Mobile Antennas

Attaining optimum performance from short antennas.

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Hearthside hams consider a quarter-wave antenna short, but the medium-frequency mobileer must get by with one that is practically gone: a fraction from 1/20 wave to 1/100.

Everybody knows that you use a loading coil with such a short antenna. But not everybody realizes that unless great care is taken a heavily "loaded" antenna turns more power into heat than signal.

Here is how to make the best of it.

Mobile short antennas are applications of the quarter-wave grounded-vertical form. Whether the antenna is fed directly, or through a line and coupler, the effective circuit is as shown in *Fig. 1a.*

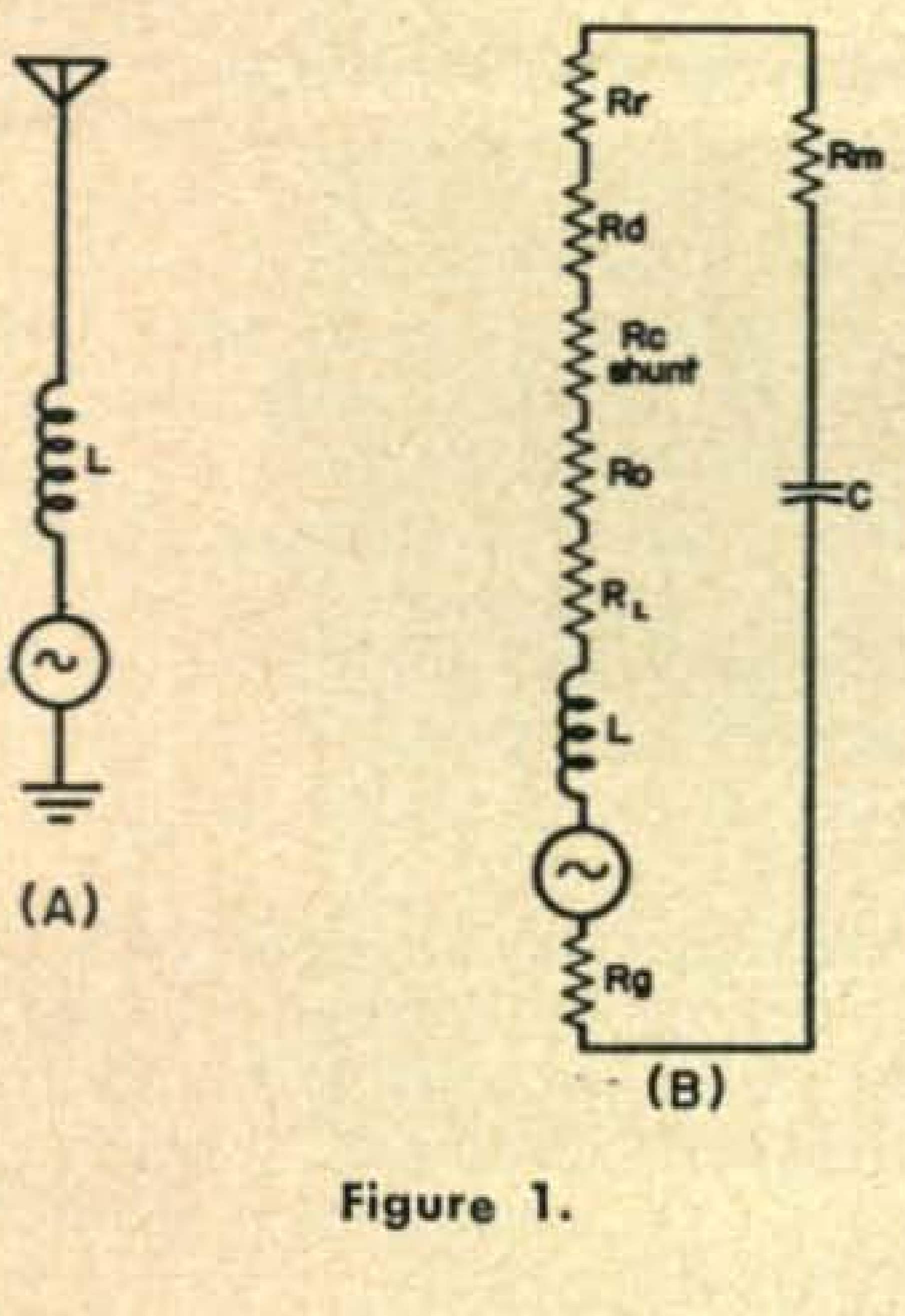


Figure 1.

Short antennas are capacitive, and this value can be measured by a capacitor checker or bridge connected between the antenna and ground. A calculation then gives the loading inductance necessary for resonance.

The equivalent circuit of *Fig. 1b* shows the resistances between which output power is divided. The resistance most desired is the radiation resistance, "Rr." For straight whip antennas this value is governed by height, according to the formula:

$$Rr = \frac{H^2 \text{ (in electrical degrees)}}{312}$$

Figure 2 plots radiation resistance versus height for lower-frequency bands. *Note that short-antenna radiation resistance is very low.*

Now for losses. Starting at the bottom of the diagram, the first encountered is ground resistance, "Rg." On automobiles, the ground circuit looks like a low-grade capacitor in series with the effective resistance of the ground underneath. This capacitance and its resistance is measured just like any other, by bridge or "impedance box." Slight reduction in ground loss may be realized if ground capacitance is made as pure as possible, by keeping tires clean and non-conductive, and possibly by fastening a copper screen to the undercarriage in the style of bottom covers used on racing cars.

Next is the resistance of the loading coil, "RL," which depends upon coil *Q*, or the relation of inductive reactance to resistance:

$$R_L = X_L/Q$$

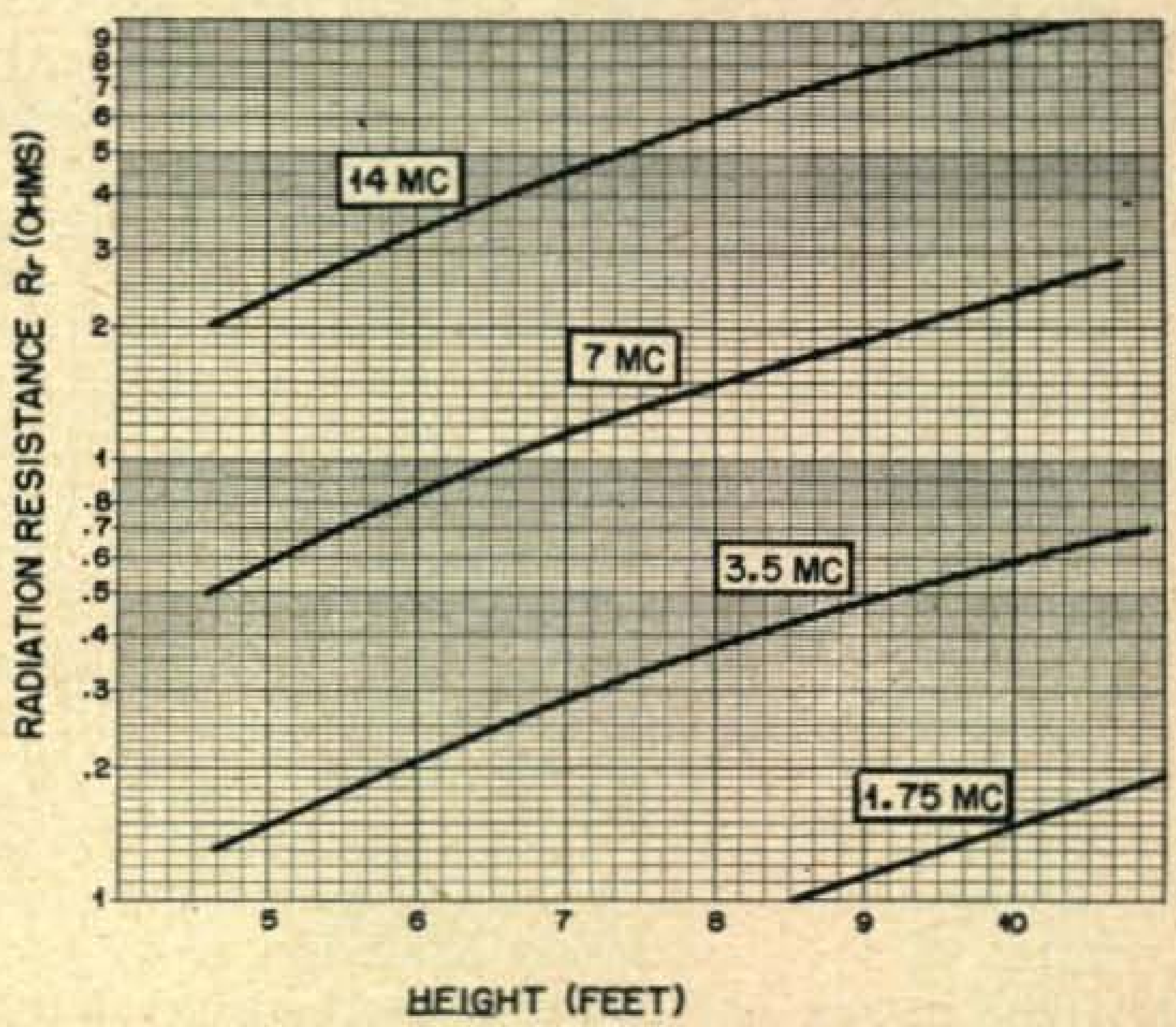


Figure 2.

Even with Q's as high as 400, more power is usually devoted to heating the loading coil than making signal. Obviously our coil should be the most efficient possible. Coil Q is measured with a Q meter, or a "Q-Box." *

Next on the list of losses is the ohmic resistance of the conductor making up the antenna, "Ro." This consists of d-c resistance multiplied by a skin-effect factor. With thin or poorly-conductive antennas this figure can be quite large, compared to radiation resistance.

Capacitance at the base of the antenna soaks up power. Although this loss is through a shunt circuit, it is evaluated easiest when transformed to a series equivalent "Rc-shunt" as shown. The greatest loss source here is the base or lead-in insulator, and how much loss depends upon whether the insulator is above or below the loading coil in the circuit.

Here is how this works. Reactance of the base capacitance is looked on as resistance of the same ohmic value, through which current flows to ground. Current leaving the circuit by this route never reaches the radiation resistance, which is where we want it dissipated.

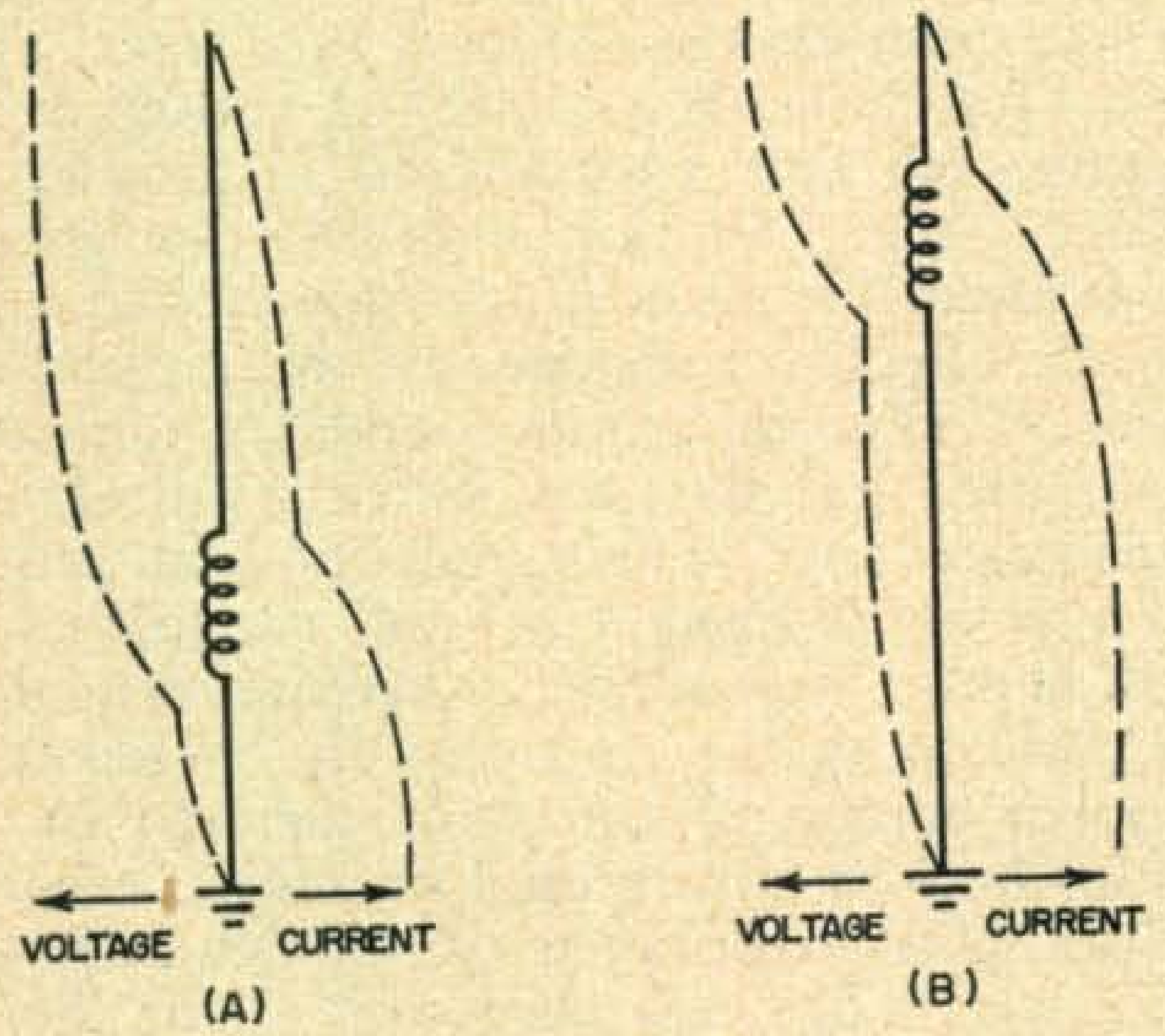


Figure 3.

As in a real resistance, current flow through this shunt depends upon voltage impressed. Now, with the usual rig, voltage at the bottom of the loading coil is in the order of tens of volts. However, at the top of the coil voltage is in the order of hundreds or even thousands of volts. The result is that a moderately-capacitive insulator above the loading coil introduces an equivalent series resistance of ohms. So use a low-capacity base insulator, and keep loss low by placing the loading coil above it in the circuit.

Similarly, base-insulator dielectric leakage introduces a series equivalent resistance, "Rd,":

$$\text{Series Equiv. Rd} = \frac{R^2 + X^2}{\text{Rd (shunt)}}$$

If the base insulator is located below the coil, a point of low reactance (and low voltage), loss will be negligible. But if the base insulator is above the loading coil, a leakage resistance of hundreds of thousands of ohms, or even megohms, introduces a loss equivalent to that which would be suffered in a series resistance of a husky fraction of an ohm, and in severe conditions, many ohms. Hygroscopic insulators are worst in this respect, but any insulator causes trouble if it is wet or dirty.

Sometimes another loss resistance is encountered—that due to absorption of mutually-coupled circuits, "Rm." This is most prevalent in maritime-mobile operation, although it is suffered on planes, and in some cases in auto operation. Rigging, structural members, or other antennas are contributory. If other conducting objects cannot be kept out of the immediate field of the antenna, see that they have a different resonant frequency, and that they are either "floating" or efficiently grounded. A coupled circuit having a low internal resistance returns some of the energy it soaks up back to the field, where the worst result is a pattern distortion. But an absorptive circuit with loss resistance of its own just soaks up power.

Until now, we've talked only of symbolic configuration of the short antenna. Let's go from symbols to actual hardware. What shape should the antenna have?

In the first place, no one design is best for all conditions. All we hope to do is arrive at something reasonably good for our own particular case. Physical and mechanical considerations are sometimes as important as electrical design, and the most efficient structure might not be satisfactory if it is offensive to the eye or if it is unsound aerodynamically.

But let's assume that through careful construction, we keep controllable losses to a minimum. Is there anything better than the plain whip we have thus far considered?

Figure 3a shows current and voltage distribution in an antenna with the coil at the bottom. If the main portion of the antenna carried more current, radiation figure and pattern would be improved. The most common means of raising the high-current section of the antenna is to move loading inductance upward, giving current and voltage distribution as in *Fig. 3b*.

However, this can't be done blindly, or any gain is gobbled up by increased losses.

Actually, radiation resistance and capacitance are not lumped, but are spread along the entire antenna, as shown by *Fig. 4.* With the

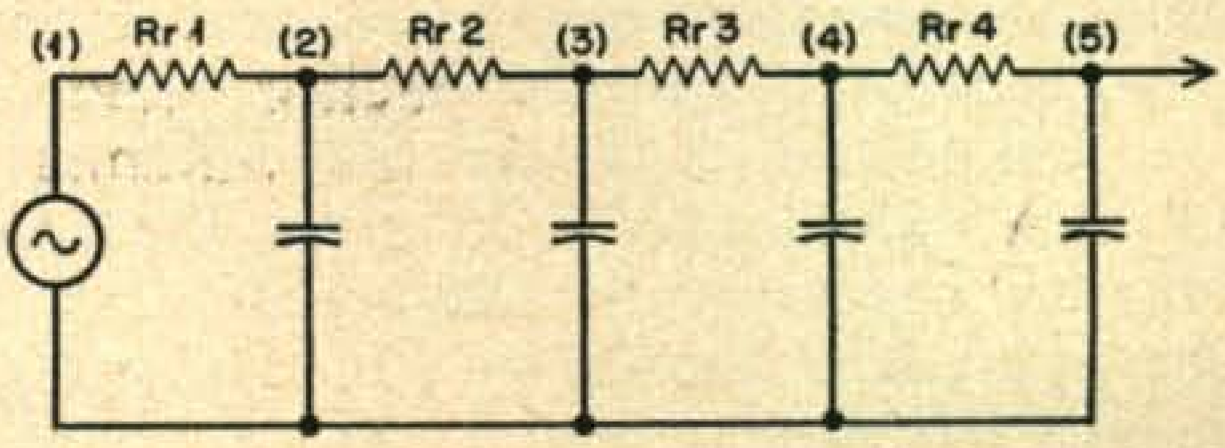
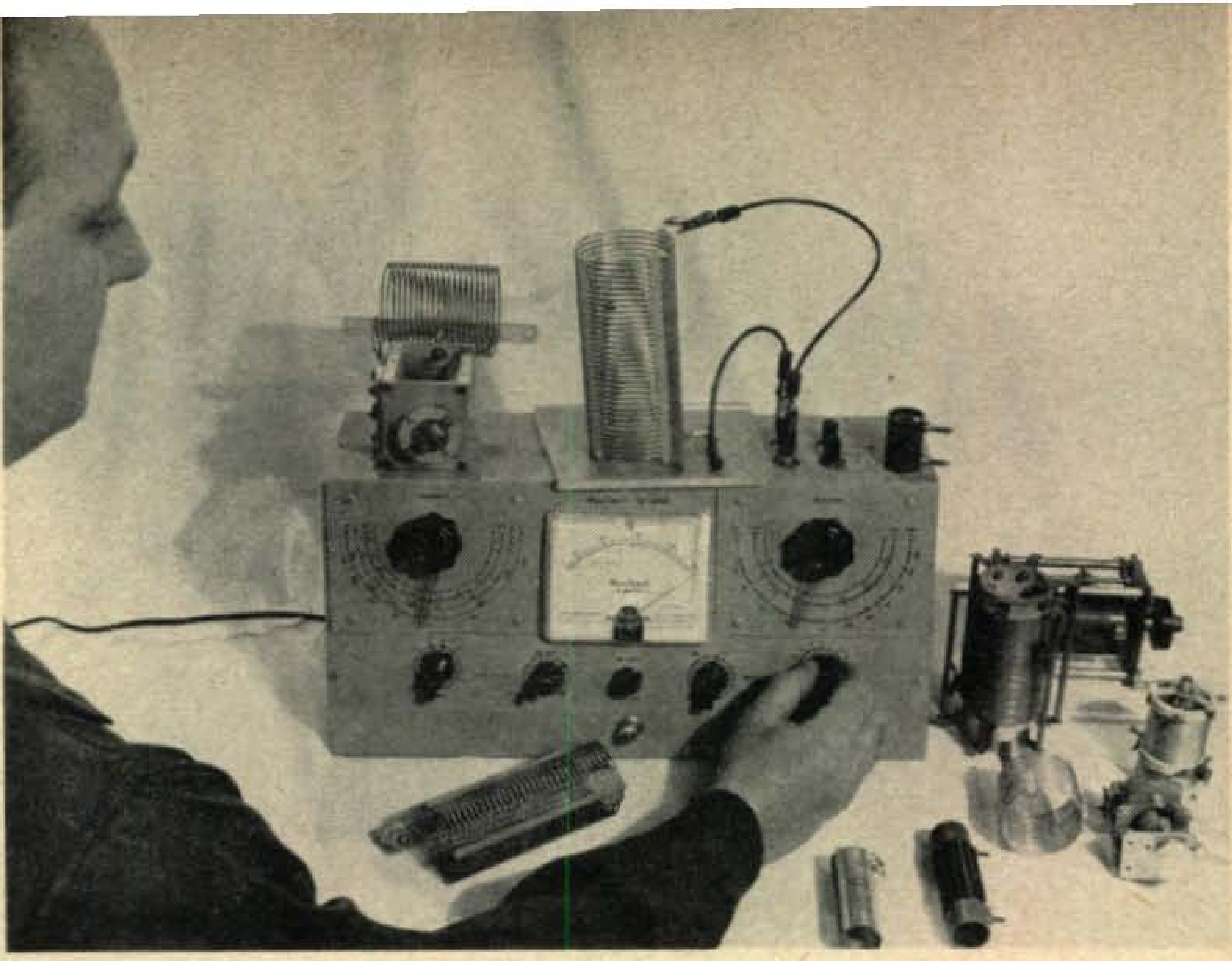


Figure 4.

* Robberson, "Q-Box" *CQ*, April, 1954, page 44.



Antenna efficiency can be decided right here

loading coil in position (1), it is resonated by the entire capacitance of the antenna.

But note that if the coil is placed at points (2), (3), (4), or (5), corresponding to increasingly-higher positions aloft, it faces less and less capacitance. Therefore, to resonate the antenna, the coil must be increasingly larger as it is raised. With the standard of construction remaining constant, resistance of a coil naturally increases as it contains more and more wire. Hence, a point is reached where gain in radiation resistance or pattern is offset by mounting coil loss.

For example, a whip that resonates with a 20-turn coil at the bottom may need 70 turns farther up. And, at the very top, the coil stops acting like an inductance and turns into a low-grade blob of capacitance, so inductance must be added below to resonate the system. Any "gain" in such a case is highly problematical.

When using coils aloft, remember that snug metal shields, dirt, or moisture also increase coil resistance. The antenna-loading coil should have the maximum *Q* attainable, no matter where it is placed in the circuit.

Now let's examine antenna loading from another angle. If the antenna capacitance (other than at the base) is increased, the amount of loading coil required for resonance is reduced, and coil loss with it. *Figure 4* also shows that the best place for the bulk of capacitance is at the end, since to reach this capacitance current must flow through the entire antenna, utilizing the entire radiation resistance. Unfortunately, the end is the poorest location mechanically. Fixed stations get by with "wagon wheels" atop the antenna, but not the family bus.

Antenna capacity can be raised by increasing diameter. A thin whip may have a capacitance of 20 μμfd. Increasing diameter to 1″ raises capacitance to 40 μμfd. Thin-wall tubing of 3″ diameter has almost twice this value. These "thick" structures need not be solid—lattice construction has an equivalent effect.

Increased capacity is realized by "fanning" two or more whips at an included angle of not more than 60°. This arrangement is light and has more "top loading than cylindrical shapes, and it can be accommodated on rear deck or bumpers. But, however we get it, capacitive top loading can reduce the amount of inductive loading required by more than one half with a consequent lower coil loss.

The relative distribution of transmitter power, and hence, efficiency of different antenna configurations, can be checked without complicated instruments. Using a dummy antenna, find transmitter-power output under standard load conditions. Then measure base antenna current with the same transmitter input. Total antenna resistance is found from the formula:

$$R_t = \frac{P}{I^2}$$

Comparing measured resistance of different elements of the system with this total gives an idea of the loss in each part, and dividing radiation by total resistance will show relative antenna efficiency. Resistances of different coils, ground systems, and radiators can be checked by this means.

But to make the finest comparisons, there is no substitute for remote field measurements. Stake out a remote field-strength meter. If you don't want to string wires, a "Signal Bouncer" * will give remote signal-strength readings by radio. Then, keeping transmitter power at a standard level, the best balance between height, capacitive, and inductive loading is determined by how much of a stir your signal makes on the air.

A little work on the antenna to reduce unnecessary loss may increase your effective power more than any other improvement you can make!

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* Robberson, "The Signal Bouncer," Radio & Television News, April 1954, page 47.