OPERATING INSTRUCTIONS FOR TYPE 616-D HETERODYNE FREQUENCY METER

FORM 375-E

GENERAL RADIO COMPANY
CAMBRIDGE A, MASSACHUSETTS

PATENT NOTICE

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1,542,995	1,943,302
1,931,530	1,955,739

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OPERATING INSTRUCTIONS FOR TYPE 616-D HETERODYNE FREQUENCY METER

PART 1
DESCRIPTION

PURPOSE The Type 616-D Heterodyne Frequency Meter is designed for use in frequency measurements either as an interpolation instrument in conjunction with harmonic frequency standards or as a calibrated frequency meter.

ADVANTAGES When used in the type of measurements formerly made with a wavemeter, the heterodyne frequency meter offers the advantage of greater accuracy and precision of setting and allows measurements to be made both above and below the fundamental frequency range through the use of harmonic methods. In addition, the calibration is easily checked against standard-frequency radio transmissions. In connection with frequency measurements based on standard-frequency harmonics, its linear scale (straight-line frequency) allows interpolations to be made at radio frequencies directly on the scale. If audio-frequency interpolation methods are used, the heterodyne frequency meter can be used as a local oscillator, the frequency of which is matched to that of the frequency to be measured, or a multiple or submultiple of that frequency. The actual frequency measured is that of the heterodyne frequency meter. This is extremely useful when weak or erratic radio signals are being measured.

The Type 616-D Heterodyne Frequency Meter is designed for alternating-current operation and relay-rack mounting. A detector and single-stage audio amplifier are included for listening to beats. The condenser has a special dial to facilitate making zero-beat settings at low frequencies and also for use in interpolating on the scale. A direct-reading finder dial is provided, with an individual scale, covering nearly 360 degrees, for each of the sixteen frequency ranges. The intervals marked on this dial vary from 1 kc at the low frequencies to 10 kc at the high.

Temperature control is provided which maintains the temperature of the coil and condenser of the oscillating circuit within $\pm 1.0^{\circ}$C for all ordinary room-temperature changes.

PRINCIPLE OF OPERATION The circuit diagram is shown in Figure 3. The oscillating circuit used is of the Colpitts type with a stabilization system included which is made possible by the use of a screen-grid tube. This stabilization system consists of the series resistors P, C, and D, and also the voltage divider E, F. When these resistors are properly proportioned, the change in frequency with screen voltage is equal and opposite to that which occurs with a corresponding change in plate voltage. The total supply voltage can therefore be varied over a wide range without materially affecting the frequency, since the ratio of screen to plate voltage is maintained constant by the voltage divider.

The oscillator anode is the screen of the tube and the output is taken from the plate circuit, which permits energy to be drawn from the oscillator by electronic coupling, so-called, and isolates the oscillator from the load. In addition, glow tube control of the plate supply voltage is provided.

Two methods of coupling are provided: the first (COUPLING 1) is capacitance coupling direct to the plate circuit of the oscillator tube; and the second (COUPLING 2) is a low-impedance output circuit in the plate circuit of the oscillator tube. In general, COUPLING 1 is used when it is desired to listen to beats with telephones connected in the heterodyne frequency meter circuits, and COUPLING 2 when an external detector is used or when beats with harmonics of the heterodyne are desired.

The temperature control system is entirely a-c operated. The connections are shown in the wiring diagram, Figure 3. On turning on the HEAT switch, the HEAT pilot light should light and current flow through the heater resistances. The rise in temperature eventually causes the mercury column in the thermostat to touch the upper contact. This short-circuits the relay coil, opening the relay contacts and cutting off the heater current. The latter is indicated by the HEAT pilot light going out. When the temperature falls, the mer-

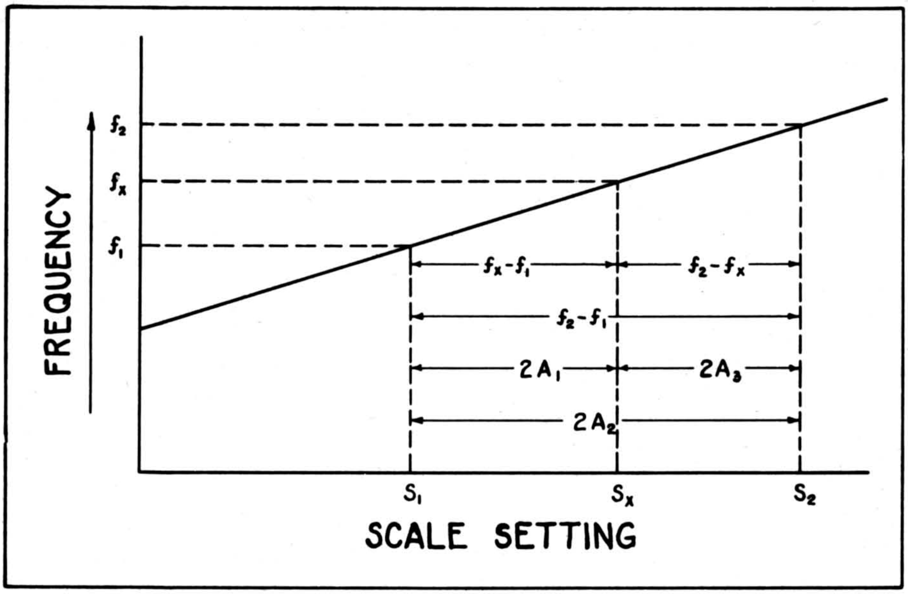

FIGURE 1. Chart Illustrating Method of Linear Interpolation

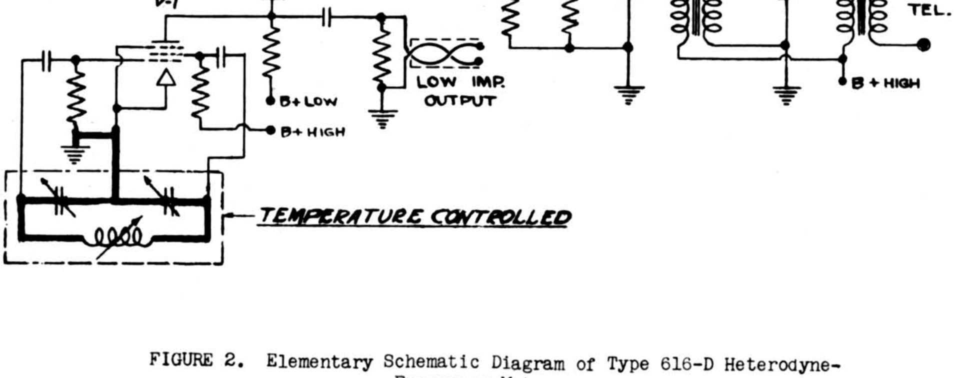

FIGURE 2. Elementary Schematic Diagram of Type 616-D Heterodyne-Frequency Meter

cury goes below the top contact of the thermostat, removing the short-circuit across the relay coil. The contacts then close, indicated by the HEAT pilot light going on. The cycle then repeats. The period of operation of the thermostat will vary with room temperature, being more rapid when the room is cold than when it is hot. For average room temperatures, the heat should be ON (pilot lighted) about 20 seconds and OFF (pilot out) about 80 seconds.

PART 2
INSTALLATION

SHIPPING LIST With each Type 616-D Heterodyne Frequency Meter are packed the following accessories and spare parts:

1 - Instruction Book
1 - 115-Volt Attachment Cord
6 - Mazda 44 Lamps
1 - Box of Fuses (0.1-ampere)
1 - Box of Fuses (1-ampere)
1 - Box of Fuses (5-ampere)
1 - RCA 6J7G
2 - RCA 6J5G
1 - RCA 6X5G
1 - RCA VR-105-30 (or VR-90)
1 - 4A1 Sylvania
1 - Thermostat, fixed
2 - Fusible Links
1 - Thermometer
1 - Plug-type connector. (When a connecting cable for an assembly of instruments is supplied, plugs are attached to the cable.)

TUBES Install the six vacuum tubes in sockets at rear of top shelf in order as marked on tube tags.

THERMOSTAT Install the mercury thermostat in the holder provided on the bottom shelf. Connect the thermostat leads to the terminals directly above.

FUSIBLE LINK The fusible link, connected across the terminals directly below the thermostat is made of a low-melting-point metal, which melts and breaks the circuit, if, owing to failure of the control system, the temperature rises to too high a value.

INDICATORS After plugging the attachment cord into the back of the instrument and connecting it to the 115-volt 60-cycle mains, the ON-OFF switch can be thrown to the ON position. Both the red bull's-eye and the dial light should light.

Normally the instrument is in the oscillating condition, a point that can be checked by turning the COIL SELECTOR switch from one of the numbered positions to a blank position. The indication of the OSC. PLATE meter should increase appreciably when the switch is on a blank position.

PART 3
FREQUENCY MEASUREMENTS BY LINEAR INTERPOLATION METHOD

PRINCIPLES OF LINEAR INTERPOLATION METHOD When the heterodyne frequency meter is used with a harmonic-frequency standard, the linear interpolation method is a convenient and rapid one to use. This process consists, in effect, of calibrating the instrument while measuring.

Since a straight-line-frequency condenser is used, a plot of frequency against scale reading is a straight line, as shown in Figure 1. This means that frequency intervals are proportional to the corresponding intervals on the scale. If S_1 is the scale reading corresponding to the frequency of a standard harmonic f_1, S_2 the scale reading corresponding to the next higher standard harmonic f_2, and S_x the scale reading corresponding to an unknown frequency f_x, between f_1 and f_2, then

$$f_x = f_1 + \frac{S_x - S_1}{S_2 - S_1}(f_2 - f_1) \qquad (1)$$

or

$$f_x = f_2 - \frac{S_2 - S_x}{S_2 - S_1}(f_2 - f_1). \qquad (2)$$

The interpolation can be made as follows:

1. Listen to the unknown frequency in an oscillating receiver or heterodyne detector.

2. Set the receiver to zero audible beat with the frequency it is desired to measure.

3. Adjust the heterodyne frequency meter to zero beat with the unknown frequen-

cy. Use the three-oscillator method described on page 8. Call this reading S_x corresponding to f_x.

4. Adjust the heterodyne frequency meter to zero beat with the standard harmonic next below f_x. Call this reading S_1 corresponding to f_1.

5. Adjust heterodyne frequency meter to zero beat with the standard harmonic next above f_x. Call the scale setting S_2 corresponding to f_2.

6. The unknown frequency can then be found from equation (1) above. When the interval $S_2 - S_x$ is less than $S_x - S_1$, a greater accuracy can be obtained by using equation (2) above instead of equation (1).

USE OF AUXILIARY DIAL In the foregoing explanation, the quantities $S_2 - S_1$ and $S_x - S_1$, or $S_2 - S_x$ are determined by taking differences of scale readings on the main micrometer dial. The auxiliary dial provides a convenient means of determining these quantities directly.

The auxiliary dial is driven from the main dial through a gear train and moves at one half the speed of the main dial. It can also be set at any arbitrary reading independently of the main dial. The scale carries two sets of numbers, one engraved in black in the same rotational direction as the main dial and the other engraved in red in the opposite rotation.

The procedure in using the interpolation dial is given below. In general, the BLACK scale numbers may be used throughout these measurements; in any case, use the BLACK numbers when progressing toward higher readings on the main scale; the RED numbers (red = "reverse" "retard") are used when progressing toward lower readings on the main scale. Using these colored scales the different readings desired may be obtained directly without the necessity of taking differences.

A. USING BLACK NUMBERS

1. Set the main dial to the point where the heterodyne frequency meter is in zero beat with the harmonic, f_1, next below the unknown frequency f_x.

2. Set auxiliary dial to zero. After making this setting do not change the auxiliary dial control knob position until the measurement is completed.

3. Advance main dial toward higher scale readings until zero beat is obtained with the unknown frequency f_x.

4. At this setting of the main dial, the reading A_1 of the auxiliary dial is equal to $(S_x - S_1)/2$.

5. Advance the main dial toward higher scale readings to zero beat with the standard harmonic f_2 next above the unknown frequency f_x.

6. At this setting of the main dial, the reading A_2 of the auxiliary dial is equal to $(S_2 - S_1)/2$.

7. Since the ratio of the two auxiliary dial readings is

$$\frac{A_1}{A_2} = \frac{(S_x - S_1)}{(S_2 - S_1)},$$

the frequency interval $f_x - f_1$ is given by

$$(f_x - f_1) = \frac{A_1}{A_2}(f_2 - f_1),$$

and, if a 10-kc standard harmonic interval is used, the unknown f_x is given by

$$f_x = f_1 + \frac{A_1}{A_2}(10) \text{ kc} \qquad (3)$$

In other words, using the BLACK numbers, in accordance with the procedure above, the ratio of the two auxiliary dial readings is the fractional part of the standard frequency interval that the unknown frequency f_x is above the standard harmonic f_1.

B. USING RED NUMBERS

1. Set the main dial to the point where the heterodyne frequency meter is in zero beat with the harmonic f_2, next above the unknown frequency f_x.

2. Set the auxiliary dial to zero. After making this setting do not change the auxiliary dial control knob position until the measurement is completed.

3. Change main dial, toward lower scale readings, until zero beat is obtained with the unknown frequency f_x.

4. At this setting of the main dial, the reading A_3, of the auxiliary dial is equal to $(S_2 - S_x)/2$.

5. Change main dial setting toward lower scale readings until zero beat is obtained with the standard harmonic frequency f_1 next below the unknown frequency f_x.

6. At this setting of the main dial, the reading A_2 of the auxiliary dial is equal to $(S_2 - S_1)/2$.

7. Since the ratio of the two auxiliary dial readings is

$$\frac{A_3}{A_2} = \frac{(S_2 - S_x)}{(S_2 - S_1)},$$

the frequency interval $f_2 - f_x$ is given by

$$(f_2 - f_x) = \frac{A_3}{A_2}(f_2 - f_1),$$

and, if a 10-kc standard harmonic interval is used, the unknown f_x is given by

$$f_x = f_2 - \frac{A_3}{A_2}(10) \text{ kc} \qquad (4)$$

In other words, using the RED numbers, in accordance with the procedure above, the auxiliary dial indicates the fractional part of the standard frequency interval that the unknown frequency f_x is below the standard harmonic f_2.

SHORT INTERPOLATION METHODS The general interpolation equations (1) and (2) on page 2, may be written in the following form:

$$f_x = f_1 + (S_x - S_1)\left[\frac{f_2 - f_1}{S_2 - S_1}\right] \qquad 1(A)$$

$$f_x = f_2 - (S_2 - S_x)\left[\frac{f_2 - f_1}{S_2 - S_1}\right] \qquad 2(A)$$

The quantity in the brackets is the "kilocycles per division", or the slope, of the calibration curve in the region where the interpolation is being made. The slope of the curve is essentially constant over the condenser scale for each coil; for accurate work it should be determined for each region where interpolation is to be done. Once determined, it will be found that this quantity remains constant over long periods of time. To guard against error, the slope values should be checked occasionally.

Calling the slope M, it may be determined, or checked, by dividing the frequency difference $(f_2 - f_1)$ between two known frequencies, such as harmonics of a frequency standard, by the difference in dial readings for these two frequencies.

Equations 1(A) and 2(A) may then be written:

$$f_x = f_1 + (S_x - S_1)M \qquad 1(B)$$

$$f_x = f_2 - (S_2 - S_x)M \qquad 2(B)$$

The Heterodyne Frequency Meter should be checked at the standard frequency f_1 (next below the unknown f_x) and then set to zero beat with f_x. The difference in these readings, in divisions, multiplied by the value of M gives at once the number of kilocycles to be added to f_1 to obtain f_x.

The same procedure may be followed when using the auxiliary dial for interpolation. The previous equations may be written:

$$f_x = f_1 + A_1\left[\frac{f_2 - f_1}{A_2}\right] \qquad 3(A)$$

$$f_x = f_2 - A_3\left[\frac{f_2 - f_1}{A_2}\right] \qquad 4(A)$$

The quantity in the brackets again is the "kilocycles per division", or slope, of the calibration curve read on the auxiliary dial. Calling this N (N = 2 M because of the gearing employed)

$$f_x = f_1 + A_1 N \qquad 3(B)$$

$$f_x = f_2 - A_3 N \qquad 4(B)$$

The Heterodyne Frequency Meter should be checked at the standard frequency f_1 (next below the unknown f_x) and the auxiliary dial set to zero. Then set the Heterodyne Frequency Meter to f_x and note the auxiliary dial reading A_1. This reading A_1 multiplied by the value of N gives at once the number of kilocycles to be added to f_1 to obtain f_x.

The second method above is not as accurate as the first, because of unavoidable irregularities in the gearing of the auxiliary dial. It is more rapid, however, since it does not require the difference of the two readings of the Heterodyne Frequency Meter to be taken.

When a frequency standard is used, the value of f_1 (or f_2) in the above equations can be identified at once from the direct-reading finder dial. The actual setting for f_1 (or f_2) is, of course, that obtained when the Heterodyne Frequency Meter is set to zero beat with the standard.

INTERPOLATION AT HARMONIC FREQUENCIES When a Heterodyne Detector, or receiver, is used with a Heterodyne Frequency Meter and a Frequency Standard, harmonics of the standard may be heard at frequenices higher than the upper limit of the Heterodyne Frequency Meter (5000 kc). In such cases, interpolation between the standard frequency harmonics may be carried out exactly as though the heterodyne frequency meter covered these frequencies, by use of a harmonic.

For example, if the frequency being measured lies between 8000 and 8050 kc (f_1 and f_2), the Heterodyne Frequency Meter may be set to zero beat at 8000 kc, using the second harmonic. The same harmonic may then be adjusted to zero beat against the frequency being measured and then against the next higher standard harmonic frequency. All of the interpolation equations apply, with the differences in dial readings, or readings of the auxiliary dial, interpreted just as before. The only difference in the final result is that the reference frequency f_1 (or f_2) is twice the value indicated on the Heterodyne Frequency Meter direct-reading dial, or, in general, n times the indicated value, where n is the number of the harmonic used.

HARMONIC METHODS Since the range of the heterodyne frequency meter is limited to frequencies between 100 and 5000 kilocycles, harmonic methods can be used to measure frequencies above 5000 kilocycles and below 100 kilocycles.

MEASUREMENT OF FREQUENCIES ABOVE 5000 KILOCYCLES When the frequency to be measured lies above the range of the heterodyne frequency meter, either of two methods may be used. The first is outlined under "Interpolation at Harmonic Frequencies", above. In the second, the fundamental of the heterodyne frequency meter is set at a frequency which is lower than the unknown signal, and one of its harmonics is set to zero beat with the unknown.

The fundamental is then measured and the result multiplied by the harmonic number.

In setting the Heterodyne Frequency Meter so that a harmonic will fall at the frequency being measured, the direct-reading finder dial is a great convenience. If the frequency desired lies just above the limit of the Frequency Meter, set the Frequency Meter to 2500 kc (one-half the rated upper frequency limit) and slowly vary the frequency toward higher values. By going over the fundamental frequency range from 2500 to 5000 kc, the second harmonic varies from 5000 to 10,000 kc. Inspection of the direct-reading dial will then give the approximate value of any frequency in this range.

For convenience a table of the harmonic frequency ranges is given below:

In some cases it will be found that the strongest harmonic signal is not obtained with the lowest possible harmonic. This is partly because of some difference in the relative amplitudes of odd and even harmonics, and partly because of the decrease in oscillator amplitude at the very highest frequencies. If a given harmonic does not give sufficient output from the Heterodyne Frequency Meter, try reducing the frequency (using a higher harmonic). For example, the fifth harmonic of 5000 kc falls at 25,000 kc. If this signal is weak, try the sixth harmonic of 4166 kc.

MEASUREMENT OF FREQUENCIES BELOW 100 KILOCYCLES For low frequencies, the signal is picked up in an oscillating receiver and the receiver is made to oscillate strongly in order to generate harmonics. Listening in the heterodyne detector, one of these harmonics is picked up and the heterodyne frequency meter is set to zero beat with it. The frequency of the heterodyne frequency meter is then measured as described and the result is divided by the harmonic number.

IDENTIFICATION OF HETERODYNE HARMONICS In general, when using harmonics of the heterodyne frequency meter, the harmonic used can be determined from the calibrations of the receiver or by means of the direct-reading finder dial of the heterodyne-frequency meter.

Fundamental Range as shown on direct-reading finder dial, kc.	Frequency Ranges						
	1	2	3	4	5	6	Harmonic Number
100 - 5,000	100- 5,000						
2,500 - 5,000		5,000 10,000					
3,000 - 5,000			9,000 15,000				
3,000 - 5,000				12,000 20,000			
4,000 - 5,000					20,000 25,000		
4,000 - 5,000						24,000 30,000	

When measuring a station whose assigned channel frequency is known, it is often permissible to assume that the station is approximately on frequency, and the harmonic number can then be determined by dividing the assigned channel frequency by the indicated heterodyne frequency meter fundamental and taking the nearest whole number

If, however, the receiver calibration is not sufficiently accurate to determine the harmonic number, a simple test can be made to identify positively the harmonic.

When listening to a signal f_x in a high-frequency receiver, if the frequency of the heterodyne frequency meter is continuously reduced, beats will be heard at points where the fundamental of the heterodyne frequency meter is

$$\frac{f_x}{2}, \frac{f_x}{3}, \frac{f_x}{4}, \text{---} \frac{f_x}{n}, \text{ etc.}$$

Suppose, then, that the frequency of the heterodyne frequency meter is determined from the direct-reading dial calibration and that it is desired to identify the harmonic number n. Reduce the frequency of the heterodyne frequency meter until another beat is heard in the high-frequency receiver. The frequency of the heterodyne frequency meter is, in the two cases,

$$f_x = nf_1 = (n + 1)f_2$$

from which

$$n = \frac{f_2}{f_1 - f_2}$$

PART 4
USE AS A CALIBRATED FREQUENCY METER

When used as a calibrated instrument, extremely good accuracy can be obtained from the heterodyne frequency meter provided the means available for checking the calibration are used.

Radio broadcasting stations (in the United States and Canada) provide a ready means of checking and standardizing calibrated apparatus. Since these broadcast stations are required to stay within 50 cycles of their assigned frequencies, the least accurate any one of them can be is just under 0.01% (50 cycles at 550 kc is 0.0091%). Actually, broadcast stations are usually much closer than this figure, and 10 cycles would be a better value.

The Type 616-D Heterodyne Frequency Meter covers the entire broadcast band so that several calibration points between 550 kc and 1500 kc can be obtained. This is done by tuning in the broadcast station on a receiver (an oscillating receiver is preferable) and setting the heterodyne frequency meter to zero beat with it. If the receiver can be made to oscillate (the older types of receivers will all do this), the zero-beat adjustment can be made to within one cycle by using the three-oscillator method described below. If the receiver is of the non-oscillating type, the exact setting can still be made by listening to the hum, noise, or broadcast in the output as it is modulated by the beat between the broadcast station and the heterodyne.

Harmonic methods must be used to calibrate those portions of the frequency range which lie outside the broadcast band. Below the broadcast frequencies, harmonics of the heterodyne frequency meter can be made to beat with the broadcast station. For example, if the broadcast receiver is set to a 1000-kc station, and the frequency meter is tuned through 500 kc, the second harmonic of the frequency meter will beat with the station in the broadcast receiver. Similarly, the third harmonic of 333.3 kc can be used, the fourth, of 250 kc, etc. Using only a few stations, a number of points can be obtained.

Above the broadcast band, it is necessary to use either an oscillating receiver or an auxiliary oscillator. If the receiver or oscillator is adjusted to zero beat with the station, its harmonics can be made to beat with the fundamental of the heterodyne frequency meter. These beats can be detected at low orders of harmonics by listening in the detector circuit of the heterodyne frequency meter. For high harmonics it may be necessary to use a receiver at the harmonic frequency. Care should be taken to prevent the oscillating receiver from radiating and causing interference.

This procedure is not restricted to the use of broadcast stations. Any radio signal known to be accurate may be used. When the 5-megacycle signals of the United States Bureau of Standards are on the air, these may be used. In checking against five-megacycle transmissions, the frequency of the heterodyne frequency meter is progressively reduced, allowing its harmonics to beat against the five megacycles exactly as when using broadcast stations as described above.

If the heterodyne frequency meter is calibrated when used, a surprisingly high accuracy can be obtained. Directly after checking the calibration against a broadcasting station, the accuracy is probably 0.005% or better. The frequency spread on the dial is about 0.01% per scale division. Therefore, since the scale can be set to one-tenth division, the precision of setting is 0.001%. The maximum error to be expected under these conditions is 0.001% plus 0.005% or 0.006%.

These figures are a good example of what can be done with frequency measurements when full use is made of the facilities available for calibration.

PART 5
THE THREE-OSCILLATOR METHOD OF MAKING ZERO-BEAT ADJUSTMENTS

The three-oscillator method has been in use for a number of years, yet there are still many people engaged in making frequency measurements who are not acquainted with it. It permits two oscillators to be set to zero beat within one cycle without any auxiliary equipment except an oscillating detector.

Suppose a continuous-wave signal is picked up in an oscillating receiver and it is desired to bring a heterodyne frequency meter into zero beat with the signal. The receiver is adjusted to give zero audible beat and the heterodyne frequency meter is brought into zero audible beat also. The precision of the zero-beat setting is limited by the fact that the range of zero audibility is several cycles wide.

If, however, the frequency of the oscillating receiver is then moved away from the zero audible beat setting until an audible beat tone of, say, 1000 cycles is heard, <u>the difference frequency between the signal and the heterodyne frequency meter will be heard in the form of a waxing and waning of the audio-frequency tone</u>. If the frequency of the receiver is varied, thereby changing the audio frequency, no change in the rate of waxing and waning occurs, showing that the beat is between the signal and the heterodyne frequency meter. If the waxing and waning note <u>does change</u> when the receiver frequency is varied, the beat is between the wrong pair of oscillators and the adjustments should be made again with more care.

After the waxing and waning beat is heard, the heterodyne frequency meter may be readjusted to bring the rate of waxing and waning to one, or less, periods per second after which the two frequencies will be matched to within a cycle.

The example of the radio signal and the heterodyne frequency meter is given merely for purposes of illustration. Obviously, any two oscillators can be set to zero beat by this method, if a third oscillator and detector are available.

PART 6
VACUUM-TUBE DATA

Voltages are measured between terminals shown with meter of 20,000 ohms per volt (d-c); 1,000 ohms per volt (a-c).

Currents are measured in series with terminal shown.

SOCKET TERMINAL NOS.			V-1	V-2	V-3	V-4	V-5	V-6	NOTES
			6J7G	6J5G	6J5G	6X5G	VR-105-30	4A1	A, B
2-7	v	ac	5.6-6.3	5.8	5.8	5.8	—	—	
8-Gnd	v	dc	0	0	7	—	—	—	
8-5	v	dc	—	0	7	—	—	—	
3-8	v	dc	10	60	162	—	—	—	
3	ma	dc	2.1	3.1	3.1	—	—	—	
4-8	v	dc	58	—	—	—	—	—	
4	ma	dc	.9	—	—	—	—	—	
5-Gnd	v	ac	—	—	—	157	—	—	
3-Gnd	v	ac	—	—	—	157	—	—	
8-Gnd	v	dc	—	—	—	177	—	—	
3	ma	dc	—	—	—	9	—	—	
5	ma	dc	—	—	—	10	9.0	—	
5-2	v	dc	—	—	—	—	102	—	
1-4	v	ac	—	—	—	—	—	3.5-4.5	

NOTES

A. Remove signal cable plug when taking readings.

B. Put coil selector switch on blank position to take readings. V-5 may be either VR-105-30 or VR-90. For VR-90, 5 = 7.5, 5-2 = 90.

PARTS LIST

RESISTORS

R-1 = 4 MΩ
R-2 = 50 KΩ
R-3 = 5 KΩ
R-4 = 25 KΩ
R-5 = 15 KΩ
R-6 = 150Ω
R-7 = 10 KΩ
R-8 = 1 MΩ
R-9 = 35 KΩ
R-10 = 50 KΩ
R-11 = 2KΩ
R-12 = 5 KΩ
R-21 = 10 KΩ
R-22 = 700Ω
R-23, R-24, R-25, R-26, R-27 = 230 v
R-28 = 14Ω approx.
R-29 = 3.8Ω
R-30 = 8Ω
R-31 = 200Ω
R-32 = 3Ω
R-33 = 500Ω

CONDENSERS

C-1 = 0.5 μf
C-2 = 0.5 μf
C-3 = 1.0 μf
C-4 = 1.0 μf
C-5 = 1.0 μf
C-6 = 1.0 μf
C-7 = 0.00004 μf
C-8 = 0.00025 μf
C-9 = 0.0001 μf
C-10 = 0.001 μf
C-11 = 0.001 μf
C-12 = 0.01 μf
C-13, C-14, C-15 = 622-400
C-16 = 0.25 μf
C-17 = 0.25 μf
C-18 = 0.005 μf
C-19 = 0.01 μf
C-20 = 0.01 μf

FUSES

F-1 = 1 ampere (7AG or 8AG), F-2 = 1 ampere (7AG or 8AG) — For 115-volt operation

F-1 = 0.5 ampere (7AG or 8AG), F-2 = 0.5 ampere (7AG or 8AG) — For 230-volt operation

F-3 = 5 ampere (7AG or 8AG)
F-4 = 5 ampere (7AG or 8AG)
F-5 = 0.1 ampere

VACUUM TUBES

V-1 = 6J7G RCA
V-2 = 6J5G RCA
V-3 = 6J5G RCA
V-4 = 6X5G RCA
V-5 = VR-105-30 RCA (or VR-90)
V-6 = 4A1 Sylvania

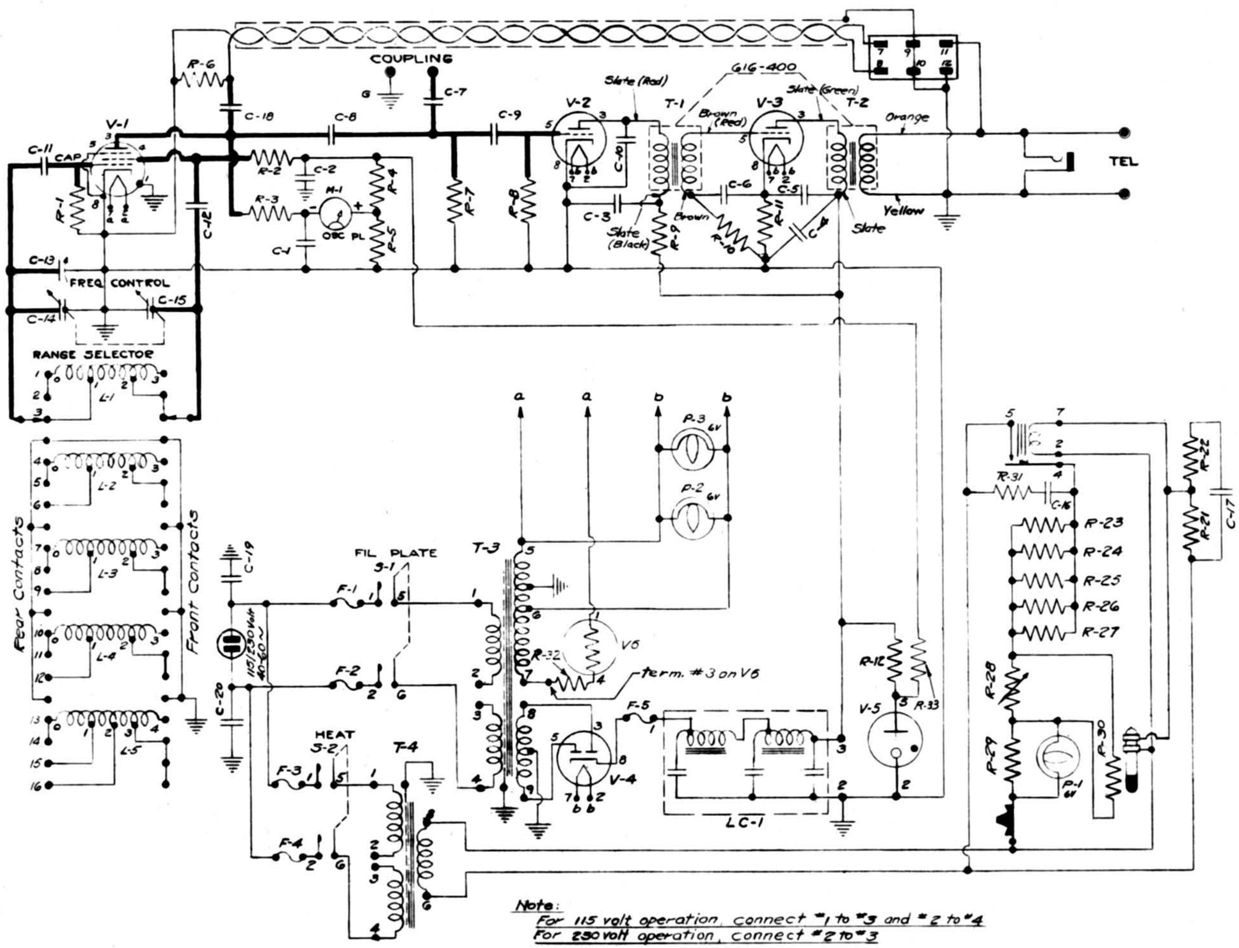

FIGURE 3. Circuit Diagram of Type 616-D Heterodyne-Frequency Meter