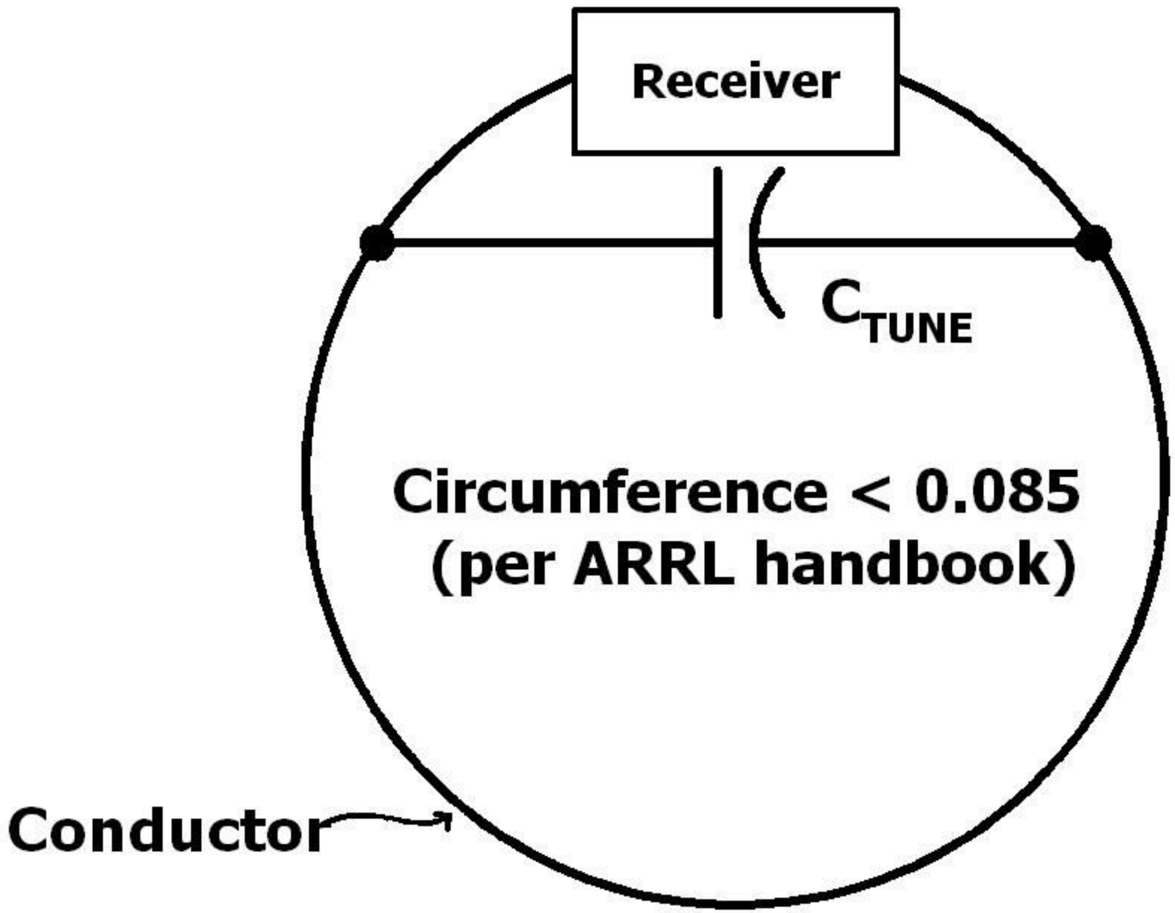
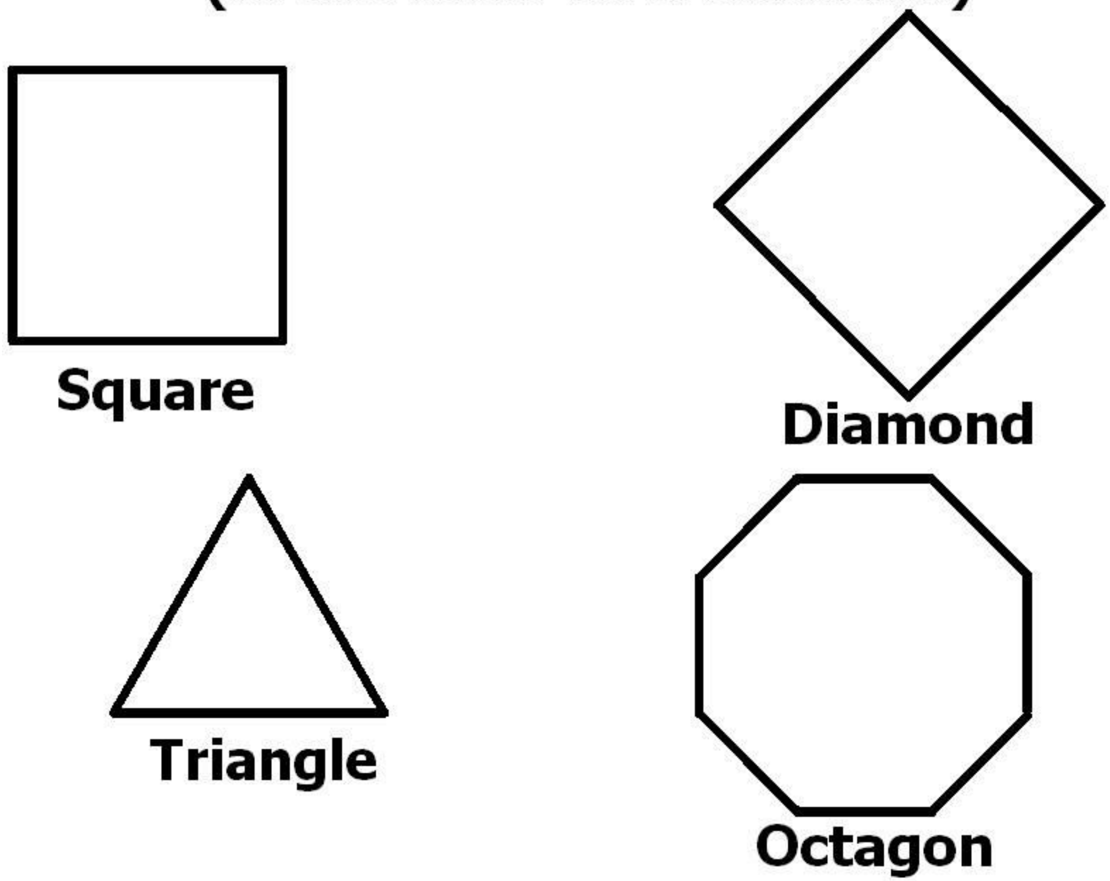
ANTENNA AND WAVE PROPAGATION

The classic loop antenna



Any symmetrical shape OK

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



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

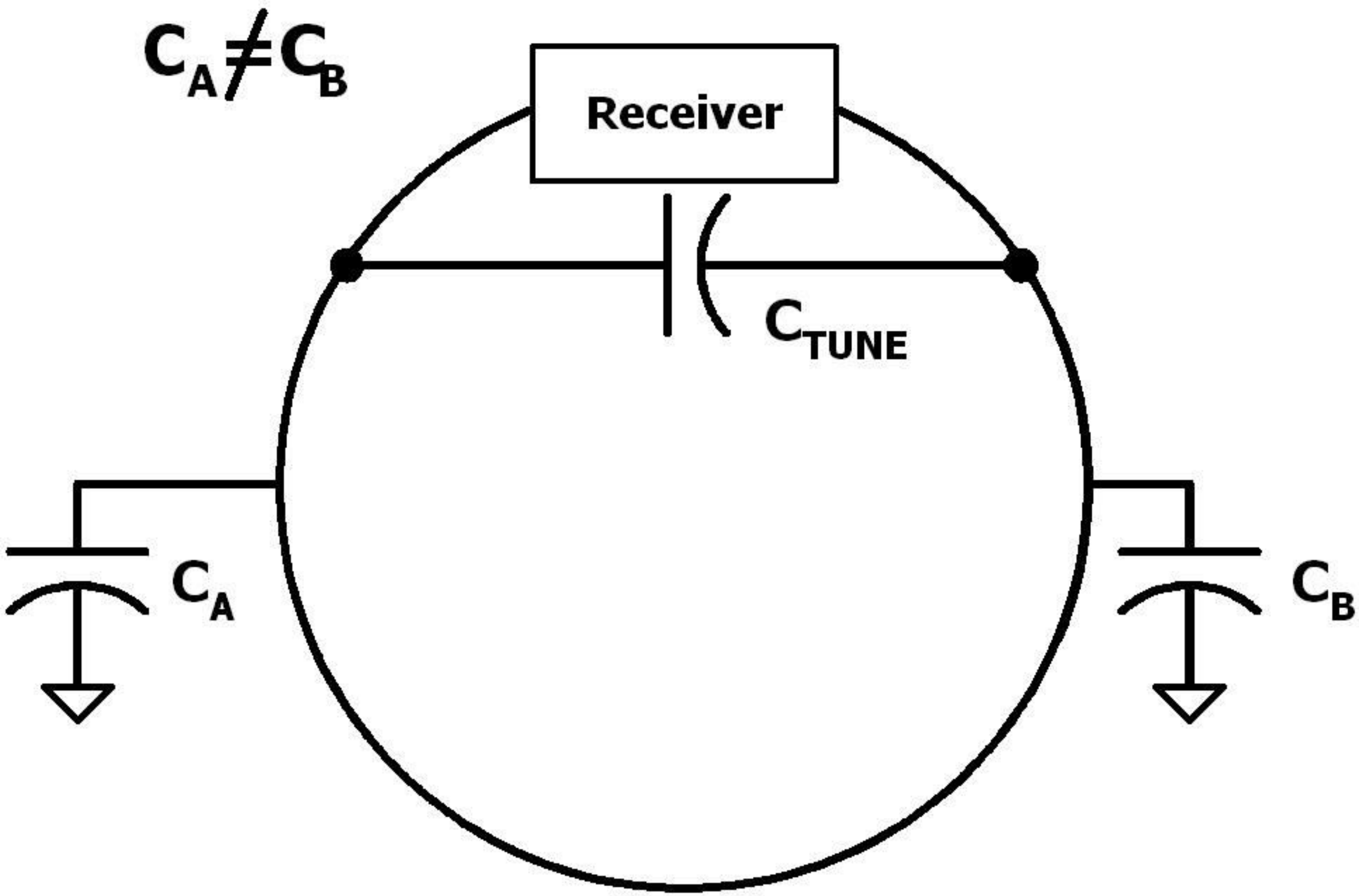
Effects of "large" loop

- 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

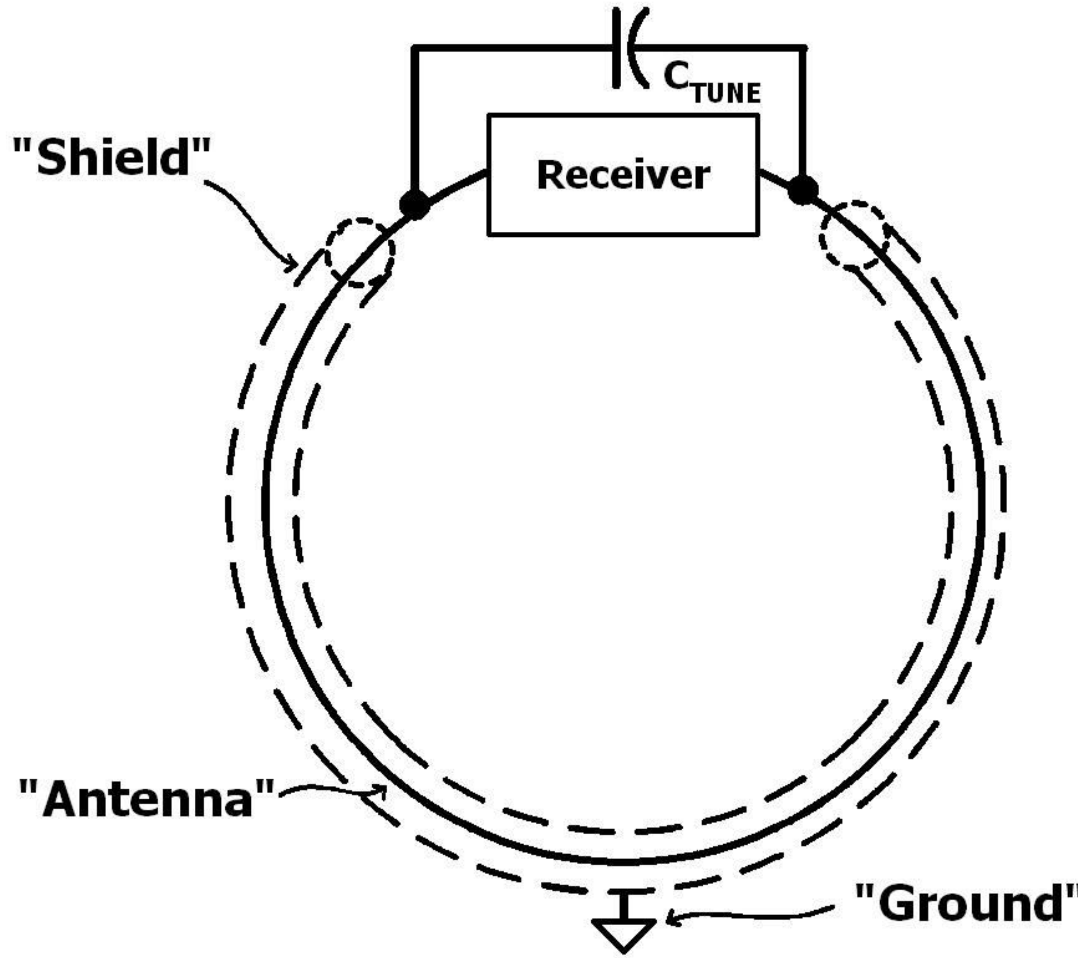
Multiturn loops

- 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



The classic “shielded” loop



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