INSTRUMENT SECTION

STANDARD RADIO WAVEMETER BUREAU OF STANDARDS TYPE R 70B

BY
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Radio communication is carried on by electromagnetic waves whose frequencies vary from 15 000 cycles or less per second to 3 000 000 cycles or more per second. With the constantly increasing number and power of transmitting stations it is important that apparatus be available to accurately measure the frequency of the waves emitted by a transmitting station. Certain frequencies are assigned by law to certain kinds of communication, and the inspector whose duty it is to enforce the law must know that his measurements are accurate.

In the widely varied fields of scientific research in which use is made of radio-frequency current, the requirements are even more exacting, both as to range and accuracy of measurement, than in actual radio communication.

A circuit composed of a capacity and inductance is resonant to electric vibrations of a frequency $f=\frac{1}{2\pi\sqrt{LC}}$ where f is the frequency in cycles per second, L the inductance in henries, and C the capacity in farads. Thrown into a more suitable working form, the equation is:

$$f=\frac{159\ 150}{\sqrt{Lp(C+C_0)}}$$

in which f is the frequency in kilocycles per second, Lp the pure inductance of the coil in microhenries, C the capacity of the condenser in micromicrofarads, and C_0 the effective capacity of the coil in micromicrofarads.

Such a circuit, with the condenser variable, is, when calibrated, a wavemeter and may subsequently be used to measure the frequency of any electric vibration within the range of variation of the instrument.

The Bureau of Standards has for a number of years been evolving for its own use standard radio wavemeters for use in testing commercial instruments and in radio research. The latest model, type R70B, is described in this paper and is shown in Fig. 1.

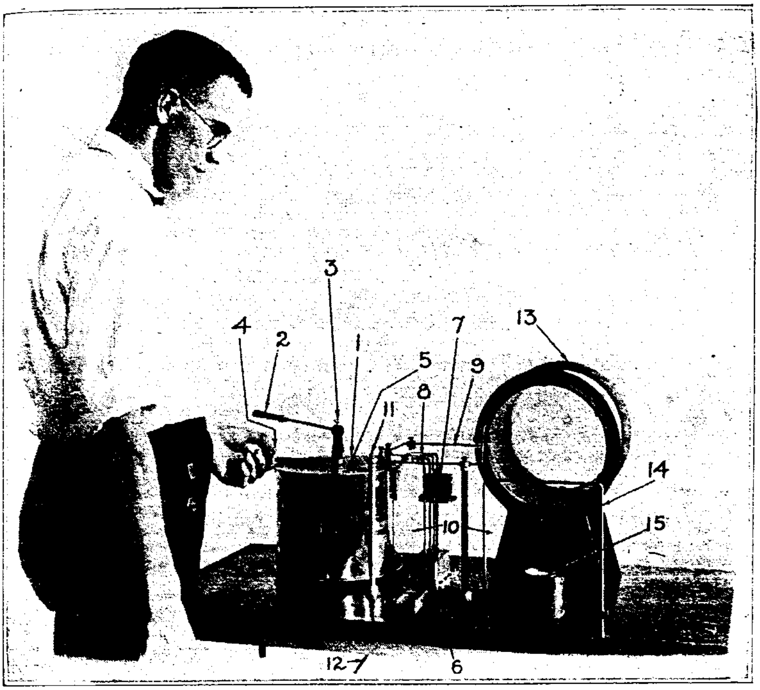

FIG. 1—Standard Wavemeter, Type R-70-B

1. Variable condenser
2. Handle of variable condenser
3. Screw, clamping condenser handle
4. Slow motion device
5. Window for reading scale
6. Fixed mica condensers
7. Fixed mica condenser, capacity 0.001 microfarad
8. Mercury wells and links
9. Leads from condensers to coil
10. Glass uprights supporting leads
11. Metal upright
12. Ground wire
13. Standard inductor (glass core)
14. Single turn to indicate resonance
15. Thermo-galvanometer

The variable condenser is of the Bureau of Standards type[1] with the following modifications. The top of insulating material

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[1] Bureau of Standards Circular No. 74, "Radio Instruments and Measurements," p. 120.

and metal has been replaced by a top entirely of metal. This top is nickel plated with dull finish. The dull finish protects the eyes of the operator against glare and offers an appearance more sightly than would a bright surface which could not be polished properly without disrespect to the condenser. The insulating part of the handle has been made shorter and the handle itself made longer. The handle axis is pierced by a vertical screw by which it can be clamped to the condenser shaft or released from it and rotated freely. With this device the handle need never obstruct the view of the scale or enter the field of the wavemeter leads. The vertical screw requires more force to clamp and release than would a horizontal screw bearing against the condenser shaft, but it escapes the tendency the latter device has to cant the handle. The scale of the condenser has graduations much narrower than the scales used on Bureau of Standards condensers previously made. The graduations are continued to 190°. This is to enable the vernier to function over the range between 171° and 180°. The vernier is engraved on a block beveled down to avoid parallax. The block extends to the rear in a flat spring by which it is securely pinned to the condenser top. The beveled edge rests lightly on the condenser scale. The 0, 5, and 10 marks on the vernier are extended and numbered and an extra division is laid off on either side of the 0 and 10 marks to aid in reading fractions of 0°.1 and 0°.9. This is a very doubtful advantage inasmuch as it is a little bewildering to read and sometimes causes errors of one degree. A reading glass is used in reading the scale. A slow-motion mechanism, shown in Fig. 2, has been attached to the condenser. An arm, extending from the rim to the center of the condenser top, is pierced to encircle the condenser shaft, to which it can be clamped

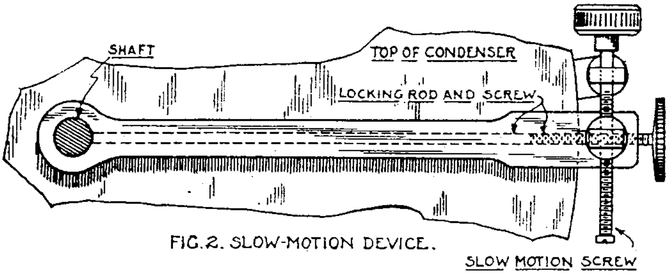

FIG. 2. SLOW-MOTION DEVICE.

by a screw. The arm and the condenser shaft so clamped can then be rotated through a limited traverse by a screw at the rim of the condenser top. The condenser bearings, through which contact is made between the movable plates and the shield, are steel on phosphor-bronze, lubricated with powdered graphite. The slow-motion device makes it feasible to have the bearings tighter than would permit precise settings without the device and thus to eliminate all detectible vertical play of the condenser shaft. The condenser shares the following features with other Bureau of Standards condensers. It is assured a constant calibration, with proper care, by its rigid construction, its shield, its unimpeded traverse through 360° without stops which jar the plates out of alignment, and its all but total lack of any dielectric except air. It has large semi-circular plates, not sheared at one edge or rounded at the corners, which give it a capacity calibration curve very nearly linear from 5° to 170°. The resistance is kept at a negligible value by the elimination of all insulating material except three short Pyrex glass rods which insulate the fixed plates from the movable plates and the shield. The condenser has a maximum capacity of 0.0012 microfarad.

Fixed mica condensers are used to supply additional capacity. Four shielded condensers are used having capacities of 0.001, 0.002, 0.004, and 0.008 microfarad respectively. None of them has a phase difference greater than 5 minutes at 500 000 cycles a second. The high-potential terminals are rods extending up to the level of the top of the variable condenser and ending there in mercury wells. Four more mercury wells are in a projection from the high-potential terminal of the variable condenser, and by means of interchangeable links between the wells any combination of fixed condensers may be put in parallel with the variable condenser. The fixed condenser of 0.001 microfarad is raised on a metal column in order to shorten its high-potential lead and thus diminish any undesirable capacity effects that might result from a long lead. Such effects will be less important with condensers of greater capacity and these are not raised but left at the lower level where they are not in the immediate field of the leads joining the condenser to the inductor.

These leads are of 1.6 mm (1/16 inch) brass rod, enclosing a square about 25 centimeters on a side. Four uprights support the leads. The two of these on the ungrounded side are made of Pyrex glass in order to keep the resistance low. The upright nearest to that terminal of the variable condenser which is connected to the shield is of metal and extends through the top of the truck on which the wavemeter is mounted, terminating in a binding post for grounding. The shields of the fixed condensers are joined to this binding post. The fourth upright is a rod of ordinary insulating material. The leads end in two binding posts, into which the coil terminals can be thrust and clamped, all the coils having terminals at the same height and distance apart.

Fig. 3—Standard Inductor

Of the seven coils to be used with this wavemeter, five are single-layer coils of polygonal cross-section like the coil shown in Fig. 3. They are wound on skeleton frames of laminated phenolic material, which furnish by their open construction as near to an air core as the requirements of rigidity and strength permit. They are wound with silk-covered "high-frequency cable" (litzendraht wire) each strand of which was tested for continuity. The turns of wire are laid in notches in the coil frame. The binding posts are securely pinned to the frame to prevent their working loose and twisting the wire. The shape of the coils is the result of compromise between considerations of low resistance, low effective capacity, and mechanical convenience. It may be shown that of all single-layer cylindrical coils with a given inductance and a given spacing between adjacent turns that one will have the least conductor resistance whose diameter is approximately 2.46 times its length of winding.[2] On the other hand the effective capacity of a single-layer coil is roughly proportional to its diameter and can hence for a given inductance be reduced by decreasing the diameter and increasing the length of winding to compensate. Since the resistance of the coil does not begin to increase at any very startling rate until the coil is made longer than it is wide, the shape may be varied until the length is as nearly equal to the diameter as is convenient mechanically. Among the five coils under discussion the average ratio of coil diameter to length of winding is about 2.1. These five coils range in inductance from 10 to 5000 microhenries. The lower limit is imposed by electrical considerations, the upper by mechanical considerations.

A coil wound on a skeleton frame similar to those of the single-layer coils but having three spaced layers and designed to have an inductance of 23 000 microhenries is now being made. For a higher inductance a coil bank-wound with high-frequency cable (litzendraht wire) on a Pyrex glass cylinder is used. The inductance of this coil is 128 000 microhenries.

The combination of condensers and coils described furnishes a range of wave-lengths from 65 meters to 85 000 meters, or, expressed in frequencies, from 4 600 000 cycles a second to 3500 cycles a second.

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[2] Bureau of Standards Circular No. 74, "Radio Instruments and Measurements," p. 290.

To indicate resonance, a single turn of 1/8 inch brass rod is coupled to the wavemeter coil. The terminals of this loop end in mercury wells fastened at the bottom of an insulating cup. Ordinarily a sensitive thermo-galvanometer rests in this cup with its terminals dipping in the mercury wells. When greater sensitiveness is desired, this instrument is exchanged for a thermo-element with leads to a wall galvanometer. This turn is fixed so that its coupling with any one coil of the wavemeter is always the same. It is grounded on the side nearest the condenser.

The carriage on which the wavemeter is mounted is a modified form of the ordinary hotel dish truck or carriage. It has a strong iron frame, which is grounded. The wheels are six inches in diameter and rubber tired. All of them are of the swivel type and have ball bearings at the swivel. The top of the truck is a heavy slab of maplewood. To it are screwed the fixed and variable condensers, the uprights supporting the leads, and the single turn used to indicate resonance. Rubber cushions are under the variable condenser to absorb shocks.

Although the wavemeter described represents the experience of the Radio Communication Section of the Bureau of Standards as a whole, its design is more especially the work of Mr. J. L. Preston.

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