AN EXPERIMENTAL STUDY OF THE HIGH-FREQUENCY RESISTANCE OF METALLIC CONDUCTORS

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The study of the variation of resistance of a metallic conductor when subjected to high-frequency current is of practical interest in radiotelegraphy and radiotelephony. In the case of non-magnetic conductors which have a constant permeability, formulae are available and the high-frequency resistance may be calculated without difficulty. But in the case of magnetic conductors such as iron, nickel, cobalt, and alloys of these metals, the permeabilities vary with the strength of the current through them. The calculation of the high-frequency resistance of these substances therefore becomes more difficult. Fortunately, there are available in the laboratory many simple and practical methods for measuring high-frequency resistance, and hence these resistances can be determined experimentally. The writer of this paper has chosen the substitution method in all his measurements in this investigation, because this method has been found to be convenient and accurate in practice.

The specimens of conductors which have been used in this investigation are straight cylindrical "Advance" wires of different sizes which were subjected to a high-frequency current between the limits of 900,000 and 6,000,000 cycles per second. "Advance" wire is an alloy composed of 55 percent copper and 45 percent nickel.

The substitution method is a well-known method in electrical measurements. The apparatus consists essentially of a wave meter, radio frequency oscillator, and a tuning circuit.

The wave meter used in this work was a precision wave meter, which, with a small inductance coil made and calibrated by the students in our laboratory, could cover a range of wave-lengths from 25 meters up to 24,000 meters.

The radio frequency oscillator may consist of any convenient oscillating circuit, but one which can give a powerful and reasonably uniform output is preferable. The oscillator used was a five-watt vacuum-tube oscillator designed by our Electrical Engineering Laboratory. It gives a constant and powerful output, and with interchangeable inductance coils it covers a range of wave-lengths from approximately 25 meters to 400 meters.

The tuning circuit consists of an inductance coil, a variable condenser, an ammeter, etc.

The testing conductors were not coiled, but stretched between two brass binding posts mounted on a long board. The distance between the binding posts is approximately 100 centimeters, so that the wires to be measured are kept always at the same length.

The tuning circuit was excited by coupling to the source or the oscillator. By means of the variable condenser the tuning circuit was

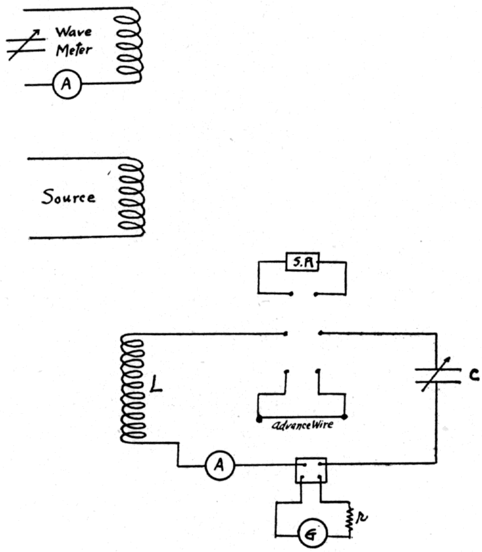

FIG. 1. Circuit for measuring high-frequency resistance of a metallic conductor by the substitution method.

brought into resonance with the impressed frequency, as indicated by the reading of the thermococouple ammeter. But since the ammeter available in the laboratory was inadequate or not sensitive enough for this indication, it was decided to use a D'Arsonval direct-current galvanometer with a vacuum tube thermocouple. In this way the resonance point can be indicated exactly.

After this point was found, a standard resistance was substituted for the unknown, and this resistance was varied until the same current or same deflection was indicated at resonance. The standard resistance used was a dial box, built especially for high-frequency work. As this resistance was not continuously variable, the deflection at resonance could not be made exactly the same as the original one. For this reason the following method was used.

The unknown resistance R_x was first inserted, and the deflection, D_x, at resonance was observed. Then by throwing the double throw switch to the other side, the standard resistance, R_n, was substituted and the deflection, D_n, at resonance observed; and finally a known resistance, R_1, was added and the deflection observed. Then from the following relations:

$$R_x + R = \frac{E}{I_x}$$

$$R_n + R = \frac{E}{I_n}$$

$$R_1 + R_n + R = \frac{E}{I_1}$$

we obtain the equation:

$$R_x - R_n = R_1 \frac{\frac{I_n}{I_x} - 1}{\frac{I_n}{I_1} - 1}$$

where R is the total resistance of the circuit exclusive of R_x, R_n, and R_1. Since the deflection of the galvanometer is proportional to the current flowing through it, we can write the equation:

$$R_x - R_n = R_1 \frac{\frac{D_n}{D_x} - 1}{\frac{D_n}{D_1} - 1}$$

The results of this investigation are shown graphically in the figures on the following page.

There was considerable difficulty in acquiring high accuracy in these measurements; much of this was due to the uncertainty of the variation of the capacities of the accessory apparatus, and to the surroundings. These stray capacities are impossible to be determined, and they may vary in an irregular manner. In this investigation, however, the conditions were kept exactly the same in all the measurements throughout, so that even though there were stray capacities, they did not vary very much.

The standard resistance used was a General Radio dial box which, as indicated by the manufacturer, was accurate to 0.25 per cent.

The source used was powerful enough to give an induced current in the tuning circuit when very weakly coupled, so that when the circuit was tuned there was no effect whatever on the oscillator. Thus it gave a fairly constant voltage in each measurement.

It is evident, from the above considerations and also from the smoothness of the curves as plotted, that this method affords a fairly accurate means of measuring the high-frequency resistance of metallic conductors. Its simplicity is such that it can be used in any laboratory possessing an oscillator, a wave-meter, and a sensitive alternating-current detector.

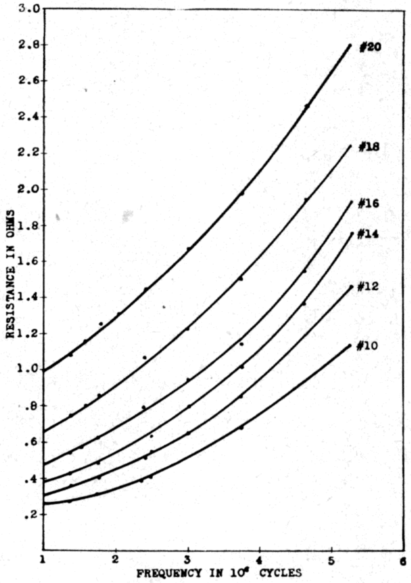

FIG. 2

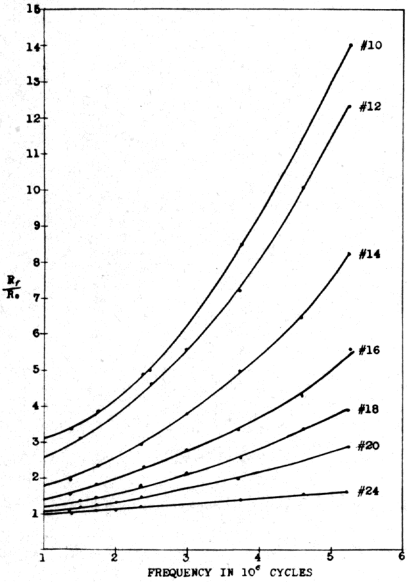

FIG. 3

FIG. 2. Variation of resistance with frequency of straight solid "Advance" wires. Numbers on curves give size of wire, B. & S. gauge.

FIG. 3. Relation between R_f/R_o and frequency for different sizes of "Advance" wires.