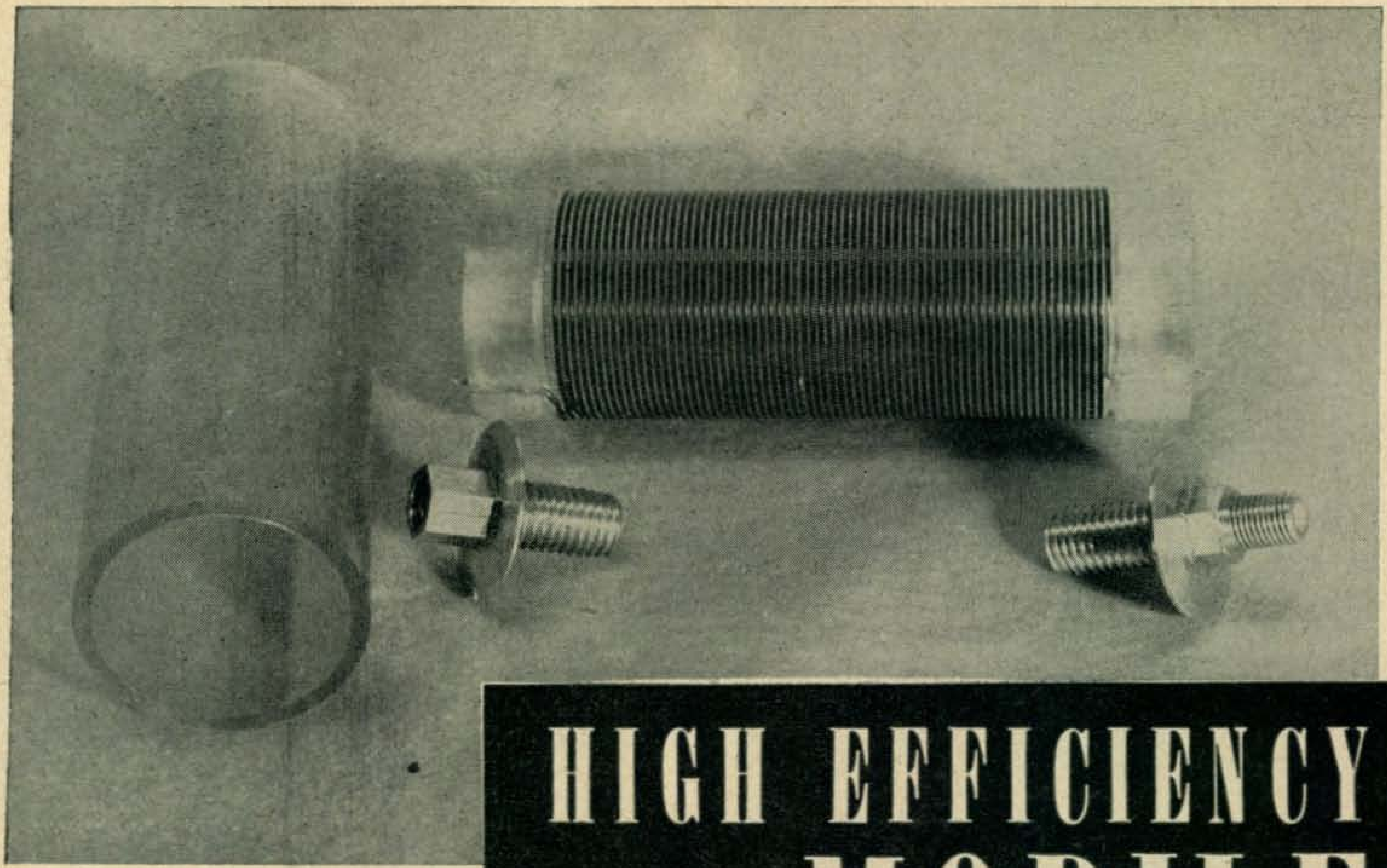

HIGH EFFICIENCY FOR MOBILE

SINCE THE LOWER-FREQUENCY AMATEUR BANDS were opened for mobile operation in 1948, such operation has been becoming increasingly popular, and within the limitations imposed by restricted antenna size, 75 meters particularly has given an excellent account of itself. The relative freedom from ignition noise, and consistent daytime range extending out to two or three hundred miles with no dead spots and little shadow effect or fading is indeed a revelation to the ten-meter mobile operator.

Unfortunately, such results are not achieved without solving a number of problems, particularly those involved in obtaining an electrically satisfactory antenna installation that does not require an advance crew to remove overhead wires, tree limbs and such.

Many 75-mobile antennas of radical design, some wondrous to behold, have been constructed, but after the novelty wears off, the old standby, a seven or eight-foot whip, usually wins out from pure mechanical simplicity. If it is properly loaded, about the only thing that can beat it is a longer whip (perish the thought) or the big antenna on the home station. It is that little phrase "properly loaded", however, that trips the unwary. Although center loading and top loading have some theoretical advantage over base loading, the increase in efficiency is small compared to the difficulty of moving the coil very far up the antenna. A short extension below the loading coil may be justified for special installations, such as on a panel truck or a station wagon where it is desirable to raise the coil to get it clear of the body, but on the usual passenger car, it has little advantage.

But to start with fundamentals: An eight-foot whip, at 4 mc, mounted well up on an automobile, has very troublesome electrical characteristics. What it actually looks like to the transmitter and loading system is a resistor of approximately 1.5 ohms, with a capacitor of approximately 25 μμf connected in series with it. The 1.5 ohms represents the radiation resistance, the thing we want to put our power into, and the capacitance is just in the way. All of the current into the 1.5-ohm resistance must flow through the 25 μμf capacitance. That is unfortunate, for the reactance of that capacitance is some 1590 ohms. If we don't let phases trip us up, we can apply Ohm's law to current through reactance as well as through resistance, so let's see what it takes to push a few watts into the radiation resistance of our antenna. Suppose we start at the receiving end, and assume a current of 2 amperes in the antenna. I^2R tells us that this represents 6 watts in the 1.5 ohm radiation resistance of the antenna. These are good watts, the ones that do the work. But to put that 2 amperes through the 1590 ohms of capacitive reactance take a radio-frequency voltage of 2×1590, or 3180 volts! And that voltage appears on the entire length of the

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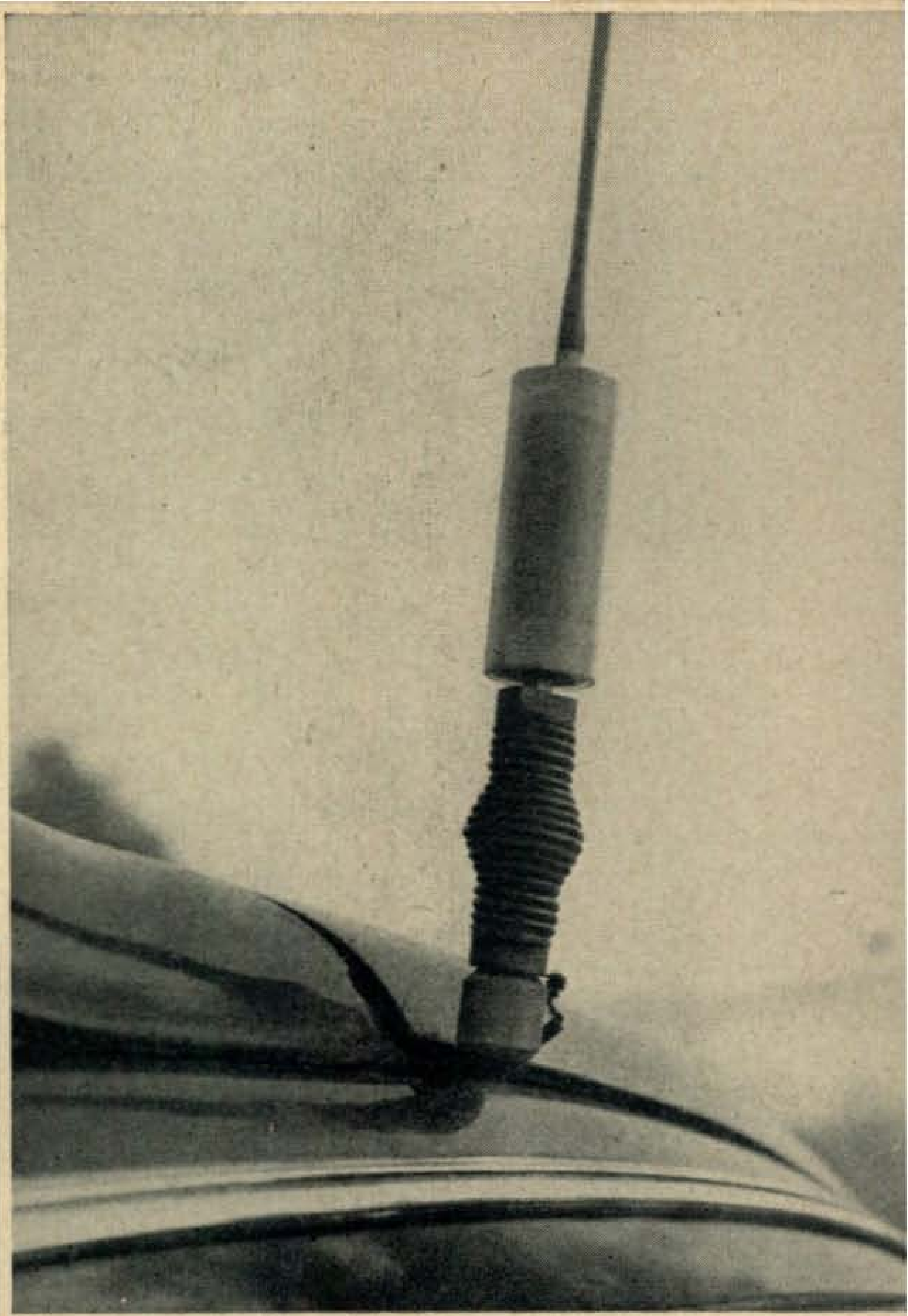
Here's some sound data on mobile antennas by one of the pioneer mobileers

GEORGE M. BROWN, W2CVV*

LOADING COIL ANTENNAS



The complete assembly

whip, above the loading coil. Now you see why good insulation is imperative. Although there is nothing dangerous about that voltage, since it is radio-frequency and the regulation is extremely poor, getting it to put on the antenna takes some doing.

Of course the first thing we think about when we have some reactance we don't like is to tune it out, and that is exactly what we do in this case. We wind a coil having 1590 ohms of *inductive* reactance, and connect it in series with the antenna. Properly adjusted, this very effectively tunes out the 1590 ohms of *capacitive* reactance of the antenna, and if it were a perfect coil, all that would be left for the happy transmitter to look at would be the 1.5 ohms of antenna resistance. This doesn't mean that the 3180 volts are no longer required—they are just produced by the series resonance of the loading coil and the antenna capacitance. They appear not only on the antenna, but across the loading coil as well. Even the Iron Curtain boys don't claim to have invented a perfect coil, however, and all physically realizable ones have resistance as well as reactance—altogether too much of it to make us really happy. The ratio of reactance to resistance of a coil is given the symbol Q; a coil having a reactance of 200 ohms and a resistance of 2 ohms is said to have a Q of 100. The first loading coil wound at W2CVV had a Q of 160, which meant that with a reactance of 1590 ohms the resistance was 1590/160, or approximately ten ohms. Since we have tuned out all the reactance, what we have left is actually the 1.5-ohm radiation resistance of the antenna, fed through the ten-ohm resistance of the loading coil.

Going back to the two amperes of antenna current we assumed to start with, pushing it through that ten ohms will soak up 40 watts, all dissipated as heat in the loading coil, and doing no one any good.

Thus with a base loading coil having a Q of 160, and that is about what the usual ones run, to put 6 watts into the antenna we have to have a total *output* of 46 watts from our transmitter, well beyond the capability of the usual mobile installation. Our coupling efficiency, neglecting such variables as ground resistance and miscellaneous losses, is only about 13%. To improve this efficiency requires either increasing the radiation resistance of the antenna or decreasing the resistance of the loading coil. The antenna resistance is pretty well determined by its length, however, and nothing much can be done about it, within practical limitation, so the problem nicely resolves itself into that of building a better loading coil. *Figure 1* curve (*a*) is plotted to show the variation of coupling efficiency with various values of loading coil Q.

A study of the rather meagre literature on the design of high-Q coils disclosed some interesting facts, not all of them favorable to our project:

1. **In general, the larger the coil, assuming a good form factor, the higher the Q.**

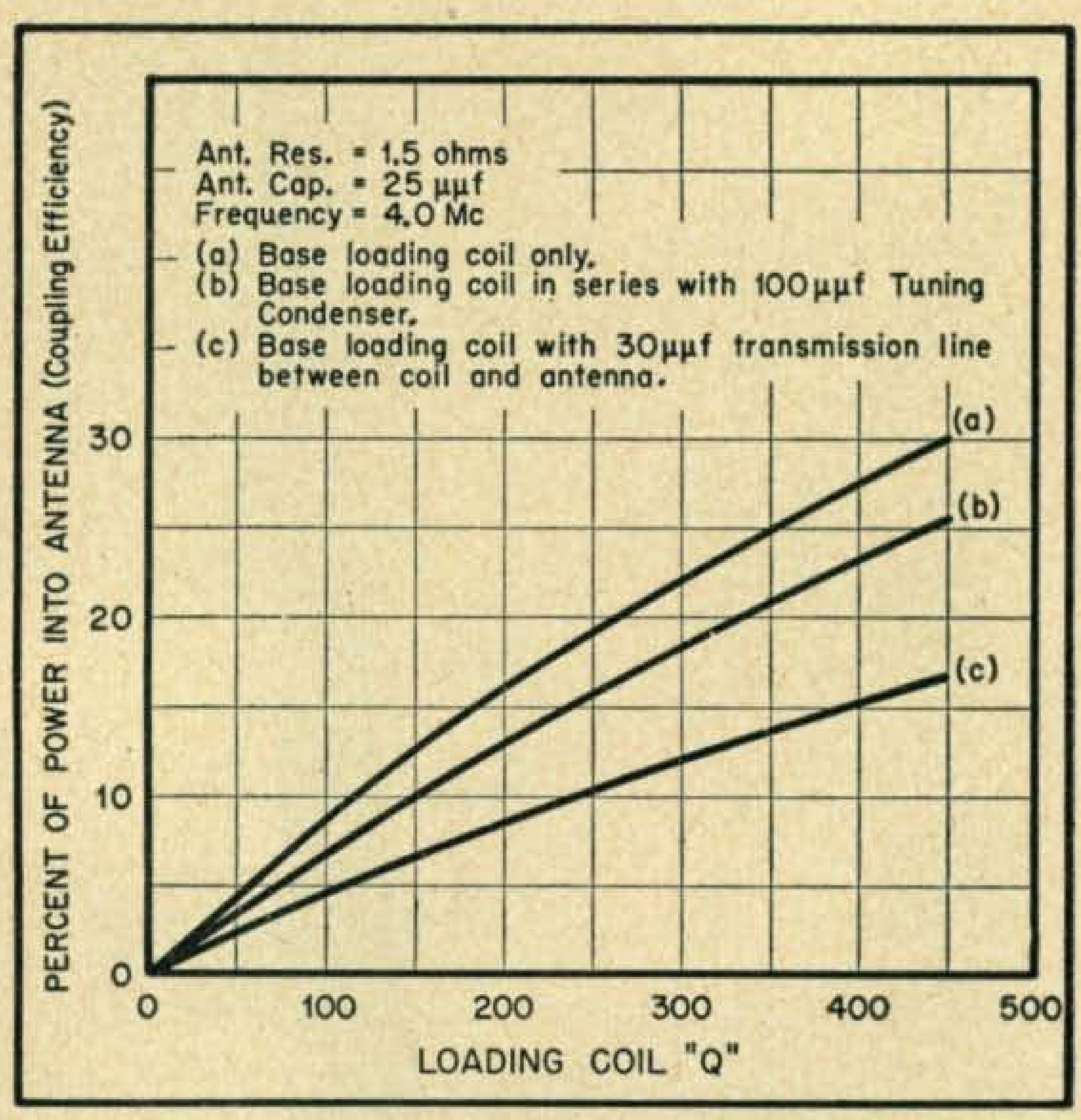


Figure 1.

2. Once the size of the form is established, the optimum wire size is somewhat smaller than the largest that will give the necessary number of turns in the space available. In other words, use smaller wire and space the turns.
3. Reasonable liberties can be taken with form factor, and since a long slim coil can be more easily mounted on a car than a squat fat one, some departure from the optimum dimensions can be tolerated, although of course very long slim designs should be avoided.

With these rather nebulous design criteria in mind, a number of dry maple forms were turned out, and quite a few experimental coils wound. The results were disappointing—it seemed that the best ones had a Q of 180. Although dry wood is supposed to have reasonably low loss, it was eventually found that "reasonably low" just wasn't good enough. Transferring one of the windings having a Q of 180 from the wood form to one of polystyrene immediately increased the Q to over 300.

The final coil design, is shown in the photograph, and *Fig. 2* shows its construction in more detail. The core is a piece of 1-$\frac{3}{4}$″ diameter polystyrene rod, undercut and threaded to take the winding of #18 wire spaced 16 turns per inch. The end fittings are made from brass, and securely anchored to the core by threading into it and then staking with a #8 screw tapped through the brass washer and on into the polystyrene. The fittings are threaded to accommodate the antenna and mounting spring that will be used. After final adjustment, the entire coil is covered by a poly sleeve, 1$\frac{3}{4}$″ inside diameter, slipped on and cemented in place. Be sure to do a careful job of cementing, since otherwise the coil will "breathe" and water will condense inside.

This final coil has a Q of well over 300—compared to the original coil, with a Q of 160, it has a coupling efficiency of over 22% instead of 13%. With the same transmitter input, it will deliver almost twice the power into the radiation resistance of the antenna that the old one would, a substantial improvement and much easier than doubling the power of the mobile transmitter.

One of the penalties that must be paid for high Q and high efficiency in the loading coil is that the tuning becomes extremely sharp. It is thus necessary to adjust the loading accurately, and to readjust it for each significant change in operating frequency. To put this in practical terms, if the frequency is shifted plus or minus 5 kc without reloading, no appreciable loss will result; 10 kc, and the output and plate current will start to drop off; 15 or 20 kc, and performance will seriously suffer. Obviously some convenient means must be provided for adjusting the loading coil or some other portion of the circuit to tune out exactly the antenna reactance at each frequency setting. A very slight adjustment of the loading coil inductance would take care of this, but with a high-Q sealed loading coil, such adjustment is hardly practical.

A tuning capacitor in series with the loading coil is frequently used, but at considerable loss in efficiency. The way it works, an oversize loading coil is used, and the excess inductance in it is tuned out by the variable capacitor. Increasing the loading coil inductance to provide something for the capacitor to tune out increases its resistance also, however, and the antenna current must flow through the total resistance. Curve (*b*) in *Fig. 1* shows the resulting loss in efficiency, plotted against coil Q. It assumes a 100 μμf setting of the variable capacitor. Note how much lower it is than curve (*a*). A much larger capacitor than 100 μμf would, of course, reduce the loss, since it would require less excess inductance in the coil, but a series variable capacitor does not seem to be the easiest way to do the job.

(Continued on page 56)

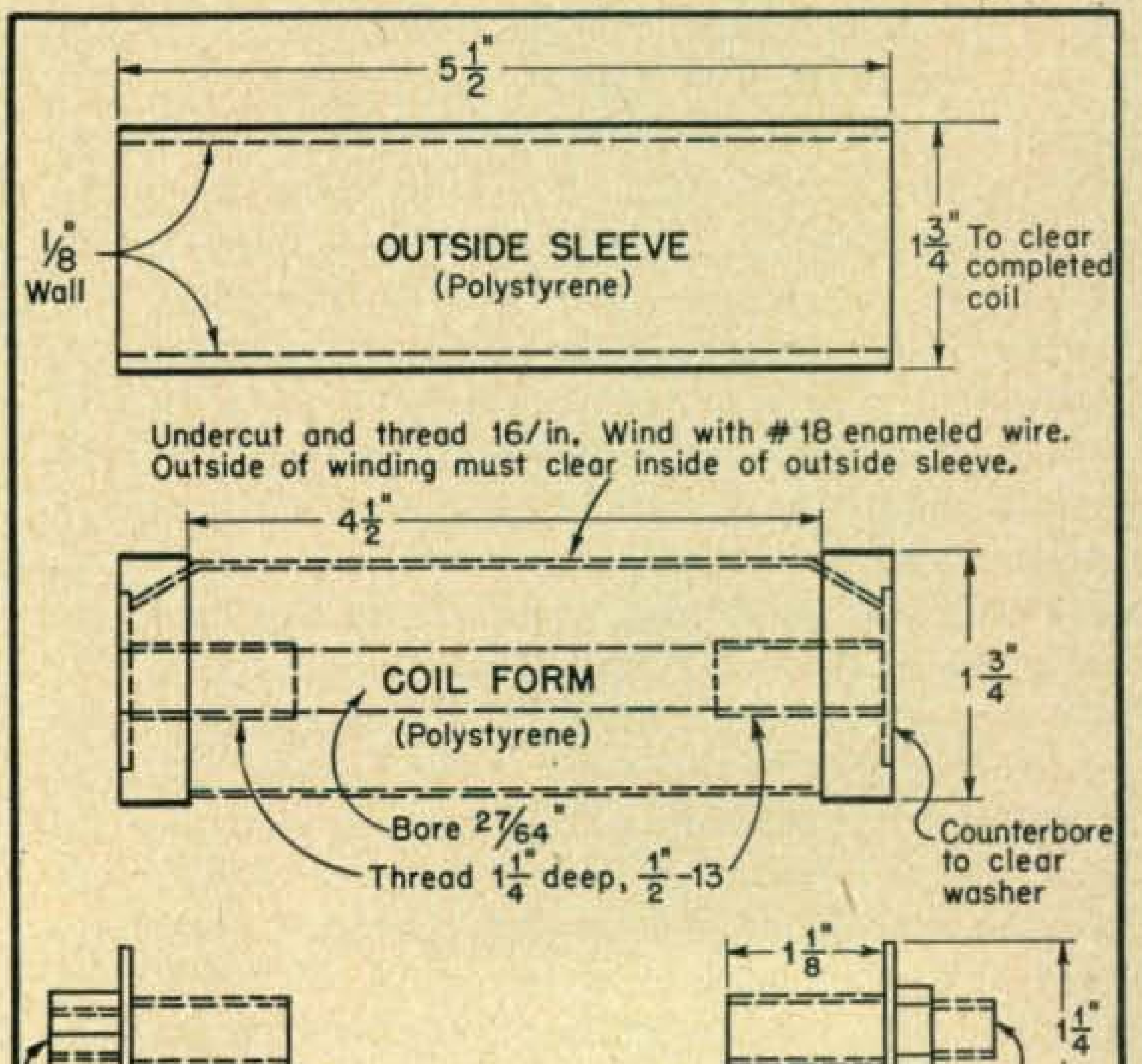


Figure 2.

amplitude. This is the case of condition 2. As these air masses may be moving from west to east at an average speed of say 15 miles an hour, it is easy to visualize how the moving hills and valleys of the discontinuity boundary may effect the multi path reflections and account for DX signals fading up and down from 0 to S9 during a QSO.

(This completes part B *of a series of articles by Mr. Underhill on VHF Radio Wave Propagation. Part 3 will discuss in greater detail the influence of the troposphere on v.h.f. band conditions, and will also set forth the latest ideas on prediction of band openings.)*

LIGHT BULBS

(from page 31)

would be difficult to determine the percentage of the total current flowing through any one branch.

Identical units, on the other hand, may be paralleled. In this case the total current is divided by the number of branches and the power found for each branch. This branch power is then multiplied by the number of branches to find the total power dissipated.

It should be noted that the ratio of hot to cold resistance varies by a factor of at least two. Thus one would be in considerable error to measure the resistance of the lamp with an ohmmeter when it was cold and use this value of resistance when the lamp is hot. Similarly, one would be in error to find the resistance of the lamp by taking the lamp ratings and applying the formula

$$R = \frac{E^2}{W}$$

and using this value of resistance when the lamp was not operating at its full ratings.

Since these measurements were made at 60 cycles, where stray capacity effects are negligible, care should be taken when the lamps are used at radio frequencies, especially at frequencies above 10 mc. Leads should be as short as possible and should be brought away from the tank coil at right angles.

It may thus be seen that by using *Figs. 2* and *3*, the power output and efficiency of a radio transmitter may easily be found; while *Figs. 4* and *5* may be used to find the resistance of a lamp bulb when the current flowing through it is known.

LOADING COIL

(from page 22)

By making the loading coil smaller than required, and then adding a variable inductor in series for adjustment, losses are not appreciably increased. Many transmitters used for 75 mobile, such as the BC-696, already have a continuously-variable loading coil of the trolley wheel type built into them, and are a natural for this method of adjustment. Similar variable coils are available on the surplus market and can be added to transmitters lacking them. If a separate coil is used, the closer it is mounted to the antenna the better. In any case, since the fixed loading coil has a higher Q than the variable one, it should be carefully adjusted to tune with the variable at minimum inductance on the highest frequency, and then inductance added in the variable to work on lower frequencies in the band.

It is important that stray capacity to ground beyond the loading coil be kept to a minimum—that is the basic reason for mounting the coil out in the weather, and letting it form the bottom part of the antenna itself. Even a very small amount of capacity will cause increased loading coil loss, since the high voltage appearing beyond the coil will produce high current in even a few micromicrofarads. An additional 25 μμf will double the capacity into which the loading coil looks, and double the current through the loading coil for the same radiated power. Of course, since this capacity combines with the 25 μμf antenna capacity to make 50 μμf, of some 800 ohms instead of 1590 for the loading coil to tune out, it requires only half the loading coil inductance, and the resistance of the coil goes down to half what it was. But the loss in the coil goes down only directly with its reduced resistance while it increases as the square of the increased current. Curve (*c*) of *Fig. 1* shows the effect of 30 μμf of stray capacity on coupling efficiency. This is about the minimum strays to be expected if the loading coil is mounted inside the trunk of a car. If RG-8/U or similar line is used to connect between the loading coil and the antenna, even more stray capacity will be encountered—RG-8/U is 29.5 μμf per foot.

Moral:

Use the longest antenna you can get away with.
Build the best loading coil you can.
Mount it in the clear.
Tune it by series inductance.

SCRATCHI

(from page 4)

gation conditions are big cause, and the club are finally adjourning for the evening.

Next morning a wee small voice keep talking to me, telling me that maybe last night are something different from just a hot DX night, so I finally taking the antenna matching network and connecting it to my small portable rig, and tuning it up on my half-wave antenna. The antenna are reely sopping up the RF out of the final, so I deciding to give it a try on the band. I turn on the receiver, tune across the band, and find nothing on except two locals practising see-w and one or two weak W9's calling seek-you. Still in the experimental mood, I connecting the receiver antenna terminals to matching network, and again listen across band.

Hon. Ed., sensational is the word. Superstupendous is a better one. You wouldn't believing it. The first thing I hearing is two VKs having ragchew. The next cupple kilocycles are running into a round table of Gs holding their afternoon tea and crummpit session. Are even finding call with prefixes I having to look up in DX Log. After shock are wearing off a bit, I rushing and phoning all ham friends, local broadcast engineers, and are even about to call local FCC inspector before