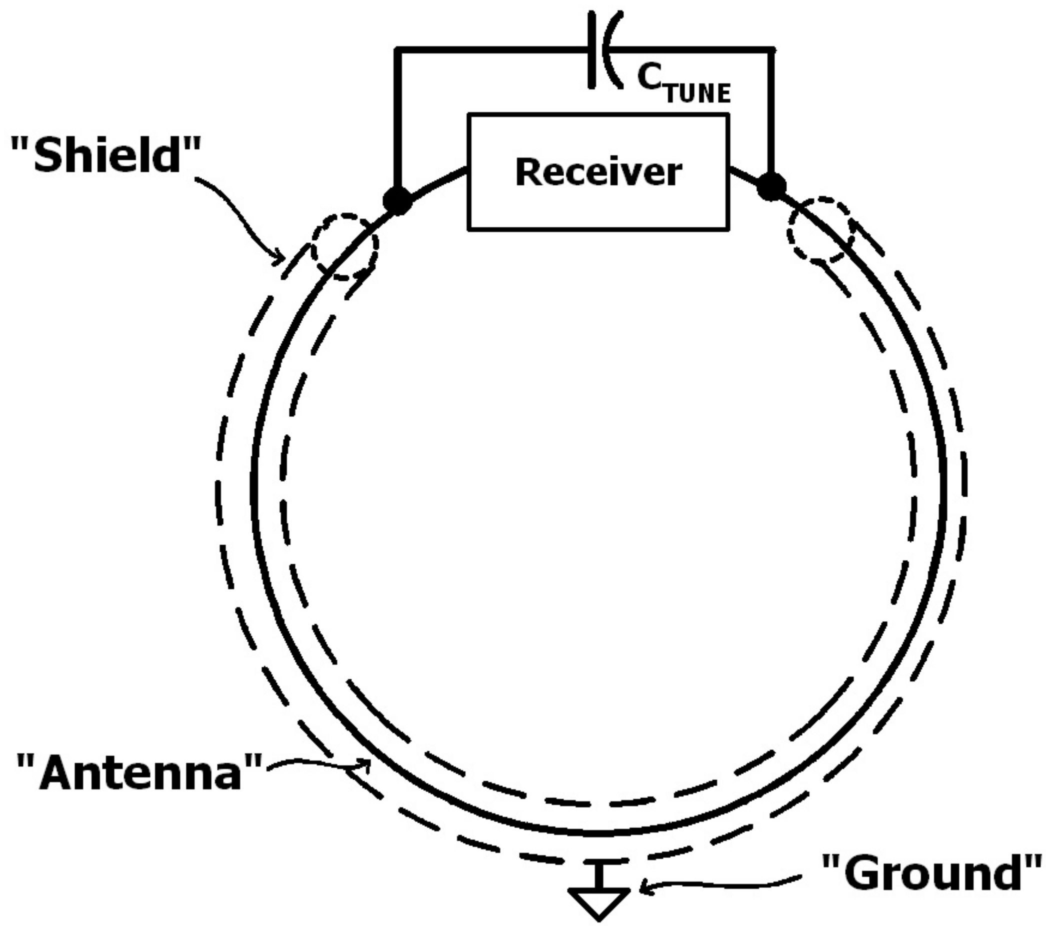
The classic “shielded” loop



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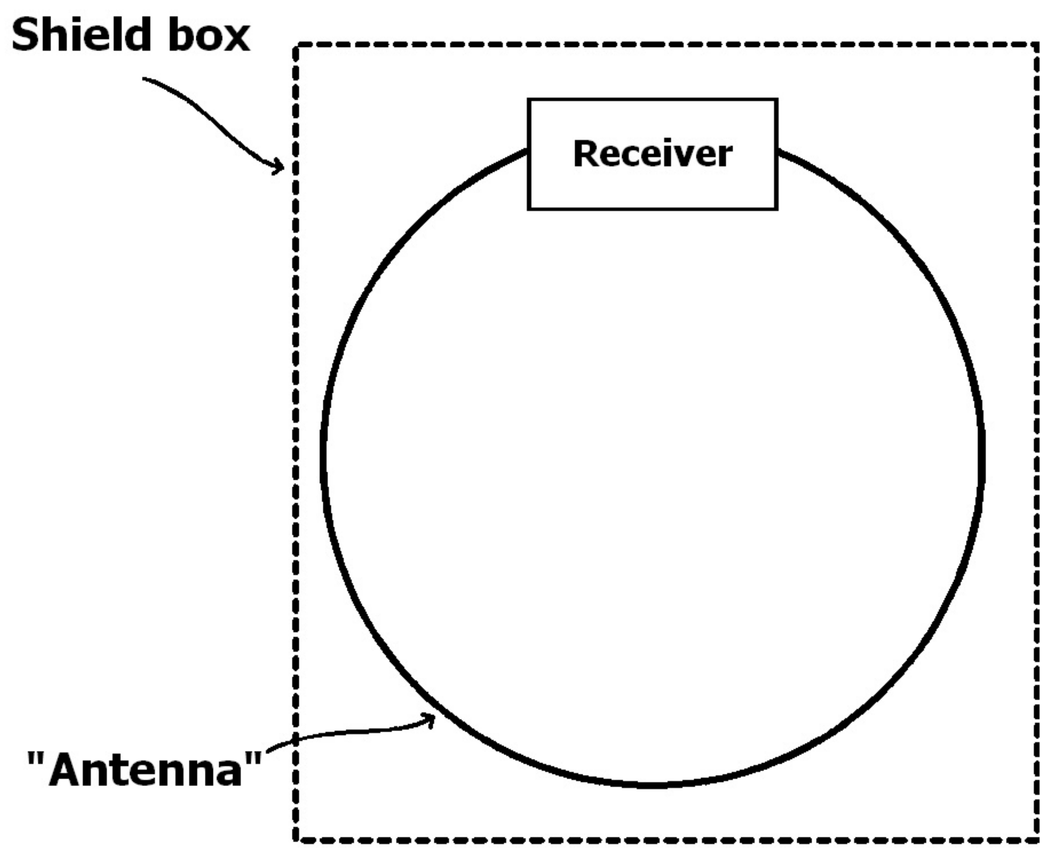
So-called “shielded loop”

- First described (incorrectly) in 1924 as “electrostatic shield” and repeated by Terman
- If the loop were really an electrostatic shield, we could enclose the entire loop in a shield box and it would still work; we know that is false
- Theory of shielded loop as published overlooks skin effect
- Shielded loop actually works and is useful, but not for the reasons given in handbooks

Disproof of electrostatic shield



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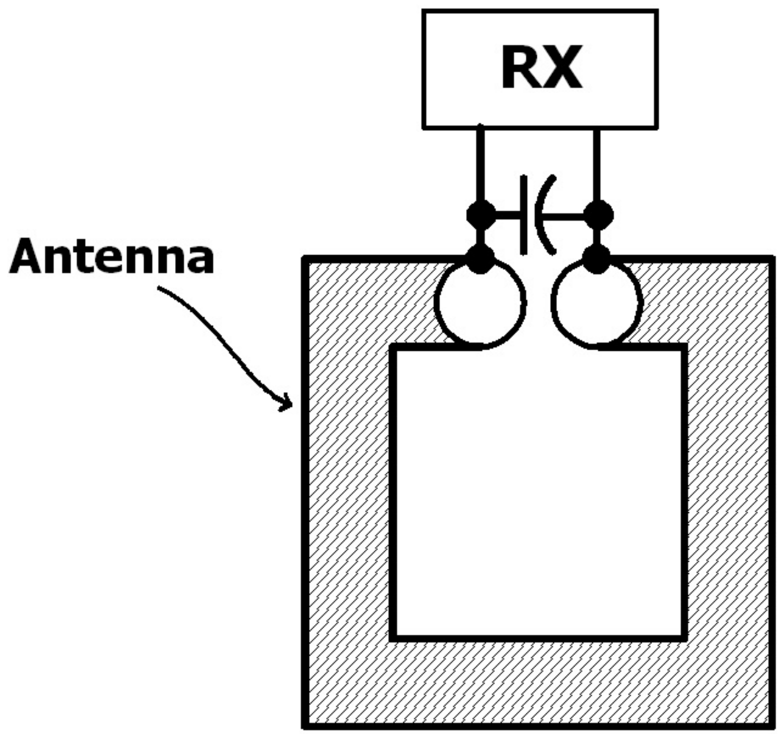
Development of classic loop into “shielded” loop

1. Make conductor a hollow tube



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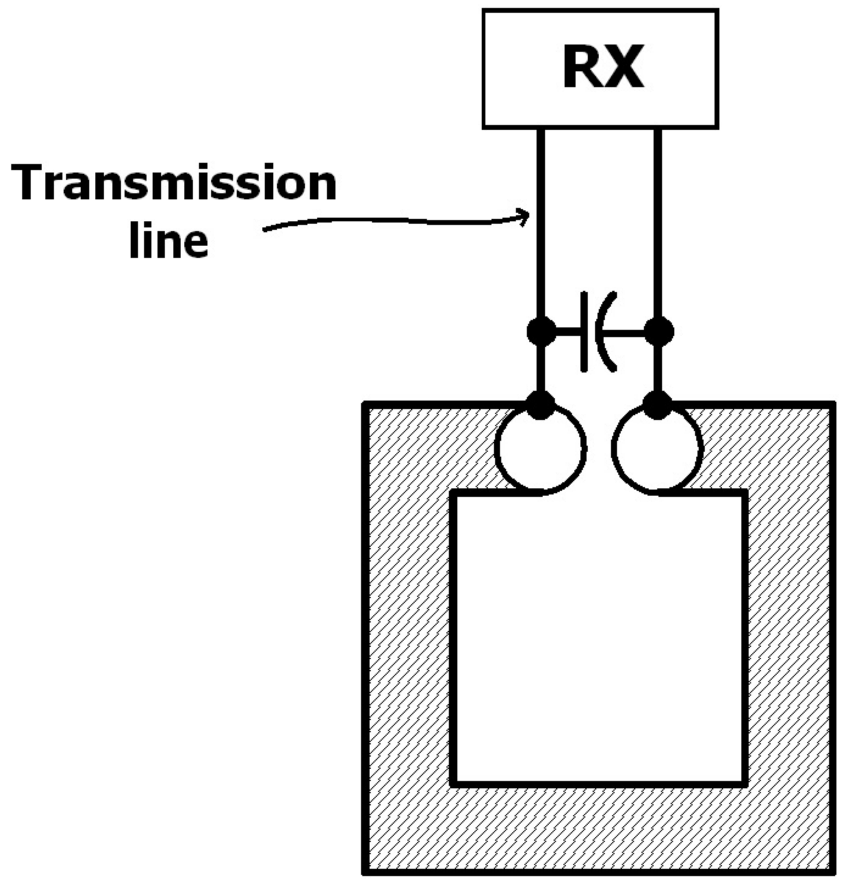
2. Add feedline to RX



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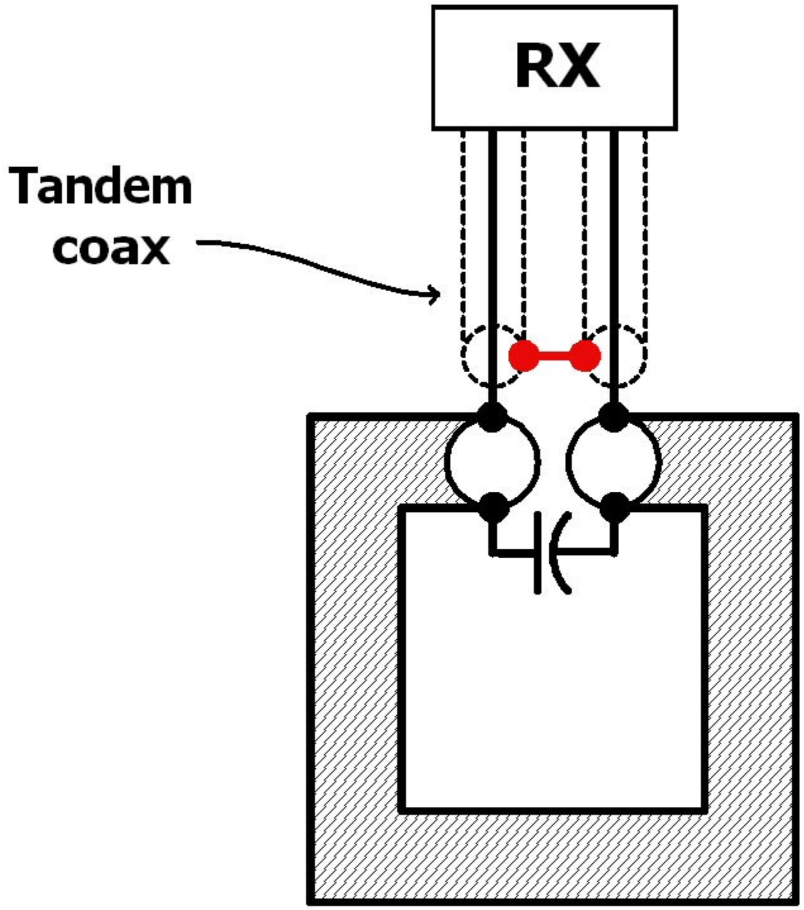
3. Change line to tandem coax



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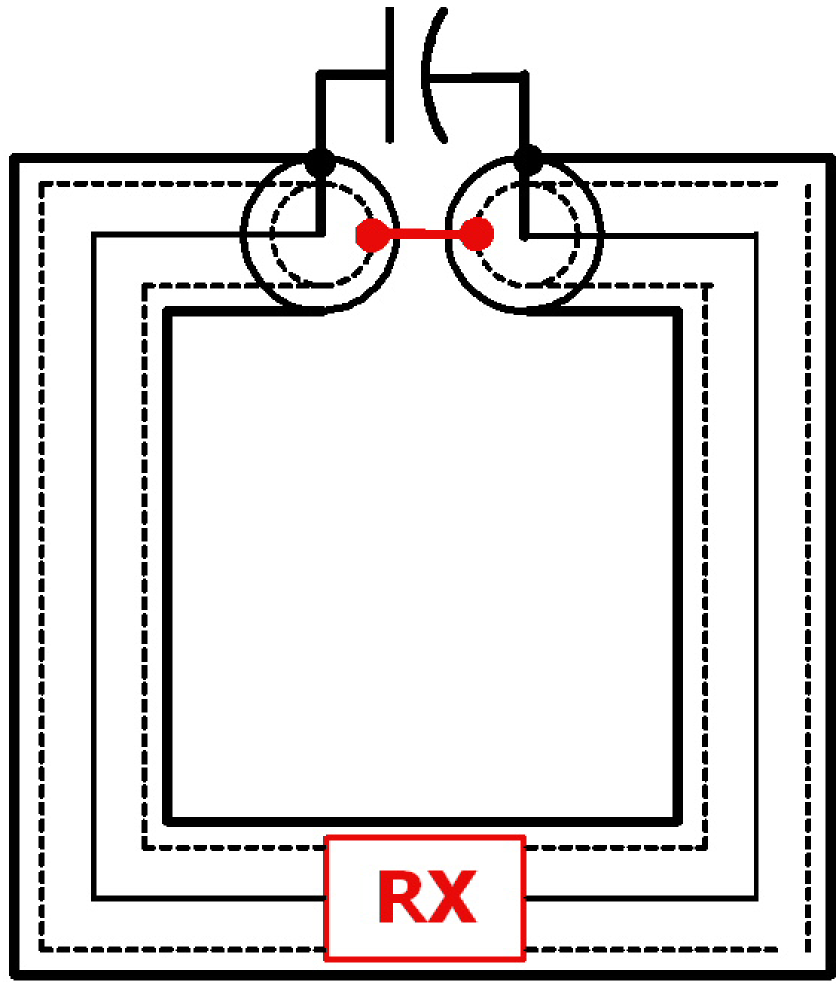
4. Re-route coax through tube



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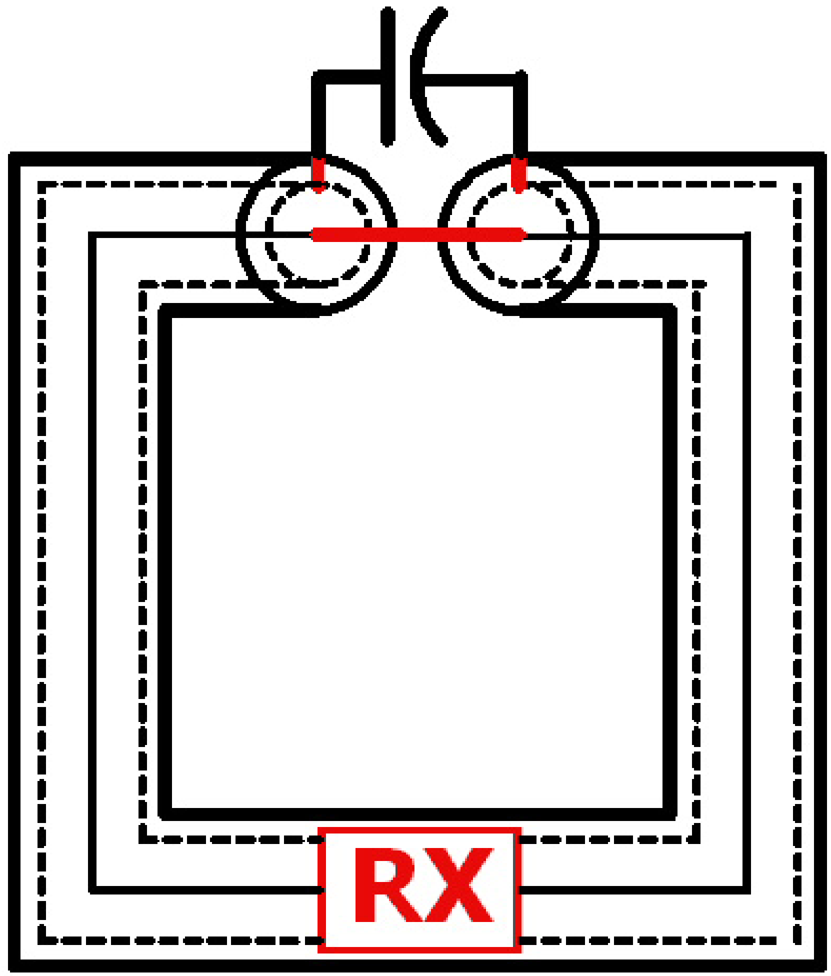
5. Swap polarity of coax



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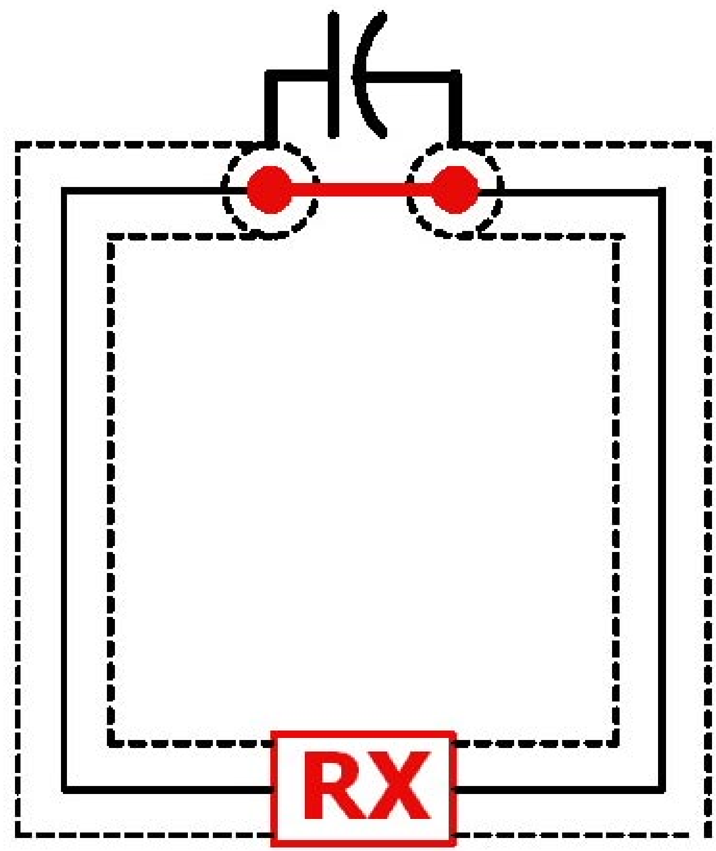
6. Delete redundant tubing

The outer surface of the coax shield is now the antenna



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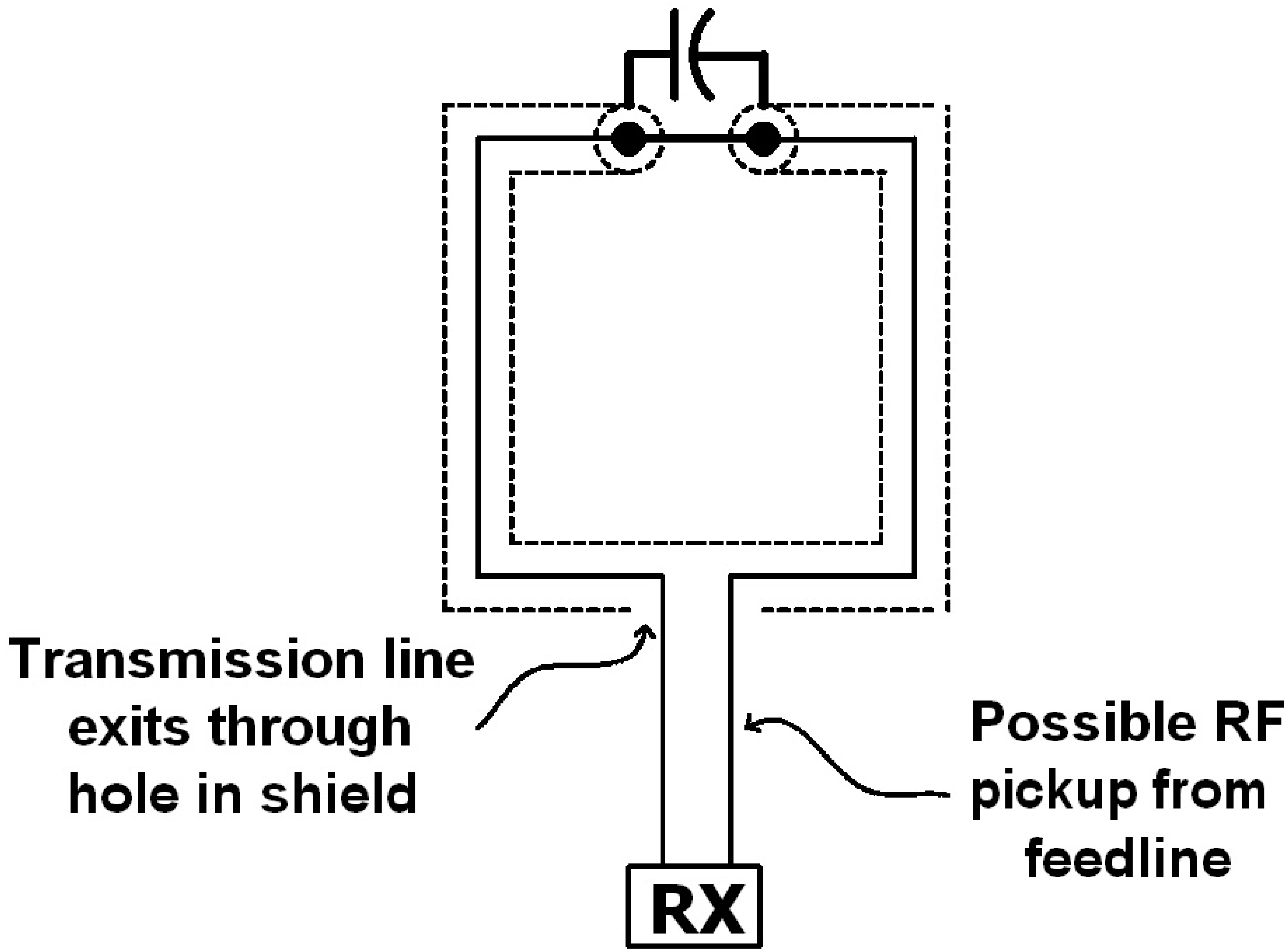
7. Add feedline to RX



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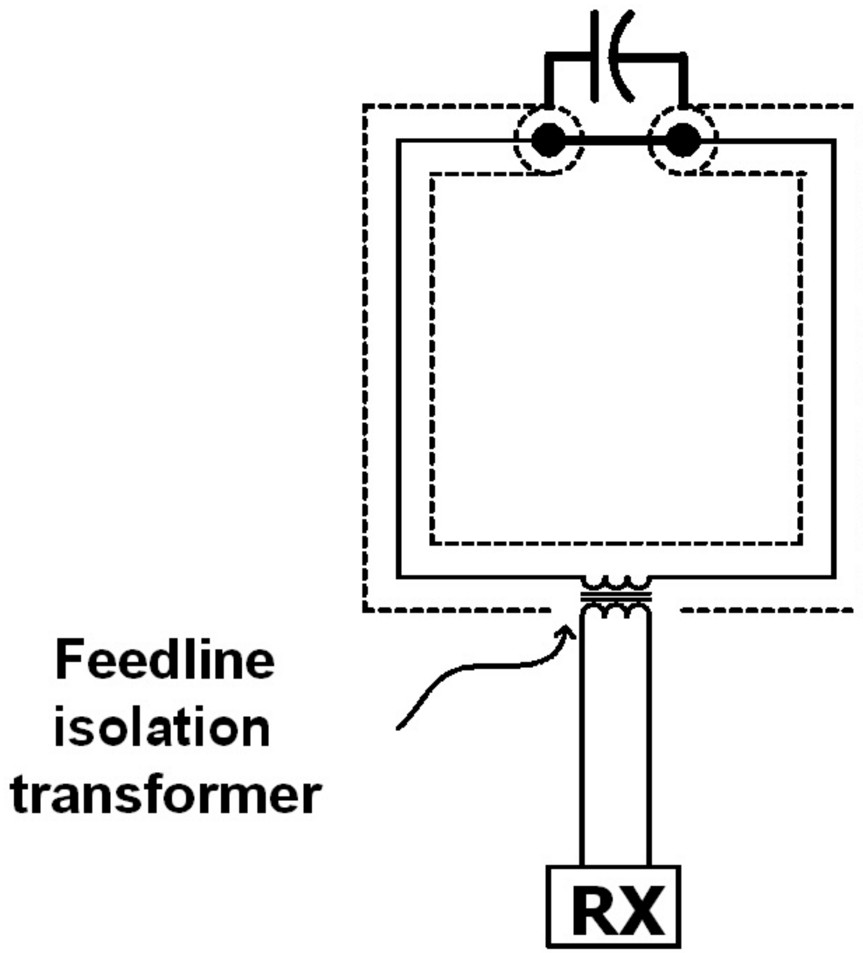
8. Feedline isolation transformer



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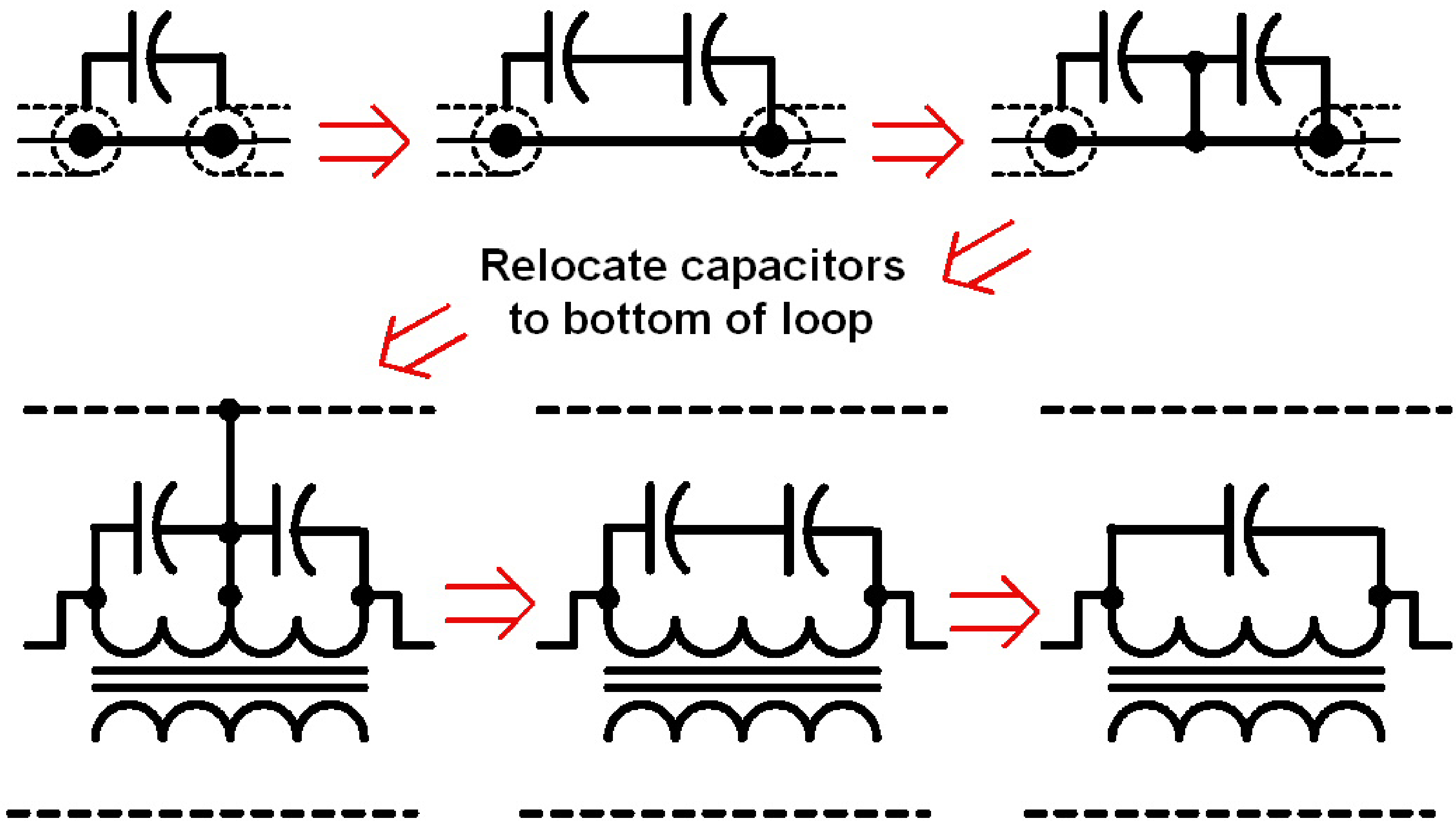
9. Relocate tuning capacitor



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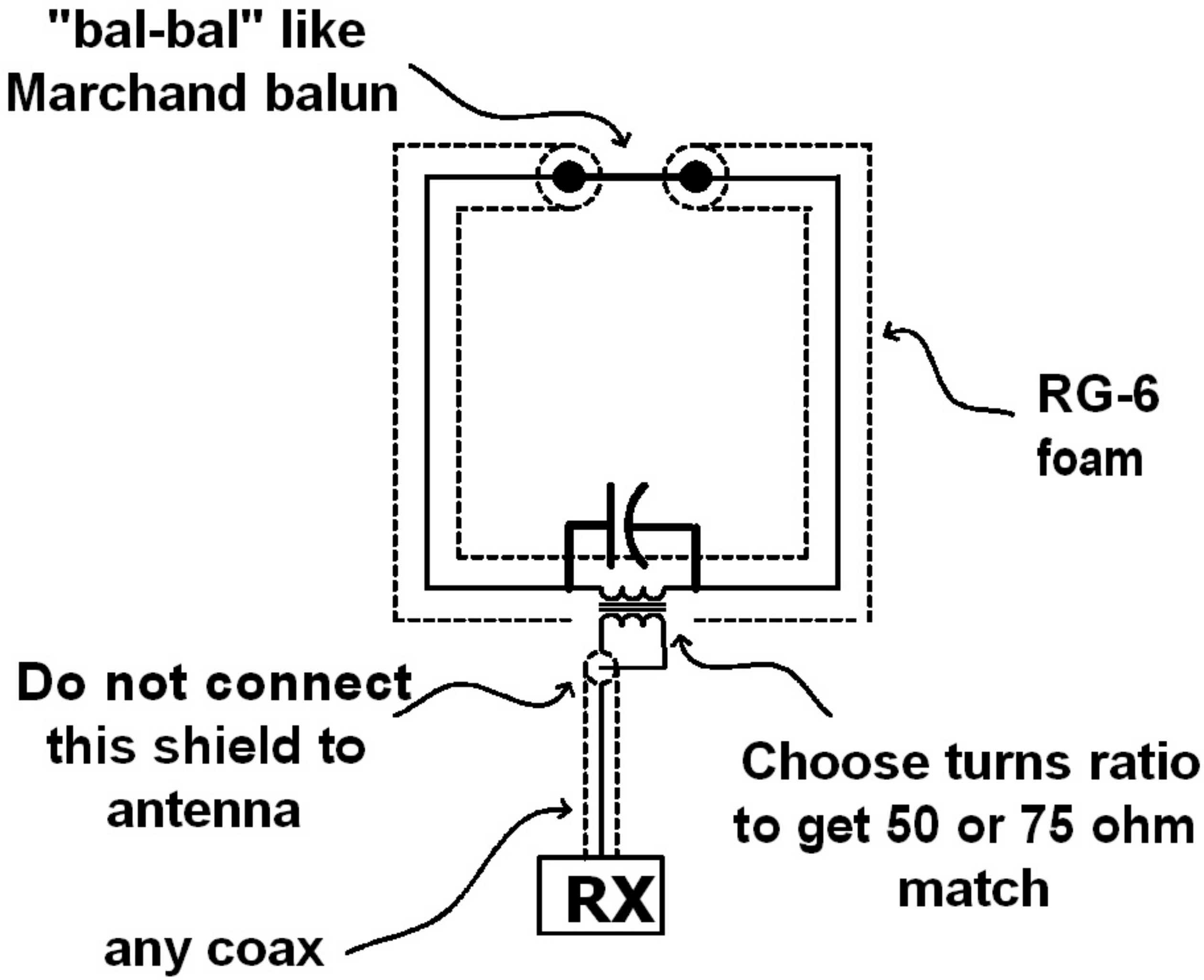
Coax capacitance

- Capacitance of coax is in parallel with tuning capacitor
- The two coax branches are effectively in series so the capacitance is halved
- Use foam dielectric 75 ohm coax to minimize loss of tuning range
- Still possible to reach maximum frequency where perimeter = 0.085 wavelengths

Complete design, fixed tuning



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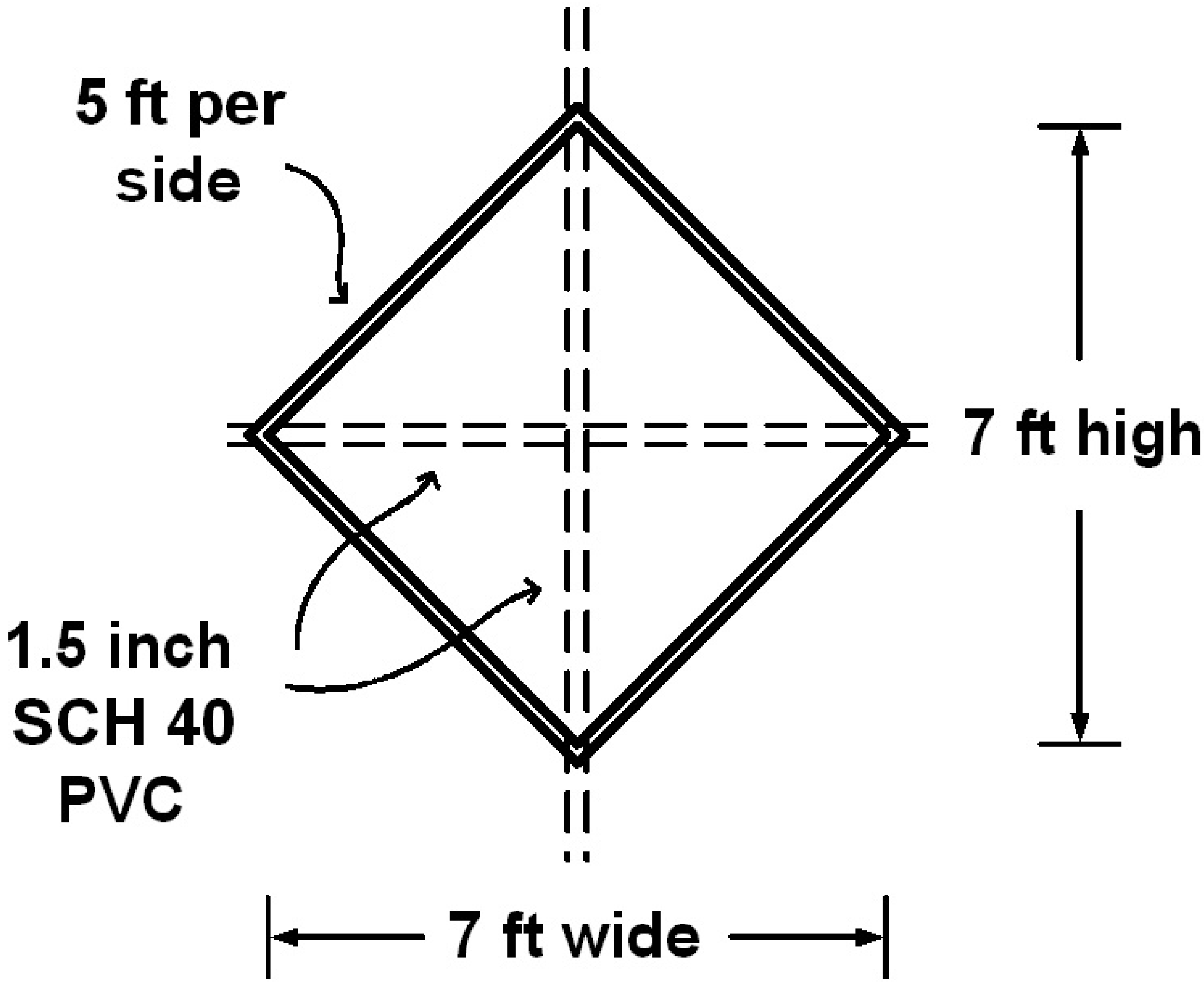
Example 160/80m loop



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Example, max size 160/80 loop

- Total length of coax, 20 ft
- Perimeter is 0.085 wavelength at 4 MHz
- Bandwidth ~25 to 50 kHz
- Gain 20 to 30 dB below transmit vertical
- Tuning capacitance 200-800 pF
- Loop impedance ~ 5000 ohms
- Transformer turns ratio ~50:5

Matching transformer

- Use a transformer, not a balun, this is not for transmit.
- Use low permeability core (μ=125), Fair-Rite 61 material, 3/8” to 1 diameter, 3/8” to ½” high
- Use enough turns to get >100 μH on the loop side, typically 50T on 3/8” high core
- Wind feedline side to match to 50 or 75 ohm feedline, approx. 5 turns
- This core has negligible signal loss

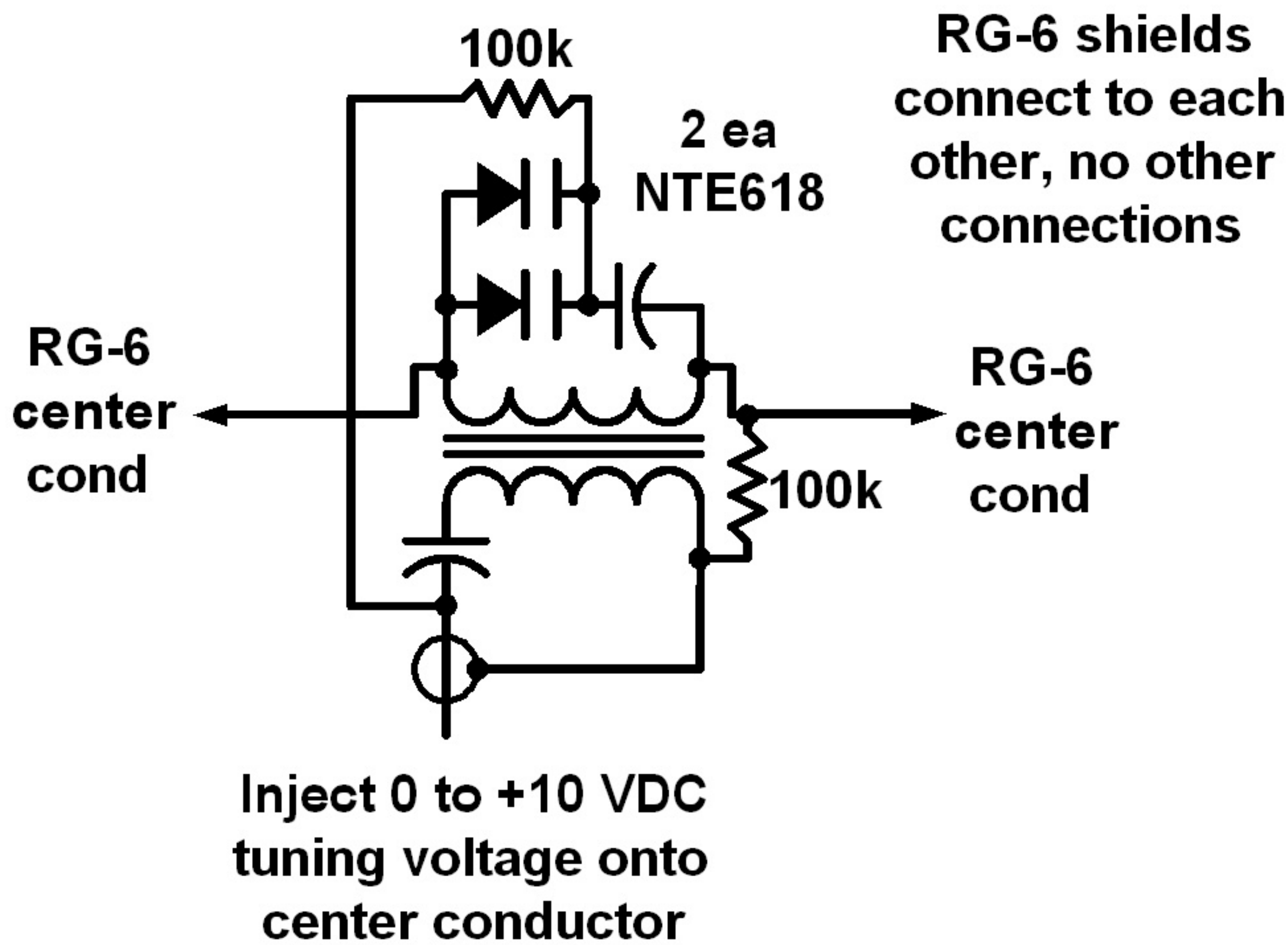
Transformer details

- Do NOT use bifilar windings
- Cover entire toroid with 50 turn winding first, then wind 5 turn winding over the top of it over whole toroid
- Wound this way, coupling is 90%
- Loss is <1%
- Wire diameter, insulation non critical
- Can also use high permeability core, such as Fair-Rite 43. Loss will be slightly higher
- Do not used powered iron (Micrometals)

Remote varactor tuning

- Use AM BCB tuning diodes
- Only source of new diodes to hams is NTE618 (available Mouser and others)
- Diodes also in surplus; or junk a BCB set
- Continuous tuning from below 1.8 MHz to above 4 MHz
- Tuning voltage 0 to +10V

Remote tuning circuit



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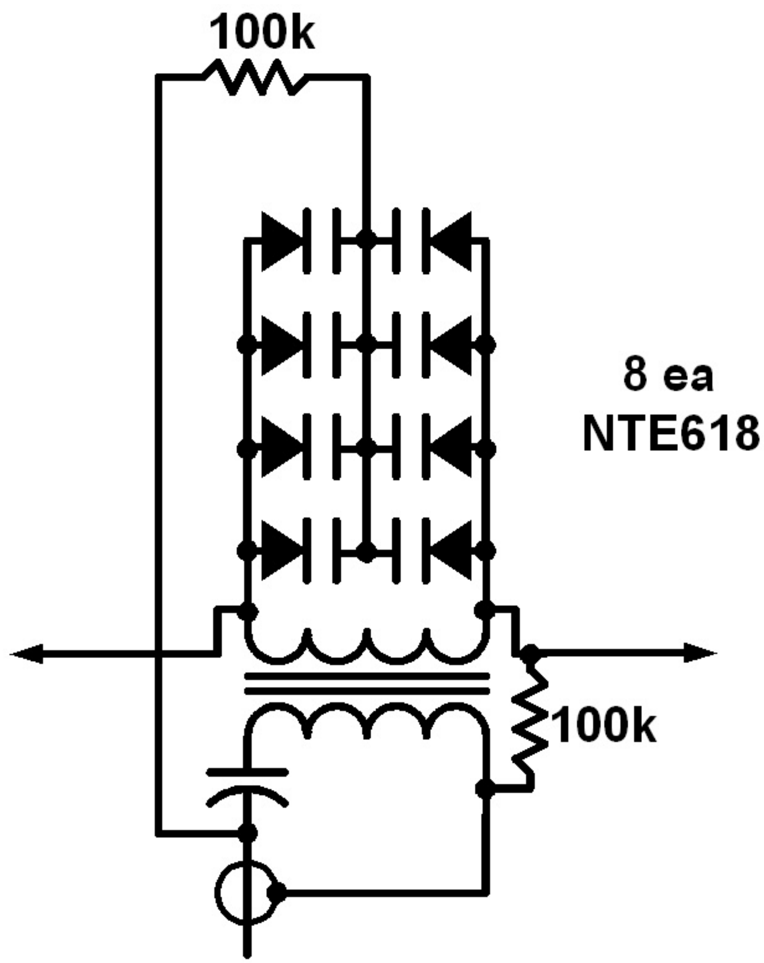
Strong signal issues

- Typically no BCB overload problem
- No problem 6 miles from 50 kW station
- Make sure birdies are in antenna, not your receiver
- In case of a problem, use strong signal varactor circuit
- For SO2, may need to avoid varactors altogether

Strong signal circuit



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Loop size issues

- Bandwidth (counterintuitively) is independent of size
- Tuning cap inversely proportional to loop width
- Gain increases 9 dB (theoretically) for doubling of loop width
- I observed more than +9 dB for full size loop on 160 meters (14 ft wide) vs 7 foot wide
- Doubling conductor diameter increases gain 3 dB, halves bandwidth
- Nulling still good on large loops

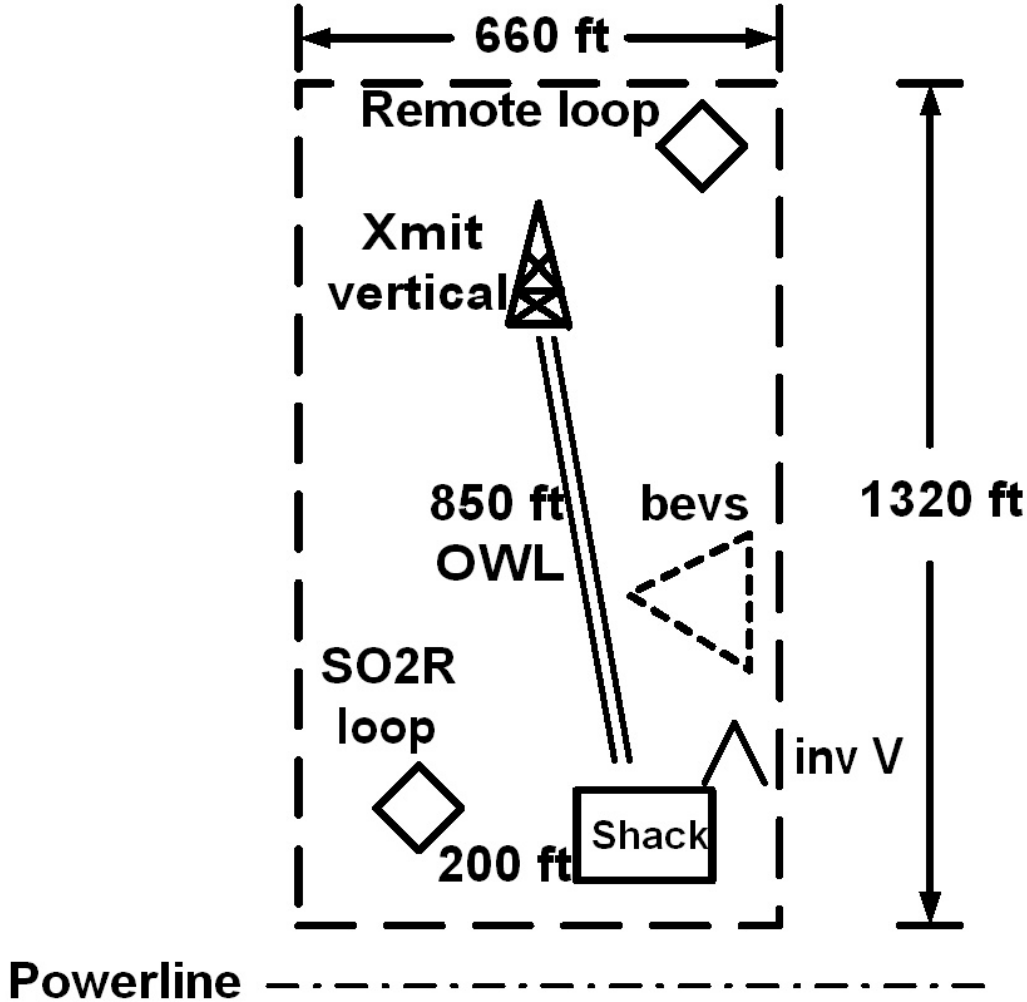
Sensitivity issues

- Noise from antenna must dominate receiver noise.
- Example loop was quite adequate for FT1000; even a half size loop was OK.
- For 160 meter remote loop at long distance, consider 14 foot size. Easier than a preamp

Applications

- Nulling power line noise, good for several S units
- Very useful for DF'ing power line noise
- Get bearing then walk to source using VHF gear to get actual pole
- Remote loop away from noise if you have the land
- Compare locations for noise using WWV(H) on 2.5 MHz as a beacon
- Null your own transmitter for SO2R

2007 Stew Perry SO2R setup



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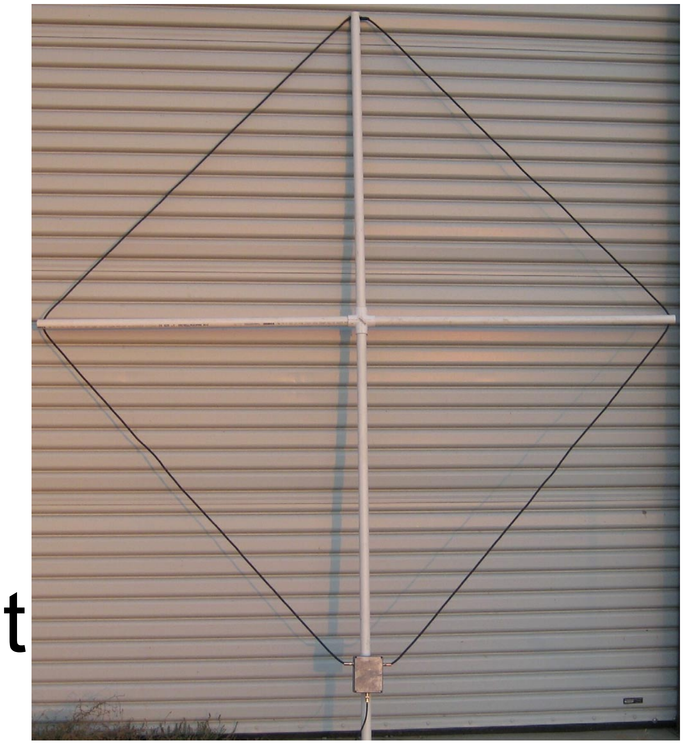
SO2R results

- Transmitted on 1801 kHz (the whole contest!)
- Receive (while transmitting) > 1805 kHz
- Transmit rig FT1000, SO2R rig TS-570
- Nulling is weird near shack, inv V, or OWL
- Location used was near 60x40x16 metal building
- 60 to 80 dB nulling. Angle tolerance a few degrees
- Able to hear about everything. CE/K7CA was a few dB worse than beverage

Construction details

- 1 inch PVC40 pipe
- 42 inches long
- 20 feet of RG6/U
- Compression F conn.
- Available: Home Depot



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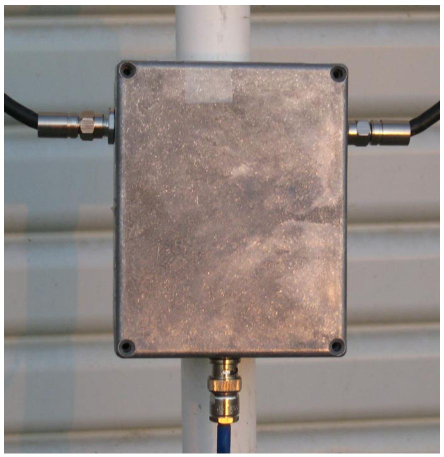
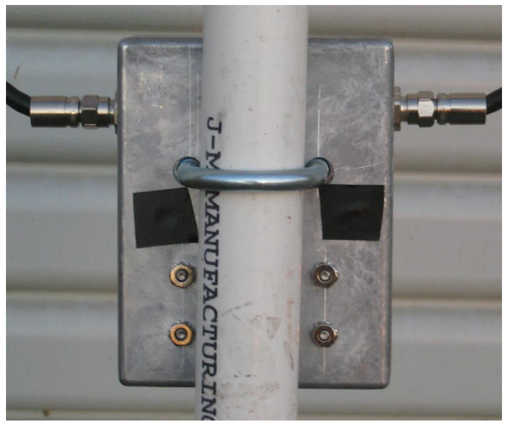
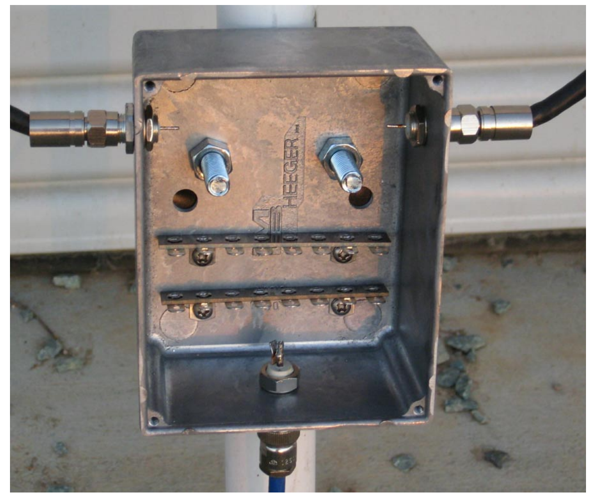
Die cast box for matching circuit

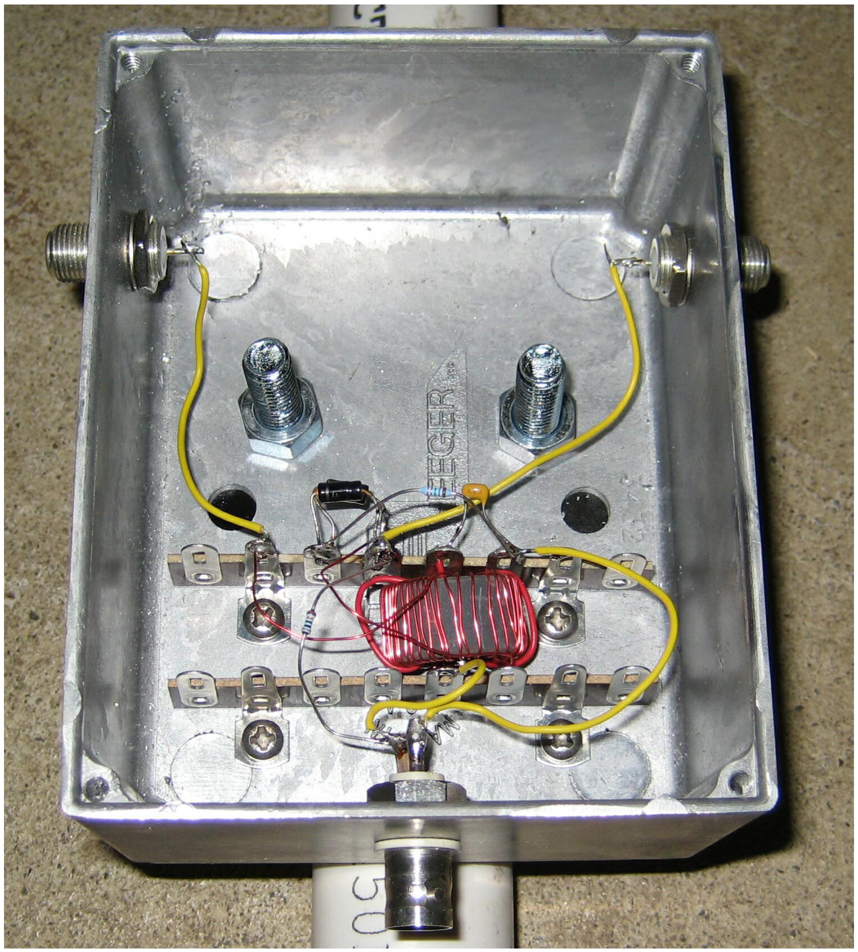
- 2 11/16 X 3 11/16 X 4 11/16 inches
- Build circuit on terminal strips

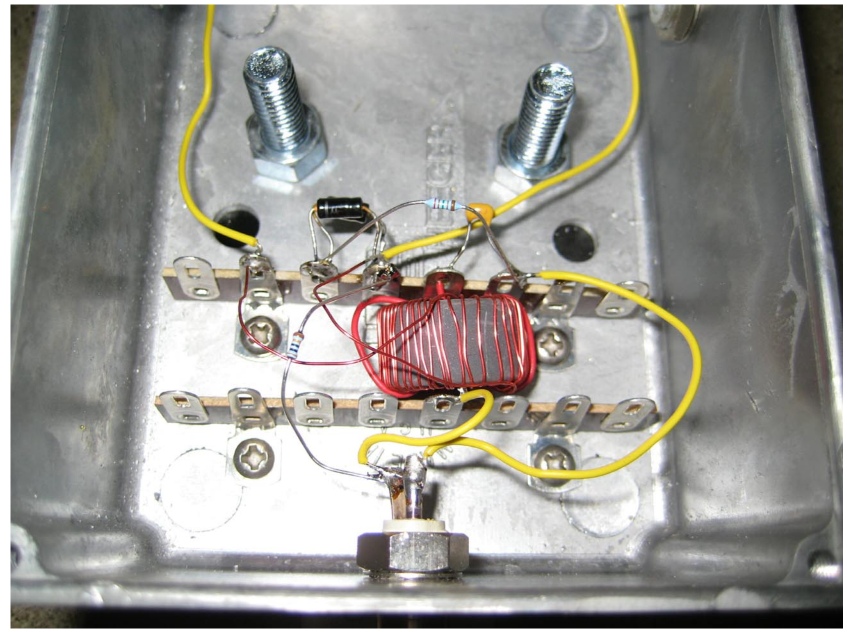


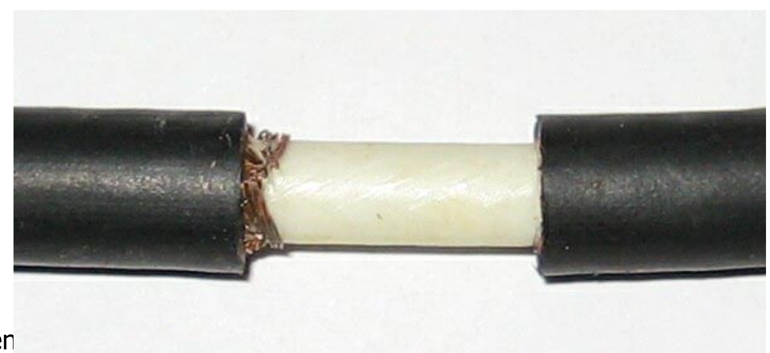




Wiring details







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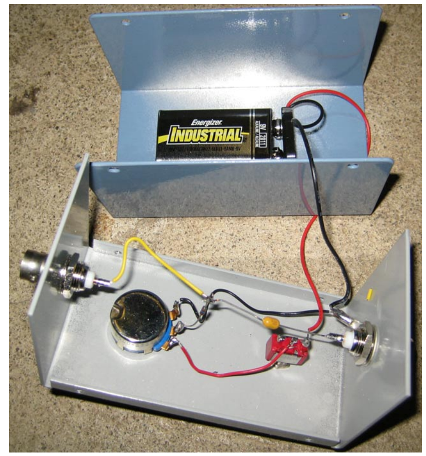
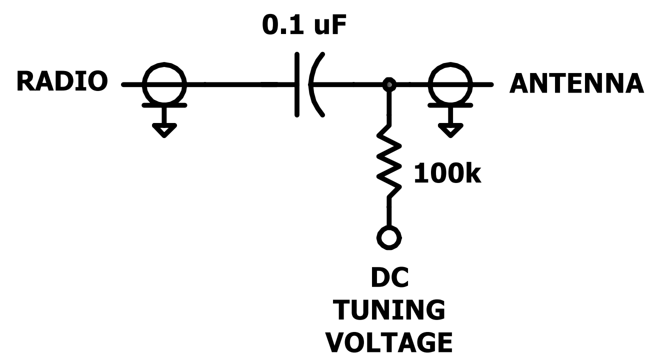
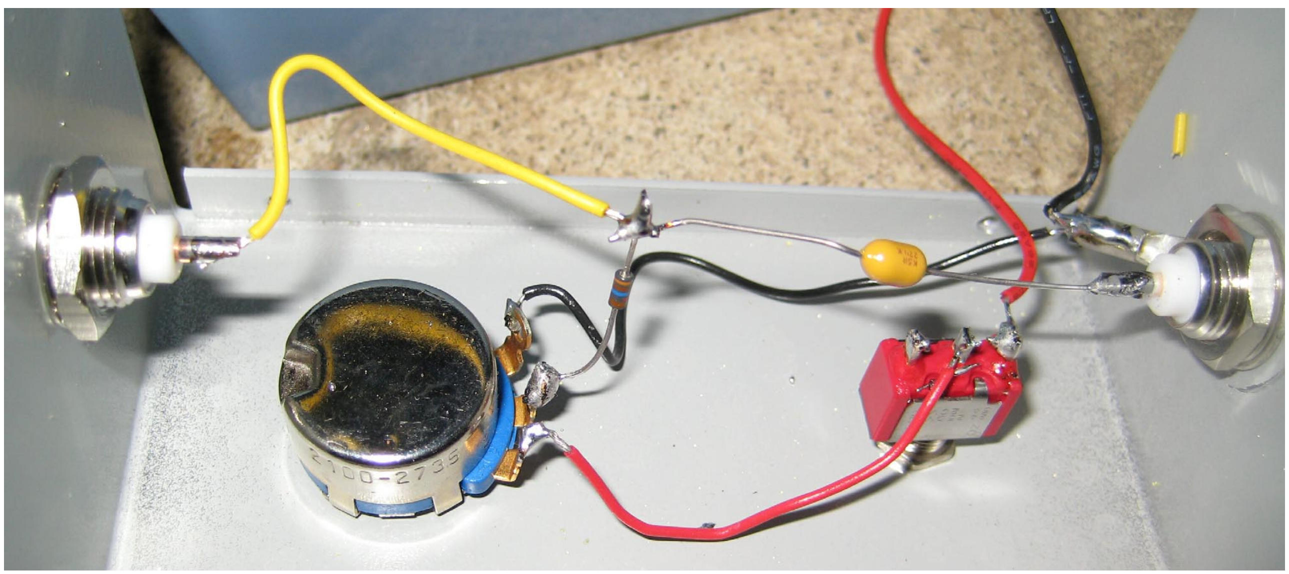
DC remote voltage feed







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Components

- NTE618 varactor (Mouser)
- MVAM109, MVAM115, MV1401 also OK if you can get them.
- FT-82A-61 toroid (Amidon) 50:5 turns
- LMB Heeger KAB-3432 die cast box
- Tyco/AMP 5227726-1 isolated BNC (Mouser)
- Two 0.1 uF caps, two 100k resistors

CU on the low bands

73, Rick N6RK

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