ATENTION

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ATENCIÓN

GENERAL RADIO COMPANY
Operating instruction
for
TYPE 224 PRECISION WAVEMETER

NOTICE

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Operating instruction
for
TYPE 224 PRECISION WAVEMETER

Cartagena – España - CE
Febrero de 2001
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Instruction Book

OPERATING INSTRUCTIONS FOR
TYPE 224
PRECISION WAVEMETERS
(TYPES 224, 224-A, and 224-L)
FORM 250A

GENERAL RADIO COMPANY
CAMBRIDGE A, MASSACHUSETTS

Additional Technical Information

Users of this instrument who experience difficulty in applying it to the solution of a definite problem are invited to consult the engineers of the General Radio Company. All questions should be specific and accompanied by all the necessary explanatory data. The type number and serial number identify the instrument; the form number on the front cover identifies this Instruction Book.

Preparing Instrument for Shipment

This instrument is mechanically rugged, but it will not withstand rough handling in transit unless protected by a wooden packing case and substantial pads of excelsior or similar material. Cabinets and wooden carrying cases cannot be relied upon to furnish sufficient protection. • • When returning instruments to the General Radio Company for recalibration and repair, it will expedite matters to write for instructions before making shipment.

Service Department
General Radio Company
Cambridge A, Massachusetts

OPERATING INSTRUCTIONS

FOR

TYPE 224 PRECISION WAVEMETERS

Type	Normal Range	
224-A	70 - 24,000 meters	4290 - 12.5 kc.
224-L	15 - 600 meters	2000 -500.0 kc.

NOTE: The Type 224 and Type 224-A Precision Wavemeters are identical instruments.

SECTION 1. PURPOSE OF THE INSTRUMENTS

1.1 Uses Both instruments are intended primarily for general laboratory and service uses where a rapid and fairly accurate measurement of frequency or wavelength is required. Beside the usual measurement of the frequencies of oscillators, radio transmitters, and received signals they can also be used to determine approximately the natural frequency of a tuned circuit, the inductance of coils, and the capacitance of condensers at radio frequencies.

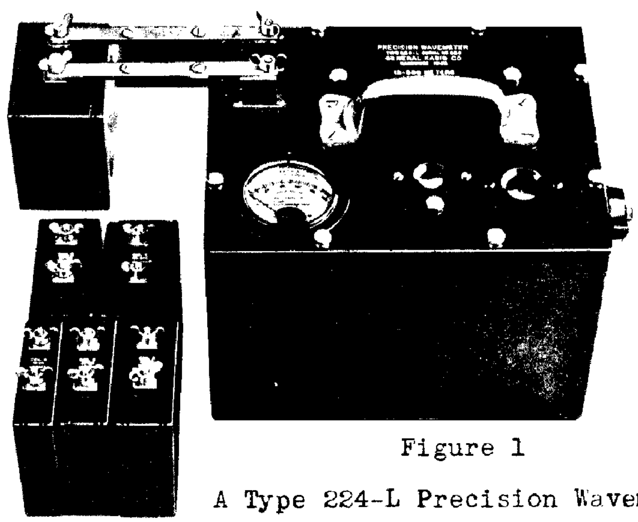

Figure 1

A Type 224-L Precision Wavemeter

SECTION 2. PRINCIPLE OF OPERATION

The term "wavemeter" is generally used to describe a tuned circuit consisting of an inductor and a variable capacitance calibrated in terms of the natural wavelength or frequency of the circuit. The circuit usually contains a device for indicating resonance as defined by maximum current in the tuned circuit.

When the inductor of a wavemeter is coupled to a source of radio-frequency energy such as an oscillator, and the wavemeter capacitance is varied through resonance for the oscillator frequency, the response of the current-indicating element is as shown in Figure 2. The condenser setting corresponding to maximum current (C_R in Figure 2) is the resonant setting.

For a discussion of wavemeters and of resonance phenomena in tuned circuits, the user is referred to the standard texts on radio communication.*

* Lauer & Brown, Radio Engineering Principles (2d ed., New York, McGraw-Hill Book Company, Inc., 1920).

J. H. Morecroft, Principles of Radio Communication (2d ed., New York, John Wiley & Sons, Inc., 1927).

L. S. Palmer, Wireless Principles & Practice (London: Longmans, Green & Co. Ltd., 1928).

E. B. Moullin, Radio Frequency Measurements (London: Charles Griffin & Company, Limited, 1926).

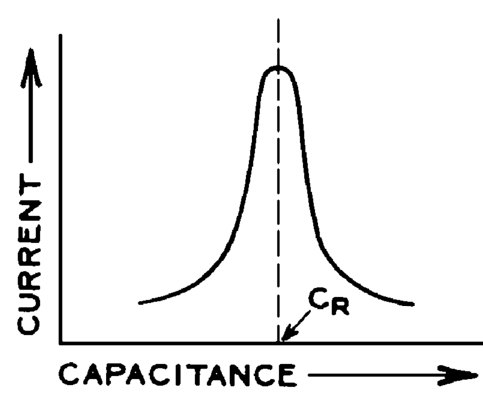

Figure 2

SECTION 3. FUNCTIONAL CHARACTERISTICS

3.1 General Each of the wavemeters is a closed low resistance oscillatory circuit consisting of an inductor, a condenser, and a current indicator in series. The natural frequency of the circuit is adjusted by means of the condenser.

A photograph of a Type 224-L Precision Wavemeter is shown in Figure 1. The appearance of the Type 224-A Precision Wavemeter is identical except that only five inductors are normally supplied with it.

SECTION 4. CONSTRUCTIONAL DETAILS, QUANTITATIVE DATA, AND CIRCUIT CONSTANTS

4.1 Constructional Details

4.11 Inductors The inductors are carefully designed to have approximately Maxwellian shape and low resistance. They are mounted in walnut cases and connect to the condenser by means of a rigid connector strap which is furnished with the instrument. Five inductors are used to cover the normal frequency range of the Type 224-A Precision Wavemeter and six for the Type 224-L Precision Wavemeter.

4.12 Condenser The condenser is of the micrometer worm-drive type (similar in construction to the General Radio Type 222 Precision Condensers).

4.13 Resonance Indicator The resonance indicator is a thermogalvanometer which is mounted on the panel of the wavemeter.

4.2 Circuit Constants and Other Data

Type	Range	Capacitance	Thermogalvanometer Resis.	Thermogalvanometer Shunt	Thermogalvanometer Max.Cur.
224-A	For complete range data see page 1 or page 4*	30-1480 mmf.	4.5 ohms	0.02 mf.	115 mla.
224-L		42- 260 mmf.	0.5 ohms	None	300 mla.

* Additional inductors for extending the range of these instruments can be built to order if necessary. We do not recommend their use because the normal range is the maximum with which a single-condenser instrument can be made to perform satisfactorily.

4.3 Range of Operation

4.31 Range of Operation: Type 224-A Precision Wavemeter

Inductor	Range	
Coil A	75 - 250 meters	4000 - 1200 kc.
Coil B	250 - 800 meters	1200 - 375 kc.
Coil C	800 - 2500 meters	375 - 120 kc.
Coil D	2500 - 7700 meters	120 - 38.9 kc.
Coil E	7700 - 24,000 meters	38.9 - 12.5 kc.

4.32 Range of Operation: Type 224-L Precision Wavemeter

Inductor	Range	
Coil A	15 - 28 meters	20,000 - 10,710 kc.
Coil B	28 - 50 meters	10,710 - 6000 kc.
Coil C	50 - 90 meters	6000 - 3333 kc.
Coil D	90 - 165 meters	3333 - 1818 kc.
Coil E	165 - 300 meters	1818 - 1000 kc.
Coil F	300 - 600 meters	1000 - 500 kc.

4.4 Calibration Two calibrations are furnished, one giving the frequency and wavelength corresponding to scale readings for each inductor, and the other giving the capacitance of the condenser as a function of its scale reading.

4.5 Accuracy The design and method of calibrating these wavemeters are such that the user can depend on their resonant frequency being within 0.25 per cent. of the values given in the calibration chart for a period of one year from date of purchase. Whether or not this accuracy is realized in practice depends on the method of measurement and the care with which the user makes the measurement. Some of the factors affecting the accuracy of wavemeter measurements are discussed in Section 5. Each wavemeter is calibrated in our laboratories with the best possible precision against an oscillator whose calibration is checked at regular intervals against the General Radio primary standard of frequency.This primary standard is a General Radio Standard-Frequency Assembly, the frequency of which is known to considerably better than one part in a million (0.0001 per cent.). Wavelength calibrations are obtained from these frequency measurements by use of the conversion factor 299,820.

Although the accuracy of calibration is better than 0.25 per cent., allowance must be made for small observational errors in drawing and using the calibration curves, and for aging and temperature effects in the tuned circuit.

These errors, although individually small, may be cumulative and they definitely limit the accuracy to which the instrument can be guaranteed.

SECTION 5. OPERATING INSTRUCTIONS

5.1 General   To use the wavemeter it is merely necessary to open the wooden carrying case, lift out the condenser by the handle, and connect the necessary inductor to it by means of the connecting strap (see Figure 1). One wavelength frequency calibration chart for each inductor and the frequency calibration chart for the condenser will be found in the carrying case.

When not in use the wavemeter should be dissembled and kept in the carrying case to protect it from dust and other unnecessary wear. If it is necessary to ship the instrument, remember that the carrying case is not of itself sufficient protection against damage. Pack it well.

5.2 Calibration Chart   While the calibration chart may appear strange at first glance, if it is held at the level of the eye and rotated through an angle of 45°, it will be seen to be a section of special non-linear coordinate paper and may be read as easily as the ordinary chart.

If it is desired to determine the frequency or wavelength corresponding to a given scale reading, proceed as follows:

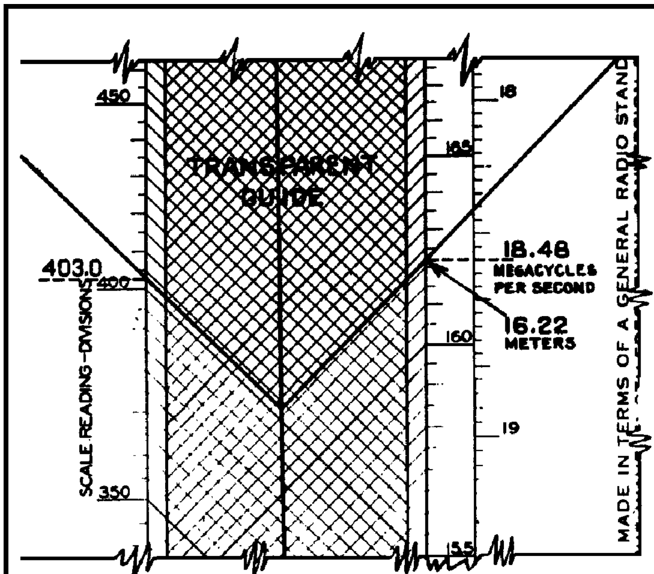

Figure 3

A. Hold the chart with its long dimension vertical.

B. Locate the scale reading at the left-hand side of the chart.

C. Follow the direction of the diagonal lines downward until calibration curve is reached.

D. From point thus determined on curve, follow diagonal lines upward to right until right-hand edge of chart is reached.

E. Read frequency or wavelength scales at right-hand side of chart.

This procedure can be greatly simplified if one right-angled corner of a card or piece of transparent celluloid such as a drafting triangle is used to follow the lines of the scale. Simply place the card on the chart so that the corner rests on the curve and the edges are parallel to the lines of the chart. (See Figure 3).

SECTION 6. SUGGESTIONS FOR USE IN MEASUREMENTS

6.1 Absorption Method To measure the frequency of an oscillator or other radio-frequency source, the wavemeter is placed in the vicinity of the oscillator in such a way that sufficient energy is absorbed by the wavemeter to produce a readable deflection on the thermogalvanometer at resonance.

The condenser of the wavemeter is varied until a maximum reading is observed on the thermogalvanometer. The scale reading corresponding to this maximum is used in entering the calibration chart to determine the frequency or wavelength. If the maximum is broad and extends over several divisions, a more precise estimate of the resonance point may be made by varying the scale reading on both sides of the maximum until the thermogalvanometer reading is reduced by a given (small) amount. The point halfway between these two scale readings, (i.e., the average of the two) may then be used to enter the calibration chart.

CAUTION: If the wavemeter is coupled too closely to a powerful oscillator the thermocouple will be burned out.

Care should be taken to avoid the wavemeter "pulling" the oscillator frequency. With a very low power oscillator where close coupling is necessary to produce a readable deflection on the thermogalvanometer, the oscillator may assume the wavemeter frequency as resonance is approached. When this occurs, the current maximum will appear to be very broad and the thermogalvanometer reading will drop suddenly beyond resonance as the oscillator assumes the frequency of its own tuned circuit. If this happens, the oscillator has not sufficient power to permit the use of the absorption method, and some other method of resonance indication must be used.

6.2 Reaction Method   If the oscillator being measured has not sufficient power to deflect the thermogalvanometer, the reaction of the wavemeter on the oscillator can be used to determine the resonant reading. As the wavemeter is varied through resonance, a slight change in the plate current of the oscillator takes place. Provided the coupling between the oscillator and the wavemeter is small, so that the reaction on the oscillator is just perceptible, this method can be used with fairly accurate results. If the oscillator has a grid-current meter, the grid-current change can be used as a resonance indicator.

6.3 Precautions to be Observed   The exact resonant frequency of a wavemeter will be influenced slightly by objects in its immediate vicinity. If a metallic body is placed in the field of a wavemeter inductor, its effective inductance may be materially changed, and the calibration is no longer correct for the conditions under which it is used. Similarly the capacitance of near-by objects will affect the frequency of an oscillator. When a wavemeter is placed near an oscillator, both effects occur; the wavemeter changes the oscillator frequency and the presence of the oscillator affects the wavemeter. Whether or not these changes are large enough to affect appreciably the accuracy of the measurement depends on the conditions under which the measurement is made and may best be determined by experiment.

Even when the capacitance effects just mentioned are negligible, another error may occur, due to "transformer action." The inductors of the oscillator and wavemeter

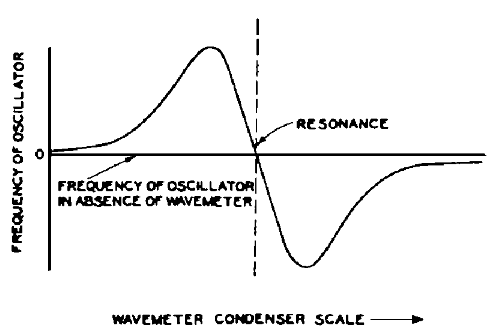

Figure 4

act as the primary and secondary windings of a transformer, and the impedance of the wavemeter is reflected into the oscillating circuit. The magnitude of the reaction depends on the L/C ratios of the two circuits, and the amount of coupling between them. When the wavemeter is set to resonance, the impedance reflected into the oscillating circuit is purely resistive, and the change in oscillator frequency thus produced is negligible. If the wavemeter is not in resonance, the reflected impedance has a reactive component, and the frequency of the oscillator is materially changed.

As the capacitance of the wavemeter condenser is varied through resonance, the frequency changes as shown in Figure 4, where the zero axis represents the frequency of the oscillator before the wavemeter is coupled to it.* The point at which this curve crosses the axis is the setting at which the wavemeter is in resonance, and this setting should be used in entering the calibration chart.

The frequency change shown in the diagram can be detected by listening in a heterodyne detector as the wavemeter condenser is varied. If the heterodyne is set to zero beat with the wavemeter far from resonance, then as the wavemeter is tuned, the frequency or pitch of the beat note will rise and then fall to zero twice. The direction of the beat-frequency change cannot, of course, be detected. For precise measurements, this is an excellent method of adjustment to use.

The exact shape of the curve of Figure 4 is not the same for all oscillators, and in some cases difficulty may be experienced in detecting it. With a very powerful oscillator and extremely loose coupling, the change may be so small that it cannot be observed. If this frequency shift is of the order of 0.25 per cent. of the working frequency, the coupling is too close.

With a given wavemeter and oscillator and a given coefficient of coupling between them, the magnitude of the change is entirely independent of the oscillator power. The higher the power of the oscillator, however, the smaller the degree of coupling necessary to produce a given deflection on the thermogalvanometer. Use the smallest coupling which will give sufficient deflection of the thermogalvanometer.

When the wavemeter is coupled to a controlled oscillator or to the output of a power amplifier, these effects

* This discussion assumes that the oscillator is uncontrolled, that is, that its frequency is determined by the reactance of its tuned circuit.

are usually negligible. The capacitance effect of the presence of the oscillator or power amplifier upon the wavemeter is, however, still present.

When using reaction methods of resonance indication the point of maximum reaction is where the greatest frequency shift occurs, so care should be taken to make the reaction as small as possible or else the setting should be made by listening to the beat note as outlined previously.

In making frequency measurements with a wavemeter, if no care is taken to eliminate or minimize the various effects which have been discussed, the best accuracy which can be realized is about 0.5 per cent., but if due attention is given to them, the rated accuracy of the wavemeter can be reached.

6.4 Use as a Heterodyne Wavemeter Through the use of the Type 423 Vacuum-Tube Oscillator, a Type 224-A or a Type 224-L Precision Wavemeter may be converted into a heterodyne wavemeter. This enables settings to be made with much more precision than with the wavemeter alone.

The wavemeter calibration is no longer correct when the oscillator is attached. Approximate corrections for the effect of the oscillator on the calibration can be made, or if desired, the wavemeter can be recalibrated with the oscillator unit attached. The absolute accuracy of the calibration is no better than the stability of the tuned circuit allows, and is conservatively set at 0.25 per cent.

The advantage of the heterodyne wavemeter over the usual resonant-circuit type lies in the ease with which settings are made and in the fact that the calibration can be checked periodically if any sort of frequency standard is available. Also, through the use of harmonics of the heterodyne wavemeter fundamental, the useful range of the instrument may be extended to many times that of the original calibration.

For price and a complete description of the Type 423 Vacuum-Tube Oscillator consult the current catalog of General Radio laboratory apparatus. If you haven't a copy, a request on your business letterhead addressed to the General Radio Company will bring you one.

6.5 Use in Other Types of Radio-Frequency Measurements These measurements require in addition to the wavemeter an oscillator continuously adjustable through the range of frequencies over which it is desired to make measurements.

6.51 Measurement of the Resonant Frequency of a Tuned Circuit The oscillator is adjusted to the natural frequency of the tuned circuit by means of the reaction on the plate or grid current when the tuned circuit is coupled to the oscillator, or by means of the "click" in the telephones if the oscillator is a heterodyne detector (oscillating radio receiver). The frequency of the oscillator is then measured with the wavemeter, and the frequency read from the calibration chart.

6.52 Measurement of the Apparent Inductance of an Inductor at Radio Frequencies The oscillator is set by means of the wavemeter to the frequency at which it is desired to make the measurement. The inductor to be measured is connected in place of the wavemeter inductor, and the condenser is varied until the wavemeter is in resonance with the oscillator. The inductance is then determined by

$$f = \frac{1}{2\pi\sqrt{LC}}$$ very closely where

f = oscillator frequency as measured by the wavemeter

L = apparent inductance in henrys of inductor under measurement

C = capacitance in farads (micromicrofarads x 10^{-12}) of wavemeter condenser when used with inductor under measurement. This may be determined from the condenser calibration.

6.53 Measurement of the Capacitance of a Condenser at Radio Frequencies While the wavemeter condenser may be used as a standard in bridge measurements of capacitance, an approximate measurement may be made by means of the wavemeter at radio frequencies with no more auxiliary apparatus than an oscillator.

The condenser to be measured is connected to the wavemeter in place of the wavemeter condenser and the oscillator is adjusted to the resonant frequency of the parallel tuned circuit thus formed. The wavemeter condenser is then replaced in parallel with the wavemeter inductor and the wavemeter is adjusted to the oscillator frequency. The capacitance of the unknown condenser is then equal to the capacitance of the wavemeter condenser at this setting.

6.54 Measurement of Inductance and Distributed Capacitance of an Inductor at Radio Frequencies The inductor is connected in place of the wavemeter inductor and the wavemeter is set to resonance with the oscillator at two frequencies, separated by a considerable interval.

If the subscripts "1" and "2" are understood to refer to the two readings and

f = frequency in cycles per second

C = capacitance (in farads) of wavemeter condenser at resonance

C_0 = distributed capacitance (in farads) of coil

L = inductance (in henrys) of coil

$$f_1 = \frac{1}{2\pi\sqrt{L(C_1+C_0)}}$$

and

$$f_2 = \frac{1}{2\pi\sqrt{L(C_2+C_0)}}$$

Solving these two equations we obtain

$$C_0 = \frac{f_2^2 C_2 - f_1^2 C_1}{f_1^2 - f_2^2}$$

$$L = \frac{1}{4\pi^2 f_1^2 (C_1+C_0)} = \frac{1}{4\pi^2 f_2^2 (C_2+C_0)}$$

6.55 Measurement of Small Capacitance at Radio Frequencies The wavemeter is set to resonance with the oscillator. The condenser whose capacitance is to be measured is connected in parallel with the wavemeter and the wavemeter condenser scale reading is reduced until the wavemeter is again in resonance with the oscillator. The difference between the wavemeter capacitances corresponding to these two scale readings is the capacitance of the unknown condenser.

6.56 Measurement of the Effective Capacitance of a Radio-Frequency Choke Since most radio-frequency chokes act like condensers over their working ranges, a choke can be measured by the method of Section 6.55 by connecting it in parallel with the wavemeter condenser.

6.57 Use of Condenser Calibration The condenser calibration is accurate to within 1 mmf. at 1000 cps.

Other General Radio Publications

In addition to the catalogs describing the standard line of instruments it manufactures, the General Radio Company publishes a monthly magazine, the *General Radio Experimenter*, for free distribution among interested persons. It contains technical and semi-technical engineering articles which are contributed, for the most part, by members of the General Radio engineering staff. Since the choice of subjects is inevitably conditioned by the trend of new developments, those who are already users of General Radio instruments should be particularly interested in receiving the publication.

There is no subscription fee for the *General Radio Experimenter*. To be placed upon the mailing list merely address a request to the General Radio Company with the following information: (*a*) your name and mailing address, printed or typed for the sake of legibility; (*b*) your business affiliation; (*c*) your position; and (*d*) the kind of technical developments in which you are particularly interested.

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