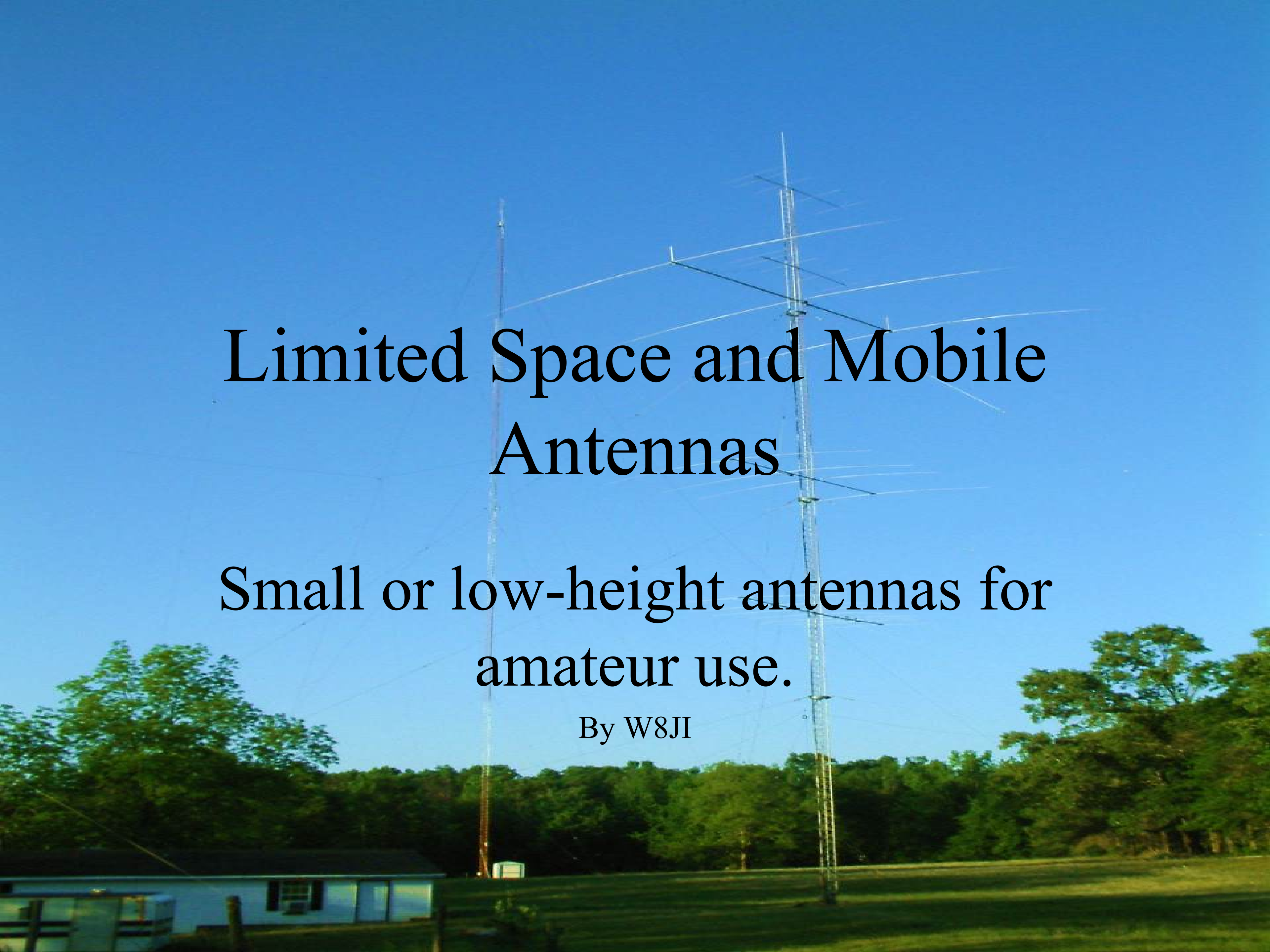
Limited Space and Mobile Antennas

Small or low-height antennas for amateur use.

By W8JI



Goals Conflict with Limitations

We want high performance….

- Horizontal antennas generally require at least ¼ wl height above earth and ¼ wl horizontal space
- Vertical antennas require ground systems at least 1/4th wl in diameter and "RF" obstruction clear areas for a few wavelengths distance

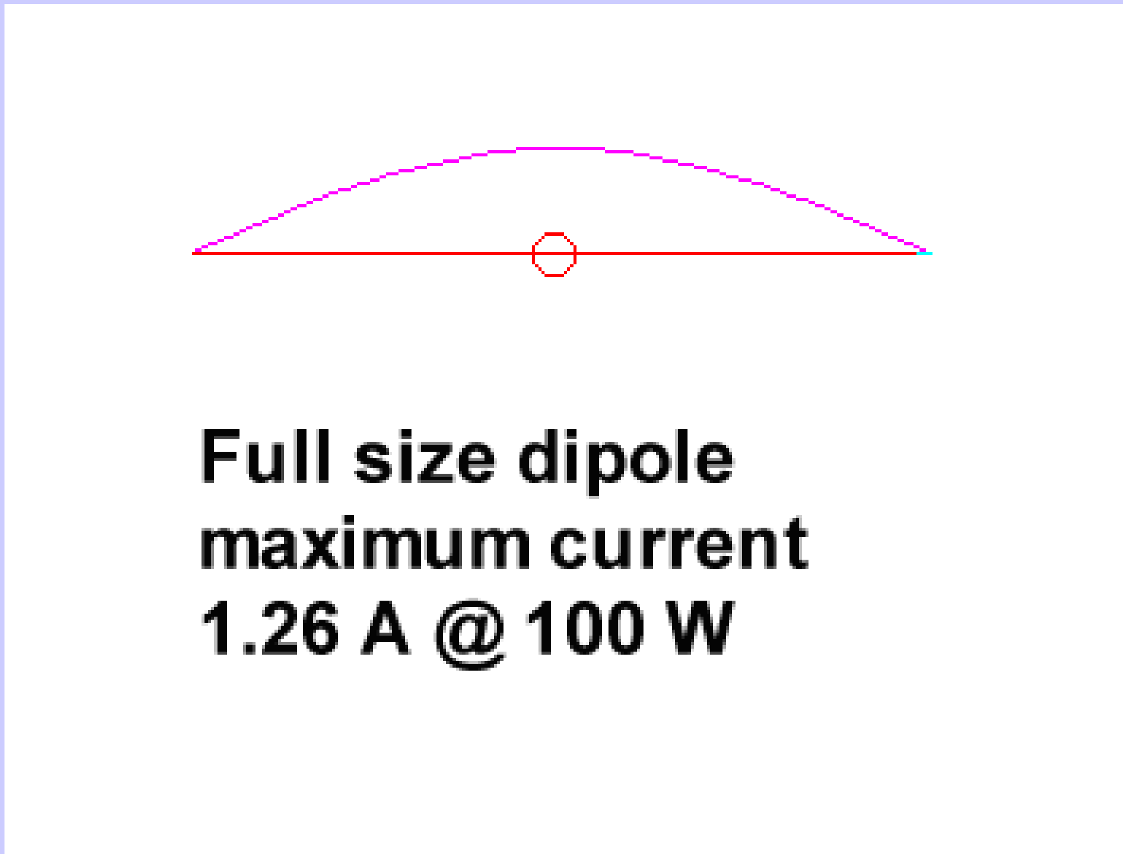
But we have no room!

- ¼ wavelength is 35 feet on 40 meters, 70 feet on 80 meters!
- "A few" wavelengths is over 300 feet on 40 meters!

We’ve received good advice over the years:

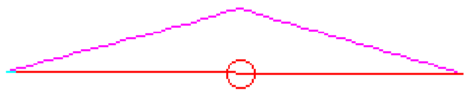
- Don’t bend high current sections
- Keep current areas as high and clear as possible
- Use well-constructed loading coils
- Don’t place coils right at the open end of antenna
- Don’t place high voltage ends near lossy dielectrics like bare soil or houses

Full Size Dipole Antenna



Radiation Comes From Charge Acceleration

- Only net ampere-feet of in-line area matters!
- Quarter-size dipole starts to has triangular current. To maintain same ampere-feet, peak current is nearly 8 times higher than the regular dipole



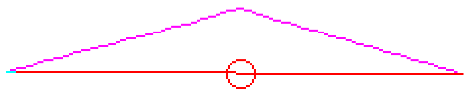
1/8-WL dipole current is almost perfectly triangular.

9.5 Ampere @ 100 watts

(up from 1.2A in full size)

Triangular Current

- Instead of smooth sine-shape decrease, we now have straight line.
- This means current is much higher for the same power (the same ampere-feet to radiate a given power).



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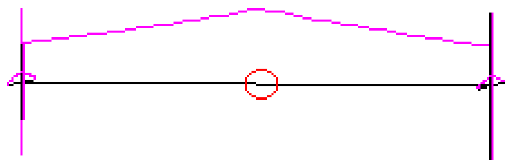
Minimize Peak Current

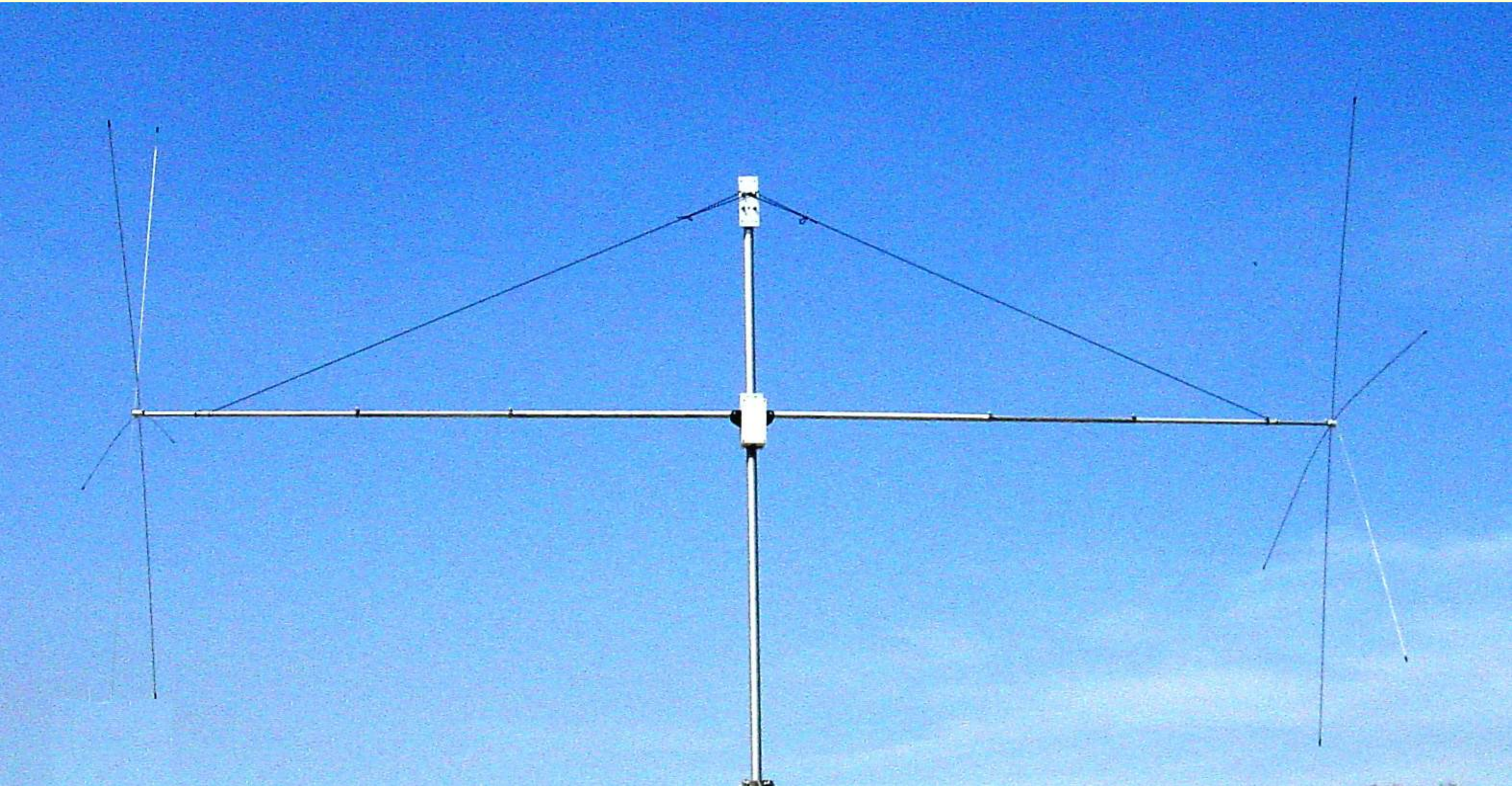
- **We must make current as uniform as possible**
- **Every area of the antenna contributes more to radiation because current is more even**
- **Center current is now 68% of value without hats in the same 1/8-wl dipole**



Hats at ends cause current to be more uniform.

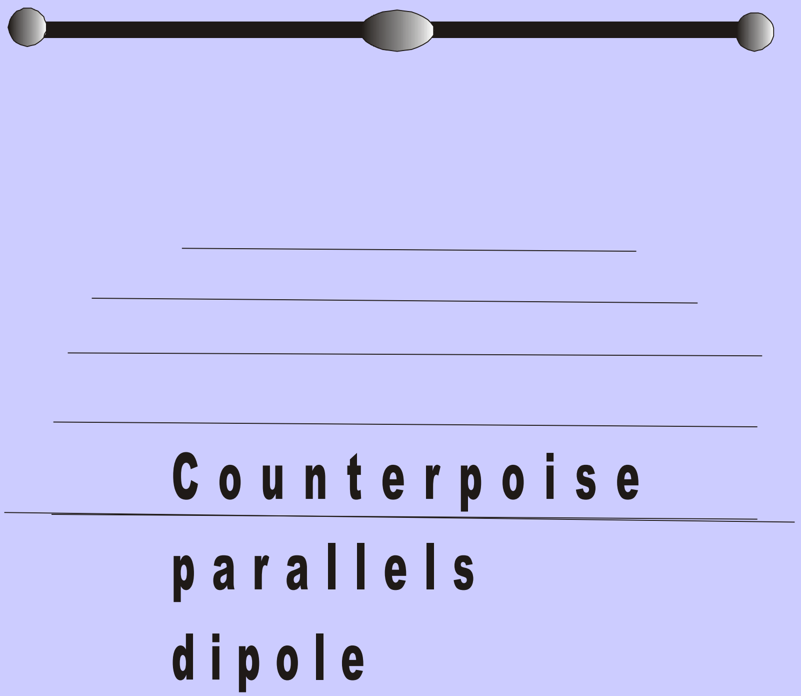
6.46 A @ 100W now compared to 9.5 A with no hats!

DX Engineering Hat Dipole
Uses: balun and large hats



Lowest Ground Loss

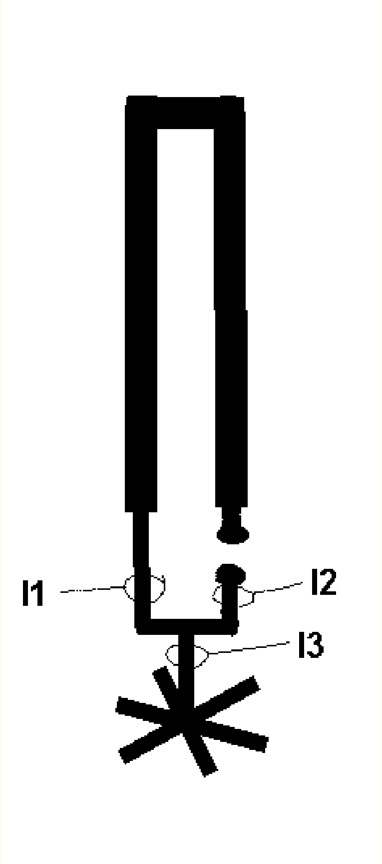
- **Requires reasonable height above lossy media**
- **As an alternative, lossy media can be “shielded” from antenna**
- **Just do the best you can**



No Magic in Folding Elements

Folding wires does NOT increase radiation resistance unless it modifies net current distribution.

I3 always equals sum of I1 and I2. I3 is almost entirely set by height and loading.



Maximum radiation resistance possible for short vertical carrying uniform current.

- H*e* is effective height
- Lambda is wavelength
- Both must be expressed in the same measurement units such as feet, degrees, meters, etc.
- 2X length = 4X Rrad

$$Rrad := 1580 \cdot \left(\frac{He}{\lambda}\right)^2$$

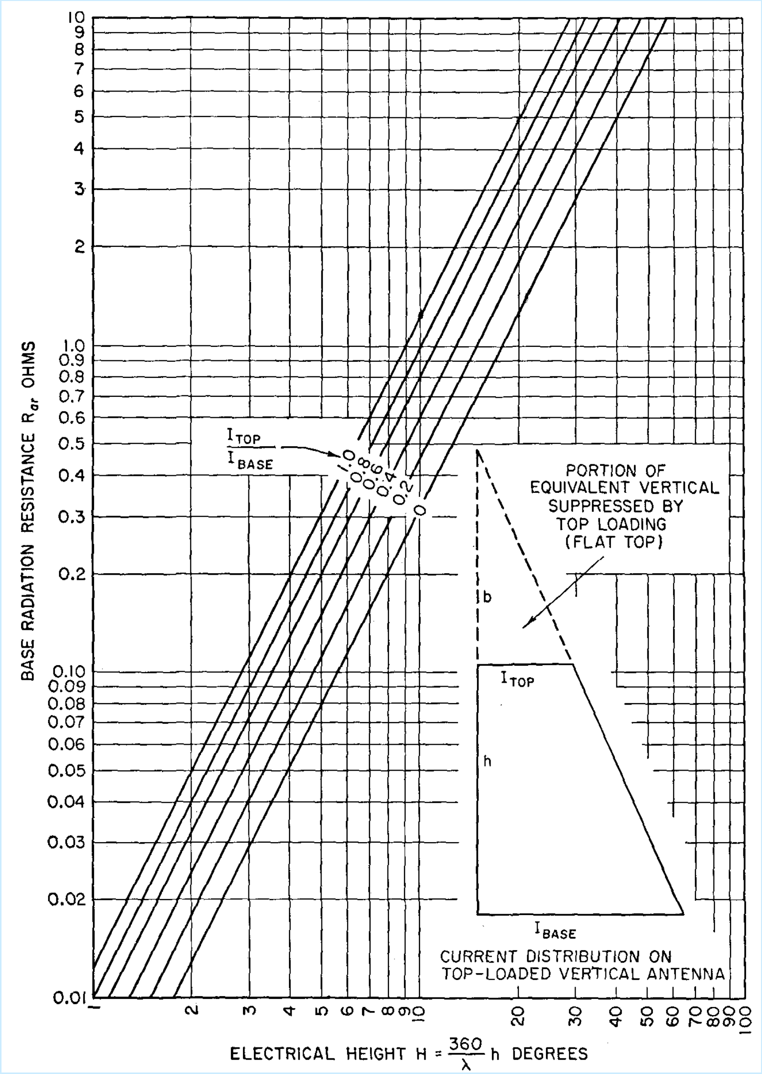
Uniform current radiation resistance examples

- ¼ wl vertical 98.8 ohms
- 1/8th wl vertical 24.7 ohms
- 1/16th wl vertical 6.2 ohms

Radiation resistance roughly proportional to square of length change! Use the longest radiating area possible.

Current

- Net or effective current distribution controls radiation resistance
- More uniform current over given area means higher radiation resistance



Changing from Triangular to Uniform Current

1. **Top-loading of verticals or end-loading of dipoles that causes current distribution to be uniform increases radiation resistance 4 times from triangular current values. It is like doubling length.**
2. **Loading coils, if small, can go nearly anywhere with no noticeable changes in current distribution if the antenna uses a large capacitance hat.**

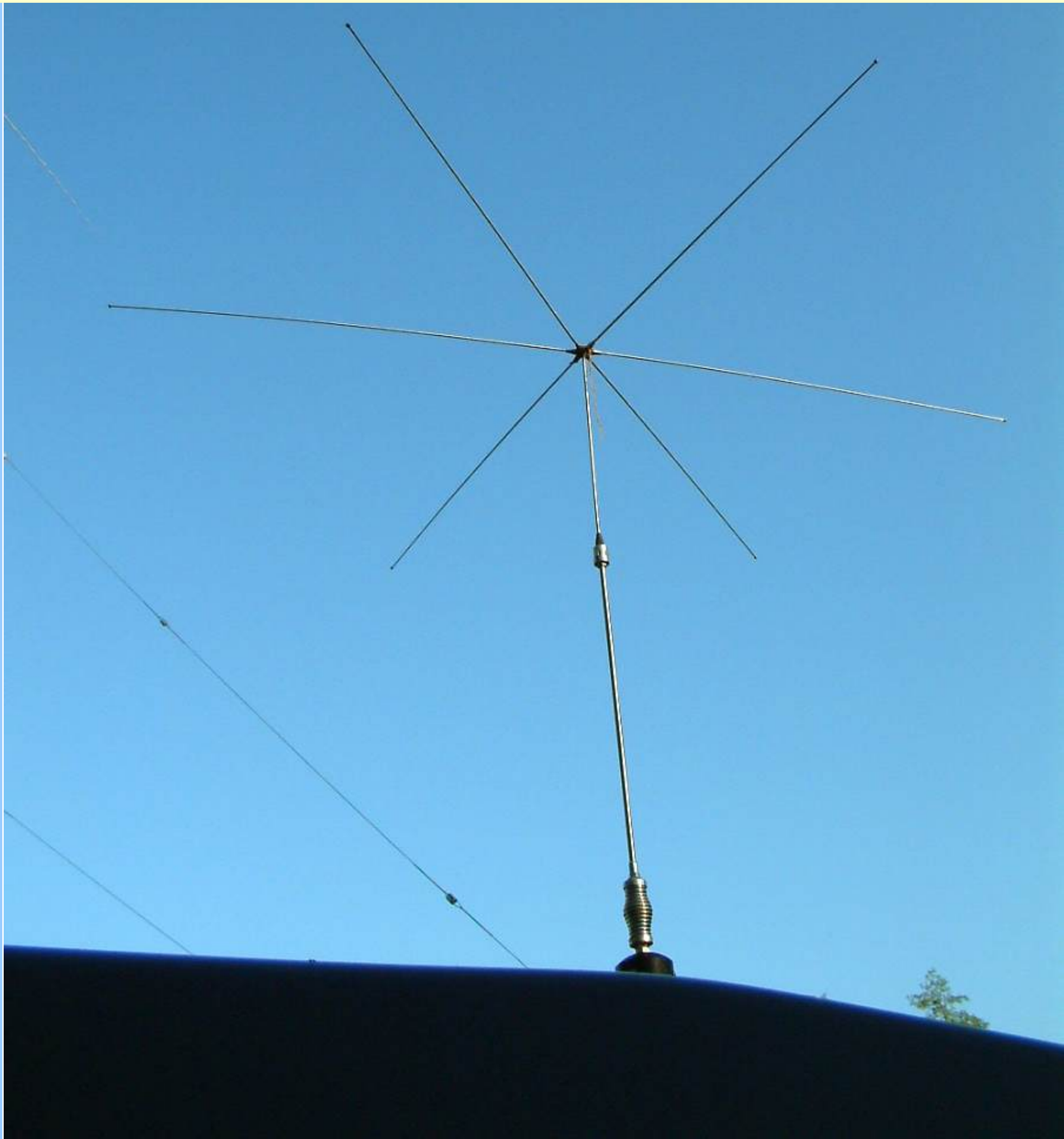
- **1/16th wl vert no-hat = 1.8 ohms Rr**
- **1/16th wl vert big hat = 6 ohms Rr**

We can’t know many variables. We should:

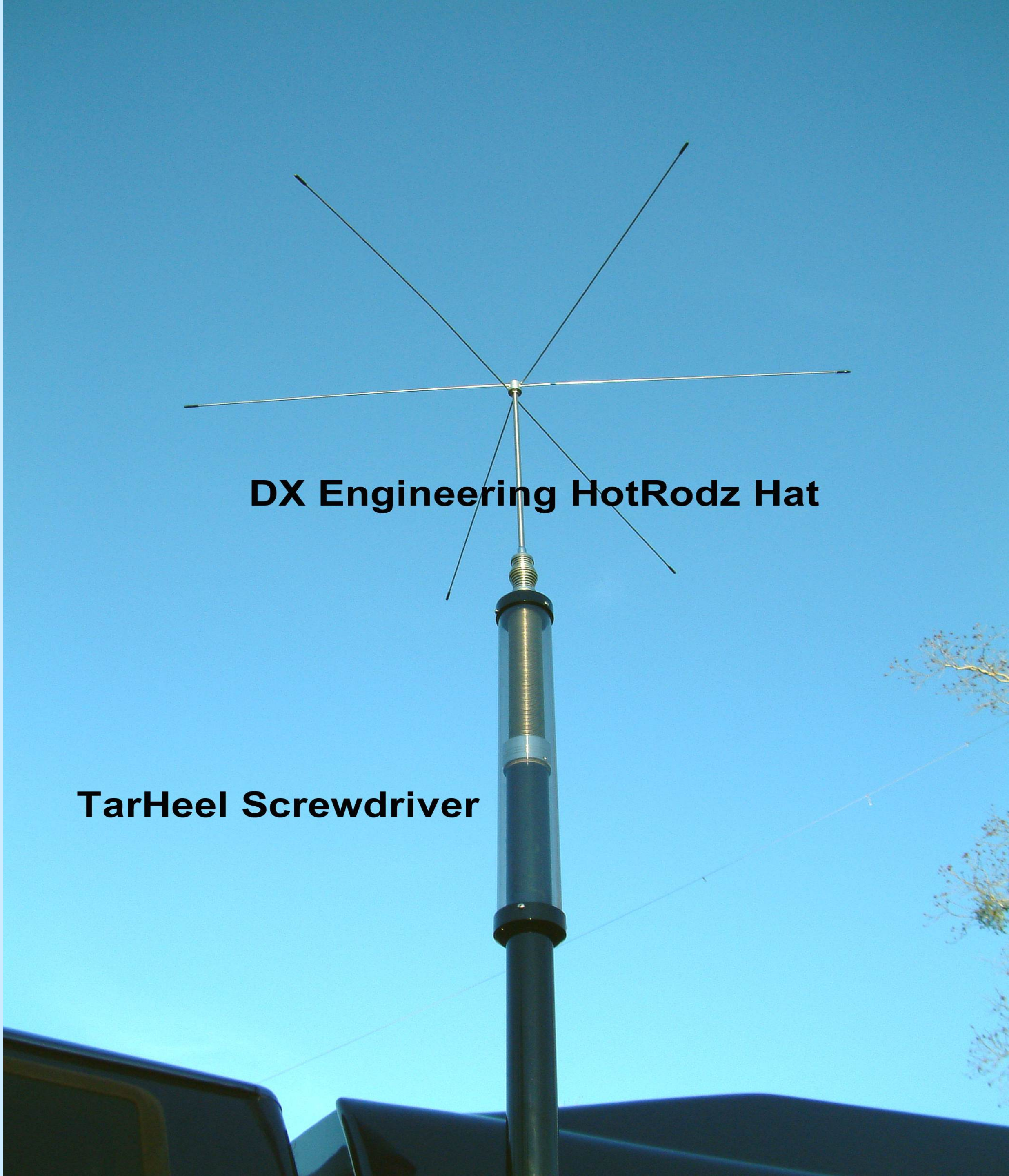
- Make ground system as large as possible
- Use a reasonably constructed coil
- Use a hat at end when possible
- Keep open ends of antenna (high voltage) well away from earth or other poor dielectrics

Large homebrew hat uses six 32” long car antennas welded to stainless “stub”.

- Increases current flowing into end of antenna
- Increases radiation resistance and efficiency
- Reduces coil resistance for given Q
- Increases bandwidth



- Commercial version of end-loading with hat to increase bandwidth and efficiency.
- The large hat provides a termination for current to flow into.
- 3-foot rod with hat approximately equivalent to 6-foot whip

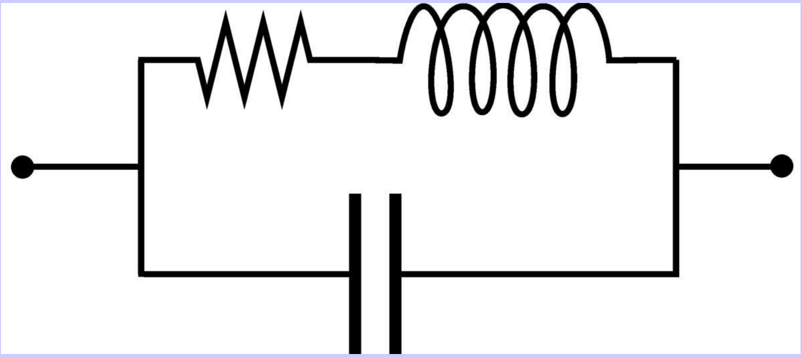


Common False Claims

- Linear Loading is more efficient than conventional coil or lumped loading
- An antenna close to ground can be made ground-independent
- An antenna ¼ wl long or less can be an "electrical half-wave"
- We can use special radiation techniques

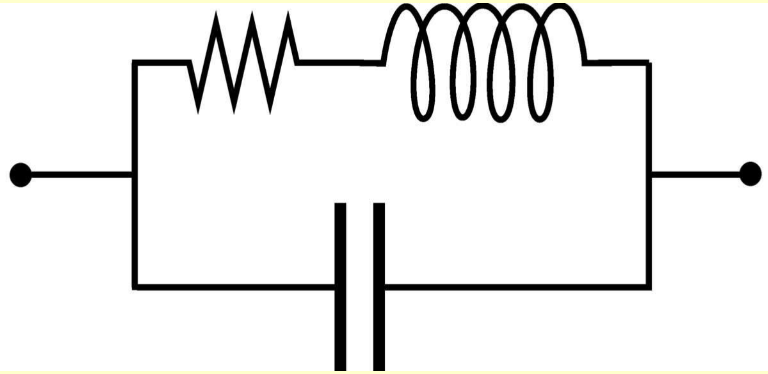
Lumped Loading

- Any form of series lumped loading will only cancel reactance at the point where it is added.
- Any form of loading, short in terms of wavelength, can be represented a capacitance in parallel with a series R and L. This is the same as a trap.



Why is this equivalent correct?

- There is stray C across the inductor
- There is an equivalent series R representing losses



Shunting Capacitance

- Shunt C increases circulating currents through coil's winding
- Shunt C reduces bandwidth
- Shunt C lowers Q almost in direct proportion to the effective increase in inductance!

20uH coil 5-ohm ESR @ 2 MHz

- 0pF ESR 5 X251 Q50
- 50pF ESR 7 X298 Q43
- 100pF ESR 11 X367 Q34
- 200pF ESR 37 X681 Q19

AVOID UNNECESSARY STRAY CAPACITANCE IN INDUCTOR!!!

Reactance going up, Q going down!

Be careful how you reduce turns!

Same 251-ohm Reactance by Capacitance Change

- We readjust L to make reactance the same.

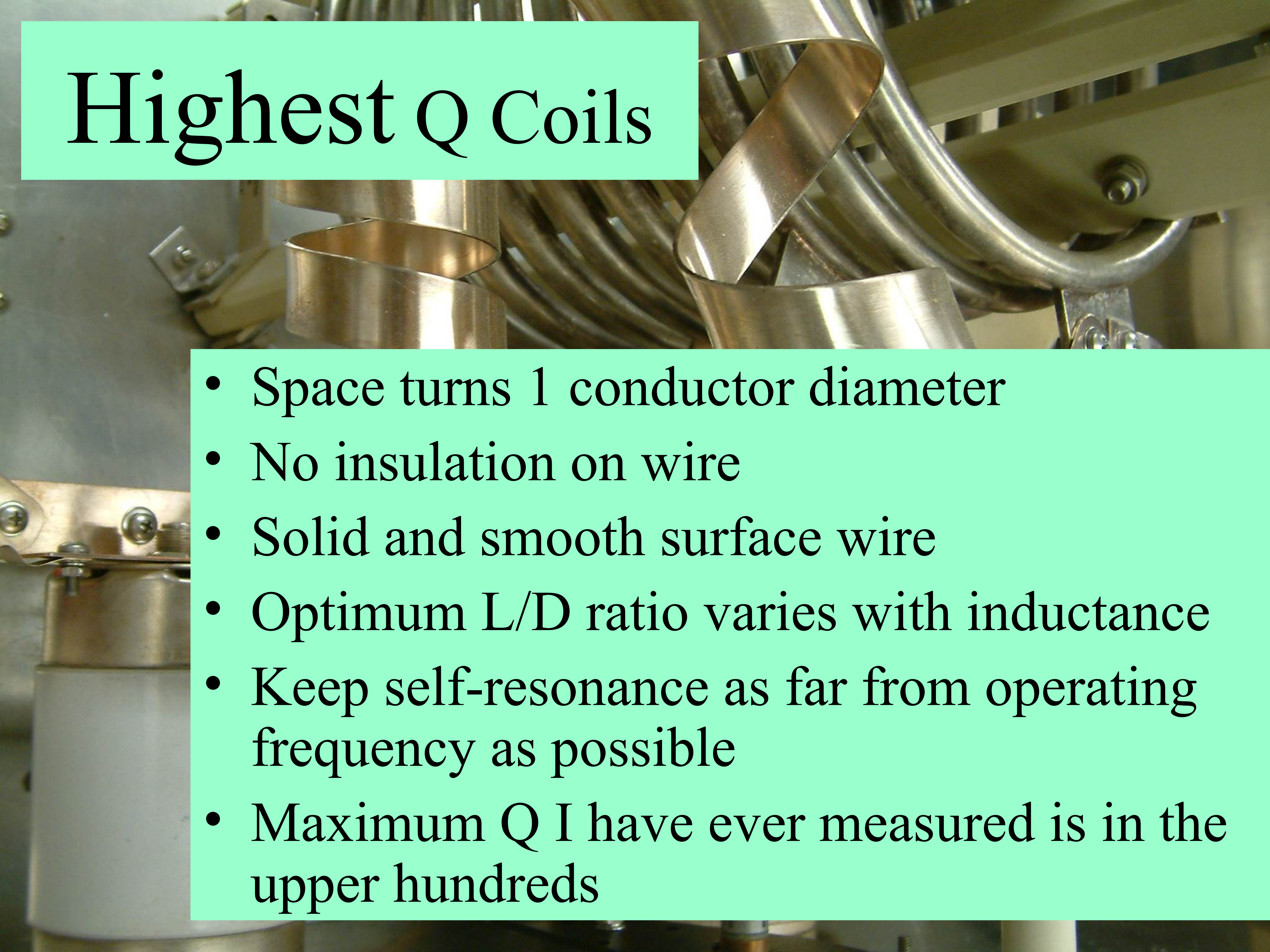
- C=0 R=5 Q=50
- C=200 R=10.5 (3.92Lr) Q=24

- Increasing stray C reduces turns 22% but doubles resistance even though we used less wire! This is why folding is bad.

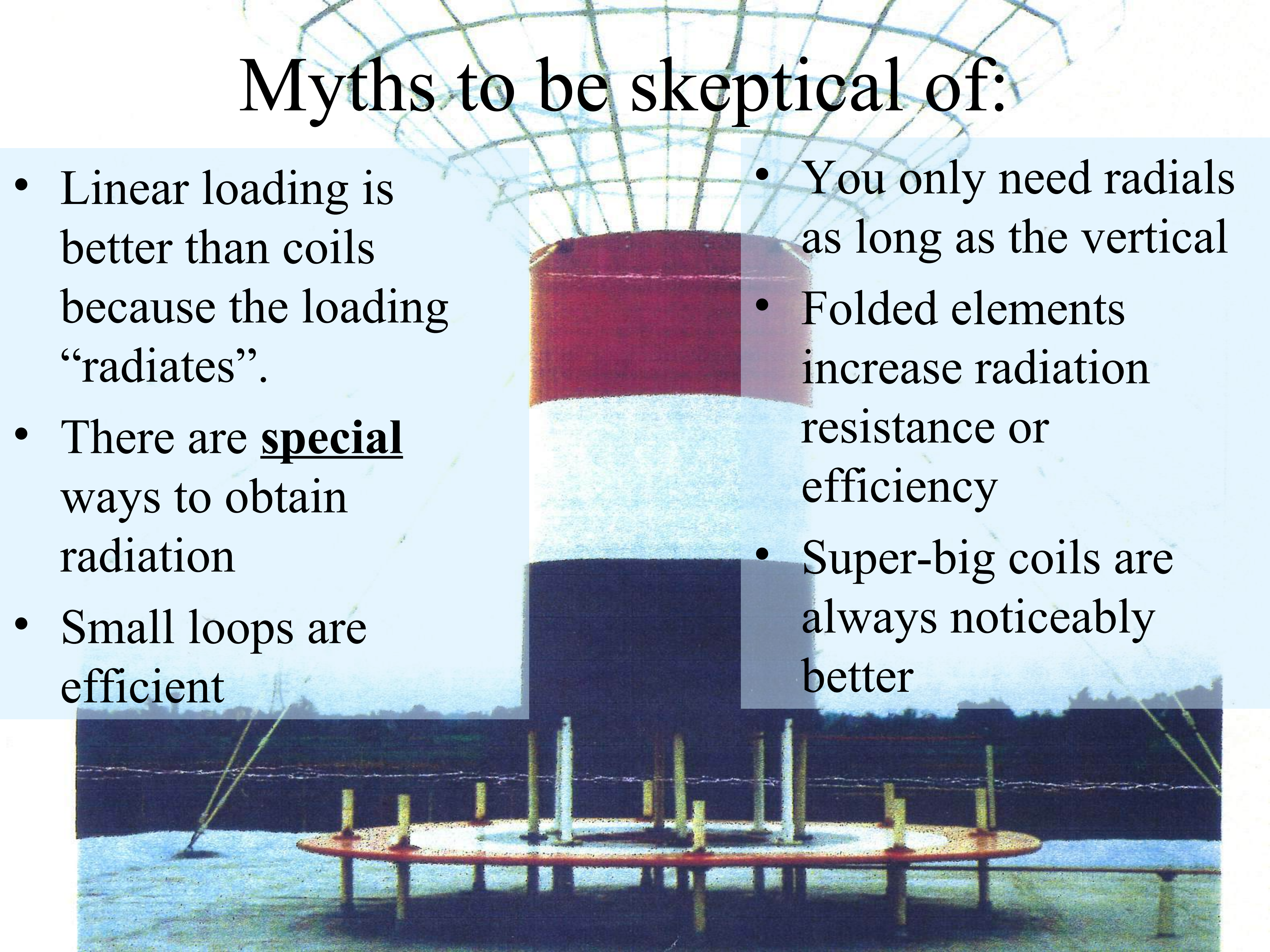
Good Ideas for loading coils

- Keep hats ½ hat radius away from coil
- Do not add large metal plates at ends of coil
- Do not mount coil near metal
- Do not add needless dielectrics in or around coil

Highest Q Coils



- Space turns 1 conductor diameter
- No insulation on wire
- Solid and smooth surface wire
- Optimum L/D ratio varies with inductance
- Keep self-resonance as far from operating frequency as possible
- Maximum Q I have ever measured is in the upper hundreds



Myths to be skeptical of:

- Linear loading is better than coils because the loading “radiates”.
- There are **special** ways to obtain radiation
- Small loops are efficient
- You only need radials as long as the vertical
- Folded elements increase radiation resistance or efficiency
- Super-big coils are always noticeably better

Mobile Antennas

10ft antenna as reference

Type	Height Base	Top Length	Hat dia	Field Strength	Frequency	Relative FS	
Reference				-18.5			best tested antenna
Large air	36"	84"	0	-18.50	7.2	0.00	3"dia #12
Large Air	36'	27"	47"	-18.70	7.2	-0.20	3" dia #12 47" hat
Small air	36"	27"	47"	-19.90	7.2	-1.40	1.5"dia #16 47" hat
TarHeel	42"	27"	47"	-21.00	7.2	-2.50	Tar with 47" dia
TarHeel	43"	84"	0	-21.10	7.2	-2.60	Tar with 7' whip
RM-20	36"	27"	52"	-21.20	7.2	-2.70	Hustler RM-20 on 40m
TarHeel	43"	27"	23"	-22.00	7.2	-3.50	Tar with 23" dia