

A METHOD OF IMPROVING THE SENSITIVENESS OF THE TELEPHONE RECEIVER AS A DETECTOR IN ALTERNATING CURRENT NULL MEASUREMENTS.

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THE numerous applications of the electrostatic condenser have lately directed attention to the necessity for a quick and accurate method of measuring the capacity of such condensers. It is generally recognized that condensers whose dielectrics are materials of low cost and of good mechanical working quality usually have electrical characteristics that seriously impair the accuracy and reliability of direct current measurements of their capacity. The presence of appreciable polarization, of residual effects, or of leakage, causes the apparent capacity as obtained by direct-current methods to be quite different from the true or Maxwellian capacity. It is true, in the case of standard condensers made from a good quality of mica, that there is substantial agreement between the results obtained by various methods; but even in this case there will always be differences, so that for the highest precision it is necessary to calibrate such condensers on circuits having characteristics similar to those of the circuits upon which the condensers are afterward to be operated.

It has been found that an alternating-current bridge measurement is most reliable in all cases, since the true capacity, unaffected by leakage, by polarization, or by dielectric loss, is directly determined. More exactly, the unknown capacity is found in terms of the known capacity of a standard or reference condenser. Moreover, since the capacity balance of the bridge cannot be obtained without a simultaneous phase balance, the same measurement affords knowledge of the phase angle of the tested condenser, and hence of the energy loss in the material comprising the dielectric. But the success of this method depends upon the detector used to indicate when the bridge is balanced. In comparing condensers of similar characteristics, for instance two good mica condensers, the ordinary high-resistance telephone receiver is quite serviceable when testing on circuits of frequency not

lower than 150 cycles per second; but the telephone receiver is extremely insensitive at commercial frequencies. Moreover, when commercial condensers are to be compared with reference condensers, which latter usually have a good grade of mica as dielectric, the exaggeration of any harmonics that may be present in the testing voltage wave, and the periodic shifting of phase of the poorer condenser, make it extremely difficult to secure a balance at the fundamental frequency, which cannot coincide with the point of balance for any one of the harmonics.

The ideal detector is, of course, the vibration galvanometer. Failing this, a mechanical rectifier with a direct-current galvanometer will give good results; but either of these devices requires for satisfactory operation a stand or table practically free from vibration. This can be secured, in more or less cumbersome ways, but the attention and expert manipulation required make these detectors suited primarily for use in the laboratory.

This paper is intended to describe a modification of the telephone detector, which the author has found extremely sensitive, and which does away with the difficulties and limitations ordinarily encountered in using the receiver as a detector. It is a fact that the human ear, although quite sensitive to a high-pitched musical tone when subjected to that tone only, becomes unable to detect the exact point of extinction of this tone when higher harmonics or overtones are present. But if another tone, slightly differing in pitch from the fundamental, be impressed at the same time, the ear will at once recognize the discord. This is true even when the discordant tones are both extremely faint; in fact, it seems to be evidenced that the most delicate sensibility prevails when this condition is realized. If, then, a steady, feeble tone of slightly different frequency from that of the testing voltage be impressed on the ear, the fact that the bridge is balanced will be indicated by the absence of "beats," although there may be still present quite audible tones due to various harmonics. This was accidentally noticed by the author during a bridge comparison of two mica condensers. An alternating-current arc lamp was being operated on the floor below, and the slight hum from the arc, coming to the ear through an opening in the floor, developed plainly audible beats when the bridge was slightly out of balance.

Several cheap and simple applications of this scheme are at once obvious. In a laboratory it will generally be found that a tuning-fork is at hand, whose frequency is but slightly different from that of the test circuit. It is best to choose a fork of higher frequency, and bring the latter down, by the addition of weights, to the required value. By arranging a very simple make-and-break contact on the fork, which may be hand- or electrically-driven, beats can be obtained by holding the test receiver to one ear, and holding to the other ear a second receiver in circuit with a single dry cell, a resistance of suitable value, and the tuning-fork make-and-break contact. The hands may be left free to manipulate the bridge, if operators' or head-type receivers are available.

In a commercial test, as carried out in a manufacturing plant, a small induction motor will generally be available. If this is of the squirrel-cage type, it may be arranged to drive a small alternator, the voltage from which will differ in frequency from that impressed on the motor sufficiently to be used in this way. If a wound type motor with slip rings is at hand, it may be driven at slow speed in any convenient way, when the voltage from the slip rings will have the desired slight difference of frequency from that impressed on the stator windings. It will be found that the ear is most sensitive to a discord giving from three to six beats per second.

The chief usefulness of this device is on circuits of frequency below 150 cycles per second; say on 25- or 60-cycle circuits, where the telephone receiver *per se* is quite useless as a detector. This method of beats will be found surprisingly sensitive; in fact, other things being equal, the sensitivity depends only upon the difference in frequency between the two tones, and it seems possible that frequencies above the audible limit may be available by the use of a modification of this method.

In conclusion, it may be said that but one obstacle presents itself to the use of this method in commercial testing; namely, the difficulty of securing a quiet place for the test. But a simple device which will secure an air-tight connection between the receiver and the outer ear will overcome this difficulty. The author has found that moistening the ear with a damp handkerchief will cause the receiver to make a sufficiently tight connection.