Vertical and Horizontal

160-80-40-15 vertical plus 80-40 Horizontal

Why to build-it
How to build-it

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Every ham at some time or other has asked himself the question: Horizontal or Vertical? At the shorter wavelengths this question is easily answered as space is not a major factor. Quite often it is merely the simple problem of trying both horizontal and vertical and then deciding which is best for the particular location. Then, in some cases, there is little choice. For mobile work a vertical is necessary as the efficiency of a horizontal antenna very close to ground approaches zero. Again, if beams are used, the tendency is to use horizontal antennas as it is usually easier to avoid coupling to adjacent obects in this way.

With the trend to suburban living, more and more hams have a backyard and space for a small antenna farm. Let us see what can be done in designing a horizontal and vertical antenna for the different bands from 160 meters down. The various factors will be discussed in the following paragraphs.

Is a ground necessary? We all know of hams working DX with no external ground or at best with a water pipe ground. The question is—could they do better with a good buried radial wire ground system. The answer as we shall see, is "yes."

Horizontal Antennas

If a horizontal antenna is used, the most serious problem is height above ground, and second is the ground system. When the horizontal antenna is on the ground, the radiation resistance is zero as the antenna current and its image current are equal and 180° out of phase and hence they cancel each other. A good ground system will not help here. Therefore the prime requisite is to operate the antenna some distance above ground. See fig. 1 which shows the driving point impedance of a horizontal half wave dipole. We see that by the time we reach an eighth wave above ground the driving point impedance is already about 30 ohms. This value is high enough to give a reasonably good efficiency. However, as the height is increased the low angle radiation tends to increase but the number of lobes in the vertical pattern of the horizontal antenna also increases. For the time being let us assume that a height above one eighth wave is satisfactory. At the impedance represented by this height, a good ground although important, is not vital.

At 160 meters which is mainly a local band, the wave does not go through enough atmospheric discontinuities to change polarization from horizontal to vertical or to circular. Hence a wave transmitted in the horizontal polarization will likely remain so until received. As most low frequency antennas are vertically polarized there is no point in having a horizontally

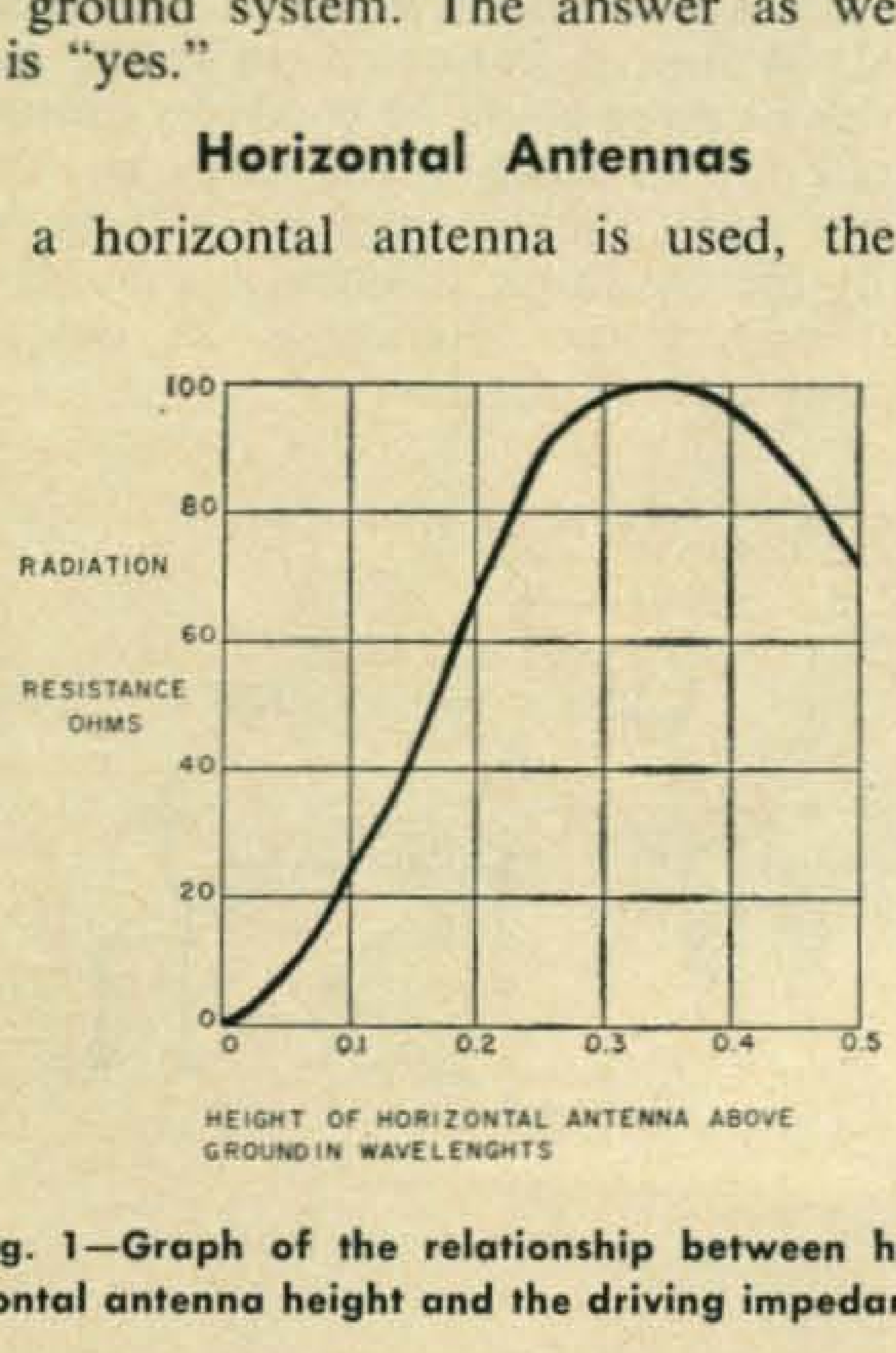


Fig. 1—Graph of the relationship between horizontal antenna height and the driving impedance.

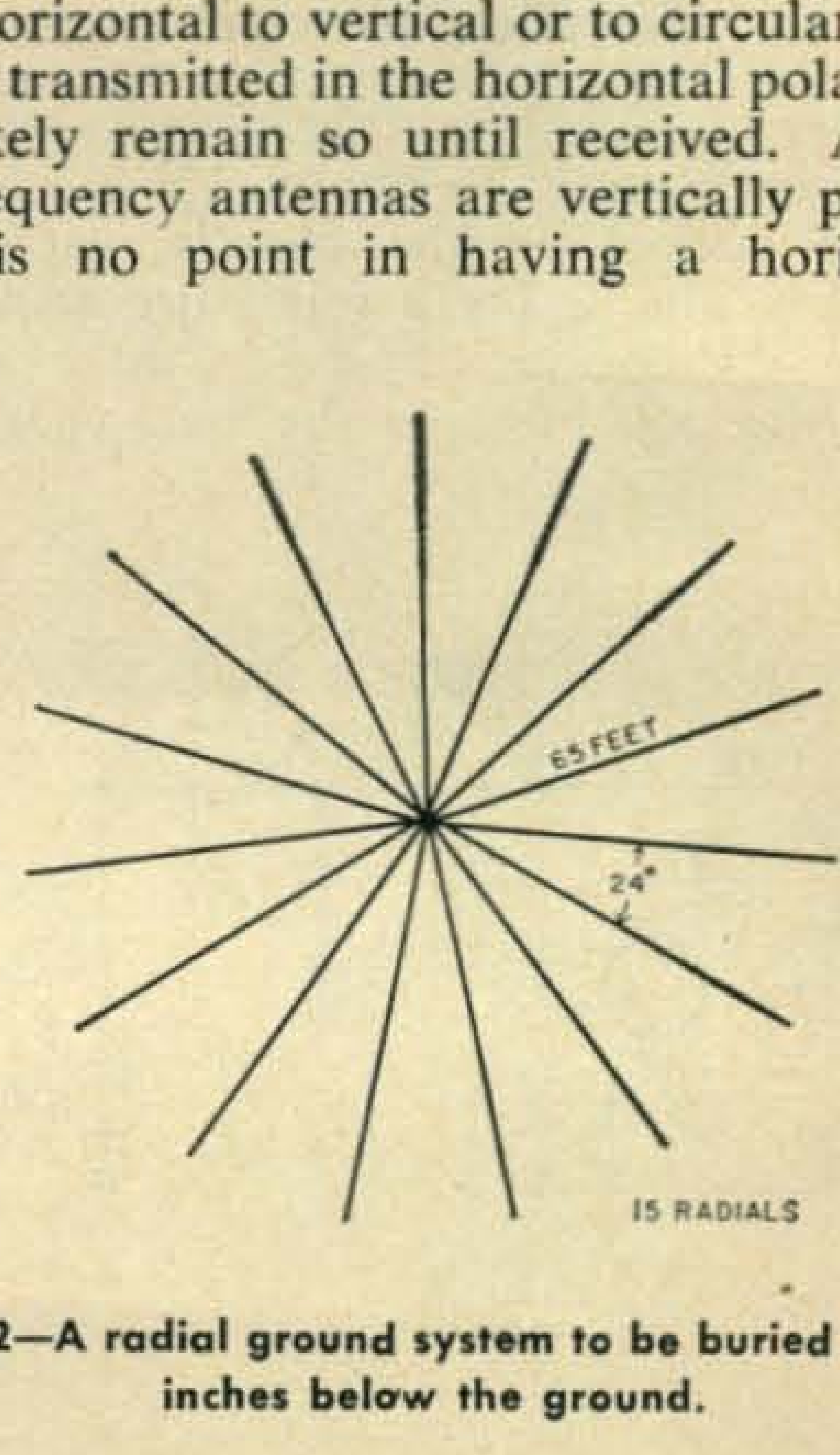


Fig. 2—A radial ground system to be buried 4 to 6 inches below the ground.

polarized transmitting antenna on 160 meters. There is also the problem of locating a 160-meter horizontal antenna far enough above ground to be efficient. On 40 and 80, however, where communication is over medium and long distances and the plane of polarization may change even over short periods of time or for different distances, it is sometimes helpful to be able to switch from horizontal to vertical polarization.

For 20, 15 and 10 meters, rotary beams are available, hence let us say our horizontal antenna will be used for 40 and 80 meters only, and will be one eighth wave or more above ground at 80 meters. The antenna itself should be at least one quarter wavelength and preferably one half wavelength long at 80 meters.

Vertical Antennas

If a vertical antenna is used, the efficiency of a short antenna is more directly tied in with the ground loss resistance. If it were not for ground losses, coupling losses, and losses in the antenna wire itself, an antenna one inch high would radiate almost as efficiently as an antenna 125 feet high at 160 meters. In fact until the antenna height is increased above one quarter wavelength, the only reason for increasing the antenna height above a few inches is to increase the ratio of the antenna resistance to the loss resistance, and hence to increase the proportion of the available power from the transmitter which is radiated. Hence we see that the shorter the vertical antenna the lower the ground resistance must be, and to lower this ground resistance a radial wire ground system should be used.

Ground System

The old idea of burying a car or house radiator below ground in a chemical solution does not produce a good radio frequency ground. It may be better than nothing but that is about all. The buried ground should consist of radials having a length of one eighth wavelength minimum. In commercial AM broadcasting installations it is customary to employ 120 or more equally spaced radials each ⅜ wavelength or more long for maximum efficiency. For ham use from 10 to 20 equally spaced radials about ⅛ wavelength long at the lowest frequency to be used would be a good compromise. (See fig. 2.) The radials should be buried from 4 to 6 inches below the surface of the ground. Any greater depth to get below a flower bed or garden will reduce the efficiency considerably. The current must flow from the ground wires to the ground itself at about the same depth at which the current will flow in the ground after it leaves the wires. This depth is known as the skin thickness and is probably more familiar to most hams in choosing the optimum size of wire in winding coils.

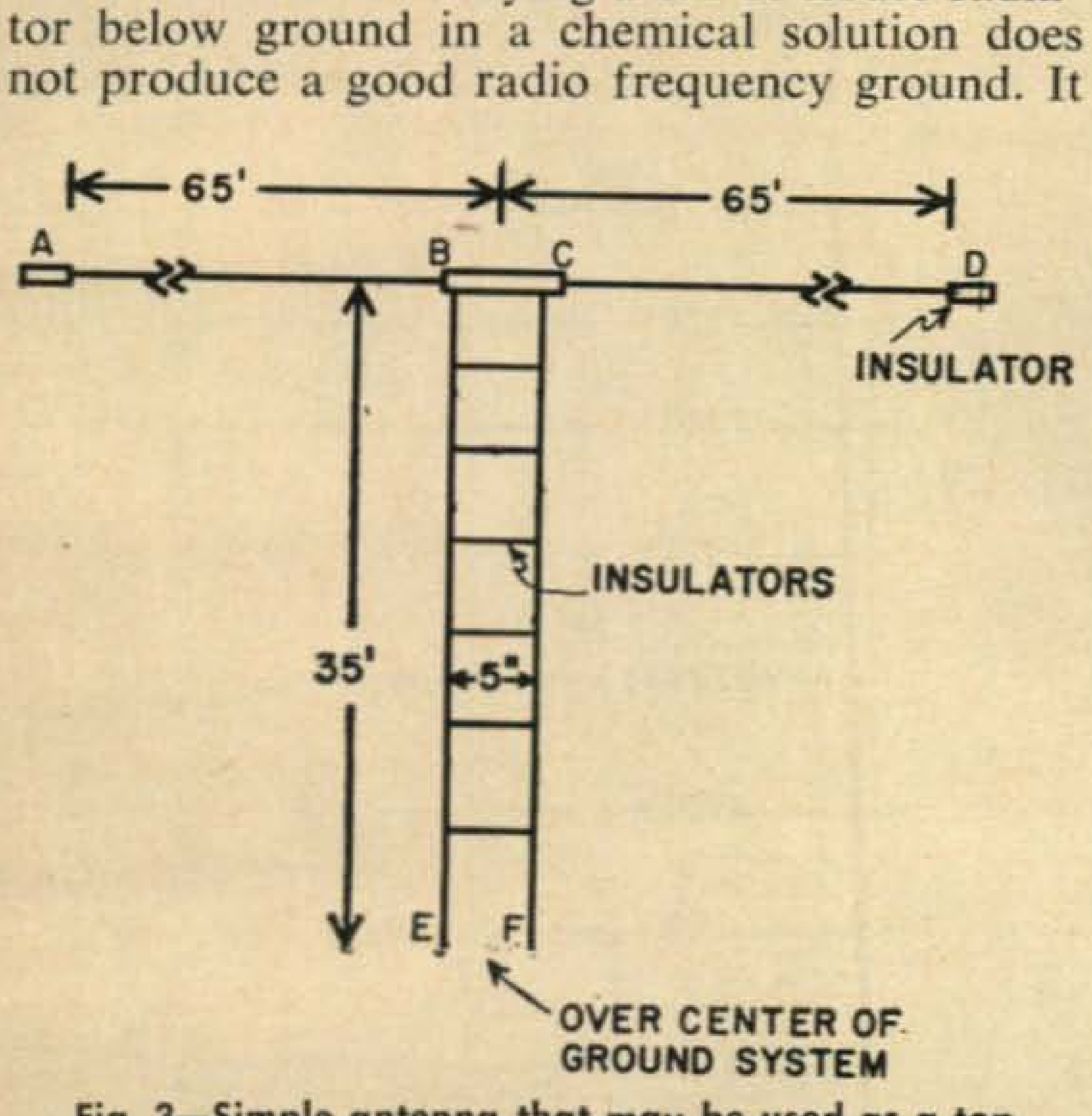


Fig. 3—Simple antenna that may be used as a top loaded vertical or a conventional horizontal as explained in the text.

Top Loading of Vertical Antennas

The top section of a short antenna does not add much to the radiated signal but does represent an appreciable amount of capacity. Therefore we can cut off a section of the top of a given antenna and then connect a piece of metal to the top of the antenna to give a capacity to ground and end up with a shorter antenna which radiates the signal almost as well as the original antenna. On the other hand we can add a capacity at the top of a given

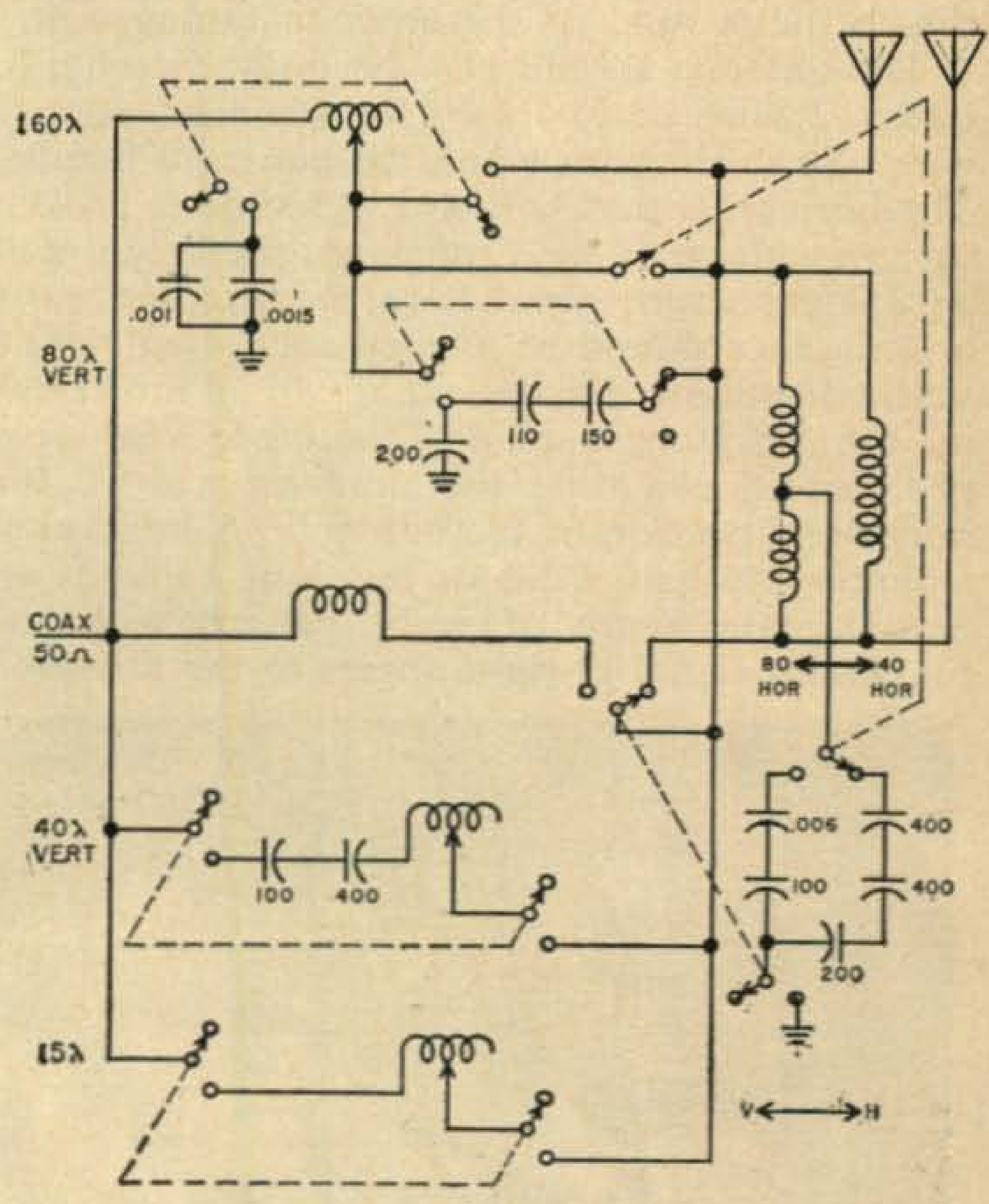


Fig. 4—An antenna tuning unit that may be placed at the base of the transmission line and connected to the transmitter through a coaxial cable. Each band is tuned separately and switching is accomplished by relays.

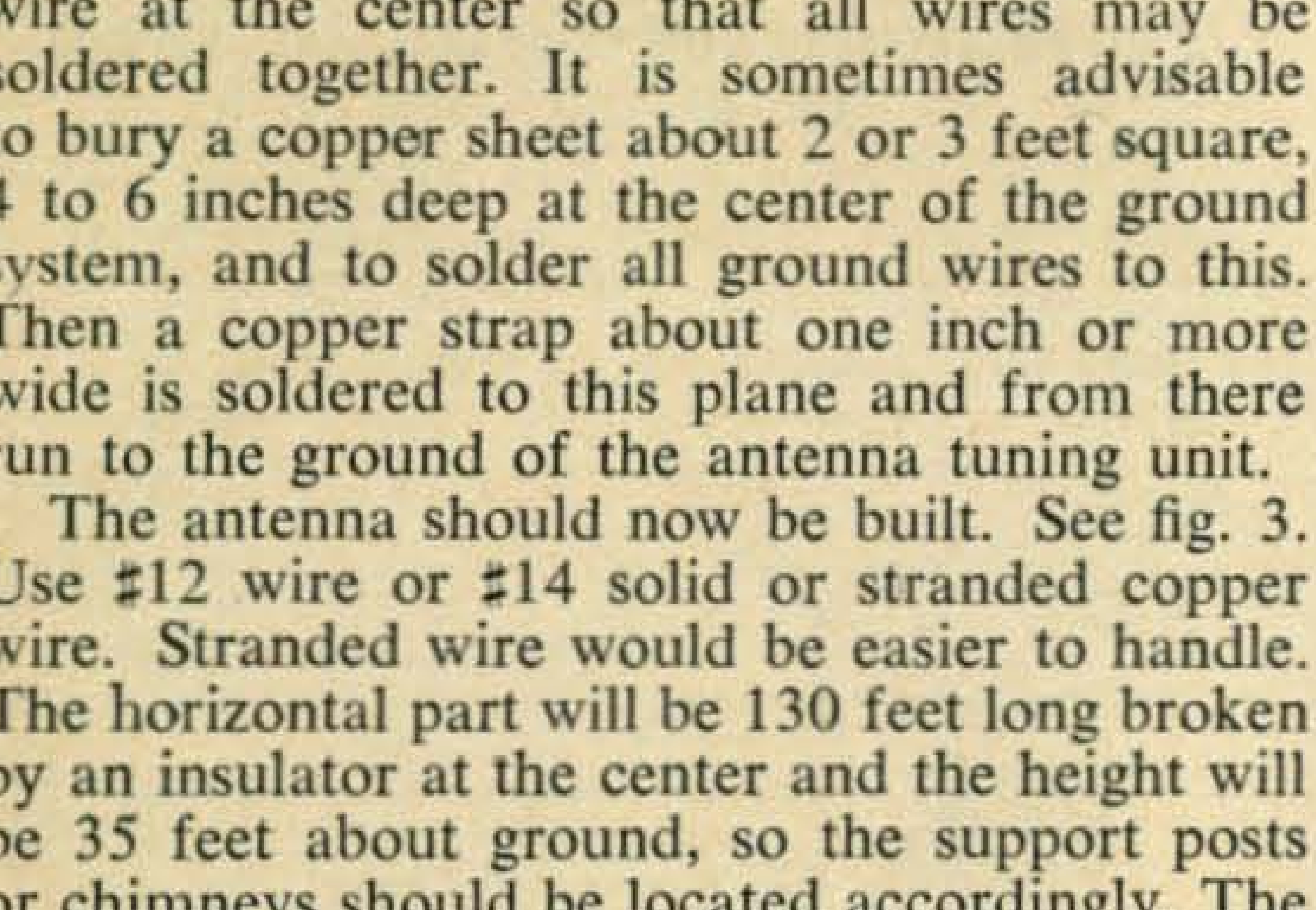
antenna and thus obtain an antenna which is as efficient as a much higher antenna.

Final Design of Complete System

Based on this discussion let us see what an antenna system, which would fulfill all these requirements, looks like. First of all a relatively flat site with its center about 60 feet from adjacent houses, trees or other projections above ground should be chosen, if possible. At the center of this site the vertical antenna lead will be erected, hence this will be the center of the ground system. If we assume that 15 radials will be used then the spacing between adjacent radials will be 360/15 or 24 degrees. The wire size to be used should be 16 or larger, not for electrical reasons only, but for strength to resist ground movement, frost, etc. The length should be ⅛ wave at the longest wavelength or about 65 feet for 160 meters.

A garden tractor with attachments could be used for laying this ground system. Just lay out fifteen troughs spaced 24 degrees 65 feet long and 4 to 6 inches deep starting at the antenna. Lay one of the ground wires in each trough and cover it with earth. Be sure to leave enough wire at the center so that all wires may be soldered together. It is sometimes advisable to bury a copper sheet about 2 or 3 feet square, 4 to 6 inches deep at the center of the ground system, and to solder all ground wires to this. Then a copper strap about one inch or more wide is soldered to this plane and from there run to the ground of the antenna tuning unit.

The antenna should now be built. See fig. 3. Use #12 wire or #14 solid or stranded copper wire. Stranded wire would be easier to handle. The horizontal part will be 130 feet long broken by an insulator at the center and the height will be 35 feet about ground, so the support posts or chimneys should be located accordingly. The vertical antenna radiates equally in all directions in the horizontal plane, therefore the only problem in orienting the antenna will be the horizontal portion of the antenna. A horizontal antenna one half wave or less long radiates an approximate figure of eight pattern with the maximum signal at right angles to the direction



Housing containing the tuning unit and remote controls.

of the antenna wire. Generally in this country, the optimum direction of the wire would be on a line somewhere between North-South and Northwest-Southeast.

But how can we make a horizontal and vertical antenna all in one? Here is the answer. See figure 3. Each horizontal leg AB, CD is 65 feet long. They are joined at the center by means of an insulator between B and C. From B and C a parallel wire transmission line spaced 4 or 5 inches is run vertically towards ground and ends at the antenna tuning unit at E, F. Now it is easy to see how it works. We connect E, F together and feed the antenna from E, F to ground. The two vertical wires being joined together at the feed point act as one, and hence this is our vertical antenna. The horizontal wires act as top loading to effectively increase the apparent height of the vertical antenna. If we disconnect E and F now and feed E and F as a balanced feeder, then the vertical part will act as a transmission line and hence will not radiate, and the top sections AB and CD will act as a horizontal antenna.

Now comes the problem of feeding the antenna. One relay must be mounted directly below the antenna down lead to switch from horizontal to vertical. Preferably all the tuning equipment should also be mounted directly below the vertical antenna. However, if this is inconvenient or impossible then a coaxial line may be run from the antenna to the transmitter shack and an antenna tuner such as the "Z-Match" used at the transmitter end of the line. This method, although convenient, does sacrifice considerable efficiency. The best method is to have individual antenna tuning for each band, remote controlled by switches at the transmitter. Such a system is shown in fig. 4. The values of

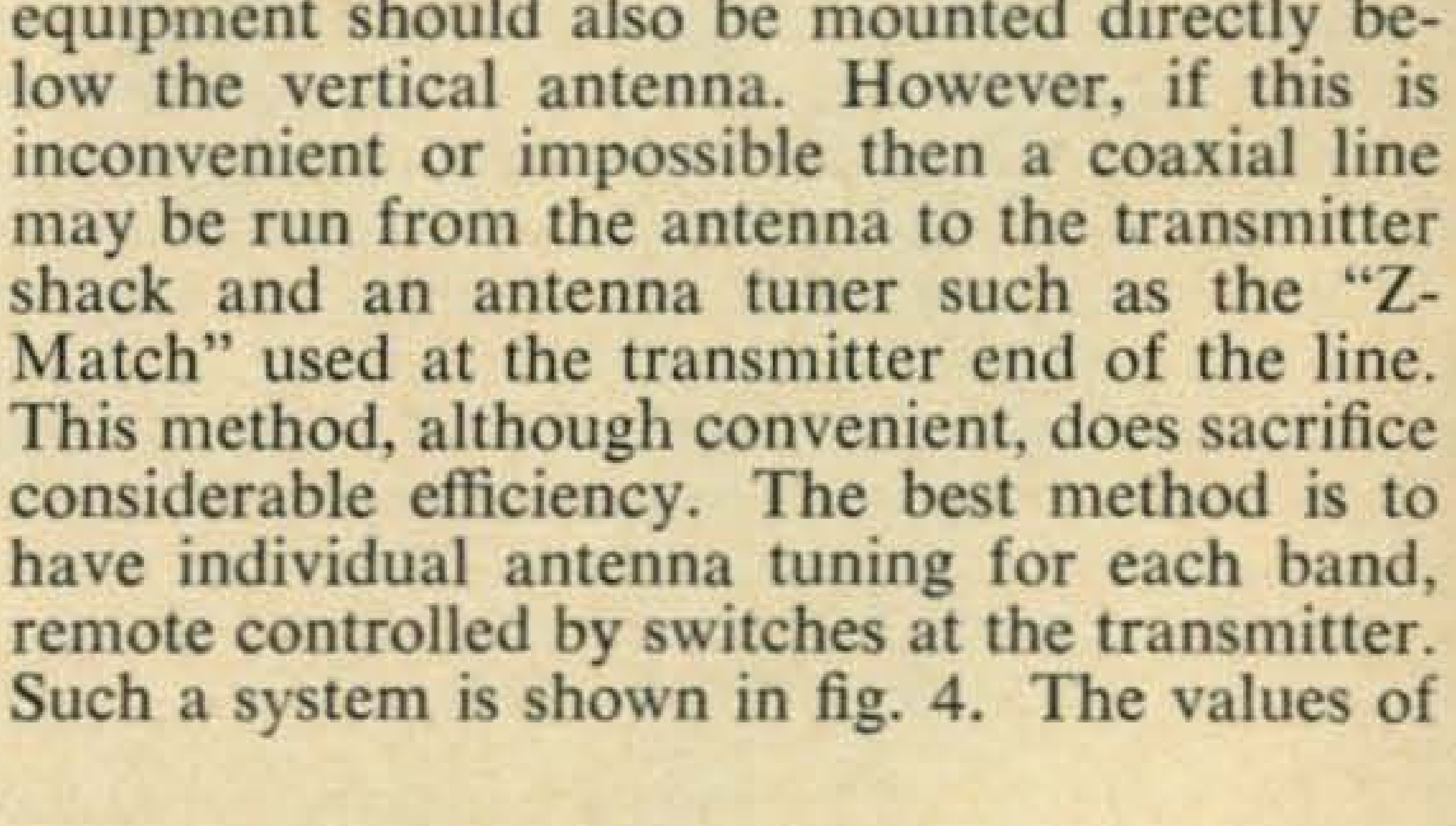


Fig. 5—Possible configurations in the tuning circuit for various antenna conditions.

Portable

KN9HII, Olive Nease with Gonset Communicator and L & J Products Two Meter Halo antenna in her Isseta.

OM Arlo Nease, K9HIH uses the Communicator and L & J Halo in his 1600 Porsche Super Convertible.

This Gonset goes everywhere. Several states have been worked from this Cessna. K9BYK, Jay, is in the plane, Arlo, K9HIH is holding the Gonset.

capacitors and inductors will change with individual installations. Generally speaking, tuning units should consist of an "L" network, as the "L" network has the least loss of any network; plus some means of transforming from a balanced to an unbalanced transmission line. The circuits used are as shown in fig. 5.

Referring to fig. 5, the following information holds: This figure is based on a 50 ohm transmission line but will hold for other values, except that component values will change.

a. The antenna matches the transmission line, hence no tuning unit is needed.
b. The antenna is 50 ohms and inductive. This inductance must be tuned out for maximum power transfer, hence the tuner will only have a capacitance reactance equal in numerical value to the inductive reactance of the antenna.
c. Similarly if the antenna is capacitive, the tuner will only have an inductive reactance equal in value to the capacitive reactance of the antenna.
d. Here the antenna resistance is not 50 ohms so an "L" network must be used. In matching, the shunt capacitor of an "L" network must always go on the side of the inductor connected to the high resistance.
   If R = high resistance, Z = low resistance

$$X_L = \sqrt{Z\,(R - Z)}$$

$$X_C = R\sqrt{\frac{Z}{R - Z}}$$

e. This is the same as (d) except a capacitor is used to tune out the antenna inductive reactance.
f. This is the same as (d) except an inductor is used to tune out the antenna capacitive reactance.
g. Here the high and low resistances are interchanged hence the L network is reversed. In this case R is now the low resistance so that now

$$X_C = Z\sqrt{\frac{R}{Z - R}}$$

$$X_L = \sqrt{R\,(Z - R)}$$

h. This is the same as (g) except that the reactance used must be the difference between (1) the inductive reactance obtained from (g) and (2) the capacitive reactance used to tune out the inductive reactance of the antenna. If the value of (2) is greater numerically than the value of (1) then the series reactance will be a capacitor instead of an inductor.
i. This is the same as (g) except that the reac-

[*Continued on page 122*]

COMMAND RECEIVER [*from page 53*]

converter output is now 7000 *kc* (second harmonic of 3500 *kc*) and tuning from 200-300 is tuning 7200-7300 *kc*. Now set the converter capacitor to minimum (3 o'clock). Converter output is now 14000 *kc* (4th harmonic of 3500 *kc*) and tuning 200-300 is tuning 14200-14300 *kc*. When a signal is heard, it is advisable to slowly tune the converter capacitor to the position of maximum signal. Note this setting for each amateur band or band segment.

Adjustment

Now that the novelty is over, make a couple of adjustments. While tuned to a signal, adjust the antenna trimmer of the BC-453 for maximum signal. Now check the receiver for frequency accuracy. The crystal frequency plus the dial reading is the incoming signal frequency. If adjustment is necessary, adjust the oscillator trimmer of the BC-453; also try to peak the *rf* and mixer trimmers. The top covers may now be replaced on the receiver.

A good choice of crystals would be 3410 *kc* to tune 3500-3960 and 7010-7370; 3500 *kc* to tune 3690-4050, 7190-7550 and 14190-14550; 6810 *kc to* tune 7000-7360 and 13810-14255; 13800 *kc* to tune 13990-14255 *kc*. Crystals higher in frequency than the desired band may be used by *subtracting* the dial reading from the crystal frequency. Example: 7520 *kc* crystal. Set receiver dial at 520 and read 7000 *kc*. For MARS members, 4450 *kc* is 330 on the dial using a 4780 *kc* crystal. With the same crystal, WWV is 220 on the dial for 5 *mc;* 440 for 10 *mc,* for dial calibration and correct time. Set receiver dial to these settings and tune the converter.

For any desired frequency between 3.5 *mc* and 14.5 *mc,* simply add *or* subtract the dial reading to or from the appropriate crystal and tune the converter. Remember that conventional surplus crystals deliver 1st, 2nd, and 4th harmonic output.

Since completing this receiver (number 4, and finally my own) I have not had occasion to use my big communications receiver, except for 10 and 15 meter contacts. For you hams who want sensitivity, selectivity, stability and low cost all in one package, here is your project. ■

V & H ANTENNAS [*from page 51*]

tance used must be the sum of (1) the inductive reactance obtained from (g) and (2), the inductive reactance required to balance out the capacitive reactance of the antenna.

Any type of balun may be used to go from balanced to unbalanced line in the case of the horizontal antenna. From then on the input of the balun is treated as the input to an unbalanced antenna. ■

DENSITOMETER [*from page 45*]

. . . but a densitometer measures light, and will happily measure the drifting swirls of cigarette smoke as they pass under the enlarger lens. If you can't seem to account for the random swinging of the needle . . . put out that butt, and try again!

Range Switch

The range-switch gives only a 5-to-1 increase in sensitivity; it may seem an inadequate spread. But we're working with light, and it's a darned sight simpler to change the light-source than to switch highly sensitive electronic circuits. Your enlarger already has built into it a mechanism specifically designed to change the light output in steps of 2X—most enlarger lenses today have click-stops for the various F-stops. I'm using the EL Nikkor F 2.8 lens, on my 35mm enlarger. That goes from F 22 to F 2.8 in 2X click-stopped steps—a range-scale giving me 64 times change of light output; the range-scale on the meter adds another 5 times, for a total of 320-to-1. And if I want more, I'll use a neutral-density filter over the photocell.

Meter Illumination

The 931-A has the usual blue-sensitive photocathode; the thing works nicely as an enlarging light-meter, because it fairly well matches, in sensitivity, the sensitivity of normal enlarging paper. Safelights do affect the photocell, but it's pretty insensitive in the yellow-orange region of the spectrum. For densitometer work, however, you need to work in darkness—hence the shielded pilot-light over the meter. (It's a standard pilot light, with a short piece of ¾ inch polyethylene black plastic tubing shoved over it. A slit in the side of the poly tubing illuminates the dial.)

931-A Light Head

The "optical system" of the 931-A light-head is something that leaves room for lots of playing around. You can't mount the tube right up against your input hole, because of the tube-socket dimensions. And a hole gives a rather marked directional effect on the sensitivity, which can be confusing. What I have is a jack-leg solution, but it works within the useful limits of what I need.

Clear polystyrene rod, the kind with polished outside surface, *not* the milky-surface type, will "conduct" light, somewhat as a wave-guide