CHAPTER XIII

Conditions for Maximum Inductance

THE conditions under which a coil can have maximum self-induction (or inductance) for a given length of wire seem to have been laid down by the great mathematician Gauss, in or about 1865, but in what form that can have been done then, I do not know. Anyhow, Clerk Maxwell, in his great treatise published in 1873, gives a number of complete formulæ for self-induction, and clearly specifies the condition for its maximum. He evidently paid great attention to the subject of mutual- and self-inductance, being probably stimulated thereto in connexion with his early determination of the absolute value of the ohm (or British Association Unit, as it used then to be called).

The first condition is that the winding should be as compact as possible, so as to bring every part of the wire as close as may be to every other part, so that as many as possible of the lines of force due to each may thread the others. That will be achieved by making the section of the wound space in the bobbin of the coil either round or square, not oval or oblong. So much

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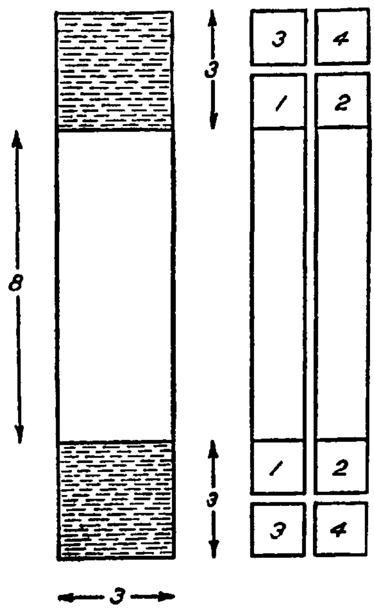
is pretty obvious because that is the most compact shape; but it is not at all obvious how big the diameter of the coil should be, in proportion to the size of the channel which contains the winding. That is what has to be worked out mathematically.

Although the working out may be considered complex, the result can be stated with great ease. Taking the channel for the wire as square, the outside diameter of the coil must bear to the inside diameter the ratio $\frac{47}{27}$, which for all practical purposes is the same as $\frac{7}{4}$, or $1\frac{3}{4}$. Hence the shape of the coil which gives maximum self-induction can be expressed in these figures: the breadth and depth of the winding 3, the internal diameter 8, and the external diameter 14.

We may take that as granted, and in this shape the coils employed in wireless telegraphy ought to be wound (though they seldom are), no matter whether the turns are packed close together or not. That is the best and most efficient shape; and by adhering to this shape —other things being equal—the deleterious capacity and resistance in the coil are reduced to a minimum.

It need not be supposed that the shape must be very precisely adhered to. It is a common property of maxima and minima that a slight fluctuation on each side makes but a small difference. That shape is the ideal to aim at, but some variation is allowable.



THE BEST SHAPE FOR COILS.

At the left is shown the best relative dimensions for a single coil; at the right is shown the arrangement of a number of coils that can be connected in series, and that will still keep the best shape for maximum inductance. To insure the lowest distributed capacity they should be connected as they are numbered: 1, 2, 3, 4.

For instance, suppose, having got one coil, we want to put another alongside it in series with it, the self-induction will be immensely increased by an amount which is quite well known if the positions are given. But the shape will no longer be the best. Still, the difference is not very important; and something like the best shape can be restored by having four coils instead of two, and putting them in pairs side by side, with one pair big enough to fit over the other. Numbering the four coils 1, 2, 3, 4, it will be best to connect them together in that order, so that the extremities of the wire, at which the greatest difference of potential will occur, are as far separated from each other as may be. The connexion 1, 2, 4, 3, or 1, 3, 4, 2, is slightly less desirable.

The effect of putting one coil outside another, instead of side by side, is only that the mean radius of the whole winding is increased somewhat; otherwise the expression for the self-induction is the same in the two cases. It is as broad as it is long, so to speak. Or, rather, whether the length exceeds the breadth, or the breadth exceeds the length, makes no difference. That is not obvious, but so it comes out from the formula, which is symmetrical as regards length and breadth of cross-section.

The advantage of a combination of coils like this is that it enables the wave-length to be easily changed; that is to say, it enables a coil to be selected which shall give approximately the order of wave-length required, fine adjustments being done by means of supplementary adjustable capacity, or by an adjustable separate self-induction, or both. But we will not trouble about these tuning details, which are quite well known and understood.

Although I have emphasized the value of a maximum self-induction shape, such considerations must not be allowed to override practical convenience; and, instead of packing multiple coils into a square section, it is usually much more convenient to arrange them either side by side, or one outside the other!—that is to say, to arrange them so as to form either a cylinder or a disk. And, again, such an arrangement has an advantage; for, though the self-induction will be less than it might be with a given length of wire, the terminals are thereby kept far apart, and the capacity therefore is diminished too.

Hence I do not propose to consider any arrangement for multiple coils. When we are dealing with the single coil, however, there is no question but that the best shape is as stated, viz. external diameter 14, internal diameter 8. Further details about this we will consider later.