Ground Calibration of the VOR

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GROUND CALIBRATION OF THE VOR*

SUMMARY

This report describes a simple and accurate method of calibrating VOR stations with a portable detector mounted on the edge of the counterpoise A portable detector was designed specifically for this application, but those already in Federal Airways service may be used, after minor modifications. An accurate method of measuring phase was developed using existing equipment. The ground-calibration method provides a means for readily determining the calibration curve without interrupting the service of the station, and it can be used as an aid in routine and preventive maintenance. The counterpoise detector also can be used to measure the antenna radiation patterns during tune-up of the station.

The calibration data obtained from ground checks were confirmed by flight tests. The calibration curves in each case had the same general trends and varied but little in total error spread. For example, a total error spread of 2.3° was measured by ground check, as compared to 2 5° for the 12-mile theodolite orbit and 3 0° for the 20-mile orbit using check points A later ground calibration had an error spread of 1.8°, and a 6-mile theodolite orbit showed an error spread of 1.9°. From the data obtained, it is concluded that flight inspections of VOR stations following repair or replacement of ground-station components may be eliminated by using the ground calibration, provided the facilities were commissioned originally by the standard flight-check procedures and a corresponding ground calibration

INTRODUCTION

One of the major problems of the Office of Federal Airways is the recertifying of a VOR facility after replacement or modification of equipment. When a station is completely shut down, as in cases where it is on "ground check awaiting flight check," much outage time is accumulated. The inspection involves the expenditure of maintenance funds and many man-hours. An accurate ground-check method should eliminate much of this outage time as well as the expense of many nonroutine flight inspections. Preliminary work on ground calibration was conducted at the Toledo, Ohio, VOR during June 1952 and was reported in Office of Federal Airways All-Region Memorandum dated August 13, 1952 Several calibration curves were taken at a radius of 100 feet and one at 20 inches above the counterpoise edge.

A method for ground checking the VOR has been developed independently at the Technical Development and Evaluation Center of the Civil Aeronautics Administration, utilizing a portable detector mounted on the edge of the counterpoise The first test using this method was conducted in April 1953 Mounting the detector on the counterpoise eliminates some of the difficulties encountered in using a detector at greater distances from the VOR antenna The reliability and accuracy of measurements have been confirmed by flight tests

This report presents the results of the developmental and operational tests of the ground-check method which were conducted on the four-loop antenna system[1] at the TDEC VOR site at Tilden, Indiana The techniques to be described appear to be applicable to any other type of VOR antenna system, and they have been used successfully on the Federal Telecommunication Laboratories, Inc., Type FTL-21A spinning antenna and the Andrew Alford Type 2602 slotted-cylinder VOR antennas Tests also were conducted to determine the feasibility of using the VOR portable field detectors currently used in the regions

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[1]Sterling R Anderson, Hugh F. Keary, and William L. Wright, "The Four-Loop VOR Antenna," CAA Technical Development Report No 210, June 1953

*Manuscript received for publication June 1955

DESCRIPTION

The portable detector developed for ground checking the VOR was designed to be small and light in weight for ease of handling, rugged and waterproof in construction for reliability, and to produce negligible course distortion when mounted on the edge of a counterpoise The latter requirement is necessary if the calibration of the station is to be made without interrupting service A photographic view of the portable detector (referred to hereinafter as the TDEC counterpoise detector), demonstrating the method of mounting, is shown in Fig 1. Internal views of two types of counterpoise detectors used in the tests are shown in Fig. 2 A germanium diode is used in the detector shown as (A) in Fig 2, and a Type 6110 subminiature tube is used in the detector shown as (B) in that figure. The detectors were designed to use a minimum number of components. Figure 3 shows schematic circuit diagrams of the two types of detectors. The antenna is 15 inches in over-all length An antenna of this length causes negligible course distortion when the detector is mounted on the edge of the counterpoise The antenna circuit is tuned to increase the detector output to the desired level. The secondary is self-resonant at 115 Mc An r-f filter eliminates the effect of stray pickup in the line connecting the detector to the monitor Each unit is housed in an aluminum box 3 inches square and 2 1/4 inches deep. The detector with the germanium diode was used for most of the ground checks, and no phase shift was noted in six months of operation, however, the output varied with changes in temperature. The latter defect of the germanium-diode model was eliminated by using a vacuum-tube diode for the detector.

A Type CA-2943 portable VOR field detector also was tested This detector was provided with toggle switches for insertion of noninductive resistors in series with each antenna element. The purpose of the resistors was to reduce the current flowing in the antenna which resulted in less reradiation and consequently less course distortion.

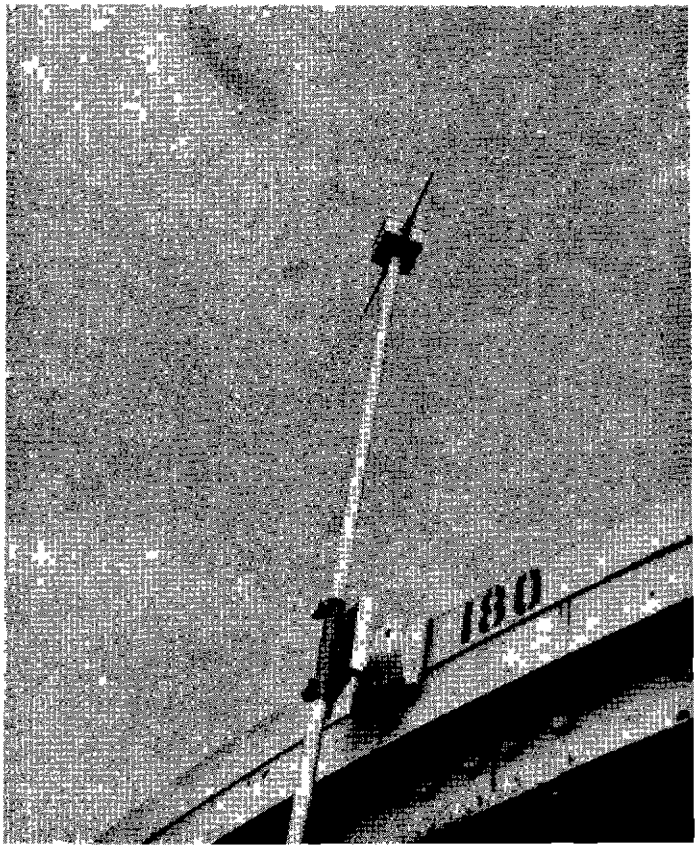

Fig. 1 View of TDEC Counterpoise Detector and Mounting

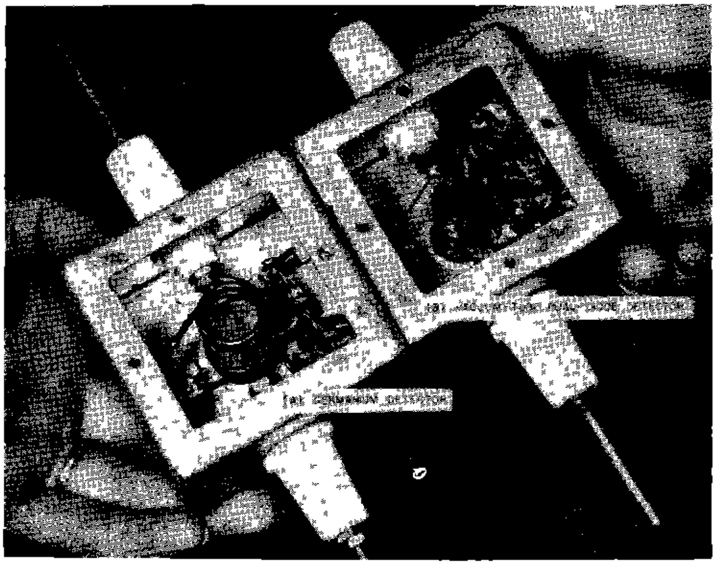

Fig. 2 Internal View of Counterpoise Detectors

INDICATOR TESTS

Equipment for measuring course errors included a modified Type CA-1277 VOR monitor,[2] a Type CA-1430 reference and variable test generator, and a Type 2559 DuMont oscilloscope A view of the instrument set-up is shown in Fig. 4. The accuracy of measurements with this equipment, including the counterpoise detector, was ± 0.2°. The large pedestal in the foreground of Fig 4 is the support for the antenna and provides the means for raising, lowering, and rotating the array

During early experiments, the coincidence of two "pips" from the phase-comparison circuit of the monitor was used for determining in-phase conditions in the monitor. Short leads to the oscilloscope were necessary in order to reduce the capacity in the circuit and to avoid a widening of the pips with a consequent loss of sensitivity. This method was found inadequate for the desired accuracy. The small amount of hum still remaining in the monitor after installation of hum-reducing modifications caused errors, because the pips which are coincident with the positive-going zero-crossings of the sine waves are very susceptible to the harmonic distortion caused by hum

The most satisfactory indicator method tested has been called the "pip-sine" method. The pip from the differentiating circuit of one channel of the monitor is applied to the vertical input of the oscilloscope, whereas the 30-cps sine wave from the other channel is applied to the horizontal input

A partial block diagram of the VOR monitor, with the oscilloscope connections, is shown in Fig. 5 The hum in both channels is measured, and the sine wave for the horizontal input of the oscilloscope is taken from the channel with the least hum, because hum is more detrimental to the sine wave than to the pip. The channel selected for the sine wave must have the limiter stages disabled to prevent the pip of that channel from appearing at the vertical input of the oscilloscope. The combination of the resistors in the phase-comparison circuit and the 0.04-mfd capacitor across the vertical input terminals of the oscilloscope partially integrates the signal.

Figure 6 illustrates the manner in which the two signals are combined in an oscilloscope. The partially integrated wave at D is applied to the vertical deflection plates, and the sine wave

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[2] R A. Forcier and C. G. Lynch, "Improvement in VOR Monitor Type CA-1277," CAA Technical Development Report No. 216, August 1955.

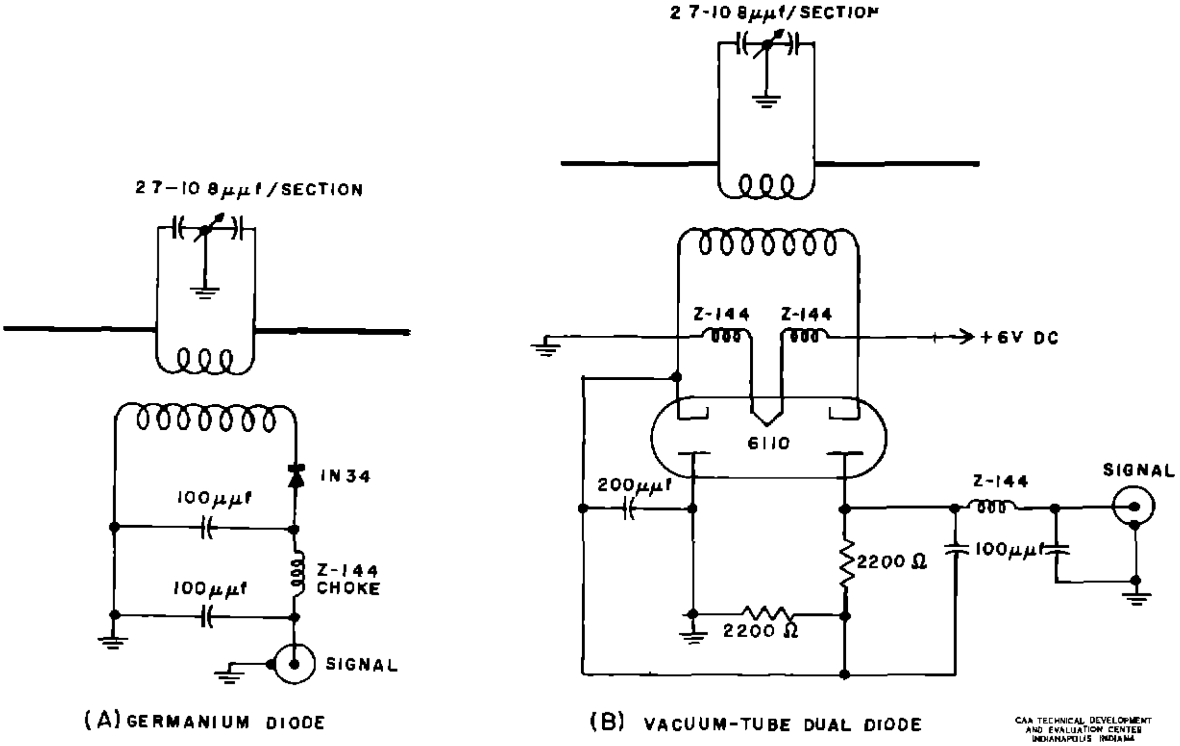

Fig 3 Schematic Diagram of Diode Detectors

at E is applied to the horizontal deflection plates The resulting pattern is shown as it appears on the oscilloscope at F. The phase of the voltage taken from the reference channel is then adjusted until the vertical portions of the pattern overlap to form a vertical line which provides a precise indication of an in-phase condition.

The dashed lines in illustrations A to D, Fig 6, show the resulting waveforms when a small 60-cps voltage is introduced into the channel from which the pip is obtained As shown at D, the pips are displaced in opposite directions. The result is a slight shift in the position of the overlapped portion of the oscilloscope trace shown at F, but there is no indicated course shift In the case where the hum is so phased that it causes unsymmetrical distortion, the displacement is still in opposite directions, but there is incomplete cancellation because the displacements are unequal. Similarly, if the horizontal sine-wave input also has 60-cps distortion, the shift may increase or decrease, depending on the phase of the interfering voltage. Generally, the effect of 60-cps distortion is reduced, resulting in only small errors in the monitor calibration. The error in the monitor calibration is of no consequence when the signal from the test generator is substituted for the signal from the detector and the bearing information read from the generator dial, assuming that the waveforms from the station and test generator are identical. Figure 7 illustrates patterns of out-of-phase conditions

A calibration curve of a Type CA-1277 monitor with de-hum modifications[3] using the pip-sine indicator method is shown in Fig 8. A 60-cps voltage equal to 5 per cent of the signal level was injected in the reference channel at the slope detector. The dashed line shows the effect on the calibration curve. Figure 9 is similar to Fig 8 and indicates the effect under identical conditions when using the double-pip method.

Figure 10 illustrates the monitor calibration error due to hum when using the "sine-sine" method The sine waves are taken ahead of the limiters, as shown in Fig 5, in the reference

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[3]Ibid.

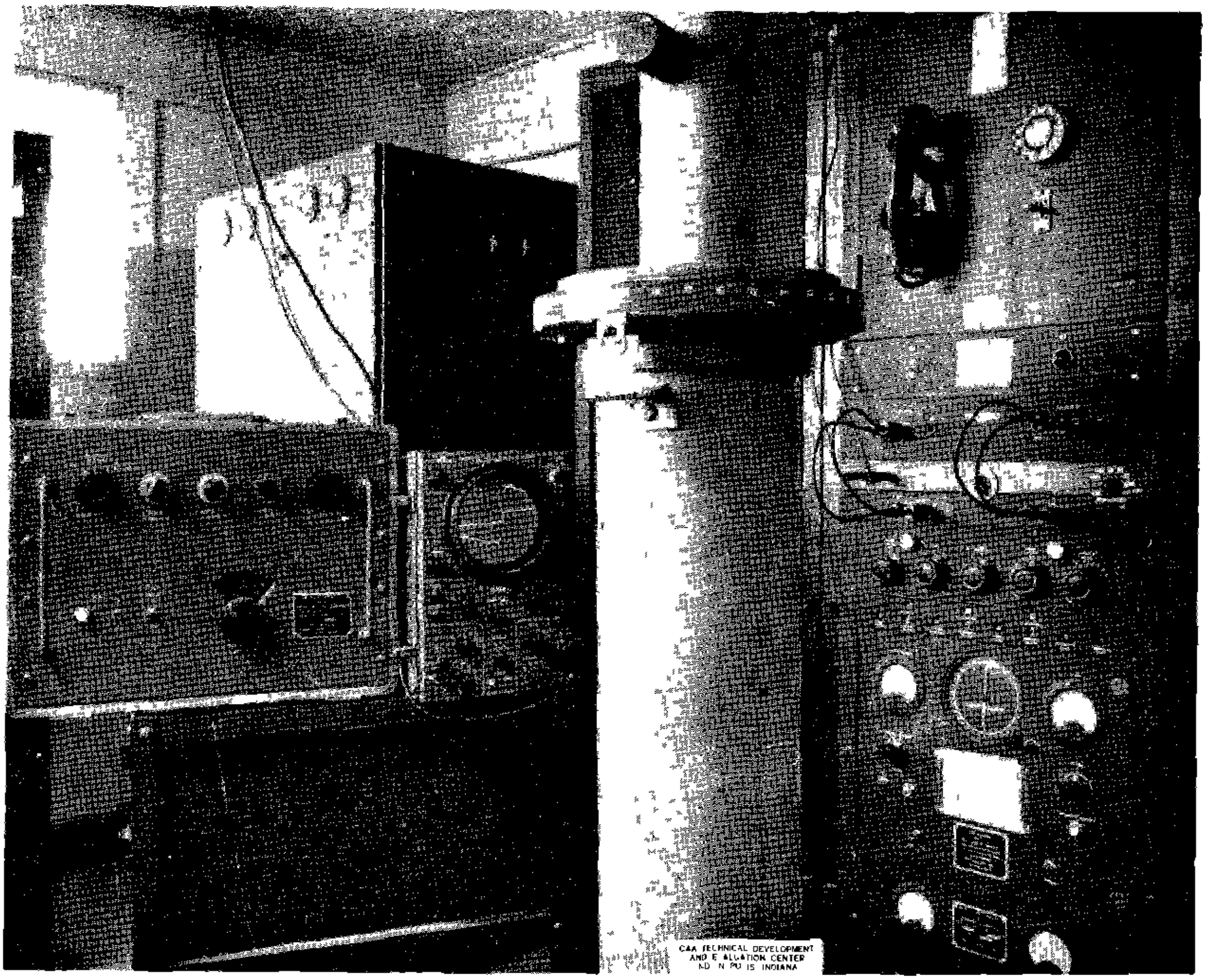

Fig. 4 View of Measuring-Equipment Installation

and the variable channels The omnibearing selector (OBS) was adjusted to provide a straight-line Lissajous pattern for an in-phase indicator Because of hum, however, the pattern was distorted into an elongated figure-of-eight, making it very difficult to determine when the two signals were exactly in phase The amount of hum in the monitor reference channel changes with the OBS setting, further complicating the technique. The repeatability using this method is not as good as when the pip-sine method is used.

Several advantages of the pip-sine indicator method should be pointed out. Shielded leads of any reasonable length can be used without affecting the calibration or sensitivity of the measuring equipment. The in-phase condition can be determined at a glance without rocking the dial or bracketing the correct reading, procedures which are necessary when using the coincidence of the two pips The sensitivity can be easily adjusted to suit the individual by varying the horizontal gain of the oscilloscope Sensitivities of one-half inch trace separation per degree are easily obtained with the Type 2559 oscilloscope

GROUND CALIBRATION PROCEDURE

A counterpoise detector is mounted successively at 20° intervals of azimuth on the counterpoise edge and is connected to one input of the Type CA-1277 VOR monitor through the

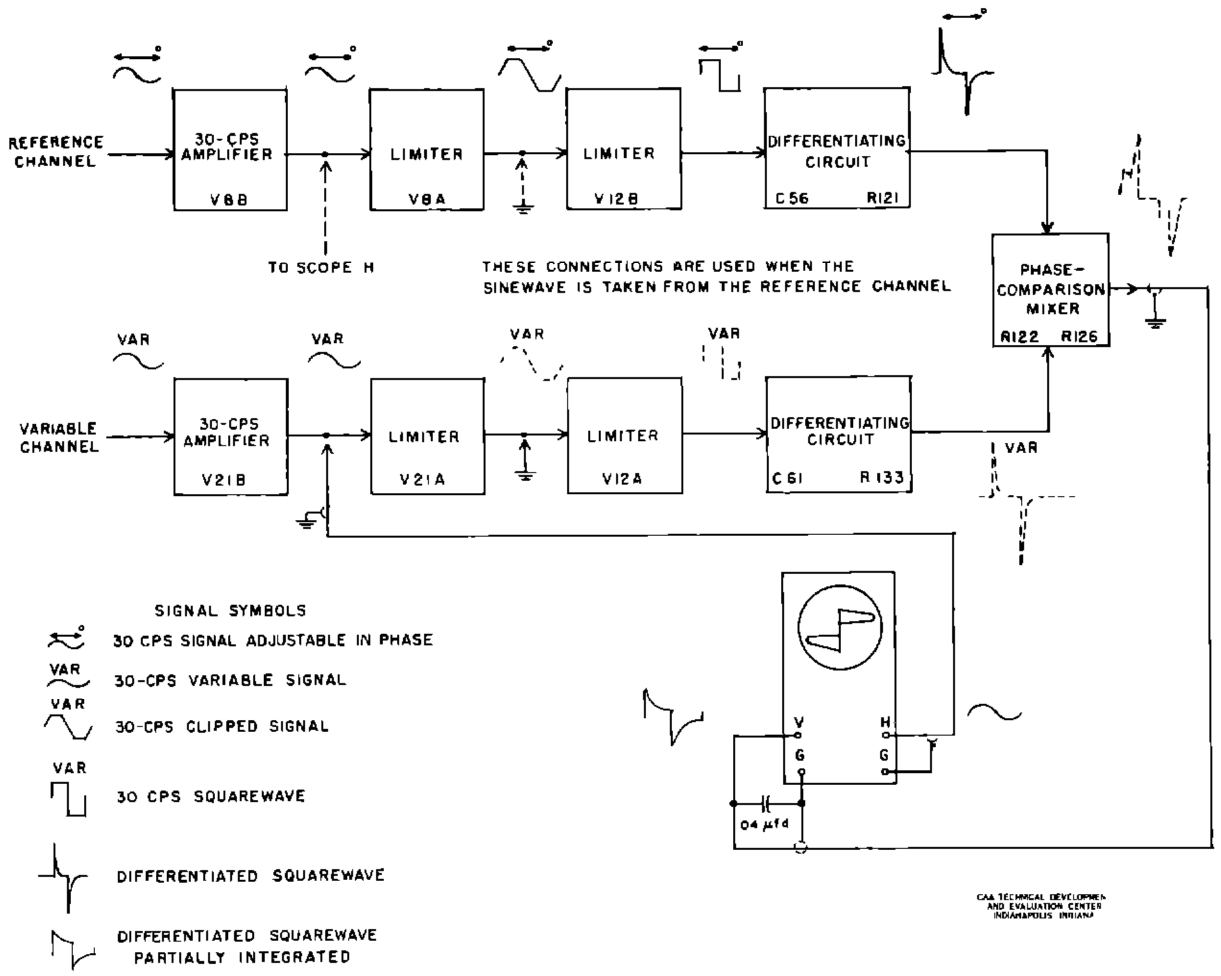

Fig 5 Partial Block Diagram of Monitor and Oscilloscope Connections

required length of RG-58A/U or K-109 cable The Type CA-1430 reference- and variable-test generator is connected to the other input of the monitor The oscilloscope is connected as described previously The course at any azimuth location is determined by adjusting the monitor OBS to overlap the vertical portions of the oscilloscope trace with monitor input from the counterpoise detector, then switching to the second input and adjusting the test generator for overlap of the vertical portions of the trace The bearing error is determined by subtracting the test-generator dial reading from the azimuth. The counterpoise detector is then moved to the next location and the procedure is repeated until all azimuths have been checked The error for each azimuth is plotted to obtain the complete calibration curve of the station.

The use of a calibrated monitor and oscilloscope without the test generator does not provide the accuracy or repeatability desired for developmental purposes. Sufficient accuracy for maintenance purposes can be obtained, however, when the complete modification of the CA-1277 monitor, as outlined in Technical Development Report No. 216, has been incorporated A newly developed monitor which uses circuits similar to those in VOR receivers has been used very successfully for ground calibrations It has the added advantage of direct readability without the use of an oscilloscope [4]

[4] R A Forcier and W. H Klein, "The Development of An Improved VOR/TVOR Monitor," CAA Technical Development Report No 271, June 1955

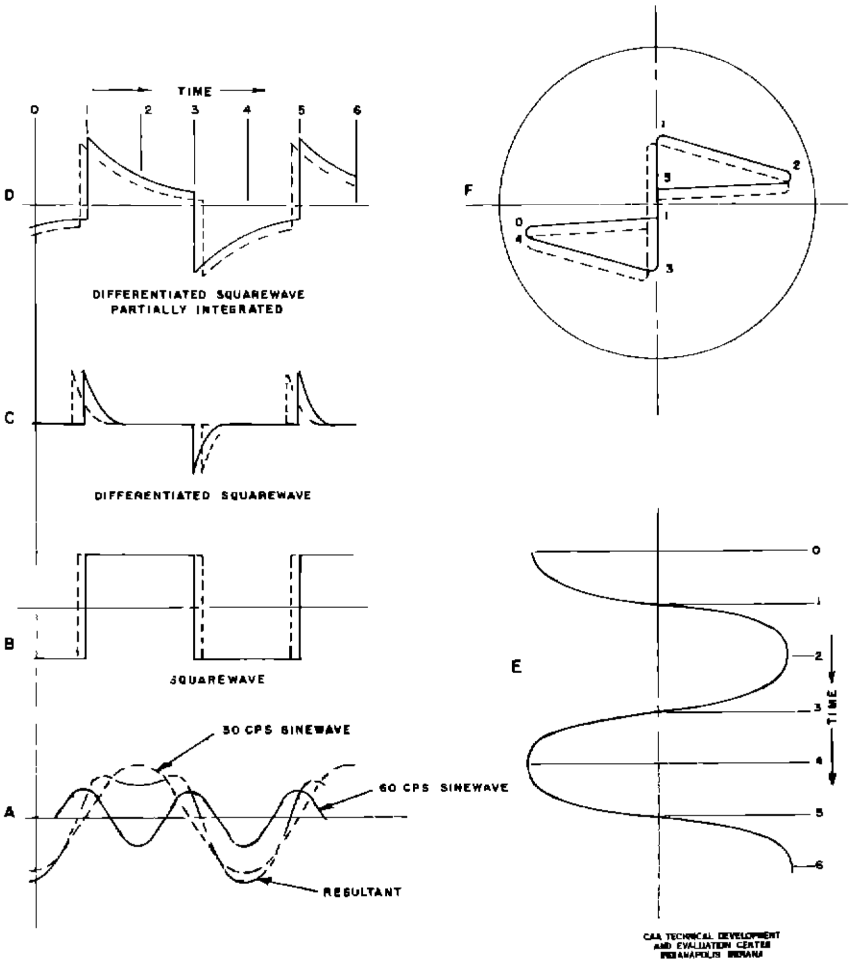

Fig. 6 Graphical Illustration of Waveforms and Resulting Oscilloscope Patterns

OPERATIONAL CHARACTERISTICS OF PORTABLE DETECTORS

Tests were conducted to determine operational characteristics of counterpoise-mounted detectors, particularly, the effect of detector height above counterpoise, 180° rotation of the detector to determine the electrical balance, course indication at various distances from the antenna, and course distortion caused by the detector when mounted on the counterpoise edge

The height of the detector was varied from 8 to 50 inches with little change in the indicated course except at very low heights. The change in indicated course plotted against height for the TDEC counterpoise detector and for the modified Type CA-2943 VOR portable field detector is illustrated in Fig. 11 Maximum course deviations of only ±0 1° for the Type CA-2943 detector and ±0 3° for the TDEC detector for heights over 10 inches indicate that the height is not critical The error for the Type CA-2943 detector increased rapidly below 10 inches because the antenna was long (46.5 inches) and not exactly horizontal, one end of the antenna being nearer the counterpoise than the other The bearing error data included in this report were taken with the TDEC counterpoise detector at a height of approximately 34 inches

The electrical balance of the detector was checked at the 0° or north position. The indicated course was measured, then the detector was rotated 180° and the course was checked again. If the two readings differed, they were made to coincide by a slight adjustment of the

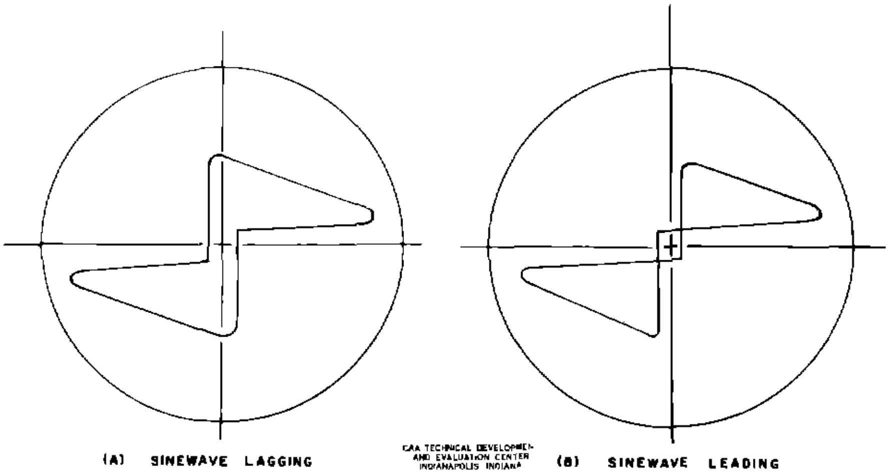

Fig. 7 Oscilloscope Patterns Showing Out-of-Phase Conditions

antenna coil When the detector was balanced, it agreed within ±0 1° of the course from the north field detector 200 feet from the antenna The unbalance measured on the TDEC counterpoise detector varied from 0 1° to 0 5°, depending on the type of circuit used The circuits shown in Fig 3 were the least critical, and they were easily adjusted for balance The test for balance with the Type CA-2943 field detector showed no difference in the indicated course and was within ±0 1° of the course indicated at the north field detector

Both types of detectors were rotated in the horizontal plane to determine the effect on the bearing. The TDEC counterpoise detector was rotated 20°, and the Type CA-2943 detector 45°, to produce an error of 0.25° This test indicates that neither detector is critical to small angular displacements in the horizontal plane.

The positions for the counterpoise mountings were determined with a theodolite mounted on the DME pedestal. A degree is approximately 3 7 inches at a radius of 17.5 feet, therefore, an accuracy of ±0 1° was easily obtained.

To compare the indicated course of a counterpoise detector with that of the north field detector, the course was read with a portable detector at distances of 8 3/4 feet, 17 1/2 feet, and 35 feet from the antenna This detector agreed with the north field detector at these distances The phasing of one sideband was changed with respect to the carrier by adding various lengths of line to simulate a faulty adjustment, and the distance check was repeated The results of this test are illustrated in Fig 12. From these curves it can be seen that a portable detector will receive the same information as the north field detector at the various distances if the station is properly adjusted, but it may indicate a larger error than the field detector if adjustments are incorrect

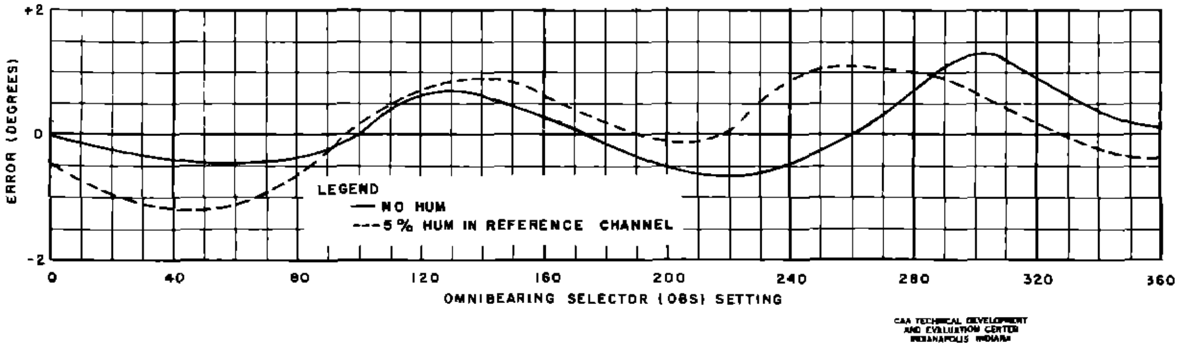

Fig 8 CA-1277 Monitor Calibration Error Using Pip-Sine Indicator Method

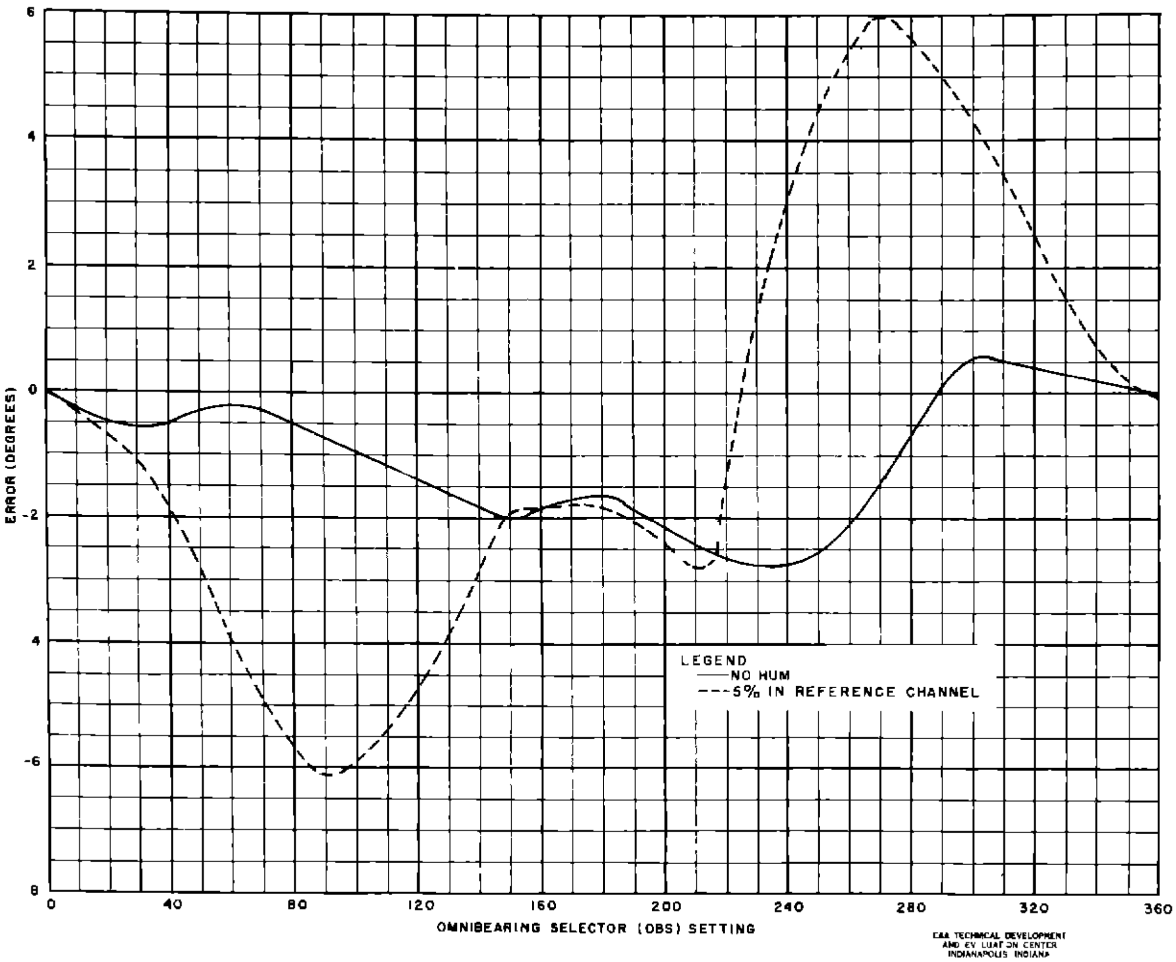

Fig. 9 CA-1277 Monitor Calibration Error Using Pip-Sine Indicator Method

To measure the course distortion, the detectors were mounted successively at each 20° position on the counterpoise edge, while the course was recorded at the receiver laboratory 10 miles from the VOR. The course distortion for both the TDEC counterpoise and the Type CA-2943 detectors is shown in Fig 13 The TDEC counterpoise detector caused a course displacement of ±0 16°, and the CA-2943 detector (two 50-ohm resistors in series with the antenna), ±0 3°. The course distortion with either of the above detectors is quite small, permitting a bearing error to be measured without interfering with the normal operation of the station The VOR portable field detector Type CA-2943, without resistors in the antenna elements, cannot be used for counterpoise measurements with the station in normal operation because the courses may be displaced as much as 3 5° at some azimuths

Tests were conducted to determine the optimum adjustments of the Type CA-2943 detector for use on the counterpoise edge A VOR receiver and recording equipment, mounted in a truck 1500 feet from the VOR, recorded the course displacement while the detector was carried around the station. It was determined that the course distortion was reduced to ±0.2° when the elements were 30 inches in over-all length, 56-ohm resistors were used in series with each element, and the height above the counterpoise edge was 20 inches

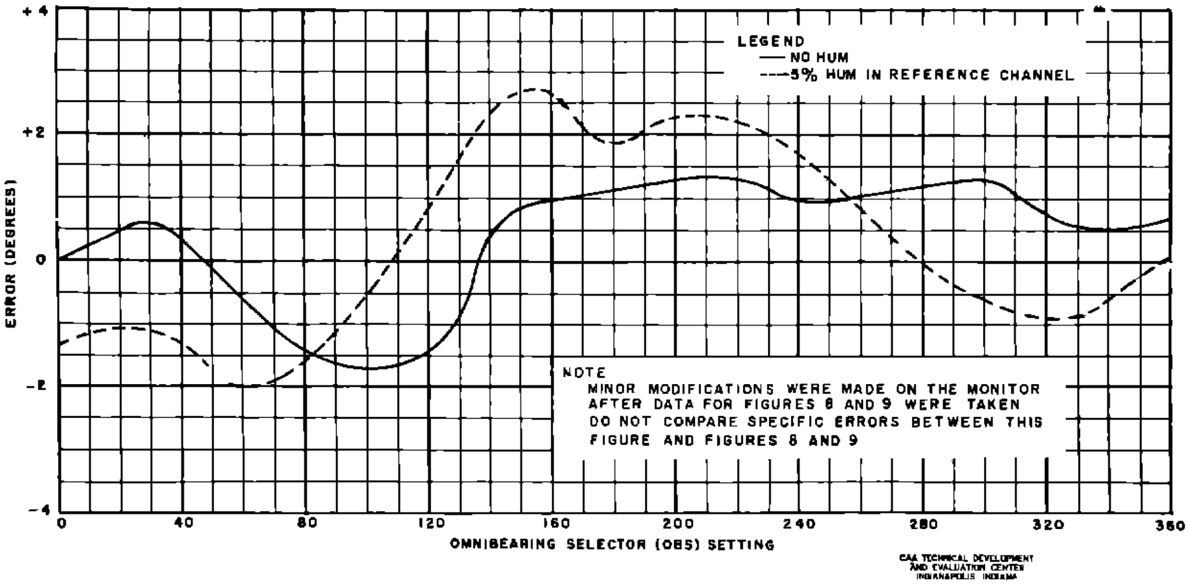

Fig 10 CA-1277 Monitor Calibration Using Sine-Sine Indicator Method

VOR CALIBRATION MEASUREMENTS

Tests to determine the accuracy of ground-check measurements using a counterpoise detector included (1) VOR antenna rotated using the north field detector at 200 feet, (2) 6-mile theodolite-controlled flight calibration (clockwise and counterclockwise circles), (3) 12-mile theodolite-controlled calibration circle, and (4) 20-mile calibration circle using ground-check points

The calibration curve of the station by the ground-check method was obtained by mounting the counterpoise detector successively at 20° intervals about the counterpoise and determining

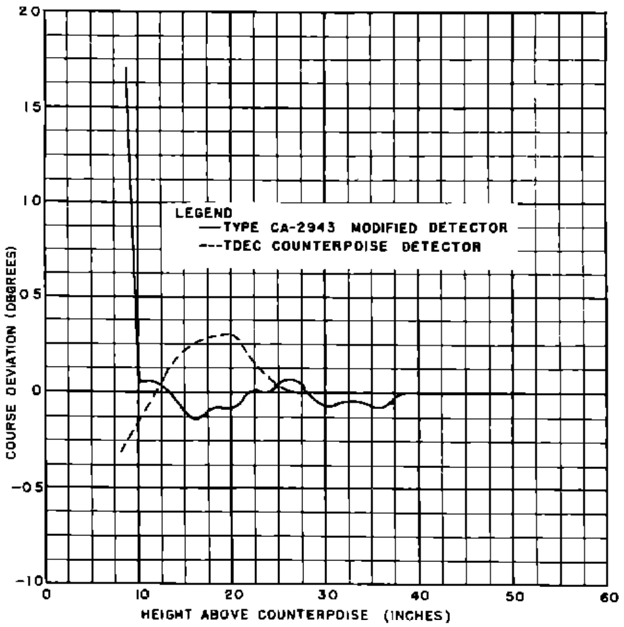

Fig 11 Course Deviation for Various Heights of Detectors Above Counterpoise

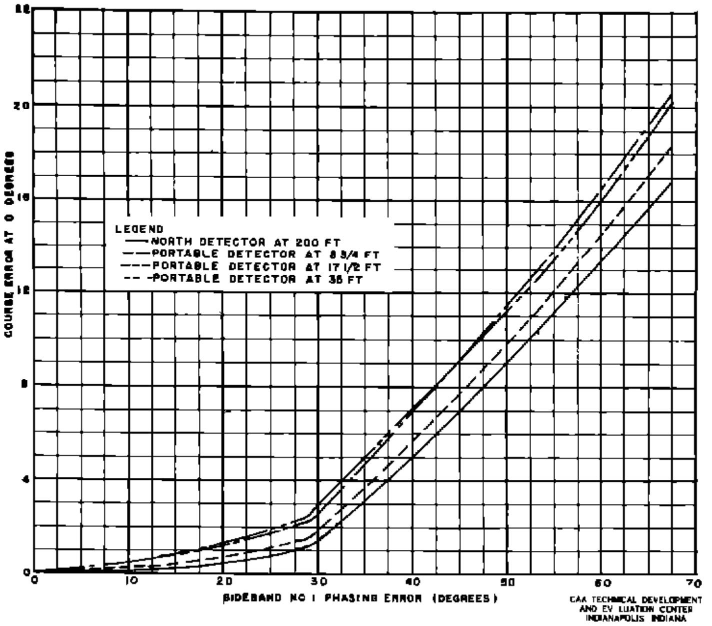

Fig 12 Course Error With Detectors at Various Distances From Antenna With Sideband No 1 Improperly Phased

the course at each position These data are shown in Fig. 14 and are compared with data obtained by rotating the VOR antenna and using the north field detector The curves have the same general shape, but they are displaced somewhat from each other The differences in the curves are attributed to mechanical difficulties encountered in rotating the antenna The curves obtained with a counterpoise detector have proved to be more consistent than those obtained by rotating the VOR antenna The total error spread measured with the counterpoise detector was 2 3°, whereas a spread of 2 6° was measured when the antenna was rotated.

Preliminary tests were conducted to determine the feasibility of using a number of fixed detectors mounted on the counterpoise Eight detectors were used at intervals of 45°. Lengths of RG-58A/U cable from each position connected the detectors to a selector switch to permit a quick check of the station. The detectors were placed at 45° intervals to check the critical

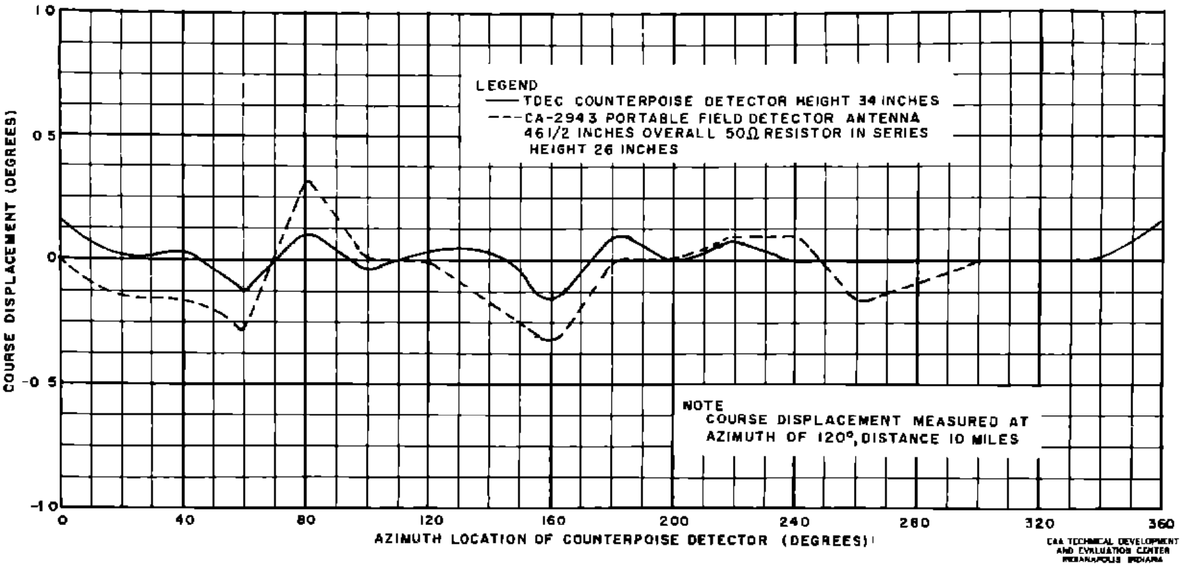

Fig. 13 Course Distortion Caused by Detectors Mounted on Counterpoise

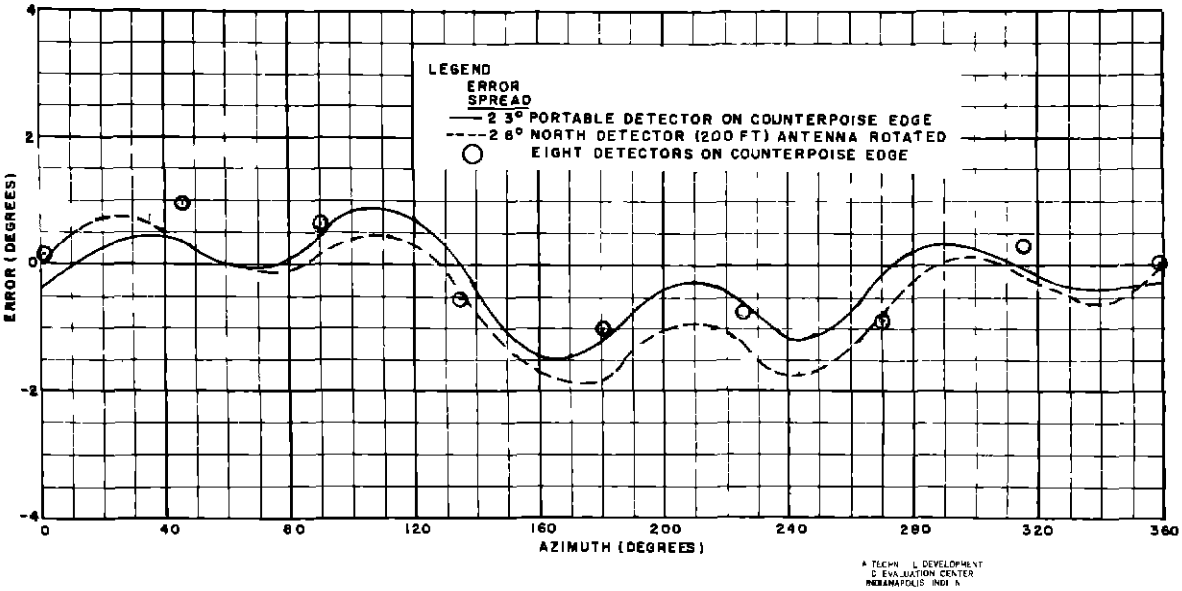

Fig 14 Comparison of Calibration Curves Taken at North Detector by Rotating Antenna and at Counterpoise Edge

points, that is, the nulls and maximums of the figure-of-eight patterns These measurements are also plotted in Fig 14 Final balancing adjustments had not been completed on the detectors, this probably accounts for the displacement of several points from the curves The single portable detector proved to be a more economical method for ground checking a VOR, and tests with multiple detectors were discontinued

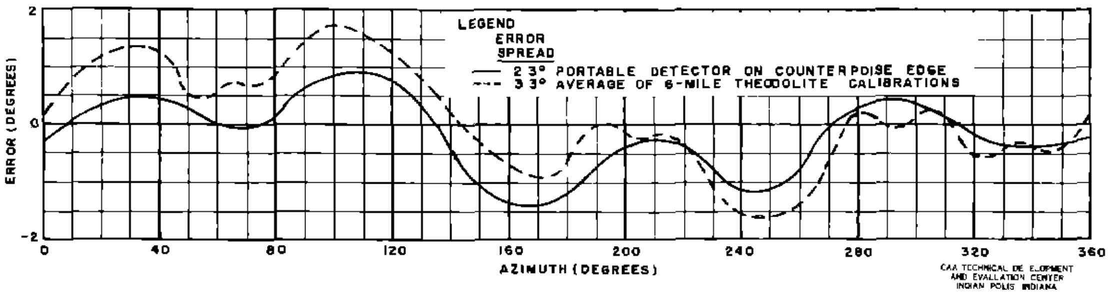

Fig 15 Comparison of Calibration Curves Taken at Counterpoise Edge and at 6 Miles

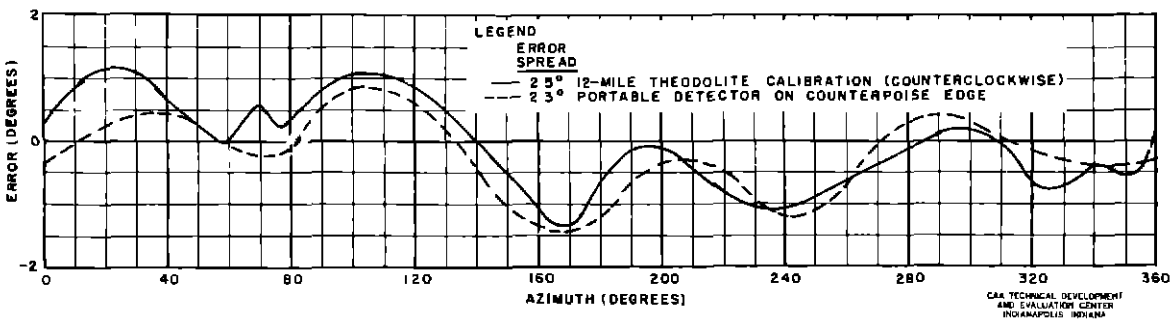

Fig 16 Comparison of Calibration Curves Taken at Counterpoise Edge and at 12 Miles

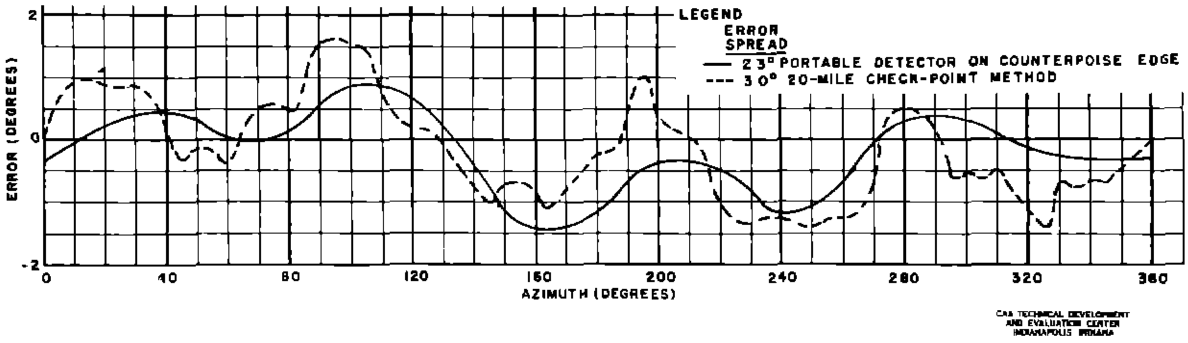

Fig. 17 Comparison of Calibration Curves Taken at Counterpoise Edge and at 20 Miles

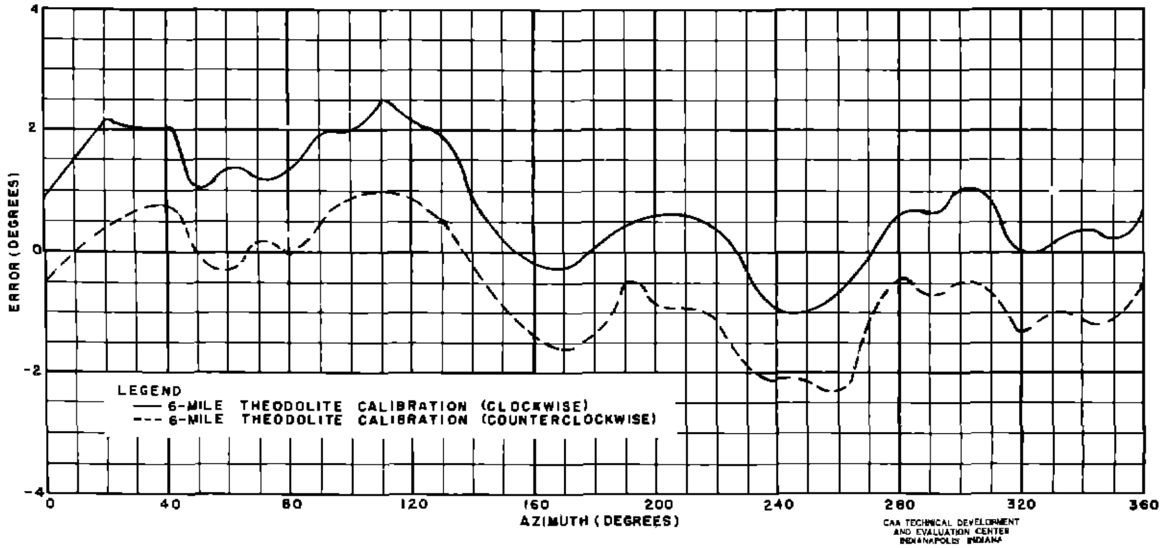

Fig 18 Comparison of Clockwise and Counterclockwise Calibration Curves at 6 Miles

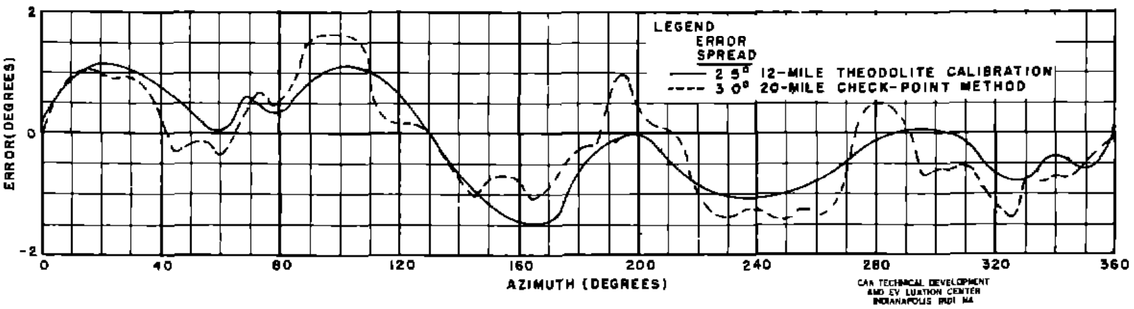

Fig. 19 Comparison of Calibration Curves Using 12-Mile Theodolite and 20-Mile Check-Point Methods

A comparison of curves obtained from the ground calibration and the 6-, 12-, and 20-mile flight calibrations is shown in Figs 15, 16, and 17 The similarity of the curves, both in shape and magnitude, is considered very good The average of the curves for the 6-mile radius clockwise and counterclockwise circles was used in Fig 15. The two curves are plotted individually in Fig 18. The difference is due to lag in the recorders and aircraft attitude effect

A comparison of the curves for the 12- and 20-mile radius circles is shown in Fig. 19 to demonstrate how the effect of siting error increases with distance from the station The irregularities in the curves at 70°, for example, were caused by scalloping from an east-west fence located 50 feet south of the antenna The fence is of wire except for wooden sections 150 feet east and 100 feet west of the station [5] The scalloping from the fence is of such a low frequency that it appears on the flight-check recordings as a fixed error From the foregoing data, it appears that an accurate calibration curve of the station, without the effects of siting, can be obtained from a ground check only It may be further stated that an accurate calibration curve can be obtained by one man in less than 20 minutes

SOME PRACTICAL APPLICATIONS OF COUNTERPOISE DETECTORS

Counterpoise detectors can be used to measure the antenna radiation patterns during initial tune-up of a four-loop VOR antenna.[6] The transmitter power is fed to one sideband pair, and the nulls of the figure-of-eight pattern can be located with a counterpoise detector, using a low-range microammeter or voltmeter as an indicator. Thus, the errors in the null locations are directly determined. The null locations of the other sideband pair are similarly determined After ascertaining that the loops are accurately spaced mechanically, the nulls may be adjusted by small changes in length of the individual loop feedlines The relative positions of the loops and nulls of each sideband pair can then be plotted on polar co-ordinate paper. Usually both nulls will move approximately equal amounts toward one loop. This is an indication that the feedline for that loop is too long, or conversely, the feedline of the other loop is too short. For a first approximation, the feedline can be shortened by the same number of degrees that each null is in error. For example, if the nulls of sideband No. 1 are at 46° and 224°, each null is 1° in error The feedline of the southeast loop should be shortened one electrical degree (approximately 3/16 inch) and the null positions rechecked. From the change in null positions, the

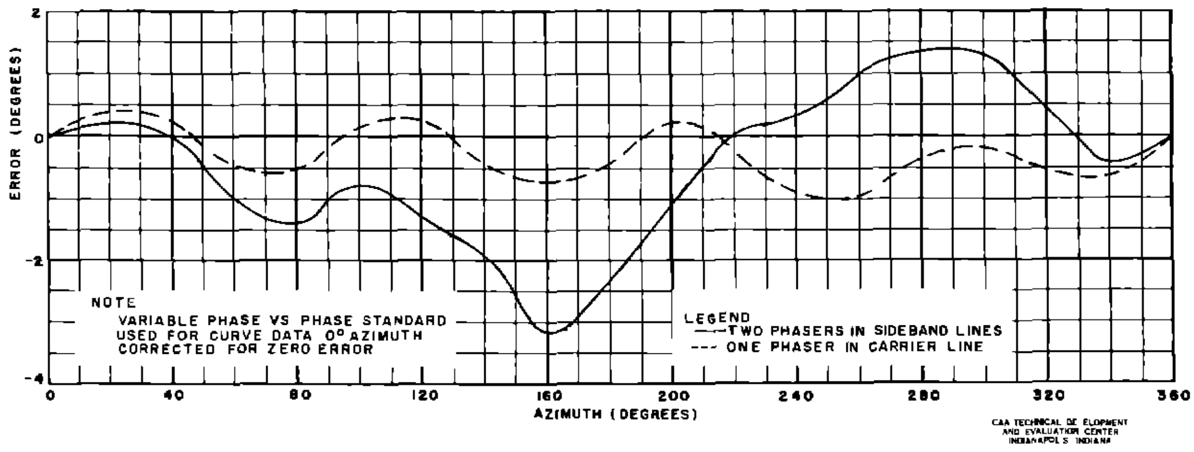

Fig. 20 Calibration Curves Showing Improvements After Installation of Single Phaser

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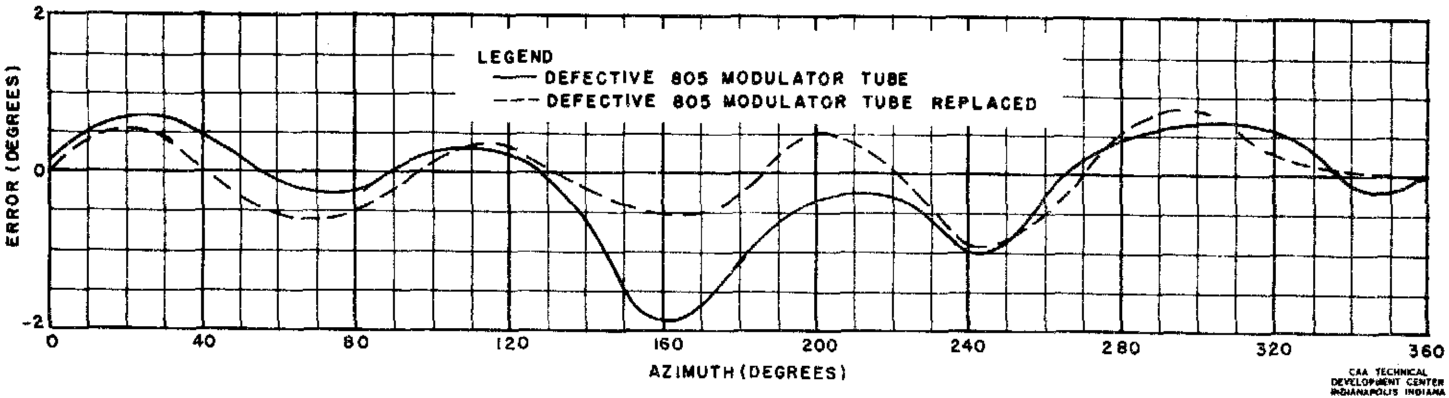
[5] S. R Anderson and H. F Keary, "VHF Omnirange Wave Reflections From Wires," CAA Technical Development Report No. 126, May 1952

[6] Anderson, Keary, and Wright, op. cit.

ERRATUM

eplacement of Fig. 21, page 15, CAA Technical Development Report No. 227, "Ground alibration of the VOR," by Robert B. Flint and William L. Wright.



he above figure replaces Fig. 21, page 15, Technical Development Report No. 227, which wa: rinted in error.

additional amount by which the line must be shortened can be estimated When the nulls are located properly, a counterpoise detector can be used to obtain approximate checks of sideband balance by measuring the sizes of pattern lobes from each sideband pair. Because of mechanical difficulties encountered in duplicating the height of the detector at each location, however, this method should not be used to make any adjustments The stubbing of the sideband lines should be adjusted so that the positions of the voltage minimums and VSWR's agree when measured at the goniometer, in order that equal loads will be presented to the goniometer

Various faults may occur in omnirange equipment with no apparent change in meter readings or in monitor indications These faults can cause minor errors in courses other than those being monitored, but a periodic calibration check will indicate their existence. Some examples of defective equipment, its effect on the calibration curve, and corrective action to be taken are discussed in the following paragraphs

The calibration curve shown in Fig. 20 (solid line) was the result of faulty sideband-phasing lines. It was found necessary to rephase these lines periodically, each change resulting in a large shift in the calibration curve No apparent defects could be found in the phasing lines, but they caused different standing waves to appear at each goniometer output. The standing waves also varied with each setting of the phasers This effect was eliminated by placing a single phaser in the carrier line and eliminating the sideband phasers The dashed line in Fig. 20 shows the resulting calibration curve. The stability of the phasing between carrier and sidebands has been excellent, with no change noted in the calibration curve due to rephasing The phasing was checked over a period of time, using both a counterpoise detector and the north field detector located 200 feet distant The difference in the phaser settings between the two locations varied from 2° to 9° Calibration data obtained at the counterpoise with the phaser shifted ±10° showed a maximum 0 25° departure from normal. This indicated that a four-loop VOR antenna with a single phaser can be phased with either detector with negligible effect on the station

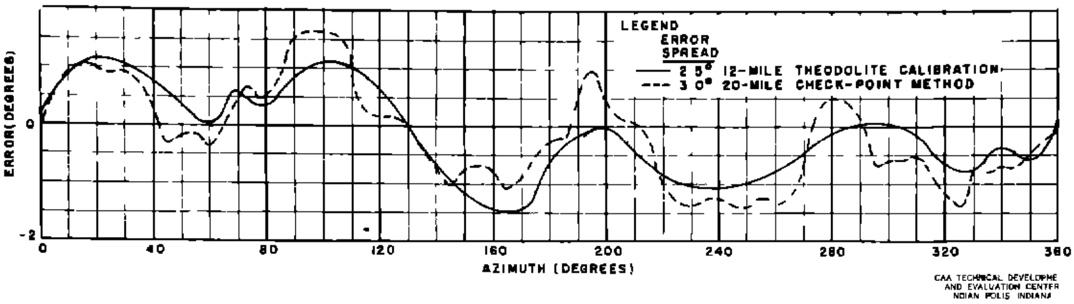


Fig 21 Calibration Curves Showing Effect of Audio Distortion in Modulator

The effect of modulator distortion on the calibration curve is illustrated in Fig 21 In this instance, one of the Type 805 modulator tubes had changed sufficiently to place most of the load on one tube The gain control had been advanced well above the normal setting, however, 30 per cent modulation at 10 kc was still available The dashed line in Fig 21 shows the calibration curve obtained after replacing the modulator tubes The curves in Figs 14 through 19 are similar in shape to that of Fig 21, probably because of distortion of lesser amounts as the tubes were deteriorating. The bearing error has been reduced to ±0 75° as shown in Fig 22, as a result of this method of ground calibration and because of corrective measures discussed in the preceding paragraphs Figure 23 shows the calibration curves obtained approximately six months after the one shown in Fig 22. Excellent correlation was obtained between the ground and flight calibrations.

CALIBRATION OF A TVOR

The counterpoise detector was moved to a radius of 50 feet and was used to calibrate the experimental TVOR located at Weir Cook Municipal Airport, Indianapolis The method used on the TVOR was similar to that used on the Tilden VOR, with the following exceptions

1. The antenna of the detector was extended to an over-all length of 28 inches to provide additional sensitivity.

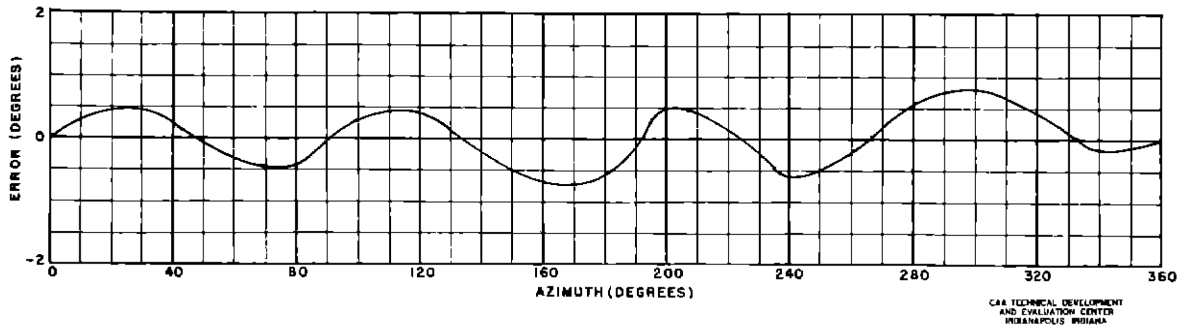


Fig 22 Final Calibration Curve of Four-Loop Array With Polarizer Using Counterpoise-Detector Method

2 Azimuth locations were marked by stakes located every 20° on the 50-foot-radius circle
3 The detector was mounted on a 12-foot aluminum pole, 2 feet above the counterpoise level
4 The pole was held vertically at each position by observing an attached spirit level

The calibration curve of Fig 24 (solid line) disclosed a spread of 6 1° The shape of the curve indicates displaced nulls as the major cause of the errors The loops and connecting lines were adjusted for more accurate null locations, and the sideband and carrier lines were rematched The dashed line of Fig 24 is the calibration curve of the station after the above adjustments were completed It has a total error spread of 2 0°

The solid curve of Fig 25, also with a spread of 6.1°, was obtained during the adjustment of the TVOR, and it shows the effect of sideband unbalance The lines had not been rematched after the null adjustment, and the VSWR was 1 27 on sideband pair No 1 and 1 1 on sideband pair No 2 Rematching the sideband lines produced the curve indicated by the dashed line of Fig 25 This calibration curve, with a spread of 2 0°, is the same curve shown by the dashed line of Fig 24

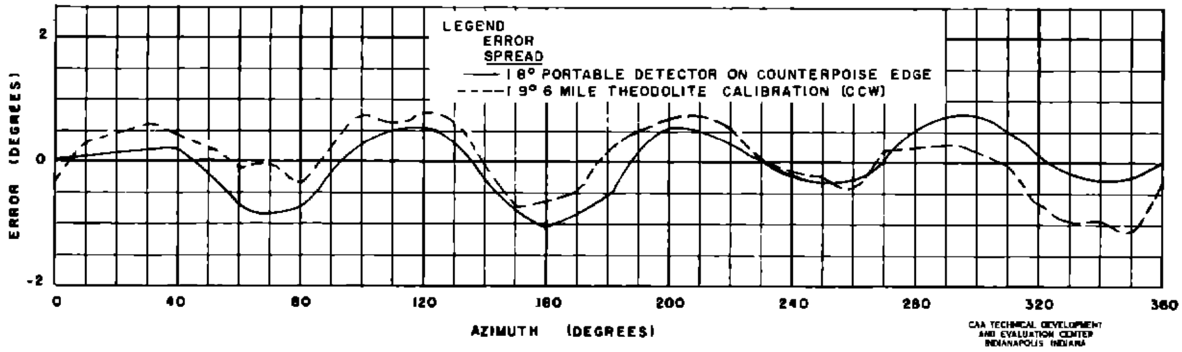


Fig 23 Calibration Curves of Four-Loop Array After 6 Months of Continuous Operation

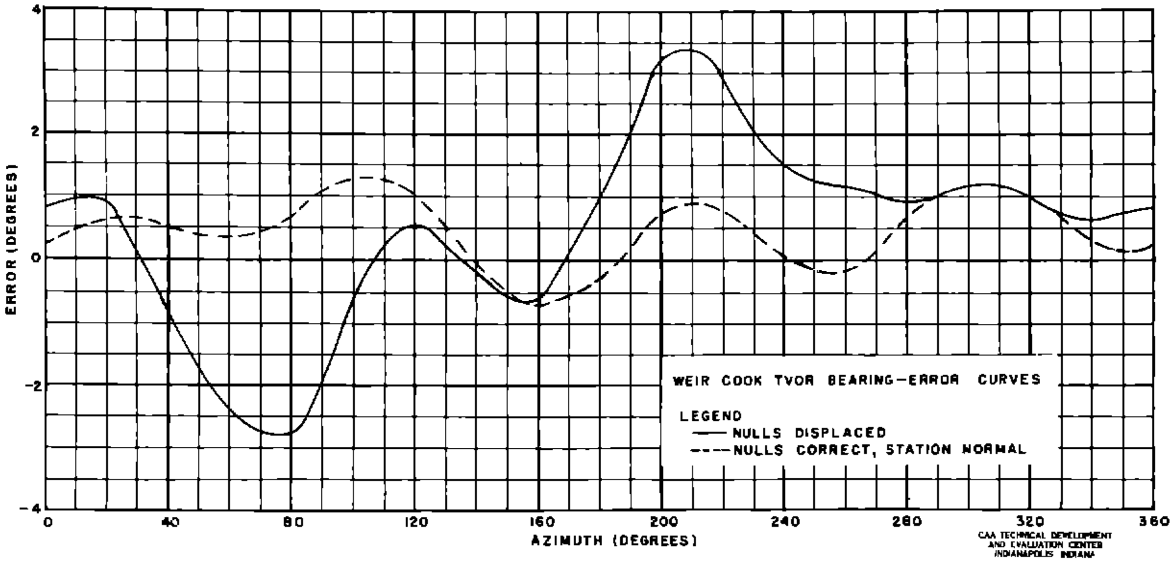


Fig 24 Calibration Curves Showing Effect of Displaced Figure-of-Eight Nulls

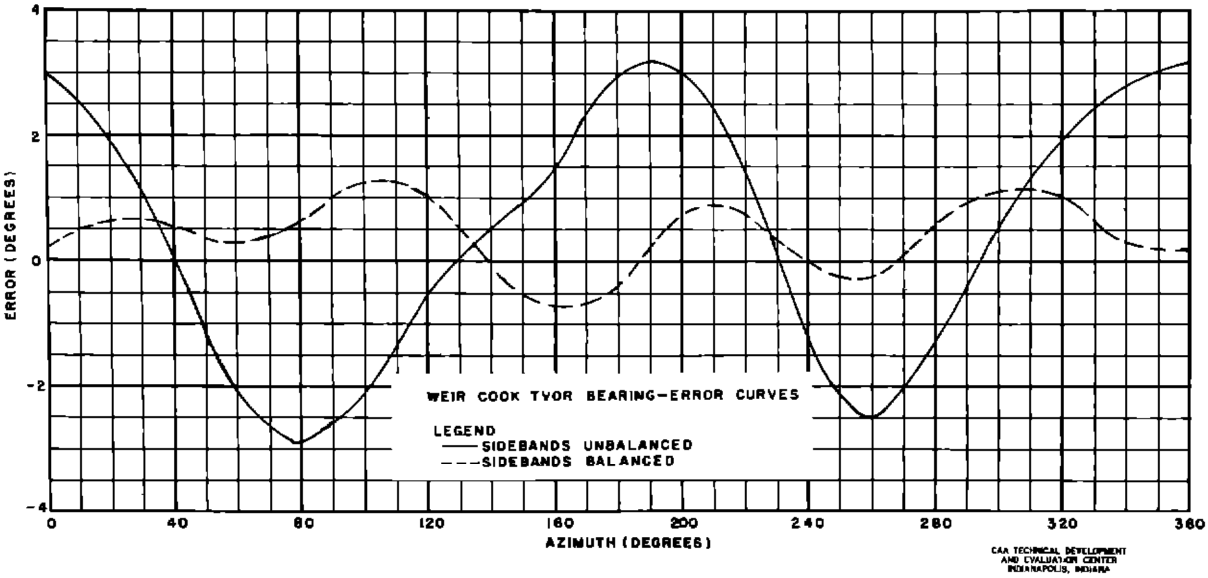


Fig 25 Calibration Curves Showing Effect of Sideband Unbalance

CONCLUSIONS

It is concluded that

1 Reliable bearing information can be obtained at the counterpoise edge, by use of a suitable detector

2 Mounting the detector on the counterpoise edge is entirely practical, both from an economical and a mechanical viewpoint

3 A method for calibrating a TVOR on the ground has been described

4 The ground calibration can serve as a valuable aid in the routine maintenance of the VOR. Calibration curves obtained before and after maintenance will indicate the effects of any readjustments or component replacements

5 Using the technique described in this report, an accurate calibration curve can be obtained by one man in less than 20 minutes

6 The calibration of the station can be obtained without interrupting normal operation

7 A VOR can be recertified on the basis of a ground calibration, provided there have been no siting changes

8 Acceptance of the ground-check method described in this report will eliminate many nonroutine flight inspections

9 The VOR portable field detectors, now used by Regional maintenance personnel, can be used on the counterpoise if they are provided with antenna resistors and a suitable mounting

10 This method of calibration makes it possible to adjust a VOR facility to much closer tolerances than has heretofore been possible Accuracies of ±0 75° have been achieved without difficulty with the four-loop antenna array and polarizer

11 The counterpoise detector is a very valuable aid in the initial tuning and phasing of the VOR