The GENERAL RADIO EXPERIMENTER

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

THE WAVEMETER YIELDS

THE tuned-circuit wavemeter was the first accurate radio-frequency-measuring instrument, and it is interesting that even now we measure frequency with far higher accuracies than any other quantity with which the radio engineer deals. While tuned-circuit wavemeters have been greatly refined, the accuracy of laboratory measurements, and indeed commercial requirements for frequency standards, have outstripped them. So, while the tuned-circuit type of wavemeter will still be used for many purposes—as a transfer instrument, and for measurement where an accuracy of about 0.1% is sufficient, it must yield its place as a secondary standard for really precise work, just as it was displaced by the crystal oscillator several years ago as a primary standard. Again it is a form of piezo oscillator which takes its place.

A few years ago, a wavemeter, especially one of the precision type, was regarded as a sufficiently accurate frequency standard for use on commercial channels. With the total number of stations on the air constantly growing, efficient use of the available radio channels demands that the frequency of each station deviate as little as possible from that of its assigned channel. The present regulations of the Federal Radio Commission specify frequency tolerances which are far beyond the practical limits of a calibrated tuned-circuit wavemeter.

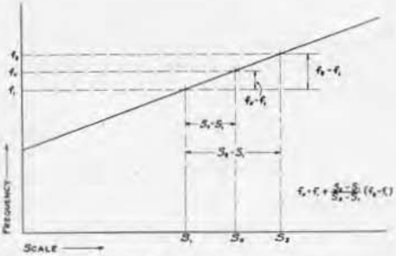
The present frequency tolerances on channels between 1500 and 23,000 kilocycles vary from 0.02% to 0.05%. To reach accuracies of this order, measurements must be made by heterodyne methods, since the best accuracy which may be obtained commercially with the tuned-circuit wavemeter is in the vicinity of 0.1%.

The development of the piezo-electric oscillator has furnished accurate and inexpensive frequency standards. As originally developed only a single frequency and its harmonics could be obtained from a single crystal. Multivibrators opened a new range of usefulness for piezo standards by enormously increasing the number of frequencies which can be obtained from a single standard. The multivibrator extends the usefulness of the standard by providing a harmonic series whose fundamental is equal to or a submultiple of the frequency of the standard and is entirely controlled by it. These two instruments in combination provide a series of standard frequencies spaced at equal intervals over the radio-frequency spectrum, which can be used for frequency measurements in much the same way that milestones on a highway can be used in measuring distance.

While this type of equipment is suitable for use as a primary standard a more flexible installation is needed for commercial frequency measurements.

Frequencies which lie within a few cycles of the standard harmonics can be measured by direct comparison methods, such as listening to beats in an oscillating detector, but in order to measure frequencies between the harmonics, an additional unit is required. For this purpose, a heterodyne frequency meter is used.

The heterodyne frequency meter is a highly stable radio-frequency oscillator with a linear scale (straight-line-frequency condenser). Since this is a tuned-circuit instrument, it is subject, of course, to the usual variations in frequency due to the temperature coefficient and the effects of aging in the tuned-circuit. Its stability over short periods is extremely high and it can be used as a calibrated frequency meter of high accuracy if the calibration is periodically checked. When used with standard-frequency equipment, however, it becomes purely an interpolating device and the only factors affecting the accuracy of measurement are its precision of setting and linearity of scale, both of which are more than adequate for commercial use.



Illustrating method of interpolation between standard-frequency harmonics

This process of interpolation may be better understood by reference to the diagram of Figure 1 which shows a plot of frequency against scale reading for the heterodyne frequency meter. By listening in a radio receiver, the heterodyne frequency meter can be successively adjusted to zero beat with the unknown frequency, the multivibrator harmonic next above the signal, and the harmonic next below the signal. This gives three scale readings, S_x, S_2, and S_1, respectively. If the frequency interval between multivibrator harmonics is 100 kilocycles, the frequency interval between f_1 and f_x is

$$\frac{S_x - S_1}{S_2 - S_1} \times 100 \text{ KC} \quad (1)$$

In other words, the frequency interval between f_1 and f_x is proportional to the corresponding fraction of the 100-kilocycle scale interval and the frequency of f_x is

$$f_1 + \frac{S_x - S_1}{S_2 - S^1} \times 100 \text{ KC} \quad (2)$$

If desired, operation (1) can be carried out by means of a chart.

The frequency of the harmonic f_1 can be easily determined from the calibration of the heterodyne frequency meter.

The following analogy may be helpful in explaining the interpolation process. Suppose, for example, that a man lives in a house between the towns of A and B, and that he wishes to determine exactly how far from A his house is situated. These towns are connected by a straight highway marked by milestones. He knows that the house is between the 8th and 9th milestone from A. His problem is therefore to determine the distance between milestone number 8 and his house. Starting out from the house he paces off the distance to the 8th milestone and finds it to be exactly 440 paces. He then turns back and counts the paces from the 8th milestone to the 9th and finds there are exactly 1760. Since 1760 of his paces are equal to one mile he knows the house is 440/1760 of one mile from the 8th milestone. His house then is located 8¼ miles from A.

While the mechanics of this distance interpolation are similar to those of the frequency measurement, there remains one outstanding difference. While it took our hypothetical householder about an hour to perform his interpolation on foot, the unknown frequency can be measured on the dial of the heterodyne frequency meter in a few seconds.

The interpolation process is not limited to the fundamental frequency range of the heterodyne frequency meter. Interpolation can be made as easily at harmonics as at the fundamental. This allows measurements over a wide range of frequency to be made with an instrument whose fundamental frequency range is limited.

The secondary standard described. It consists of the following items:

TYPE 616-A Heterodyne Freq'cy Meter	$500.00
TYPE 592-A Multivibrator . .	150.00
TYPE 575-D Piezo-Electric Oscillator	215.00
TYPE 480-B Relay Rack . .	15.00
TYPE 376-J Quartz Plate (for oscillator)	85.00
TOTAL . .	$965.00

(Blank panel is not included in this price)

For use in this method of frequency measurement, the General Radio Company offers the assembly shown in Figure 2.

This assembly is capable of measuring frequencies from below 100 kc to about 30,000 kc. The overall accuracy is better than 0.01%. It is suitable for the measurement of the frequencies of transmitted and received signals and for the standardization of receivers and other calibrated apparatus.

It is particularly recommended for small communication companies engaged in furnishing a limited class of service as, for instance, airplane communication.

The piezo-electric oscillator is the same instrument used in the General Radio visual frequency monitor for broadcast stations. Its absolute accuracy with TYPE 376-J Quartz Plate is guaranteed to be within 0.002%. The multivibrator is of the type used in the General Radio Class C-21-H Standard-Frequency, a precise primary standard.

The TYPE 616-A Heterodyne Frequency Meter is a highly stable tuned-circuit oscillator using a straight-line-frequency precision condenser. It is entirely alternating-current operated and uses the voltage stabilization feature described in the August *Experimenter.* Its fundamental frequency range is from 100 to 5000 kilocycles. By using harmonic methods, it can be used to measure frequencies from 10 to 30,000 kilocycles. A detector and audio amplifier are included.

A portable, battery-operated heterodyne frequency meter is also available. This instrument, TYPE 615-A Heterodyne Frequency Meter, covers a frequency range of from 275 to 5000 kilocycles. It is similar in appearance to the model shown on page 8 of the August *Experimenter.* The portable feature is often an advantage, since the instrument can be checked in the laboratory against a frequency standard and then used for frequency measurements at points remote from the laboratory. Its price is $375.00. Substituting this instrument for the relay-rack model of Figure 2 makes the price of the complete assembly $840.00.

—CHARLES E. WORTHEN

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A LABORATORY HETERODYNE

IN the whole range of frequencies above audibility there has not been commercially available equipment for demodulation and amplification of super-audible frequencies, yet such equipment is a necessary accessory for many types of laboratory measurements, and greatly extends the usefulness of other standard equipment. Bridge measurements, for example, can be made at frequencies above the broadcast band. In frequency measurements, a heterodyne is of course indispensable.

To be sufficiently flexible for general use, such an instrument must cover an extremely wide frequency range with a fairly uniform sensitivity. Commercial receivers are available for certain frequency bands, but no single instrument of such characteristics has been available which would cover the entire frequency band from 85 kilocycles to 20 megacycles.

The TYPE 619 Heterodyne Detector, while originally designed for use in a frequency-monitoring system, meets these conditions very well and is

Type 619-A Heterodyne Detector

entirely suitable for use as a general-purpose heterodyne.

It consists of a tuned, regenerative detector whose frequency range extends from 85 to 6000 kilocycles, and a two-stage audio amplifier. This range of frequencies is covered by the standard set of twelve coils furnished with the instrument. In addition, six extra coils are available which extend the range to 20 megacycles. A regeneration control is provided so that the detector can be used in either the oscillating or the non-oscillating condition.

This control is extremely silent in operation and no "fringe howl" or clicks are noticeable when the detector goes into oscillation.

The amplifier output transformer is designed to work into a pair of telephones.

This instrument is available in two models, one battery operated and the other designed for operation from a 110-volt, 60-cycle, alternating-current line. Both models are intended for relay-rack mounting, but can be supplied in cabinet mounting at a slight increase in cost.

The minimum-detectable signal with the battery-operated model is about 40 microvolts with a signal 30% modulated at 1000 cycles and with heterodyne reception of an unmodulated signal it is about one microvolt.

The alternating-current model has slightly higher background noise level and its sensitivity to the modulated signal is about 100 microvolts over most of the frequency range. Using beat reception with this model a signal of about 2 microvolts can be detected.

These values are for threshold sensitivity, the weakest signal which can be heard.

The price of the a-c model (Type 619-AR) is $250.00 and that of the battery model (Type 619-BR) is $225.00.

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A RADIO-FREQUENCY OSCILLATOR FOR THE LABORATORY

Type 484 Radio-Frequency Oscillator. The drawer provides storage space for extra coils

A RADIO-FREQUENCY GENERATOR covering a wide range of frequency is often needed for laboratory measurements.

The Type 484-A Modulated Oscillator has been designed to fill the need for a general-purpose instrument which can be adapted to a variety of problems. Among its features are a wide frequency range, straight-line-frequency condenser, precision dial, internal modulation, output control, and low external field.

The normal frequency range is from 490 kilocycles to 40 megacycles covered with 5 plug-in inductors. Two additional inductors are also available. One spans the intermediate frequencies used in superheterodynes. The other operates at 100 kilocycles. The small change of frequency with dial setting on this coil, combined with the slow-motion dial, permits setting the oscillator with extreme precision at 100 kilocycles, in comparison with a standard.

The frequency ratio of each coil is approximately 3:1. The condenser is controlled by a Type 706-B, 6-inch precision dial, which has a slow-motion drive with a 3:1 reduction ratio. Its total scale length is 450 divisions and it can be set to within one-fifth division.

Modulating voltage is supplied from a 1000-cycle vacuum-tube oscillator which is included in the instrument. The modulation oscillator is a plug-in unit, and units for other frequencies are easily substituted. The percentage modulation is approximately 30%. A short-circuiting plug is provided which replaces the audio-frequency coils when it is desired to use the oscillator unmodulated.

The output is controlled by a potentiometer having an Ayrton-Perry winding. The maximum output voltage available is 2.0 volts. At the highest frequencies this drops to 0.2 volt. Over the range of any one coil the voltage varies by a ratio of approximately 1.5 to 1.

The oscillator is battery operated and uses two 230-type tubes. Batteries are self-contained.

This oscillator is a suitable power source for use with the Type 516-A Radio-Frequency Bridge. Other uses include resistance measurements at radio frequencies, testing receiving circuits, and determining detection characteristics of vacuum tubes.

It is an exceptionally useful instrument for experimental and demonstration use in college laboratories.

The price, less tubes, batteries, and inductors, is $125.00.

Code Word—CREST.

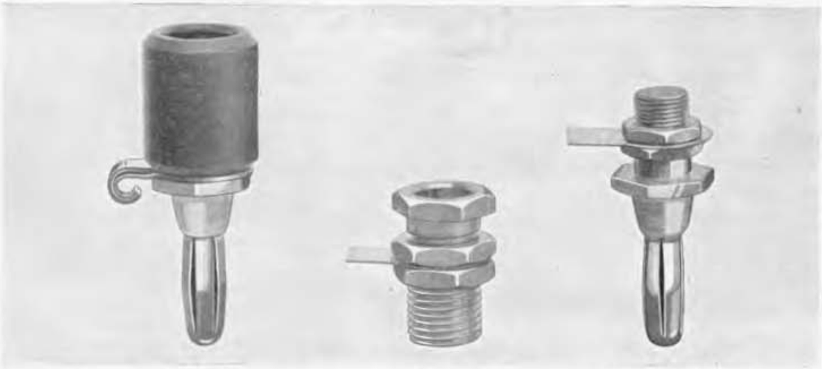
Inductors available are listed below:

Type	*Frequency Range*	*Price*	*Code Word*
484-P1	23.5 mc to 40 mc	$8.00	MODOSCBIRD
484-P2	8.9 mc to 27 mc	8.00	MODOSCDESK
484-P3	3.2 mc to 10.5 mc	8.00	MODOSCFORD
484-P4	1220 kc to 4225 kc	8.00	MODOSCGIRL
484-P5	490 kc to 1650 kc	8.00	MODOSCGOAT
484-P11	160 kc to 270 kc	8.00	MODOSCHYMN
484-P12	100 kc	8.00	MODOSCMILK
484-P21	400-cycle oscillator unit	12.00	MODOSCPALM

Weight........32 lbs.

Dimensions: 14½ deep x 12½ high x 19¾ inches long

A NEW PLUG GROUP



Type 674-D Type 674-J Type 674-P

The Type 674 Plugs, illustrated, are similar in features and convenience to the well-known 274 type.

They are capable of carrying much heavier currents (up to 50 amperes) and have a low contact resistance.

A conical shoulder on the plug fits smoothly into a similar recess on the jack, and the main path of current is not through the plug springs.

Provision is made for attaching heavy leads to the plugs. A turned over lug is provided which clasps both the bared end of the wire and the insulated body. The latter feature removes the strain of the heavy lead from the joint.

The plugs are particularly convenient for mounting transmitting inductances. Copper tubing 5/16-inch diameter can be fitted directly into the jack end of the TYPE 674-D Plug.

A precaution should be observed in soldering to the plugs. The phosphor-bronze spring should be held with a wet cloth, otherwise the long heating necessary for soldering the large connections may damage the temper of the plug spring.

TYPE 674-P All-Metal Plug	$0.25
TYPE 674-J Jack	.35
TYPE 674-D Insulated Plug with Jack Sleeve	.50

BRIDGE MEASUREMENTS AT HIGH FREQUENCIES

THE July (1932) *Experimenter* contained an article describing a bridge suitable for measurements at radio frequencies. This article mentioned an oscillator that was being developed which would be suited for use with the TYPE 516-A Bridge. This oscillator (the TYPE 484-A) is announced in this issue of the *Experimenter*. It is shown set up for use with the high frequency bridge in Figure 4 of the July article.

In the bridge article, a broadcast receiver was suggested as a null indicator. This is probably the most satisfactory detector at broadcast frequencies, but where work is to be pursued over a wide range of frequencies above and below the broadcast range a more flexible instrument is needed. The features of the TYPE 619 Heterodyne Detector, described in this issue, recommend it for use with the TYPE 516-A Bridge. The frequency range of the heterodyne detector includes nearly all frequencies at which the bridge would be used. Its sensitivity is sufficient for good bridge balance. The following figures indicate the accuracy of balance at representative frequencies, using the TYPE 484-A Radio-Frequency Oscillator and the TYPE 619-B Heterodyne Detector. The TYPE 619-A (a-c type) has a slightly higher noise level, and less accurate balances can be obtained with it.

Frequency	*Modulated*	*Unmodulated*
200 kc	10 µµf	0.15 µµf 0.7 ohms
1000 kc	0.5 µµf 0.5 ohms	0.05 µµf 0.025 ohms
2500 kc	0.05 µµf 0.03 ohms	0.005 µµf 0.01 ohms

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