The Technician Explains

Inductance Coil Design

(By "CATHODE")

THIRD INSTALMENT.

WE have now dealt both with the number of turns required to obtain a given inductance and with the best or "optimum" diameter of wire for any given broadcast coil. It will be appropriate now to consider the dimensions and shape likely to produce the best results from such a coil under differing circumstances.

In Figs. 1, 2, and 3 are given the theoretical high-frequency resistances of the coils previously discussed when wound with the optimum diameter of wire. It will be remembered that we discussed this question of optimum wire diameter in the issue of September 27, and that the optimum diameter was there given for a series of coils for which the required number of turns was given alongside; this previous paper should be referred to in order to gain a complete understanding of the present one.

A tremendous amount of information can be gained from these charts by the experienced designer. For the present, however, we are only concerned with a comparison of efficiencies; a little later the charts will be put to a more fitting use in assisting in the design of the primary of radio-frequency transformers. It is for this latter purpose that the high-frequency resistance (or radio-frequency resistance) has been given at two frequencies—one would have sufficed for our present purposes. Note, in passing, that the resistance increases with the applied frequency of 1000 kilocycles per second (corresponding to a wavelength of 300 metres) is substantially higher than that presented to an applied frequency of 640 kilocycles per second.

The reason for this increase in resistance with increasing frequency is, as may have been guessed, that the "skin effect" and "proximity factor" discussed in the last paper both increase in a most decided fashion with the frequency. In dealing with very high frequencies (e.g., short-wave reception) these phenomena render it very difficult indeed to design coils having any pretentions to efficiency, the most promising results being obtained with windings of copper ribbon or a number of parallel wires flat-wise wound. Both these expedients aim at reducing the "skin effect," the scheme of winding with a number of parallel wires also assisting in reducing the proximity factor by reason of the two outer stands shielding the inner ones from the a.c. field of the adjacent turns.

The first of the two points which, for the present, arise out of the resistance charts, is that of the best, or "optimum" ratio of length to diameter. Here it is necessary to explode another little theory which has at various times held sway in quarters where it should not have been entertained for one moment. The theory referred to is one arising out of the fact that, in winding a wire of given length into a coil of given diameter, the greatest inductance will be reached when the diameter is 2.46 times the winding length.

From this fact it was injudiciously assumed that a coil fulfilling this ratio of length to diameter would be of the greatest possible efficiency. Nothing could be further from the case. So far is this assumption from the truth, indeed, that if we double the winding length—even if we more than double it, making it equal to the coil diameter, we have still not reached the optimum ratio of length to diameter.

As a matter of fact, there is no constant ratio of length to diameter giving maximum efficiency. So far as the broadcast band is concerned, however,

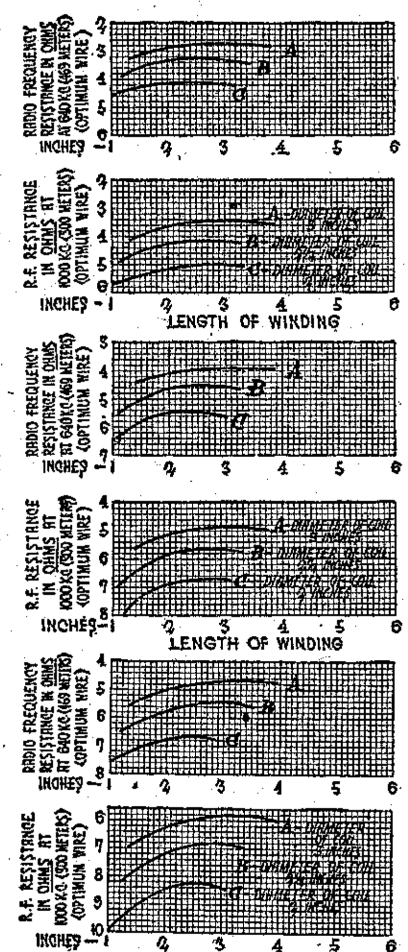

Fig. 1.—Wire Data for 200 m.h. Coil to be tuned from 200 to 600 metres with .0005 mfd. Condenser. Fig. 2.—Wire Data for 280 m.h. Coil to be tuned from 230 to 580 metres with .00035 mfd. Condenser. Fig. 3.—Wire Data for 340 m.h. Coil to be tuned from 250 to 550 metres with .00025 mfd. Condenser.

we can gain some idea of what ratio is desirable from a study of Figs. 1, 2, and 3. From these it will be seen that there is practically no advantage in increasing the winding length beyond 1 1-8 or 1¼ times the coil diameter. In practice, the increase in resistance involved by a reduction of the winding length until it equals the diameter is likely to be more than compensated by the less extended magnetic field of the smaller coil and the consequent reduction of absorption losses occasioned by surrounding apparatus.

Thus it would seem that, so far as a single coil is concerned, there is every reason for so designing it that its winding length is approximately equal to its diameter. If anything, the winding length should be less than the diameter rather than more, as the increase in resistance will be but slight provided the length is not made less than three-quarters the diameter, while the reduction in incidental losses by reason of the smaller field may be substantial. It is not always that a single coil is used for coupling, the principal instances of this form of coupling in present-day practice being a tuned-plate or a parallel-feed coupling following a screened-grid valve. Both tuned-plate coupling and parallel feed are too familiar to the average constructor to merit description here, parallel feed in particular having been treated by the writer in a simple analysis in these columns quite recently (The Efficiency Parallel Feed, "Radio Record," October 4, 1929).

When two coupled coils are concerned, as in the case of a radio-frequency transformer following a three or four-electrode valve, the problem is somewhat complicated by the necessity of securing a high coupling-factor. It would seem, however, that this subject can most appropriately be treated in a future article dealing generally with the design of the primary. For the present it will be sufficient to mention that the desirability of a high coupling-factor usually renders it desirable to reduce the winding length still further; where efficiency is aimed at, however, it should never be reduced to less than half the diameter.

Optimum Coil Diameter.

HAVING disposed of the ratio of winding length to diameter for the present, we arrive at the next problem, that of the optimum coil diameter in any particular circumstances. There are so many different factors to be considered in making a decision regarding this question that it is impracticable to lay down any set rules. The most that can be done is to indicate the factors which should receive attention, showing their relative effect and perhaps making one or two guiding suggestions; for the rest the individual designer must make his own decision.

This much is clear: that, within the limits ordinarily encountered, the greater the coil diameter, the greater the efficiency. It can readily be seen from Figs. 1, 2, and 3, that a coil having a diameter of 3 inches has a substantially less resistance than one (of the same inductance and shape) having a diameter of 2 inches. Thus, if coil efficiency were the only thing to be considered, there would be little object in contemplating the use of coils of a less diameter than 3 inches, although coils of greater diameter might be objected to on account of their bulk.

It is, in fact, the case that in a receiver employing only one coil, or, where wide separation can be readily obtained, two coils, the greatest sensitivity can be secured with coils having a diameter of 3 inches or more, provided that no further apparatus or screening is mounted adjacent to the coils to introduce absorption losses; this is at least one thing that can be stated definitely. It is unfortunately the case that such conditions are seldom encountered. More often we wish to mount two or more coils in fairly close proximity without encountering instability, or we are anxious to make our receiver compact, or to screen each stage in a metal shield, or to use screened coils, or to do some other thing which, were coils of larger diameter to be used, would result in either excessive losses or instability.

Causes of Instability.

SINCE instability is the thing principally to be avoided, it may be dealt with first.

In a receiver employing for high-frequency amplification either a screen-grid valve or a neutralised three-electrode valve, instability can result only from magnetic coupling between a coil in the plate circuit of the amplifying valve and one in its grid circuit—or, what is the same thing, one in the plate circuit of the preceding valve; the measure of this coupling is the mutual inductance of the two coils.

In case the term "mutual inductance" should not be a familiar one, it may be explained that where two coils are mounted so that their magnetic fields interlink, the total inductance of the two coils is not merely the sum of their separate inductances, but is greater or less than this by twice the "mutual inductance," which may be either aiding, that is, adding to the sum of the separate inductances, or opposing, that is, subtracting therefrom. It is this "mutual inductance" forming, as it does, a part of both plate and grid inductances, which is responsible for the feed-back causing instability; therefore, in arranging a high-frequency amplifier without screening, it is necessary to ensure that the mutual inductance is too low to provide adequate feedback to sustain a condition of oscillation.

A number of experiments served to show that, even with fairly efficient broadcast coils, a reduction of the