PROCEDURE FOR CALIBRATING COLLINS 51R-1 NAVIGATION AND BC733D LOCALIZER RECEIVERS

By

Francis J. Gross
Electronics Division

Max Kincaid
Office of Federal Airways

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SUMMARY

Procedures are described for accurately calibrating omnirange and localizer receivers with a Boonton Radio Corp Type 211 radio-frequency signal generator and the Collins 479S or the Wedd Laboratories CA-1374 audio signal generators Procedures also are described for accurately calibrating the signal generators with a conventional audio oscillator, oscilloscope, and with voltmeters so that standard receivers are no longer required

INTRODUCTION

Those who are experienced in operating or maintaining the airborne radio receivers used with the VHF omnirange and localizer facilities are well aware of the necessity for calibrating the receivers, and of the advantages that result from an accurate calibration and adjustment Equipment which may be used to adjust and calibrate any localizer receiver on the bench, so that the deviation indicator in an aircraft will be centered when the aircraft is within a small fraction of a degree of the center line of a properly equipped runway, is commercially available The same equipment will enable one to adjust the course sensitivity of the localizer receiver so that the deviation indicator reaches full scale when the aircraft has deviated 2 5° from the runway center line This equipment also may be used to calibrate an omnirange receiver to a precision of 0 1° and to adjust the course sensitivity so that full scale deflection occurs on the deviation indicator when the aircraft deviates a specific number of degrees from the omnibearing line to which the bearing selector is set

Procedures are described in this report by which VHF omnirange receivers and localizer receivers may be calibrated with radio-frequency signal generator similar to the Boonton Radio Corp Model 211-A and either the Collins Radio Co Type 479S audio signal generator available commercially or the Type CA-1374 audio signal generator built by Wedd Laboratories, Inc for the CAA

The procedures described in this report are designed primarily for use in calibrating omnirange and localizer receivers used in CAA patrol aircraft for inspecting or commissioning CAA ground facilities This report is available to the public in the belief that these techniques and procedures will be useful in shops or depots where omnirange and localizer receivers are calibrated and adjusted for the airlines, military agencies, or the private pilot It is probable that for these organizations, the receivers will be adjusted to more liberal tolerances than those suggested for use in CAA patrol aircraft

It is important to note that with the aid of auxiliary test equipment and the procedures outlined in Appendices I and II the signal generators themselves may be accurately calibrated without the aid of standard receivers

CALIBRATION OF COLLINS 51R-1 NAVIGATION RECEIVER AS MODIFIED FOR CAA

When the Collins 51R-1 navigation receiver is removed from the aircraft for calibration, the omnibearing selector and the omnibearing indicator (if used) also should be removed and used in the final calibration if highest accuracy is desired However, sometime during the course of the calibration, another omnibearing selector should be substituted to make sure that no major error is introduced by the aircraft bearing selector because of loose gears slipping on the shaft or other malfunction

In addition to the units removed from the aircraft the following equipment is required

1 A radio-frequency signal generator equal to Boonton Radio Corp Model 211-A which has been calibrated in accordance with Appendix II

2 An audio signal generator equal to either the Type CA-1374 built by Wedd Laboratories, Inc or the Type 479S built by Collins Radio Co and calibrated in accordance with Appendix I

3 A wiring harness and instrument panel

that will permit the operation of the receiver and its associated instruments on the bench This bench wiring should be electrically identical to that in the aircraft The wiring harness should include a frequency selector equal to that provided in the aircraft for the particular receiver See instruction manual for the receivers

4 A microammeter, having a smallest scale division of 2 5 microamperes or less, should be connected into the bench wiring harness in place of the ID-48 or Weston Model 888 deviation indicator This instrument should have a zero center scale reading 150-0-150 microamperes and a resistance of 1,000 ohms ±2 per cent A Weston Model 430 microammeter with the proper internal resistance can be supplied on special order from the factory If only one such indicator is used in the bench setup, then it should be shunted by a resistor of 500 ohms ±1 per cent to simulate a 3-indicator load

5 A milliammeter with suitable series resistance should be connected into the wiring harness to replace the flag alarm movement associated with the course deviation needle The milliammeter and series resistor, together, should offer the same resistance to the flag circuit of the receiver that is offered in the aircraft installation (usually 500 ohms) A Weston Model 301 instrument having a full scale deflection of one milliampere normally offers a resistance of 105 ohms, and this in series with 395 ohms will be electrically equal to the flag alarm movements of two indicators as they are normally connected in the aircraft

6 Two 180-ohm ±10 per cent resistors will be required if the omnibearing indicator (OBI) is not used They must be connected between ground and the receiver pins which are normally connected to the OBI stators The pins normally connected to the OBI rotor should be grounded See addendum sheet in the instruction books of receivers modified for the CAA

7 A dc supply capable of maintaining the same voltage at the receiver terminals on the bench as exists during flight in the aircraft

8 A dc voltmeter for indicating the voltage at the receiver terminals

9 An ac meter with 2- and 8-volt scales and with at least 20,000 ohms input impedance on both ranges This is to be used for measuring 9,960-cps reference voltage, 30-cps variable phase voltage, and 90- and 150-cps filter volts, when this information is required for correlation with flight tests of CAA ground facilities

In describing the following calibration procedures it is assumed that the reader has available the appropriate manufacturers' instruction books for the test equipment and the receiver which is being calibrated It is also assumed that the manufacturers' recommendations will be followed except in those cases where they may conflict with those given here

A Signal generator adjustments Turn on the test equipment and adjust in accordance with the detailed instructions of Appendix III When making these adjustments, check off the appropriate items on the top half of the data sheet of Appendix IV Use of the Boonton Radio Corp Type 94031, 50-ohm radio-frequency cable adapter or Boonton Radio Corp 505-A attenuator pad will satisfy the "series 53-ohm" requirement of Item 3 in Appendix IV

B Receiver wattmeter balance adjustment Adjust the receiver omnibearing selector (OBS) to exactly 300° with lever on OBS to the left, and rotate the test omnirange dial to the reading (near 120°) at which the deviation indicator is zero Note the reading of the test set azimuth dial The TO-FROM indicator on the OBS should read TO Throw the lever switch on OBS to the right and observe the deflection of the deviation indicator Reduce this deflection to one-half by adjusting the meter balance control R-231 in the receiver Return the OBS lever to the left-hand position and, if the deviation is not zero, repeat the entire procedure See Section 5 5 13 of receiver instruction manual for further information on component R-231

C Adjustment of the balance of the resolver amplifiers in the receiver Adjust the OBS to exactly 300° with lever to the left and rotate the test set omnirange dial to center the deviation indicator Note the difference between test set omnirange dial reading and 120° Readjust OBS to 345° and adjust the test set omnirange dial to have the same difference from 165° as it had from 120° Adjust R-280 in the receiver to center the deviation indicator Repeat if necessary

Another method of adjusting this balance is to use a voltmeter similar to Ballentine Model 300 with a suitable 9,960-cps rejection filter, and adjust R-280 so that the voltages measured across the stator windings of the OBS are equal Both methods should give the same results

This voltmeter method also should be used to balance the voltages across the resolver stators of the automatic omnibearing indicator (OBI) or the voltages across the 180-ohm resistors used when the OBI is not connected In this case resistor R-278 is adjusted to attain the balance See Section 5 5 9 and 5 5 10 of the Collins receiver manual

D Phase splitter test Adjust the OBS to exactly 30° and rotate the test set omnirange dial to the setting nearest 210° that centers the deviation indicator Be sure that the lever switch on the OBS is to the left Compare the bearing error observed with that observed with the OBS at 300° The two errors should be within ±1 5° If the error is excessive, the phase splitter needs maintenance Also see Section 5 5 2 of the receiver instruction manual, which describes a more accurate method using an oscilloscope

E Course sensitivity adjustment of receiver Adjust the OBS to 300° and the test set omnirange dial to a reading nearest 120° that centers the deviation indicator Select a value for R-233 that results in a deviation deflection of 150 microamperes when the test set azimuth dial is displaced 15° from the above reading This makes the course sensitivity 30° for 150 microamperes left to 150 microamperes right

F Reduction of average error to zero Using a form similar to that given in Appendix IV, determine and record the test set omnirange dial readings that center the deviation indicator Compute the errors It is desirable that the maximum and minimum error be of opposite algebraic sign and equal If they are not, adjust capacitor C-245 until they are A convenient method for doing this is to determine the number of degrees the error curve must be shifted, and then try various values of C-245 that will produce this shift when the OBS is set at 300° See Section 5 5 7 of the instruction manual

G Final record of calibration After all adjustments are completed, make calibration measurements and fill out a form similar to that in Appendix IV The error spread should be not more than 2 5°, i e , the sum of the maximum positive error and the maximum negative error should not exceed 2 5° If the error spread exceeds 2 5°, the receiver is in need of maintenance A form similar to Appendix IV may be used for calibration of the omnibearing indicator

H Radio-frequency sensitivity Adjust the signal generator in accordance with Appendices III and IV and adjust the test set azimuth dial to center the deviation indicator for any convenient setting of the OBS Current in the flag milliammeter should be approximately 0 8 milliamperes Reduce the radio-frequency attenuator of the signal generator until the flag current reads 0 4 milliampere The radio-frequency attenuator should read less than three microvolts (this assumes that the Boonton Radio Corp Type 91031, 50-ohm radio-frequency cable adapter or Boonton Radio Corp Type 505-A attenuator pad is connected between the signal generator and the receiver) If the attenuator dial reads more than this, maintenance of the receiver is indicated

I Tone localizer adjustment Adjust the test set in accordance with the instructions given in Appendix V When making these adjustments check off the appropriate items at the top of the form in Appendix IV, particularly Items 3 and 10 With "localizer-glide path" knob of the audio signal generator set on zero db, adjust resistor R-240 in the receiver to center the deviation indicator Adjust R-234 in the receiver until the deviation indicator deflection is 90 ±2 microamperes when the "localizer-glide path" knob is set on four db ratio, blue or yellow See Section 5 5 12 of the instruction manual

To insure accurate centering of the receiver, it is important that the audio signal generator is adjusted so that the modulation corresponding to the "cal 150" or "loc blue calibrate" setting of the audio signal generator is exactly the same as that for the "cal 90" or "loc yellow calibrate" setting

The accuracy of course sensitivity adjustment will depend directly on the calibration accuracy of the ac and dc voltmeters used during the procedure described in Appendix II The voltmeters will contribute an error that is equal to the algebraic difference of the errors of the two voltmeters For example, if 100 times the error of the dc voltmeter divided by its reading in volts is subtracted algebraically from 100 times the error of the ac voltmeter divided by its reading in volts, the sum will be the per cent error which the meters contribute to the course sensitivity calibration The highest accuracy of course-sensitivity calibration will be obtained when the voltmeters used in the procedure of Appendix II are calibrated by a good commercial testing laboratory or by the National Bureau of Standards

Localizer receivers calibrated at the Technical Development and Evaluation Center by the preceding methods agreed with standard localizer receivers within two per cent

For use in CAA patrol aircraft the localizer course sensitivity of the Collins 51R-1 receiver may require more frequent calibration than is required for the BC733D receiver The difference in stability between the receivers is not accurately known, but it may be great enough to concern CAA Flight Inspection personnel It is not great enough, probably, to be noticed in airline operations The circuit in the 51R-1 receiver which is responsible for the condition is that circuit which includes the avc amplifier and gate tube V115

CALIBRATION OF THE BC733D LOCALIZER RECEIVER USING THE BOONTON TYPE 211 SIGNAL GENERATOR

Connect the localizer receiver to the Boonton Radio Corp Type 211 signal generator with the 95-ohm radio-frequency adapter cord or the 507-A attenuator pad Adjust the radio-frequency attenuator to 1,000 microvolts Connect the meter circuits of the receiver so that they are electrically equivalent to the corresponding circuits in the aircraft Energize the receiver so that the dc voltage at its terminals is the same as it is in the aircraft Use the M-O circuits of the signal generator and tune to 109 9 Mc by the zero-beat method with the aid of an external 6 9 Mc crystal-controlled oscillator which is loosely coupled to the intermediate-frequency circuit of the receiver Adjust the test set so that for a zero db ratio the modulation is 20 per cent each, of 90 and 150 cps, by the method outlined in Appendix III of this report and calibrate the receiver in the same manner that has been recommended above for the localizer function of the Collins 51R-1 receiver

The remarks concerning the accuracy of adjusting centering and course sensitivity of the localizer function of the Collins 51R-1 receiver also apply to the calibration of the BC733D receiver

APPENDIX I

Procedure for Calibrating Omnirange Dial of Audio Signal Generator

In order to calibrate a VHF omnirange receiver properly it is necessary that the calibration of the audio signal generator be correct The procedure known as the "interference method" has been agreed upon as a good laboratory method of calibrating the omnirange dial of the test sets at either the 90° or the 270° points This method originally was suggested by engineers of the Air Materiel Command at Wright-Patterson Air Force Base

The minimum equipment required consists of an oscilloscope of good quality such as the Dumont Models 208 and 304, and an audio oscillator capable of operating at 30 cps and 9,960 cps, and of providing an output of approximately 75 volts at 30 cps with relatively low distortion

The procedure is described here for either the Wedd Laboratories Type CA-1374 audio signal generator or the Collins Radio Co Type 479S audio signal generator The audio signal generator has its function selector set to "calibrate" and its signal selector set to "variable phase 30 cps " The audio signal generator, the audio oscillator, and the oscilloscope are connected as shown in Fig 1 The wire labeled "tone-wheel output" is connected directly to the terminal strip adjacent to the tone wheel to pick off the tone-wheel voltage immediately after it passes through the AM filter The oscilloscope pattern of Fig 2 is obtained when the time relationship

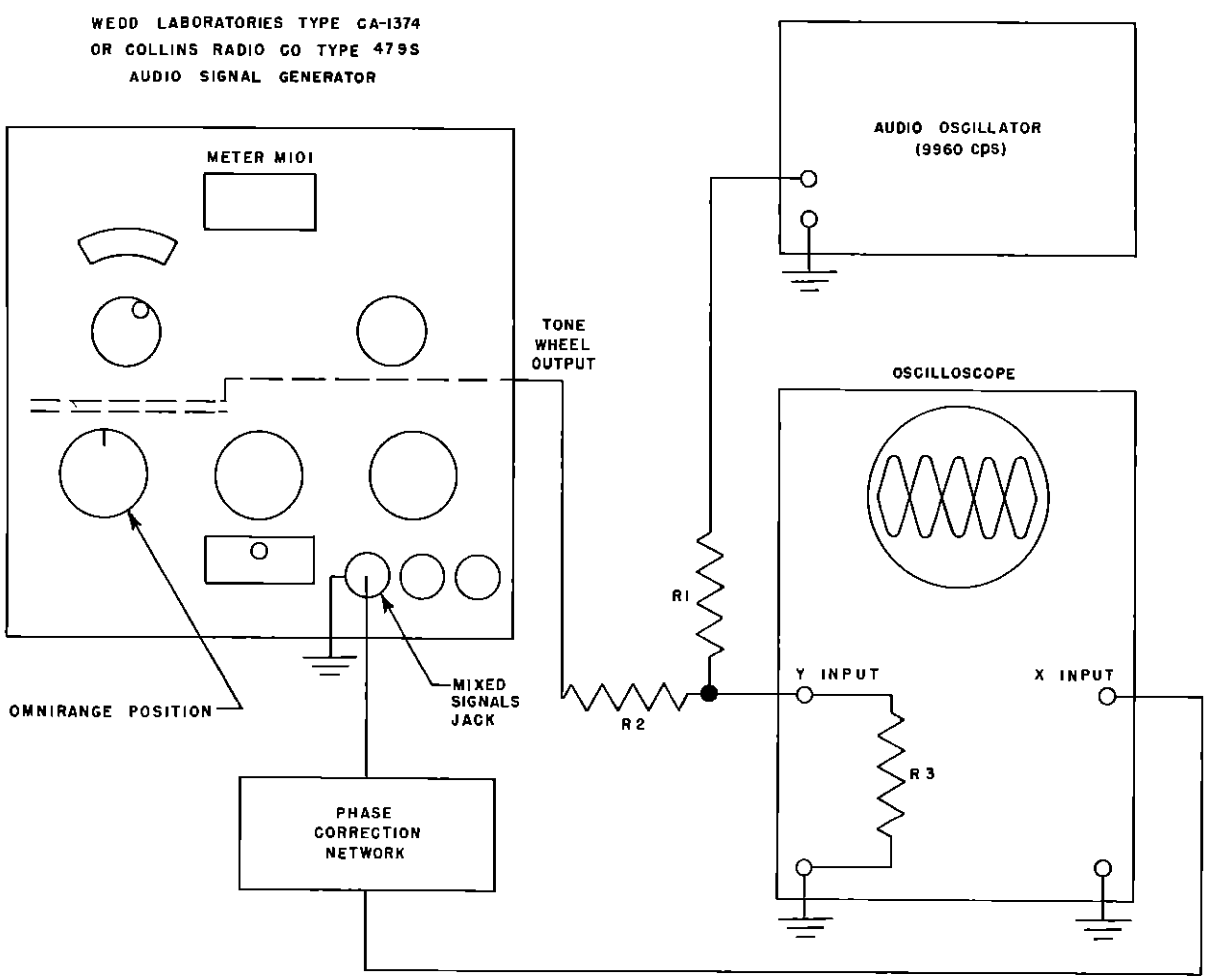

Fig 1 Calibration Connections for Both Wedd Laboratories CA-1374 and Collins 479S Audio Signal Generator

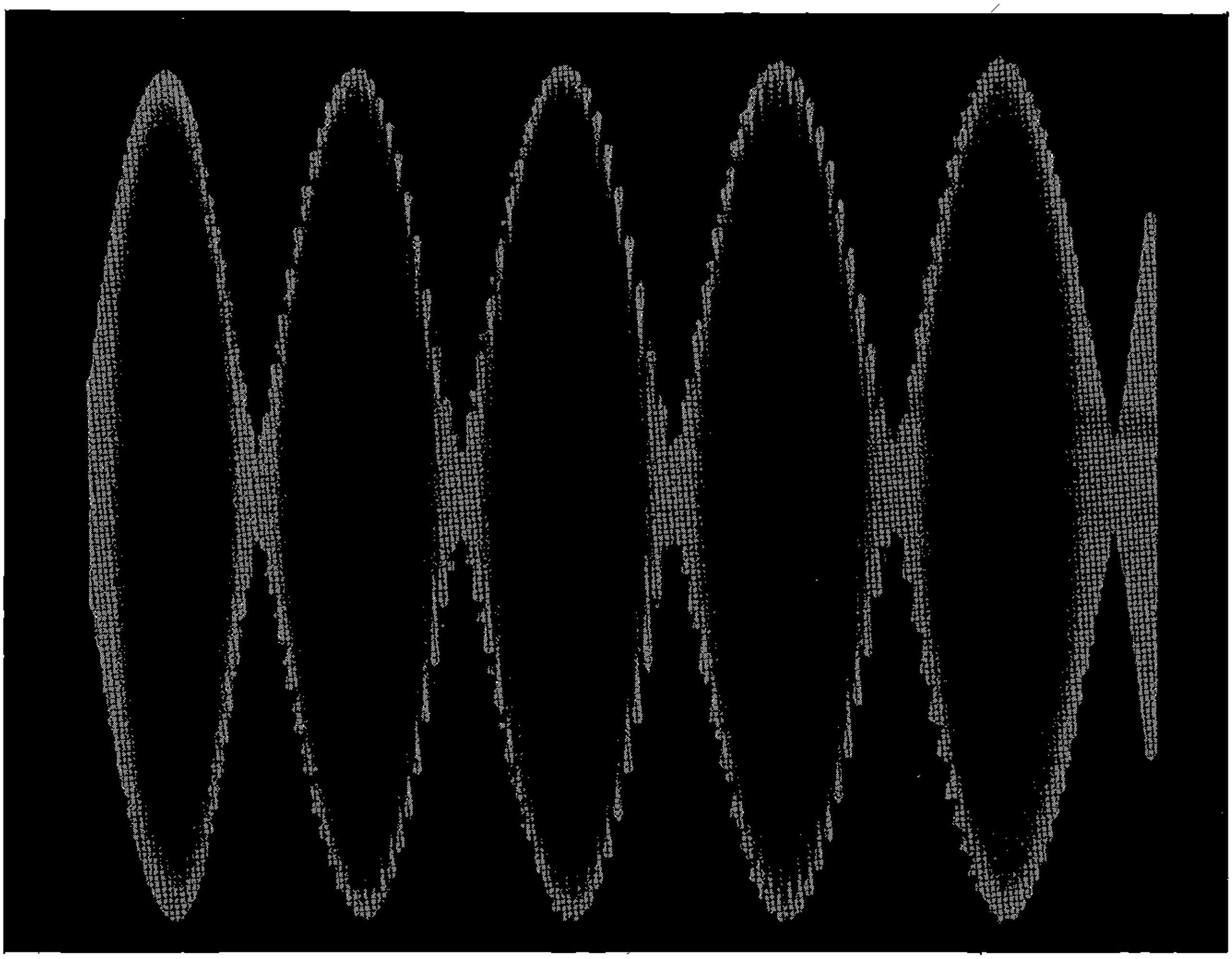

Fig 2 Oscilloscope Pattern for 90° Displacement of Variable and Reference Phase Modulations

between the 30-cps output and the tone-wheel output of the audio signal generator is the same as the time relationship between the corresponding components of an omnirange signal received by an aircraft on a magnetic bearing of 90° or 270° from a properly adjusted omnirange station Fig 3 shows the pattern obtained when the signals are similar to those for an aircraft on a bearing of 88° or 268° If the dial of the audio signal generator does not read exactly 90° when the pattern of Fig 2 is obtained, then the tone-wheel pick-up arm should be readjusted The pattern also can be observed when the dial is adjusted to 270° although the dial engraving is accurate and calibration at only one point is necessary

The oscilloscope used for calibration purposes should not introduce phase shift or harmonic distortion at 30 cps Late model oscilloscopes of good quality such as the Dumont Model 304 or 304-H and the Tektronics Model 512 have negligible distortion and negligible phase shift In general, an oscilloscope having a frequency response curve that is flat from dc to 100 kc or higher will have only a few minutes of phase shift at 30 cps Older model good quality oscilloscopes such as the Dumont Model 208 also have low distortion, however, phase shift is small but not negligible Phase shift, if present, may vary slightly with variation of voltage level and with different settings of the attenuator controls Phase shift at 9,960 cps is of less importance since a 30° phase shift of the 9,960 cps FM signal is equivalent to approximately

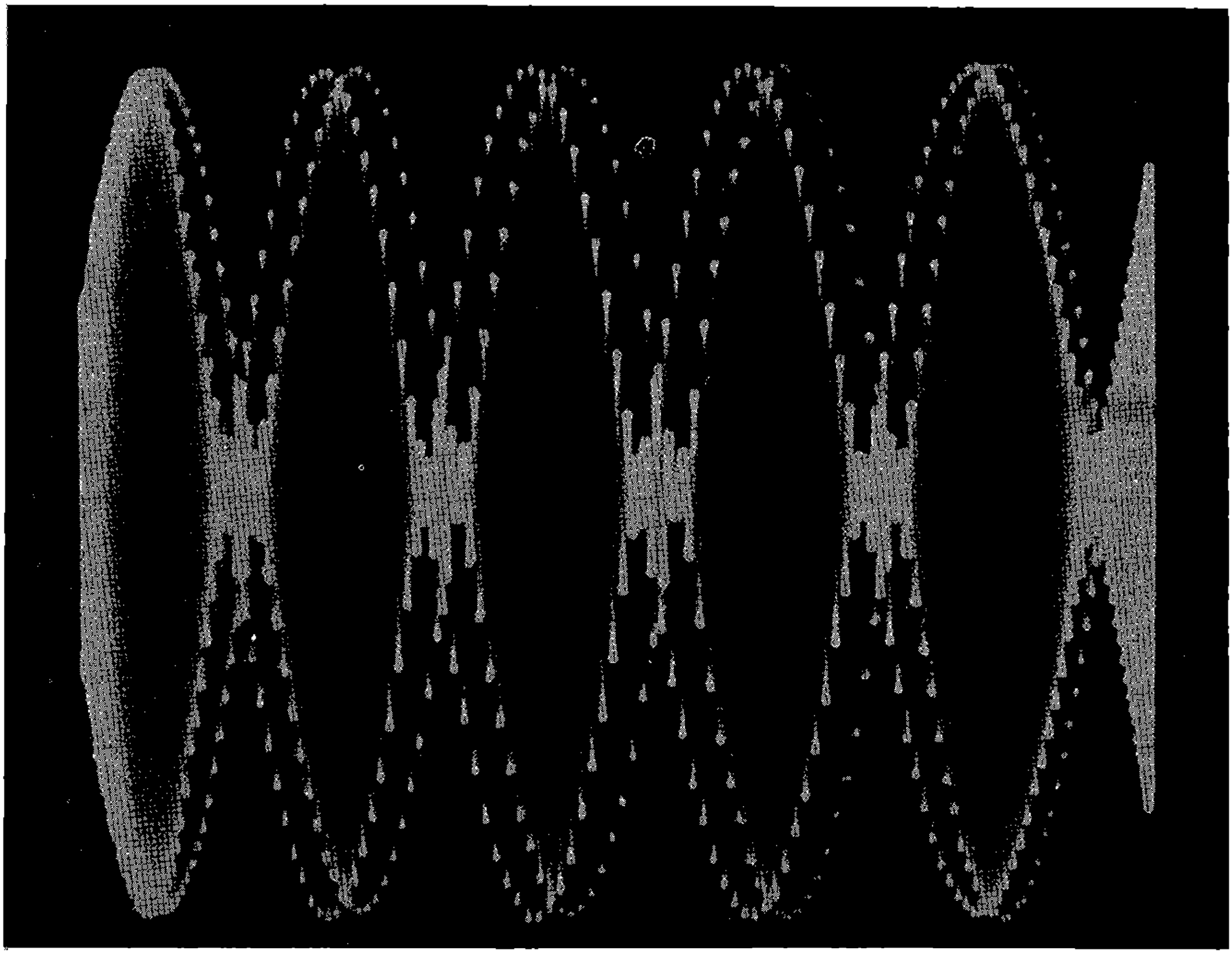

Fig 3 Oscilloscope Pattern for 88° Displacement of Variable and Reference Phase Modulations

0 1° at 30 cps

If there is a phase shift at 30 cps in the oscilloscope amplifiers, it may be eliminated by inserting a phase correction network in series with the oscilloscope input terminals This network consists of a resistor and capacitor and the values of resistance and capacitance are determined experimentally The 30-cps oscillator and oscilloscope connections are made as shown in Fig 4 For this determination, the jumpers ordinarily used to connect the Y-amplifier to the deflection plate terminals are disconnected, and the full voltage output of the audio oscillator is connected across the Y-deflection plate terminals The portion of the audio oscillator output voltage developed across resistor R_5 is connected to the X-input terminals The values of R_4 and R_5 should be such that R_4 is very much greater than R_5, and the voltage developed across R_5 is equal to the 30-cps voltage at the MIXED SIGNALS jack when the 30-cps voltage is the only signal present This voltage will be approximately 1 0 volt if output voltage levels have been properly established in accordance with the instruction book for the audio signal generator For the Type 479S generator a suggested value for R_5 is 560 ohms since this value is approximately the same as the output impedance of the generator at the MIXED SIGNALS jack Resistance R_5 should be approximately 4,000 ohms for the Type CA-1374 generator If the oscillator is capable of furnishing 75 volts, then the value of R_4 would be approximately 47,000 ohms for the Type 479S, and 330,000 ohms for the Type

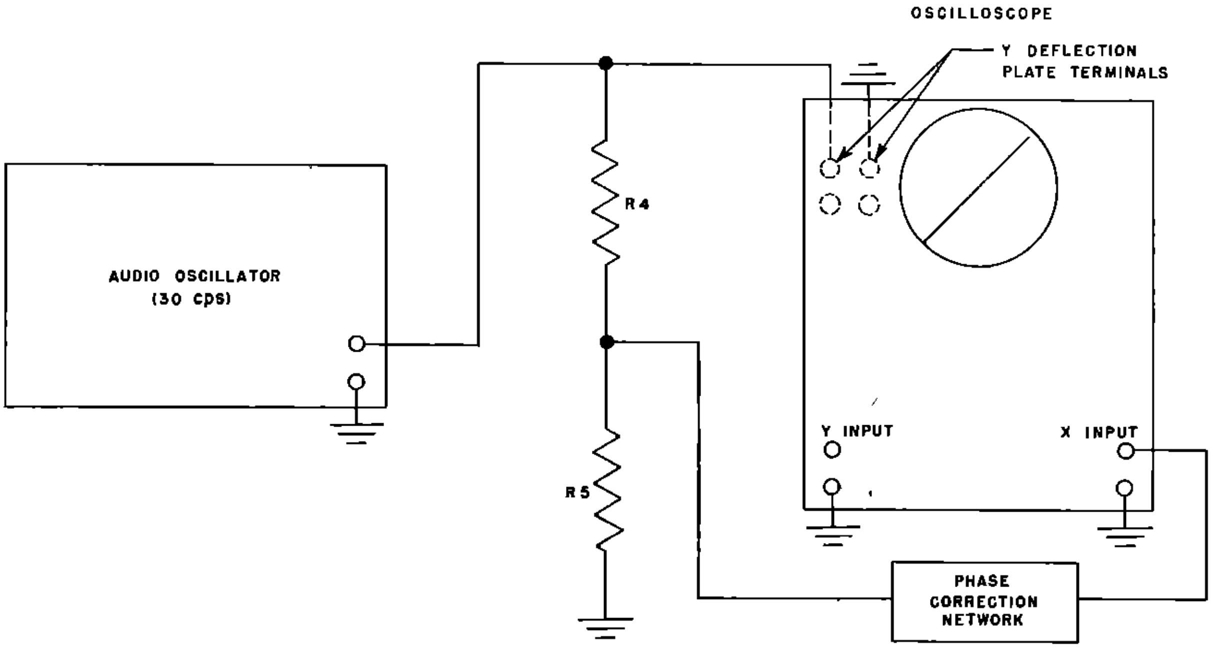

Fig 4 Oscilloscope Calibration Connections

CA-1374 generators

If there is no phase shift or distortion in the oscilloscope, a straight line will be observed The X-channel attenuator should be adjusted so that the line is approximately 45° from horizontal position, and the length of the line should be equal to or greater than the diameter of the screen If the trace is not a single straight line, then phase shift or distortion, or both, exist in the oscilloscope Ordinarily, the phase shift correction network consists of a capacitor directly across the oscilloscope input terminals, and a resistor connected in series with the ungrounded input terminal It may be necessary to interchange the resistor and capacitor in order to close the trace The values of resistance and capacitance depend upon the amount of correction required The series impedance of the resistance and capacitor must be very much larger than that of R_5 so that the correction will be independent of the source impedances encountered In general, the series impedance should be of the order of 100,000 ohms Since the phase shift of the correction network is correct for one frequency only, it is very important that the oscillator operate at exactly 30 cps Commercial power line frequency will provide a suitable reference in most cases If the phase shift of the oscilloscope varies with attenuator settings, it is important that the attenuator setting used during the determination of the correction network constants be the same as that used during the audio signal generator calibration

Appreciable out-of-phase second harmonic distortion in the oscilloscope amplifier or in the oscillator output will produce a narrow figure-of-eight pattern If the harmonic distortion occurs within the oscillator, the waveform can be improved by use of a filter If the distortion occurs in the oscilloscope, the oscilloscope should be checked for faulty tubes, faulty high-voltage supply filter capacitors, improper biases, and the like Small amounts of second harmonic distortion do not cause serious errors

Third harmonic distortion will cause serious errors if it is not in phase with the fundamental An example of this type of distortion is shown by the trace in Fig 5 in which the Y-axis deflection is free of distortion and the X-axis has five per cent of third harmonic that is 90° out of phase with the fundamental For smaller amounts of distortion the deviation from the straight line trace in Fig 5 would be proportionately less

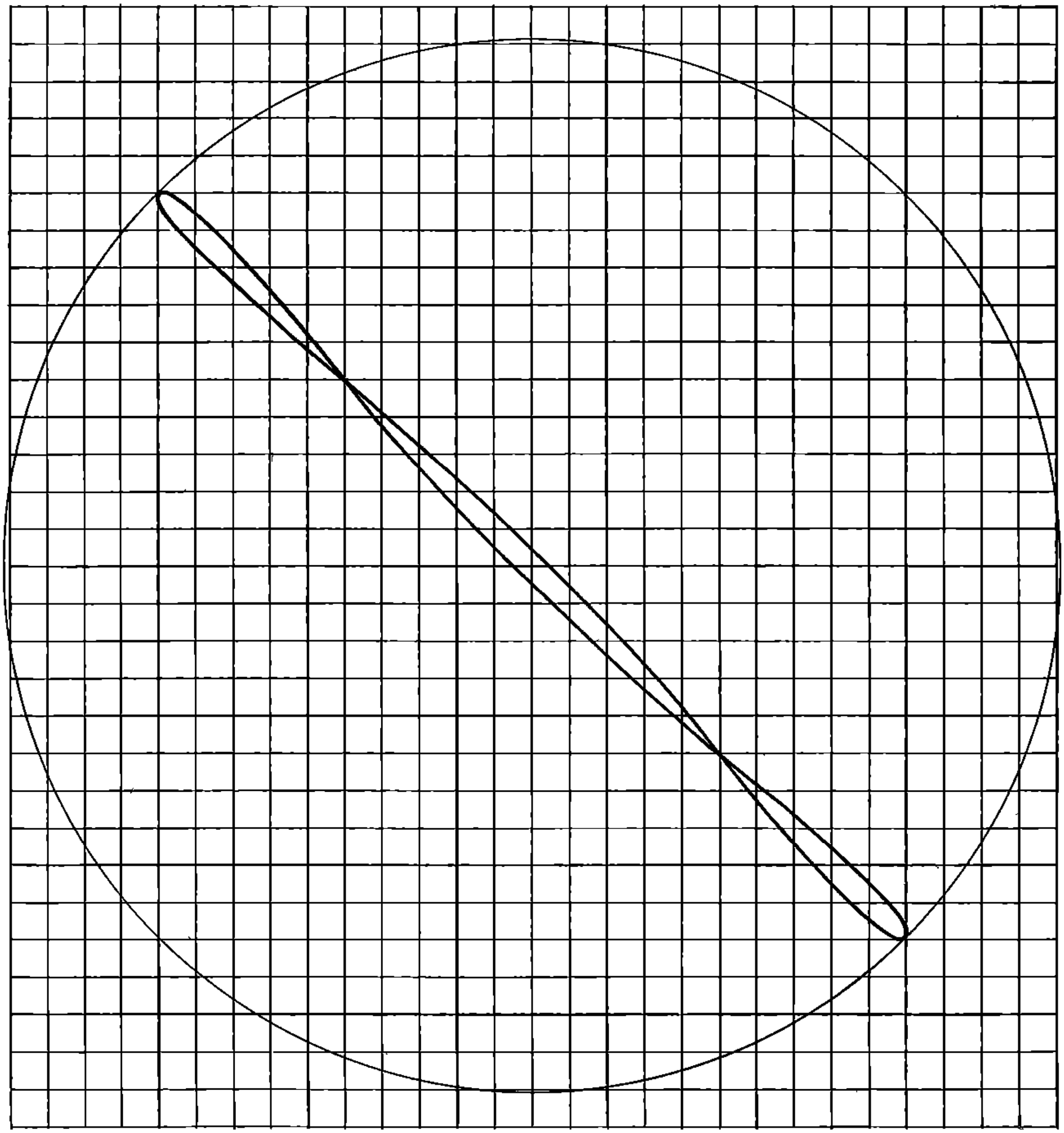

Fig 5 Lissajous Figure with Sin 2π30t in "Y" Axis and Sin 2π30t + 0 05 Sin (2π90t + 90°) in "X" Axis of Oscilloscope

If this type of distortion occurs within the oscilloscope, it must be eliminated before the audio signal generator is calibrated It can be shown that any third harmonic component present in the 30-cps signal obtained from the audio signal generator unit is in phase with the fundamental

After the phase correction network has been determined, the oscilloscope jumper connections should be replaced and the audio signal generator, oscilloscope, and audio oscillator interconnected as shown in Fig 1 Resistor R_2 should be connected to the output of the AM filter of the tone wheel For either generator this is the left-hand terminal on the terminal strip near the tone wheel The function selector should be in the "calibrate" position, and the "test signals" or "signal selector" knob should be in the 30-cps variable phase position The 30-cps signal should be taken from the MIXED SIGNALS jack The values of R_1, R_2, and R_3 are not critical and the only function of the network is to provide a means for mixing the tone wheel and 9,960-cps oscillator outputs Suggested values are R_1 = 100,000 ohms, R_2 = 100,000 ohms, and R_3 = 20,000 ohms

All of the equipment used for the calibration should be operated for at least 30 minutes before the calibration is made To obtain the required alignment pattern, set the omnirange dial of the audio signal generator to approximately 90° Then adjust the audio oscillator frequency to 9,960 cps to obtain a stationary pattern It may be somewhat difficult to maintain a stationary pattern and therefore it will be necessary to make frequent small adjustments of the oscillator frequency dial For very small frequency variations the entire pattern will drift to the right or to the left If the oscillator frequency is incorrect, the type of pattern shown in Fig 2 cannot be obtained It will be impossible to align the patterns so that only 5 1/3 envelopes are visible Furthermore, the envelopes appearing to lie behind the front envelopes will drift in one direction, while the front envelopes will drift in the opposite direction

When the correct oscillator frequency is established, the dial is set at exactly 90° and the tone-wheel pick-up arm position is adjusted to align all the rear patterns with all the front patterns The tone-wheel pick-up arm is adjusted by loosening the vertical locking thumb nut at the left of the arm and rotating the worm by means of the horizontal thumb nut at the right of the arm The locking nut should be tightened securely when the adjustment has been completed and the pattern alignment should be rechecked to determine that the alignment remains correct

Connections to the audio signal generator that are more convenient than those shown in Fig 1 can be used for this calibration However, in choosing a more convenient connection, care should be taken that the 30-cps variable phase signal undergoes the same phase shift during this calibration as when it is taken from the MIXED SIGNALS jack during calibration of a receiver Electrical phase shift of the tone-wheel output is of minor concern since a phase shift of 90° in this signal will affect the calibration of the omnirange dial only 0 27°

For example, in Fig 1 it is more convenient to connect R_2 to the MIXED SIGNALS jack and to connect the phase correction network to the VAR ϕ GEN jack For these connections the audio signal generator should have its function selector set to "calibrate" and its signal selector set to "9,960 cps FM" One of the methods of testing for phase shift of the variable phase 30-cps signal consists of using a Lissajous figure to compare the output of the REF ϕ GEN jack with the output of the MIXED SIGNALS jack and with the output of the VAR ϕ GEN jack To make this test connect the output of the REF ϕ GEN to one axis of any oscilloscope and connect the output of the VAR ϕ GEN jack to the other axis of the oscilloscope Then rotate the omnirange dial until a straight line trace is obtained Adjust the function selector to "calibrate" and the signal selector to "variable phase 30 cps" and disconnect one axis of the oscilloscope from the VAR ϕ GEN jack and connect it to the MIXED SIGNALS jack If there is no change in the Lissajous figure, the more convenient connection may be safely used This test for the 30-cps phase shift can be made at infrequent intervals since it will change only if the failure of certain vacuum tubes or resistors cause a capacitance or an inductance to be shunted across one of the output jacks Slightly different values of R_4 and R_5 may be necessary with any of these more convenient connections

The presence of small amounts of second harmonic distortion in the 30-cps output of the audio signal generator will make it impossible to align all the rear envelopes with all the front envelopes If the distortion does not exceed one per cent, the calibration error will be negligible if the front and rear center envelopes are aligned If the second harmonic distortion is greater than one per cent, the general appearance of the entire pattern is unsatisfactory Distortion measurements of several audio signal generator units indicate that the second harmonic distortion to be expected is considerably less than 0 5 per cent Excessive second harmonic distortion in the oscilloscope also will prevent alignment of all the rear and all the front envelopes simultaneously

Some audio oscillators may have a 60-cps component in the output voltage The effect of the 60-cps component on the pattern may be reduced by connecting a capacitor having a capacitance of approximately 0 001 microfarad in series with R_1 at the oscilloscope input terminal The phase shift will be negligible if R_1 has a value of approximately 100,000 ohms

It has been determined that the presence of one per cent of third harmonic distortion in either the Type 479S or Type CA-1374 generator 30-cps signal will cause a calibration error of 0 5° if the third harmonic is 90° or 270° out of phase with the fundamental The third harmonic distortion of several audio signal generator units has been measured, and it is believed that the distortion will not exceed 0 5 per cent Furthermore, the third harmonic is essentially in phase with the fundamental so that its effect is negligible It is important that the oscilloscope be free from third harmonic distortion that is out of phase with the fundamental For this reason it is very important that a straight line trace be obtained during the determination of the phase correction network constants

Before the calibration is made, the waveform of the audio signal generator 30-cps and 9,960-cps signals should be observed on the oscilloscope to ascertain that no 1,000-, 90-, or 150-cps voltages exist

The mathematical equation for the pattern in Fig 2 can be derived readily The derivation is presented here for those who may be interested in the theory

If the equation for the tone-wheel output is represented by

$$e_{tw} = E_1 \sin (2\pi 9960t - 16 \cos 2\pi 30t) \qquad (1)$$

and if the output from the audio oscillator in Fig 1 is represented by

$$e_{osc} = E_2 \sin (2\pi 9960t + \theta) \qquad (2)$$

then the Y-axis input to the oscilloscope in Fig 1 is represented by

$$e_y = E_1 \sin (2\pi 9960t - 16 \cos 2\pi 30t) + E_2 \sin (2\pi 9960t + \theta) \qquad (3)$$

which can be modified as follows

$$e_y = E_1 \cos (16 \cos 2\pi 30t) \sin 2\pi 9960t - E_1 \sin (16 \cos 2\pi 30t) \cos 2\pi 9960t + E_2 \cos \theta \sin 2\pi 9960t + E_2 \sin \theta \cos 2\pi 9960t \qquad (4)$$

$$e_y = [E_1 \cos (16 \cos 2\pi 30t) + E_2 \cos \theta] \sin 2\pi 9960t - [E_1 \sin (16 \cos 2\pi 30t) - E_2 \sin \theta] \cos 2\pi 9960t \qquad (5)$$

$$e_y = \left\{\sqrt{[E_1 \cos (16 \cos 2\pi 30t) + E_2 \cos \theta]^2 + [E_1 \sin (16 \cos 2\pi 30t) - E_2 \sin \theta]^2}\right\} \sin [2\pi 9960t - \phi] \qquad (6)$$

where

$$\phi = \arctan \frac{E_1 \sin (16 \cos 2\pi 30t) - E_2 \sin \theta}{E_1 \cos (16 \cos 2\pi 30t) + E_2 \cos \theta}$$

$$e_y = \left\{\sqrt{E_1^2 + E_2^2 + 2E_1E_2 \cos \theta \cos [16 \cos 2\pi 30t] - 2E_1E_2 \sin \theta \sin [16 \cos 2\pi 30t]}\right\} \sin [2\pi 9960t - \phi] \qquad (7)$$

In Fig 1 the voltage to the X-axis input can be presented by

$$e_x = E_{30} \sin (2\pi 30t + B) \qquad (8)$$

The envelope of the lobes in Fig 2 is represented mathematically by the square root term in Equation (7) In Fig 2 the angle θ is 116° and B is 90° In Fig 3 the angle θ is 146° and B is 88° The envelopes shown in Figs 2 and 3 can be plotted graphically by inserting these values for θ and B in Equation

(7) and plotting the values of e_y versus e_x for 0 0006 second increments of t between 0 and 0 035 seconds Different values of the angle θ do not affect the four center lobes but change the shape of the partial lobes on the right and left ends of the pattern only However, small deviations of the angle B from 90° cause the front and back lobes to separate, thereby providing a precise method of adjusting angle B to 90° Angle B is controlled by adjusting either the omnirange dial on the front panel of the audio signal generator or the tone-wheel adjusting arm in the rear of the panel

APPENDIX II

Procedure for Calibrating Per Cent Modulation Meter of Boonton Radio Type 211-A Signal Generator

The procedure described herein was suggested by the Boonton Radio Corp and tested with excellent results on three signal generators at the Technical Development and Evaluation Center However, it has been determined by experiment that if tube V-204 (Type 12AX7) has a mutual conductance of less than 750 micromhos, an error will be introduced even though the procedures described later are complied with Therefore it is recommended that tube V-204 be replaced whenever its mutual conductance decreases to a value outside the limits of the JAN-1A specification These limits are 1,250 to 2,000 micromhos when measured with 250 volts dc on the plate and minus two volts grid bias

The method suggested by the manufacturer for calibrating the radio-frequency monitor meter and the modulation meter in the field is as follows

Equipment

DC Voltmeter

Range - 30 to 50 volts full scale (read 26 volts)

Resistance - 300,000 ohms or higher

Accuracy - one per cent or better (as required for over-all error allowable)

AC Voltmeter

Range - approximately 10 volts rms full scale and 25 volts rms full scale (read 5 62 volts, 13 1 volts, and other readings between 1 and 20 volts)

Impedance - 300,000 ohms or more at 400 cps (must have series capacitor in input)

Accuracy - two per cent or better (as required for allowable error in results)

Procedure

Follow sequence of steps

(1) Parallel the ac and dc voltmeters with the ground side of the ac voltmeter (if indicated) connected to the negative terminal of the dc voltmeter Connect the paralleled combination between the arm of P304 in the Model 211-A generator chassis and the arm of P310, making sure that the positive terminal of the dc voltmeter is connected to the arm of P304 In the 211-B signal generator, these circuit points are available at a terminal strip

(2) If the dc or ac voltmeters require mechanical "zero" adjustment, do this before turning on the generator

(3) After the generator has been warmed up for several minutes, turn S-303 to OFF Electrically "zero" both the radio-frequency monitor meter M302 and the dc voltmeter, using P310 Zero should occur simultaneously on both meters

(4) Electrically "zero" the "Mod per cent" meter M301, using P309

(5) Switch S303 to M O Adjust the radio-frequency level control P307 to give exactly 26 volts dc as read on the dc voltmeter M302 should read exactly on the red line If it does not, reset it, using P304

(6) Repeat steps (3), (4), and (5) for greatest accuracy

(7) With S301 on "400" positions, adjust P305 for a reading of exactly 5 62 volts rms as read on the ac voltmeter Set S302 to "30 per cent " Reset M302 to line if necessary Meter M301 should read 30 per cent If it does not, reset it, using P303 (Note Measurements may also be made with S301 in EXT position and an external oscillator of the desired frequency connected to the EXT MOD jack)

(8) Switch S302 to "100 per cent," readjust P305 for exactly 13 1 volts rms, as read by the ac voltmeter, reset M302 to line if necessary, and read M301 It should read 70 per cent If not, adjust P302 to bring it to exactly 70 per cent

(9) Repeat steps (7) and (8) for greatest accuracy

APPENDIX III

Adjustment Procedures for Airborne Receiver Test Equipment

A Initial Adjustments

Turn on the power switch of both the audio and radio-frequency signal generators and allow approximately ten minutes for warm-up *

B Setting up test equipment to check receiver for VOR functions

(1) Turn oscillator selector switch on radio-frequency signal generator to OFF position and adjust zero on radio-frequency monitor meter

(2) Place oscillator selector switch of radio-frequency signal generator in XTAL position

(3) Select 114 9 Mc on the crystal selector switch of radio-frequency signal generator

(4) Tune the Mc frequency dial for maximum signal on radio-frequency monitor meter

(5) Adjust radio frequency level to red line

(6) Place modulation selector switch of radio-frequency signal generator on EXT position

(7) Place modulation range control on 30 per cent and with no input applied to the radio-frequency signal generator, adjust per cent modulation meter to zero

(8) Turn 30/9,960-cps motor generator switch on Type CA-1374 audio signal generator to ON position

(9) Place function selector switch of audio signal generator in calibrate position

(10) Place "signal selector" or "test signals" switch of audio signal generator in 30-cps variable position

(11) Adjust audio output of signal generator to approximately one volt on output meter by setting 30-cps variable potentiometer in recessed compartment on front panel

(12) Adjust modulation level control of radio-frequency signal generator to produce 30 per cent modulation

(13) Turn signal selector switch on audio signal generator to 9,960 cps FM position and adjust 9,960 cps FM potentiometer to produce 30 per cent modulation on per cent modulation indicator on radio-frequency signal generator

(14) Switch modulation range control on radio-frequency signal generator to 100 per cent position

(15) Switch function selector switch of audio signal generator to omnirange position

(16) Adjust attenuator on radio-frequency signal generator to 1,000 microvolts

Signal is now available at radio-frequency output connector to test receiver on 114 9 Mc Phase shift between the reference and variable signals may be obtained by rotating the omnirange control knob on the audio signal generator

* All adjustments are made after the equipment has been connected in accordance with information contained in individual instruction books and adjusted in accordance with Appendices I and II of this report

APPENDIX IV

Department of Commerce
Civil Aeronautics Administration

Report of Calibration of VHF Omnirange Receivers

Date of Calibration ______________________

The data tabulated below are those recorded on the receivers corresponding to the serial numbers indicated These data were compiled when the operating conditions were as follows

(1)	Modulation percentage for 9,960 cps and variable 30 cps	30 per cent each
(2)	Signal frequency	114 9 Mc
(3)	Radio-frequency signal input (in series with 53 ohms resistance)	1,000 μ volts
(4)	Supply voltage (measured at receiver input terminals)	volt
(5)	Indicator load (three deviation indicators in parallel)	333 ohms
(6)	Flag alarm load (two 1,000-ohm movements in parallel)	500 ohms
(7)	Warm-up time	30 minutes
(8)	Lever on the face of the bearing selector was to the left for all measurements in which the ambiguity meter read TO, and to the right when reading FROM	
(9)	The signal from the test set is the same as that which would be received at a bearing from the omnirange station that is equal to the test set dial reading	
(10)	Modulation for 90 and 150 cps	20 per cent each

Manufacturer ______________ Type ______________ Serial No ________

Omnibearing Selector Serial No ________

Calibrated with omnibearing indicator connected
(Mark out one)
Resistor substituted for omnibearing indicator

Bearing Selector Dial of Receiver (degrees)	Test Set Dial When Ambiguity Meter Reads TO (degrees)	Test Set Dial When Ambiguity Meter Reads FROM (degrees)
0		
30		
60		
90		
120		
150		
180		
210		
240		
270		
300		
330		

Tone Localizer Calibration at 110 1 Mc
Current in one of three indicators for four db ratio 90-150 cps voltage ______ μ amps
Current in one of three indicators for four db ratio 150-90 cps voltage ______ μ amps

APPENDIX V

Setting Up Test Equipment to Check Receiver for Tone Localizer Functions

(1) Turn oscillator selector switch to OFF position and adjust "zero" of radio-frequency monitor meter

(2) Turn oscillator selector switch of radio-frequency signal generator to XTAL position

(3) Turn crystal selector switch to 110 1 position

(4) Tune the Mc frequency dial for maximum signal on radio-frequency monitor meter

(5) Adjust radio-frequency signal generator output level to red line on radio-frequency monitor meter

(6) Place modulation selector switch of radio-frequency generator on EXT position

(7) Turn modulation range switch of radio-frequency signal generator to 30 per cent for Type 479S and 100 per cent for Type CA-1374 signal generator, and with no input applied to the radio-frequency signal generator, adjust "zero" of per cent modulation meter

(8) Turn 90/150 motor-generator switch on Type CA-1374 generator to ON position

(9) Set function selector switch of audio signal generator to calibrate position

(10) Set signal selector switch of audio signal generator on 90 cps plus 150 cps position

(11) Set "localizer-glide path" or "localizer" attenuator control on audio signal generator to either one of the two calibrate positions

(12) Adjust associated 90- or 150-cps potentiometer control to approximately one volt on output meter of audio signal generator

(13) Adjust modulation level control of radio-frequency signal generator to produce 20 per cent modulation or per cent modulation meter if Type 479S audio signal generator is used, or 40 per cent if Type CA-1374 audio signal generator is used

(14) Turn "localizer-glide path" attenuator position to other calibrate position

(15) Adjust associated 90- or 150-cps potentiometer control to exactly the same modulation on radio-frequency signal generator per cent modulation meter as that used in (13)

(16) Repeat above 90-150 calibration procedure several times to determine that two signals are exactly equal

(17) Set "localizer-glide path" attenuator to zero db Operations (13) and (15) insure modulation of 20 per cent each of 90 and 150 cps at the zero db setting

(18) Turn function selector switch to tone localizer position

Signal is now available at radio-frequency output connector to test receiver on 110 1 Mc for tone localizer operation The "localizer-glide path" attenuator control will produce the indicated db ratio of 90- to 150-cps voltage for calibrating the receiver Caution Readings of the per cent modulation meter of the radio-frequency signal generator and the output meter of the audio signal generator indicate relative values only when reading the resultant value of several mixed voltages However, on single frequency voltages, meter accuracy is five per cent, unless recalibrated in accordance with Appendix II

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