

THE

General Radio EXPERIMENTER

VOLUME XVIII No. 5

OCTOBER, 1943

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

CALIBRATION OF EQUIPMENT IN THE LOW AND MEDIUM RADIO-FREQUENCY RANGES, IN SMALL STEPS OF FREQUENCY

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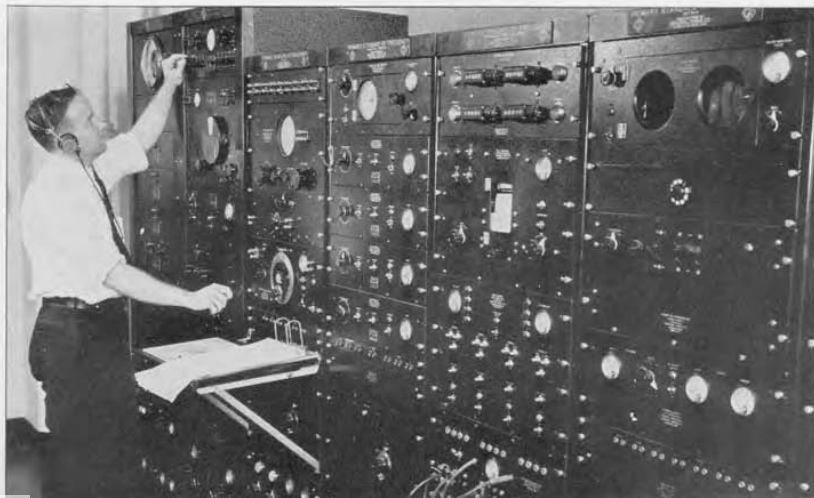
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● THE PROBLEM of calibrating an oscillator or receiver, at well separated points, in terms of harmonics from a frequency standard is well understood, and is easily solved. Referring to Figure 2a, if the harmonics from the standard are multiples of 10 kc, or of a higher frequency, a calibrated receiver serves to identify the individual harmonic frequencies without ambiguity. The combined selectivity of the tuning of the receiver, the limited pass band of the audio frequency part of the receiver, the telephones, and the operator's ear serve to suppress very largely the "extraneous" beats. If the receiver can be made to oscillate, or if any noise or hum is present, then the oscillator can be set, with high precision,

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FIGURE 1. Measuring frequencies in the General Radio laboratories.



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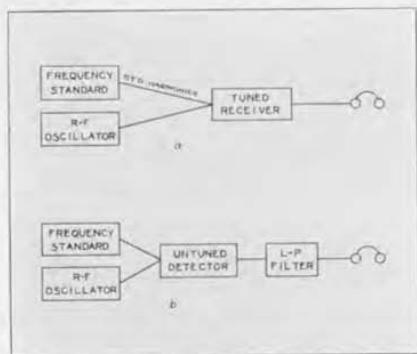


FIGURE 2. Block diagrams showing the method of calibrating an oscillator in terms of a harmonic frequency standard; (a) with tuned receiver, (b) with an untuned detector.

to zero beat with the standard harmonic frequencies by adjusting it so that the "flutter" heard on the audio beat tone, or background noise, is brought to a very low frequency.

If now it is necessary to calibrate the oscillator in smaller steps of frequency than 10 kc, and harmonics of a lower fundamental frequency, such as 1 kc, are used, a very confusing series of beat tones is heard in the telephones. This is brought about because the principal receiver output no longer consists of the beat between the oscillator and a *single* standard frequency harmonic. When using a 1-kc harmonic series, and with the oscillator set near zero beat against one harmonic, beats between the oscillator and standard are passed by the receiver for several harmonics both above and below the one to which the oscillator is adjusted.

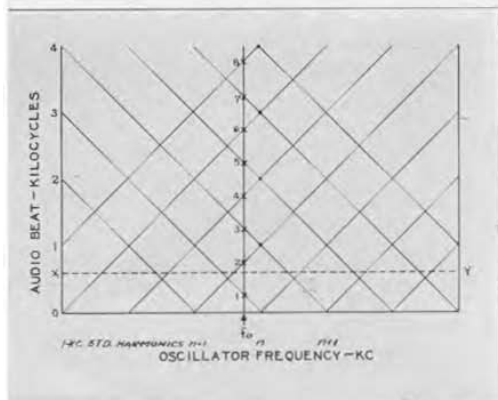
This situation is illustrated in Figure 3. As the oscillator frequency is increased, beats are heard in the receiver output which increase in frequency for standard harmonics below the oscillator frequency; beats are also heard which decrease in frequency for standard harmonics above the oscillator frequency. The upper extent of the diagram is limited by the over-all receiver pass band, as mentioned above.

For a particular oscillator setting, such as represented by f_0 , Figure 3, the receiver output contains the various beat frequencies 1, 2, 3 . . . up to the limit passed by the receiver. These are seen to be the desired beat frequency represented by 1 and other beats which consist of multiples of the standard frequency (1 kc) plus or minus the desired beat frequency, represented by 2-3, 4-5, etc.

If the receiver output is deliberately given a sharp cut-off at a frequency slightly greater than one half the standard frequency, represented by the line X-Y, Figure 3, then the confusing beats are entirely eliminated except for a very small region halfway between standard frequency harmonics. In this small region both beats are very nearly one half the standard frequency. If the oscillator is set very nearly halfway between two standard harmonics, the receiver output consists of two frequencies, one very slightly more than one half the standard frequency and one very slightly less. These two frequencies combine to give the effect of a single frequency waxing

FIGURE 3. Illustrating the formation of beat frequencies as the oscillator frequency is varied.

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and waning in intensity at a rate equal to the difference in frequency. If the oscillator is set so that the waxing and waning takes place very slowly, or the "flutter" is brought to a very low frequency, then the oscillator is adjusted with considerable precision to a frequency just halfway between two standard harmonic frequencies.

For many purposes it is desirable to avoid the need of tuning a receiver to successive standard frequency harmonics, when an oscillator is being calibrated. An untuned detector can be used, as shown in Figure 2b, if separate means are used for identifying key points on the oscillator calibration. To avoid confusing beats, a low-pass filter, with a cut-off frequency slightly over one half the standard frequency, should be used.

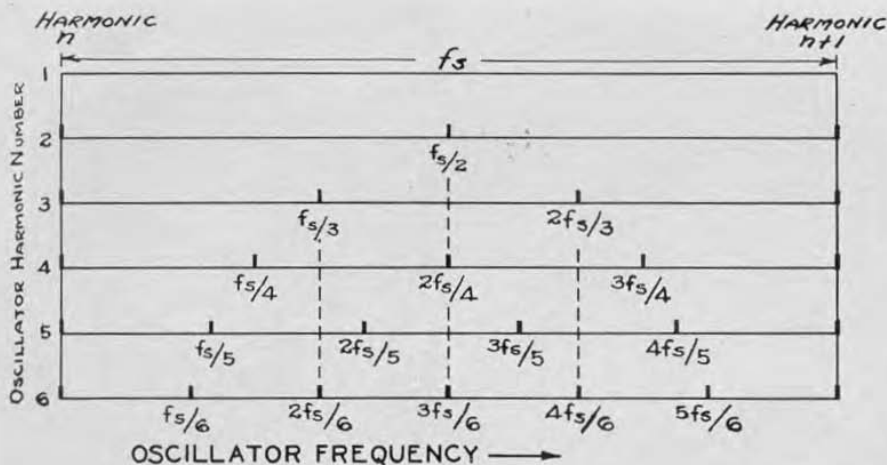
Because no radio frequency selectivity is provided, a new series of extraneous beat frequencies will be heard in the detector output, if the oscillator output contains harmonics. These beats are formed as follows: while fundamental frequency of the oscillator being calibrated is changed from one standard frequency harmonic, n , to the next higher, $n + 1$, the second harmonic of of

the oscillator is changed from twice the first standard frequency, $2n$, to twice the second, $2(n + 1)$ or $2n + 2$. In other words, the second harmonic of the oscillator has moved over two harmonic intervals. If the oscillator is set halfway between the two harmonics n and $n + 1$, the frequency is $n + \frac{1}{2}$. The frequency of the second harmonic is twice this, $2(n + \frac{1}{2})$ or $2n + 1$, which is a standard harmonic point.

As judged by the fundamental frequency of the oscillator, this simply means that if the oscillator is set halfway between two standard harmonics a zero beat is heard, due to the second harmonic. The second harmonic divides the fundamental interval in half. Similarly, the third harmonic divides the interval into three parts; the fourth harmonic divides it into four parts, and so on.

It is important to realize that this pattern of subdivision of the interval between two successive standard harmonics is always the same regardless of the numbers of the harmonics and regardless of the value of the standard fundamental frequency. The pattern is illus-

FIGURE 4. Pattern of harmonic beats which subdivide the standard-frequency interval.



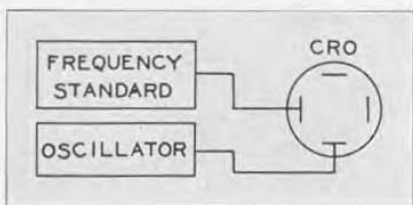


FIGURE 5. Block diagram showing how standard and unknown frequencies are connected to a cathode-ray oscilloscope for obtaining Lissajous figures.

trated in Figure 4 which gives the values of all of the frequencies corresponding to zero beat points in one harmonic interval, for harmonics up to the sixth. These points are easily identified and in some cases are a very useful means of subdividing a given standard frequency interval into smaller parts.

A cathode-ray oscilloscope is a very useful and versatile device for use in making frequency comparisons and measurements. The simplest application is illustrated in Figure 5, where a standard frequency is applied to the horizontal deflection plates and an oscillator to be calibrated is connected to the vertical deflection plates. The familiar Lissajous patterns will only be briefly described here.* In Figure 6 is shown the type of pattern obtained when the oscillator frequency is three times the standard frequency. When the pattern stands still, the oscillator is exactly three times the standard frequency; the form of the pattern depends on the phase difference of the standard and oscillator voltages.

*For detailed descriptions of patterns see, for example, Merwyn Bly, "A Guide to Cathode-Ray Patterns," John Wiley & Sons, Inc., 1943.

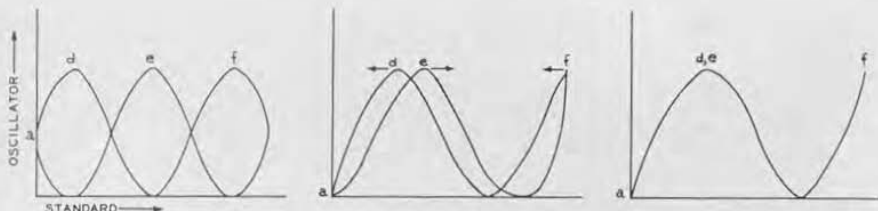
If the oscillator frequency differs very slightly from the standard, the pattern changes progressively through the forms shown and back again. The ratio between oscillator and standard frequencies is found, for any pattern, by counting the tangent points along a horizontal side, such as d, e, f, and dividing by the number of tangent points along a vertical side, such as "a."

Theoretically fractional ratios, involving other than small integers, such as 27/19, could be identified, but with complicated figures checking is very time-consuming. Also, the principal interest is generally attached to integral ratios.

If the functions of identifying the frequency ratio and setting for exact frequency ratios are separated, then the effective range can be very greatly extended. For example, if patterns of the type shown in Figure 6 for integral frequency multiples are used, with a large horizontal deflection voltage (from the standard), the oscillator can easily be set at multiples of 1000, or more, to one. By using higher standard frequencies, identification of key points on the oscillator calibration can be made with simple patterns. Points can then be filled in for every kilocycle or even every half-kilocycle, using a 1-ke standard. The arrangement is illustrated in Figure 8.

When the horizontal deflection voltage is increased, the central section of the pattern only is observed. This pattern appears as a few cycles of two

FIGURE 6. Lissajous pattern for a 3:1 frequency ratio.



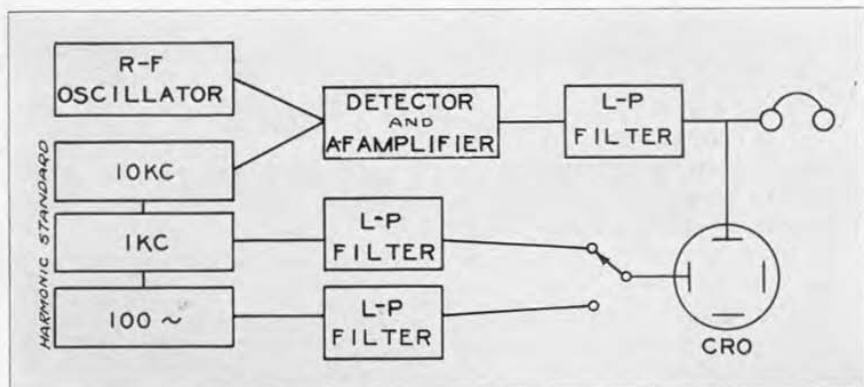


FIGURE 7. Block diagram of audio beat system for obtaining small calibration intervals.

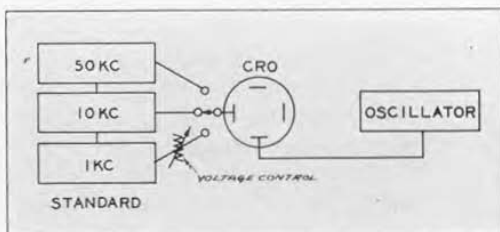
waves, one progressing from left to right, the other from right to left, due to the forward and return traces caused by the sinusoidal sweep voltage. When stationary, the oscillator frequency is an exact integral multiple of the standard frequency. The $(n + \frac{1}{2}):1$ patterns appear as two chains, one moving to the right and one to the left. Higher ratio patterns are recognizable and can be used if desired.³ A typical pattern is shown in Figure 9.

In some cases, the use of very high multiples of a given standard frequency will not extend the calibration to sufficiently high frequencies because of the difficulty of opening out the pattern for easy identification of the multiples of the standard frequency. By using a detector or receiver as in Figure 7, with comparatively high frequency standard harmonics, the very small frequency intervals can be set using the cathode-ray oscillograph in the audio, instead of radio, frequency range.

³F. R. Stansel, *Journal of the Institution of Electrical Engineers (British)*, June, 1943, p. 73.

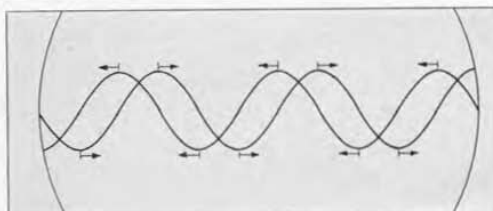
FIGURE 9. Appearance of pattern when oscillator being calibrated is set very nearly to a high multiple of a standard frequency. One trace appears to move slowly to the right; the other slowly to the left, as indicated by the arrows.

FIGURE 8. Block diagram of system for spreading out pattern to obtain small calibration intervals.



The oscillator under calibration, the standard frequency source, and the detector system are, in effect, a beat frequency oscillator, which in turn is calibrated by the audio-frequency checking system. In the intervals between the radio-frequency harmonics of the standard, the oscillator can be set to any multiple of the standard audio frequencies, and, with the cathode-ray oscillograph, just as readily to multiples of one half of these frequencies. In terms of the standard frequency values given in Figure 7, this means that the oscillator could be calibrated easily to every 50 cycles in its radio-frequency range.

—J. K. CLAPP





THE WAR HAS BROUGHT ITS GRIEFS TO GENERAL RADIO

● THROUGHOUT THE AGES history has recorded the courageous deeds of women in warfare and in the relief of suffering on the battle front. In the coming decades historians will no doubt expound upon the contributions of women to the present world-wide conflict and will rightfully emphasize the important share in the final victory won by our women, both in the armed services and in industry.

About a year ago so many of the younger members of the General Radio organization had left us to join the armed forces that a serious shortage of personnel arose in our testing, inspection, and certain manufacturing departments. Breaking a lifelong custom with some slight trepidation, it was happily decided to build up a corps of women employees for this work—a decision which has met with gratifying success.

The Army has its WACS, the Navy its WAVES, the Coast Guard its SPARS, so it was but natural that General Radio should have its GRIEFS. The latter is a most inappropriate title in its literal meaning but, with a poetic license in spelling, is the inevitable contraction of General Radio Emergency Inspection Force.

A group of about a dozen girls were recruited for the initial GRIEF platoon to which were added two feminine members of our drafting department, one of whom is now on our Honor Roll as a Marine. The work which these young women were to do required some real knowledge of the theory and operation of our products, so that it became the happy privilege of the writer to have these young ladies in charge for a six-

weeks' instruction period. The majority of the group had obtained more or less of a background of science and mathematics in high school, college, and ESMWT classes. Several of the girls held collegiate degrees but, what was far more important, all were anxious to stand behind husbands, sweethearts, and brothers in Bataan, in Africa, and on the high seas.

Guided by previous experience in teaching, the GRIEF class program started with a study of the fundamental principles of electrical science, first in d-c and then in a-c systems, and subsequently led into the manifold practical applications of this basic theory in the operation and testing of General Radio equipment. Several members of the engineering staff contributed valuable discussions concerning their specialized fields—lectures which served as material for a "graduation thesis" from each of the girls.

Morning sessions with ohms, farads, kilocycles, and rainbow-colored circuit diagrams in the classroom were followed by afternoons of graduated practice work in the inspection department. At the completion of the course the GRIEFS were ready to go into the testing and calibrating laboratory and really to hold their own in friendly competition with the masculine engineering assistants in this department. This training program clearly demonstrated the abilities of these enthusiastic young women to do this important work, and proved that some real knowledge of the subject matter considerably enhanced these abilities and heightened the personal satisfaction of the GRIEFS in their





THE GRIEFS AT WORK





work and accomplishments. Several of the girls had the ambition to supplement a full day in the laboratory with further evening courses in mathematics and radio.

A most happy esprit de corps has developed between the GRIEFS and the heretofore lordly males, as demonstrated in lunchtime poker games, in certain activities of that legendary fellow with a bow and arrow, and in numerous other ways.

Since the first group of GRIEFS added pulchritude to precision in the General Radio laboratories, Uncle Sam has made further demands upon our

masculine staff and to date four platoons of GRIEFS have successively joined our personnel to compensate for our expanding Honor Roll. Certain of these young ladies have found their talents and inclinations more adapted to manufacturing than to testing and inspection activities, so that they are now doing a grand job in the construction of precision mica capacitors and a multitude of other component parts.

War brings its suffering and sorrow to a nation, but to General Radio it has introduced a very special and enjoyable form of GRIEF.

—HORATIO W. LAMSON

MAINTENANCE WITH THE STROBOTAC

Manufacturers and users of radio communication equipment are finding increasing use for Strobotacs in design and maintenance work. This photograph, taken in the radio shop of the Eastern Air Lines at Miami, Florida, shows a vibrator power supply being studied with a General Radio Strobotac. Mechanical action of the reeds and contacts is observed under actual operating conditions. Trouble is diagnosed by correlation of mechanical data supplied by the use of the Strobotac with electrical data supplied by a cathode-ray oscillograph.



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