The Engineering Measurements of Radio Telegraphy

By ALFRED N. GOLDSMITH, Ph.D.
Instructor in Radio Engineering, the College of the City of New York

Copyright, 1919, by Mercier Publishing Corporation

ARTICLE IV

In the article published in this issue the principles of distributed capacity are discussed in detail. Its effects are told of and a table is published for the purpose of calculation. The author takes up the subject of measurement of distributed capacity at radio frequencies and low voltages, and describes the theory of the practice.

II.—MEASUREMENTS OF DISTRIBUTED CAPACITY

12. General Considerations.—We have shown various methods of measuring capacities at radio or audio frequencies, and at high or low voltages. In all the cases treated, the device, the capacity of which was determined, was a condenser; that is, a device specially arranged to have electrostatic capacity and consisting essentially of (nearly) inductance-free conducting surfaces, insulated from each other. The capacity under these conditions is localized in the circuit, and the circuit has been assumed to contain no capacity such as was concentrated in condensers. This assumption is, in general, only approximately true, for the inductances used in these experiments contain what is known as distributed capacity. Since the notion of distributed capacity is so easy to grasp than that of ordinary or localized capacity, we shall discuss it in detail. Its effects, particularly in incorrectly designed receiving sets, are very marked, and may lead to greatly diminished efficiency of the set as a whole.

In Figure 17 a number of turns of an inductance is shown. If a varying current is passing through this coil, there will be a difference of potential between the ends, A and B, of the coil, quite independent of its ohmic resistance. Between turn 1 and each of the other turns a difference of potential will exist, and consequently electrostatic lines of force will pass from each point of turn 1 to every point of the coil which is at a different potential. It is to be noted that we are not referring to the magnetic lines of force which are interlinked with the entire coil. Some of the electrostatic lines of force between turns 1 and 2 are shown in Figure 17. We have then the interesting conditions that turns 1 and 2 are, in effect, plates of a condenser. Electrostatic energy is stored in the space between each portion of a turn and every part of every other turn; and, since such energy can be stored only in capacities, we have distributed capacity along the entire coil.

It is evident, therefore, that the coil can no longer be considered as a simple inductance, but must be treated as an inductance across the terminals of which a capacity (equal to the total distributed
The distributed capacity of a coil may therefore be very objectionable, particularly if work is being done at short wave lengths where the permissible external (and adjustable) capacity, C, is already quite small.

Another point of difference between a coil having distributed capacity and a simple inductance is of importance. Even if no capacity be connected across its terminals, such a coil may vibrate electrically. It is, in fact, a so-called open oscillator, and behaves in this respect quite like the usual antenna of a radio station. If, in Figure 19, G is a generator of radio frequency alternating current, and L, an inductance which couples it electrically to the coil, L, a having distributed capacity C, it will be found that for some particular frequency of excitation the coil, L, will vibrate powerfully electrically. The particular frequency in question will be (if the coupling between L and L is very loose), the natural frequency of L. The second circuit, L, C, will then indicate this frequency by means of a maximum reading of the indicator, I, provided that its capacity and inductance are properly adjusted. This last circuit will therefore serve as a "wave meter," or more strictly, a frequency meter.

If we consider more carefully the mode of electrical vibration of the inductance L, which possesses distributed capacity, we find it differs considerably from that proportion to the inductance, the more to be expected in a simple inductance. It is possible to calculate the distributed capacity of an inductance from its measurements. A convenient formula for practical purposes, and a quite accurate for all, is given by Drude. It is the following:

\[ C = \frac{\pi}{2} \left( \frac{L}{\alpha} \right)^{2} \left( \frac{h}{\alpha} \right)^{4} \quad (32) \]

where h = length of the coil, \( \alpha = \) diameter of the coil to the middle of the wire.

\[ \alpha \] is a factor depending on value of h/\( \alpha \), and given in the following table.

<table>
<thead>
<tr>
<th>h/( \alpha )</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>0.6</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>0.7</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>0.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>0.9</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>1.0</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

The voltage or potential distribution along the coil is similarly shown in the second curve, to the right of the first. It will be found that the potential is highest of the ends of the coil, but that the current is greatest at the middle. Remembering that the ordinary antenna corresponds roughly to one-half of such a coil, the ground connection being the analogue of the middle of the coil, it is immediately evident why the current in an antenna is greatest at the bottom, but the potential highest at the top. And a coil having distributed capacity resembles an antenna in another respect; it serves as a radiator of electromagnetic waves, and the greater the distributed capacity

The free period of a coil of inductance, \( L \), and distributed capacity, \( C \), can be directly calculated from the formula

\[ T = 2\pi \sqrt{LC} \quad (30) \]

and its free wave length from

\[ \lambda = \frac{1885}{(\pi)} \sqrt{LC} \quad (30) \]

with \( L \) expressed in henrys and \( C \) in farads.
period of the primary. In order that impulse excitation should be secured, the primary circuit should be highly damped and its coupling to the secondary not too close. We shall meet these requirements by making the primary circuit actually aperiodic, so that no free alternating currents can occur, in it at all, but only individual highly damped pulses of current. We shall then couple it loosely to the secondary circuit, which is the inductance having distributed capacity, thus causing that coil to vibrate in its natural period. Suppose that the indicator I which is shunted across the capacity $C_0$ is of so high a resistance that its influence on the period of the circuit $L_0C_0$ is negligible. This is the case if its resistance is much larger than the quantity

$$\sqrt{L_0C_0}.$$

We may then take the period of this last circuit as

$$T_1 = 2\sqrt{L_0C_0},$$

and the period of the inductance itself as

$$T_2 = 2\sqrt{L_0C_0}$$

If the condenser $C_0$ is varied while $L$ is in vibration until a maximum indication is obtained, $T_1 = T_2$, and therefore

$$C_0 = \frac{L_0}{L} \quad (35)$$

which enables us immediately to calculate $C_0$.

It was mentioned that the primary circuit was to be made aperiodic. The condition for this is that, if $R_1$ is the resistance of the primary exciting circuit, $C_1$ its capacity, and $L_1$ its inductance, the resistance must be at least as great as the value of $R_1$ given by the equation

$$R_1 = \frac{1}{\sqrt{L_1C_1}} \quad (36)$$

$R_1$ may be made larger than this, but nothing is gained by so doing.

(1) Arrangement and Description of Apparatus.—A wiring diagram of the apparatus is given in Figure 21. A, B, C, D, are the terminals of a high pitch buzzer, $F$ if the battery which operates the buzzer, and $E$ is a regulating resistance for controlling the buzzer current, injected across the gap of the contacts of the buzzer are $L_0$, $R_0$, and $C_0$ all in series. As indicated, $L_0$ is loosely coupled to the coil $L$, which is the inductance having distributed capacity under measurement. $L_0$ and $C_0$ are the inductance and capacity (both known) of the wave meter circuit, $D$ is a detector, and $T$ a telephone receiver. With the apparatus as actually used, $F$ was a 10-volt storage battery, $E$ was from 10 to 25 ohms, $C_0$ was a 2-microfarad No. 21-D Western Electric Condenser, $L_0$ a single turn or two turns of No. 18 lamp cord wound around $L$, and $R_0$ was between 10 and 200 ohms. $L$ (in one case) was a coil of 17 turns of multiply stranded wire (so-called "Stenfridt") consisting of 7 sets of wire, each set made up of 7 strands of No. 32 enameled copper wire, the sets being all twisted together and the whole triple silk insulated, radius 8.045 cm, length of winding 31.7 cm. The wave meter circuit $L_0C_0$ consisted of the inductance $L_0$, which was made up of 16.8 turns of No. 18 lamp cord wound on a core 8.7 cm in diameter. Its inductance was 18,820 cm. The capacity $C_0$ was a small variable air condenser, maximum value being 0.00004 µf. The detector, $D$, was a usual crystal rectifier, and the telephone a 2,000-ohm double head band receiver.

The actual arrangement of the apparatus is shown in the photograph, Figure 22. To the left are seen the enclosed buzzer, and the resistances, $E$ and $R_0$. The condenser, $C_0$, and a long coil, the distributed capacity of which is being measured, are in the middle. The two turns of the coupling inductance $L_0$ are shown wound around $L$. To the right,
In the practical demonstration of the apparatus, the application of the device to wire telephony was shown. A pair of ordinary wireless telegraph headphone receivers were connected to the audion amplifier. The first audion was then connected to a single magento telephone receiver. The currents produced by the vibration of the single magento receiver when near to the faintest sounds were sufficient to cause clear reproduction in the double headphone receivers. When a handkerchief was dropped on the single magneto telephone the feeble electric currents generated by the impingement of the sound waves upon the telephone diaphragm were sufficiently amplified by the audions to produce a considerable racket in the ear-pieces.

The single magneto telephone was then taken to a distant room and the audion amplifier connected to three loud-speaking telephones. Dr. DeForest’s assistant in the distant room whispered into the magneto receiver and the electrical impulses thus produced were sufficiently amplified to be heard over the entire lecture hall.

It was stated that it is proposed to use the audion in connection with long distance wire telephony as an amplifier and that it might make transcontinental (New York to San Francisco) telephony possible.

A demonstration of the application of the audion in connection with wireless telegraphy was given. Radio signals coming from several wireless telegraph stations in the vicinity of New York had been recorded on the steel tape of the Ponslen telegraphone. The audion amplifier reproduced radio signals from the telegraphone records, which were so faint that they could not be heard on the telegraphone in the regular way. They were, however, sufficiently increased in intensity by the audion amplifier to make them audible. It was possible in this way to record the sound of the human breath on the telegraphone records and reproduce it quite distinctly.

A new type of audion having double grids and double plates was shown. With this arrangement it is possible to light all three filaments from one storage cell, which, of course, is conducive to the simplicity of operation of the set.

---

**Fig. 22**

![Diagram](image)

**This is the fourth article by Dr. Goldsmith, in a series on the engineering measurements of radio telegraphy. The fifth will appear in an early issue.**

---

**DR. DEFOREST ON THE AUDION**

At a November meeting of the Radio Institute at Fayweather Hall, Columbia University, an interesting lecture was delivered by Dr. Lee DeForest on the Audion—A Detector and Amplifier. The lecture was followed by a practical demonstration of the device.

The inventor gave a novel explanation of the operation of the audion, asserting that it did not obey the rectifying principle, but that the effect of the incoming oscillations from a transmitting station was to suddenly increase the resistance of the local circuit containing a high-voltage battery: this in turn, he said, caused a fluctuation of current that reproduced the radio signals in the head-phones.

After describing the steps preliminary to the discovery of the audion, Dr. DeForest showed in an elementary way the circuits of the audion as an amplifier.

The instrument on exhibition consisted of four audions, each of which gave an increase of intensity of signals over the one preceding it; thus, amplifications of 20 times the original strength of signals received in the first audion were obtained, according to the speaker.
How to Conduct a Radio Club

By E. E. BucHcr

ARTICLE II

READERS of the series on How to Conduct a Radio Club will be interested to learn that the Bureau of Navigation, United States Department of Commerce, has concerned itself with the plan outlined relating to the formation of an organization, and suggested that the following be published:

"Radio station licenses can only be issued in the name of a club if it is incorporated in some State of the United States; otherwise the license must be in the name of some individual of the club who will be held responsible directly for its operation.

"Radio clubs having a club station should apply to the radio inspector of their district for the assignment of an official call signal which must be used for all radio communication."

In view of recent developments in radio telegraphic research the writer of these articles has decided to vary the practice generally employed relating to the order of publication; thus this article is written specifically for members of radio clubs already in existence, in the hope that it will spur them on to renewed efforts in investigating.

In it will be described two methods for the amplification of radio telegraph signals. As a rule, amateurs try to make the loudest noise possible when receiving signals from distant transmitting stations. At all radio stations, in fact, commercial or amateur, efforts are invariably made to obtain the greatest intensity of signals possible. Of the two methods presented for the amplification of signals, the second is not original with the writer, but was obtained as a result of his attendance at a lecture delivered recently at a meeting of the Institute of Radio Engineers. The first method was not brought out at the meeting, but suggested itself to the writer during the lecture.

Many amateurs are already familiar with the audion detector and the method of its application to wireless telegraphy, but there are some who are absolutely without knowledge relating to the device. For the benefit of the latter readers the audion will be explained in all of its details, accompanied by a diagram; a brief description of the construction and operation of the audion will also be given.

The audion detector is not a new apparatus, having been in use since about 1900. For some reason, however, it has not been employed generally in commercial service. This is probably due to the fact that, because of the battery current required, it is believed to be a device of considerable expense. The writer will show that this impression is erroneous.

In the equipment of every radio club should be included an audion detector. The apparatus, however, should be placed in the charge of responsible members of the organization, for through careless usage it may easily be burned out.

The audion detector is shown in Fig. 1, and consists of a 4 to 6 volt lamp filament, F, a nickel-plated grid, G (which may also be a plate bored full of holes), and a plate, P, to which is connected one side of the local headphone circuit. The grid, G, is connected to one side of the closed oscillatory circuit of the receiving tuner and the filament, F, to the opposite side of the circuit. Either the B or A side of the filament may be connected to the lead D; the B side will generally give the best results.

The secondary of the receiving tuner is represented at L, which is shunted by a variable condenser, V. The variable condenser is of very small capacity; the maximum need not be more than 0001 mfd. In fact, it may consist of two very small concentric brass tubes sliding over one another.

The members of radio clubs should