EVALUATION OF THE MELPAR AURAL BEARING GENERATOR

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by

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SUMMARY

This report presents the results of the evaluation of an improved Melpar VOR gross error detector (now called the aural bearing generator) designed to be attached to a VHF omnirange (VOR) ground station. The resultant system, called the visual aural omnirange (VAOR), is designed to give the pilot a simple aural check of gross errors in airborne VOR receivers without additional equipment.

The accuracy of aural bearing observations on flight checks was made by comparison with the omnibearings of a navigation receiver. Observations of aural bearings by several observers ranged from +4.0° to -10.5° in error, with average errors from 2.1° to 3.75°.

The maximum bearing error spread of the VOR station on ground check was 1.8° before the aural equipment was installed and 2.4° after the equipment was installed. A later reinstallation of the aural equipment caused the VOR bearing error spread to decrease from 2.2° to 2.0°. Course deviations caused by the rotating aural goniometer did not exceed ±0.25° at any azimuth.

The equipment was easily installed and adjusted. The stability of the equipment was good during the several weeks it was in operation. There were minor variations in the bearing error.

A monitor, which renders the equipment inoperative in the event of failure is included. The operation of the monitor was satisfactory, except in the case of a power failure.

INTRODUCTION

A production model aural bearing generator for converting a VOR to a VAOR developed by Melpar, Inc., was installed at the Tilden experimental VOR site of the Technical Development and Evaluation Center of the Civil Aeronautics Administration, Indianapolis, Indiana[1]. This station uses a four-loop VOR antenna system[2].

[1] R. B. Flint, W. L. Wright, T. S. Wonnell, "Evaluation of the Melpar VOR Gross Error Detector," Technical Development Report No. 200, May 1953.

[2] S. R. Anderson, H. F. Keary, W. L. Wright, "The Four-Loop VOR Antenna," Technical Development Report No. 210, June 1953.

The purpose of the VAOR is to enable the pilot to determine gross errors in the aircraft VOR receiving equipment. The aural bearing generator produces a clockwise rotating figure-of-eight pattern which contains 585-cps sidebands. The pattern rotation speed is 1 rpm. Voice announcements, giving the bearing of the antenna pattern nulls, are transmitted through the VOR voice channel every 10°. The bearing that is heard by the pilot during the tone null will be either the correct bearing, or its reciprocal.

The service provided by the aural bearing generator is not continuous, but shares time with the station identification system as illustrated in Fig. 1. The tone signal and the voice-announced bearings from 350° through 190° azimuth are transmitted while one null of the antenna pattern rotates through this sector. This requires 35 seconds and, upon completion, the VOR station identification is transmitted for 25 seconds. Then, the tone signal and the voice announced bearings from 170° through 10° azimuth are transmitted for an additional 35 seconds while the antenna pattern null rotates through this sector, making it unnecessary for pilots to determine reciprocal bearings. Twenty degrees of overlap are provided so that aircraft at 0° and 180° from the station will have no difficulty in distinguishing the tone null.

It should be pointed out that the system has an inherent 180° ambiguity which can be resolved by a simple flight procedure. A 90° turn to the right from a radial course will cause the bearing to decrease when going toward the station and increase when going away from the station. The ambiguity can then be resolved by referring to a magnetic compass.

DESCRIPTION

The aural bearing generator is housed in a cabinet 42 x 21 x 16 1/2 inches. Two views of the equipment are shown in Figs. 2 and 3. The four chassis mounted in the cabinet are, from top to bottom; the power supply and sideband generator, the monitor, the tape drum and goniometer, and the rf bridges.

Unmodulated rf power is obtained from the VOR by means of a power pick-off unit located in the coaxial line between the VOR goniometer and the modulation eliminator, as shown in Fig. 4. This unmodulated signal is fed into the grid circuit of the sideband generator. The plate tank circuit of the sideband generator receives an audio signal of 585 cps from a Wein bridge type oscillator and power amplifier circuit, located on the same chassis. The output of the sideband generator, consisting of frequencies equal to the VOR carrier ±585 cps, is obtained from the plate tank circuit by a pick-up loop, and fed to the aural bearing generator goniometer. This unit changes the signal amplitude and phase so that when it is applied to the antenna system a rotating figure-of-eight electric field is produced.

A magnetic drum type recorder is mechanically geared to the goniometer shaft. Voice-announced bearings at 10° increments from 350° to 190° azimuth are recorded on the one half of the drum, and bearings from 170° to 10° azimuth are recorded on the other half of the drum. These voice announcements are synchronized with the null in the antenna pattern. The magnetic drum voice output is amplified by a compensated audio amplifier and fed through the switching unit to the VOR modulator for modulation of the carrier.

The switching unit, which is also mechanically geared to the goniometer shaft, contains cams that control the timing cycles. Two timing cycles are available, through the use of a timing switch. On the two-minute position, the system operates alternately with the VOR station identification as described previously. However, on the four-minute position the aural bearing generator system operates for 35 seconds, the station identification for 25 seconds, the aural bearing generator system for another 35 seconds, followed by 145 seconds of station identification. Voice from the INSAC takes precedence over the gross error transmissions.

The aural bearing generator uses the VOR antenna. This is accomplished by feeding the outputs of both the VOR and aural bearing generator goniometers to the antenna through two rf bridges as shown in Fig. 4. These bridges permit dual use of the antenna, while providing effective isolation of the two signals. An adjustable shorting stub connected to the output of each rf bridge is adjusted for minimum effect of the aural bearing generator goniometer on the VOR sidebands.

A monitoring system is included in the aural bearing generator system which renders the equipment inoperative should an error of more than ±3° develop in the null positions. A remote monitor detector consisting of a tuned rf receiver is included with the equipment. However, a simple diode detector located at distances up to 200 feet will provide adequate signal for the monitor. The monitor uses 585-cps tone signal to develop a narrow trigger pulse which corresponds to the null in the radiated pattern. This narrow pulse is fed to the grid of a one-shot multivibrator. The grid is normally grounded through a cam-operated microswitch. The controlling cam, located on the goniometer shaft, opens the switch once each revolution and unless the trigger pulse is produced during the time the microswitch is open, the multivibrator will not be triggered. If the one-shot multivibrator is not triggered after three successive "active nulls" pass the remote monitor, a control tube stops conducting current, thereby allowing a relay to open, cutting off the supply voltage to the equipment. Active nulls are tone nulls which occur at the remote monitor during the time that the aural bearing generator is operating. If the aural bearing generator fails, the switching unit automatically allows normal transmission of station identification.

MEASUREMENTS

Tests were made to determine the accuracy of the VOR with the aural bearing generator installed, and the accuracy of the aural bearing equipment The tests included ground measurements of the aural and VOR bearing errors, and flight tests to determine the accuracy of the aural indications. Changes in the operating conditions resulting from the addition of the aural equipment also were included.

Measurements were taken at 10 miles from the VOR to determine the effect of the aural equipment on the VOR courses. A course deviation of ±0.25° was the maximum error observed. A sample of a recording of the course deviation indicator is illustrated in Fig. 5. This variation in the course is caused by unbalance in the aural bridges which permits some VOR sideband energy to enter the aural goniometer. The energy entering the aural goniometer causes an impedance change in the transmission lines between the VOR goniometer and VOR bridges. Balancing stubs on the outputs of the aural bridges provide a means for obtaining nearly optimum bridge balance and isolation of the VOR and aural sidebands.

The bearing error curves of the station before and after the aural equipment was added are shown in Fig. 6. The maximum error was 1.8° before the aural equipment was added and 2.4° after completion of installation and adjustments.

After the equipment had operated three weeks, the station was restored to normal and a bearing error curve was obtained, The aural equipment was then placed back in operation and again a bearing error curve was obtained. The VOR bearing error spread decreased from 2.2° to 2.0° with the addition of the aural bearing generator. These curves are illustrated in Fig. 7 and are nearly identical to those in Fig. 6, except for minor variations in the magnitude of the error. These curves show that the gross error equipment may introduce errors that either add to or subtract from the initial VOR bearing error curve.

The most critical adjustment of the aural equipment was that of the balancing stubs at the outputs of the aural rf bridges. After three weeks of operation, these stubs had to be readjusted slightly to maintain optimum balance. The stubs are connected to the rf bridges with General Radio Type 874 connectors which are designed for laboratory work. For a permanent installation, Type N connectors probably would provide greater stability.

Measurements of operating conditions are shown in Table I. The addition of the aural equipment did not cause a substantial decrease in the radiated power from the VOR.

TABLE I
Equipment Measurements

Conditions	Normal	With Aural Equipment
Carrier power output referred to normal VOR	67.5 w	60 w
9960 cps modulation on modulation eliminator output (60 ma cathode current)	2 %	2 %
Modulation eliminator power divider scale reading	49	55
20 Per Cent of 585-Cps Space Modulation		
Power input to VOR goniometer	2.25 w	4 w
Power input to aural sideband generator		1 w
Total output of aural sideband generator		1.2 w
Total power taken from modulation eliminator	2.25 w	5 w

The residual 10-kc modulation on the output of the modulation eliminator was unchanged with the addition of the aural equipment. The life expectancy of the modulation eliminator diodes should be the same since the cathode current was maintained constant at 60 ma.

The bearing error curves of the aural figure-of-eight nulls are illustrated in Fig. 8. The displacement of the nulls was due to an unbalance of the sideband outputs of the aural generator plus the inherent antenna system error. This unbalance is shown in Fig. 8, which is a plot of the aural bearing generator figure-of-eight horizontal plane pattern compared with a sinusoidal pattern. With properly balanced outputs, the tone null errors of the rotating aural pattern should be no greater than the errors of the VOR at any given azimuth.

Various simulated failures in the aural equipment such as a shorted or open input line to the sideband generator, shorted and open circuits in the aural goniometer rf line, produced negligible changes of the VOR courses. However, the unbalance of one of the rf bridges in the aural equipment will cause large course errors. To simulate such a failure, a 52-ohm load was paralleled with one of the bridge loads and the effect on the bearing error is shown in Fig. 10. Grid and plate tuning and phasing adjustments of the aural sideband generator produced a maximum of 0.2° change in the VOR courses.

Measurements to check the operation of the aural monitor were made by recording the plate voltage of the relay control tube. Input for the monitor was obtained from a crystal-diode detector mounted at 45°

azimuth on the counterpoise edge. The recording covered an operating time of 16 hours and showed a pulse delivered to the control tube once each minute with only one pulse missed. This indicates the action of the monitor to be positive, and that it should give satisfactory operation. However, the aural equipment requires a restart feature which restores the equipment to normal operation after a power failure.

The monitor automatically turned off the aural equipment when the detector was moved more than ±3° from the 45° azimuth position or, when the 585-cps tone was turned off.

FLIGHT TESTS

Flight tests were conducted on the aural bearing equipment installed at the Tilden VOR to determine the accuracy of aural bearings by various observers. Each observer recorded his interpretation of the aural bearing while the flight engineer recorded the indicated bearing of the omnireceiver. The observations were made at distances of 15 to 20 miles from the VOR. The interpretation of the observers are plotted against the receiver omnibearing in Fig. 11. The bearing errors of the station were neglected since they are small compared to the observer error. The average of the various observations indicate that as the observer gains experience, the interpretations become more accurate. From the data in Fig. 11, it can be assumed that with experience, the average observer can be expected to interpret the aural bearing with an accuracy somewhat better than ±4°.

The distance range for accurate observations is dependent on the signal-to-noise ratio. As the noise level rises (or the signal decreases), the width of the aural null increases, making the observations less accurate. The approximate distance range is 65 per cent of that of the VOR.

CONCLUSIONS

1. The aural bearing generator can be installed with little difficulty.

2. The operation of the aural bearing generator was relatively stable during the four weeks of the evaluation.

3. The equipment has an unresolved 180° ambiguity.

4. The addition of the equipment initially caused the bearing error spread of the VOR to increase from 1.8° to 2.4°. Three weeks later, reinstallation of the aural equipment caused the bearing error spread of the VOR to decrease from 2.2° to 2.0°.

5. The rotation of the aural goniometer introduced a maximum course variation of ±0.25°.

6. The observers interpreted the aural bearing with an average accuracy better than ±4°.

7. The monitor included in the equipment operated satisfactorily and rendered the equipment inoperative during failure of the tone or shift in the null position. However, no provision is made for monitoring of the voice bearing announcements.

8. The most common objection to the equipment from the pilot's point of view was that continued use induces fatigue.

9 The aural bearing service will be limited when this equipment is installed at a facility with a large volume of voice communications.

10. The introduction of the aural bearing generator increases the probability of an increase in VOR bearing error, however, no substantial difficulty was experienced during the limited evaluation period.

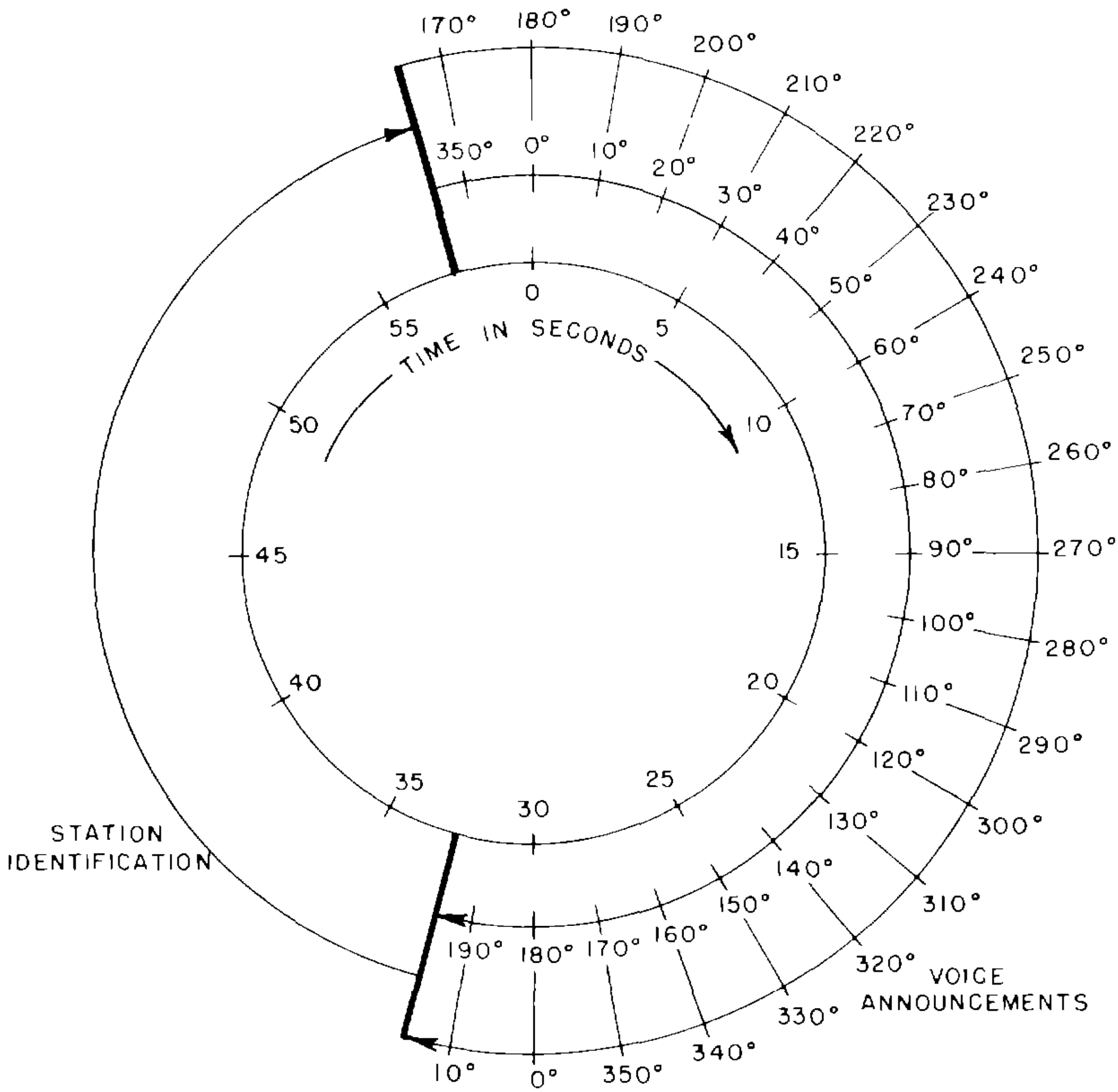

FIG 1 VAOR TIME-SHARING DIAGRAM

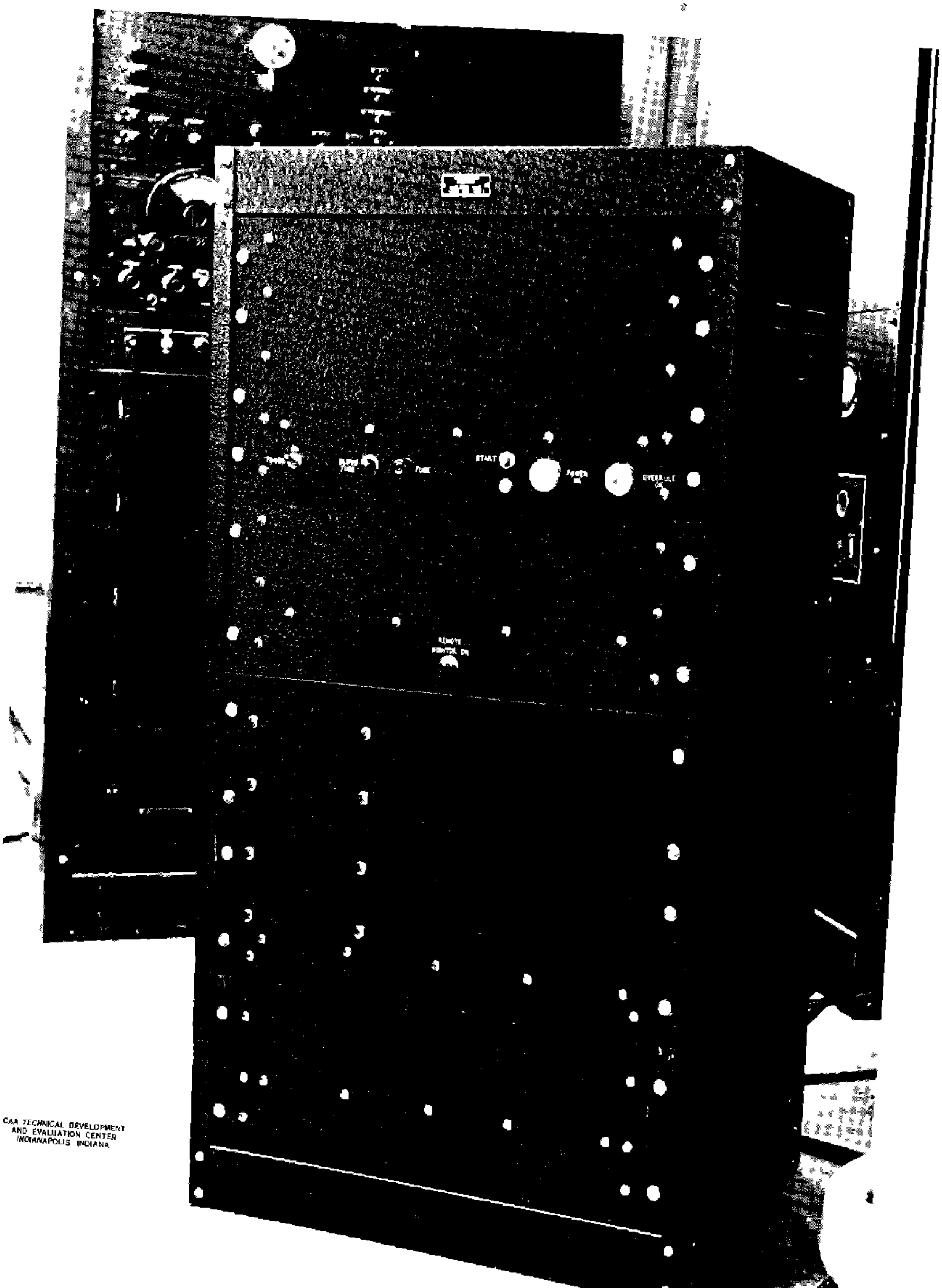

FIG 2 FRONT VIEW OF AURAL BEARING GENERATOR

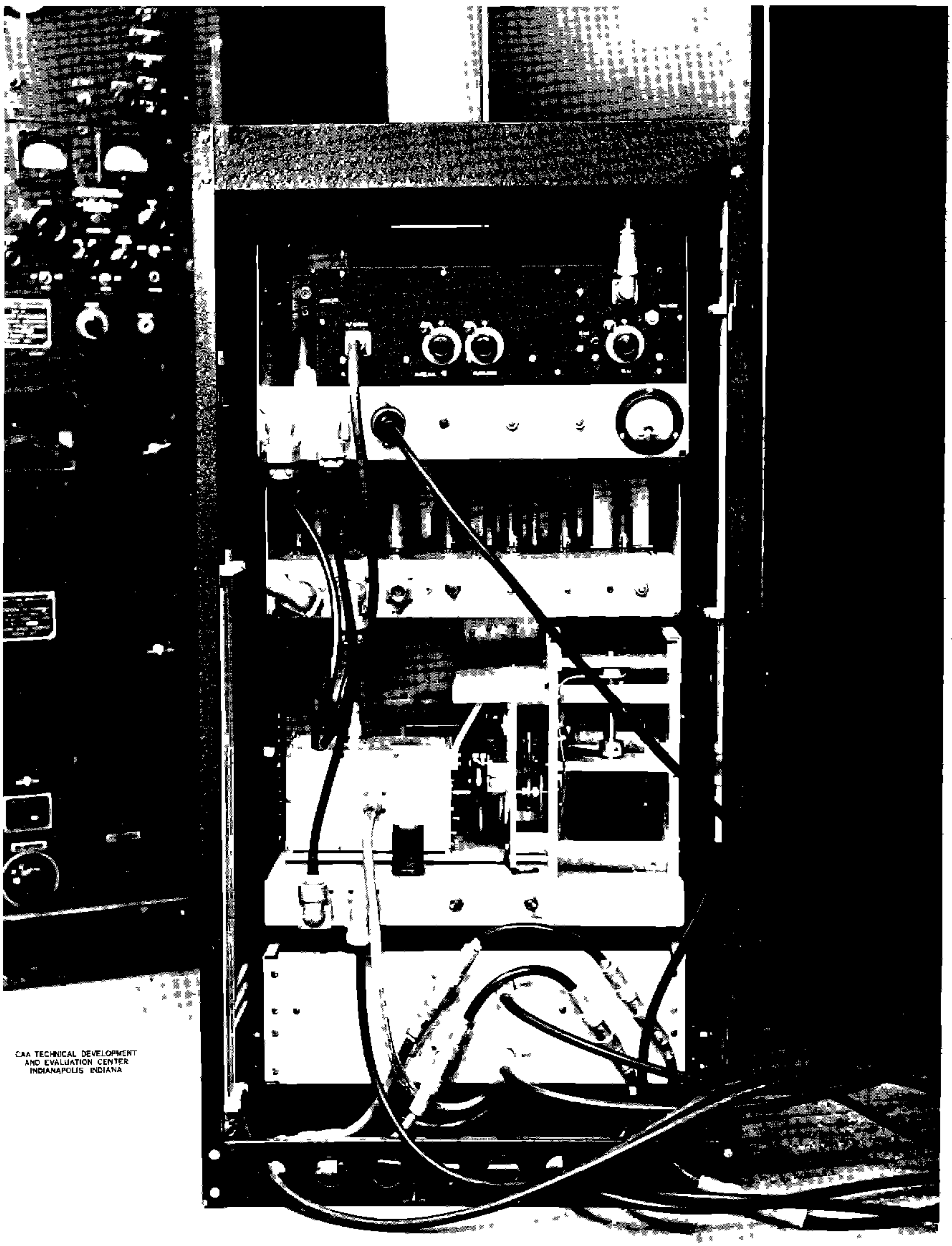

FIG 3 REAR VIEW OF AURAL BEARING GENERATOR

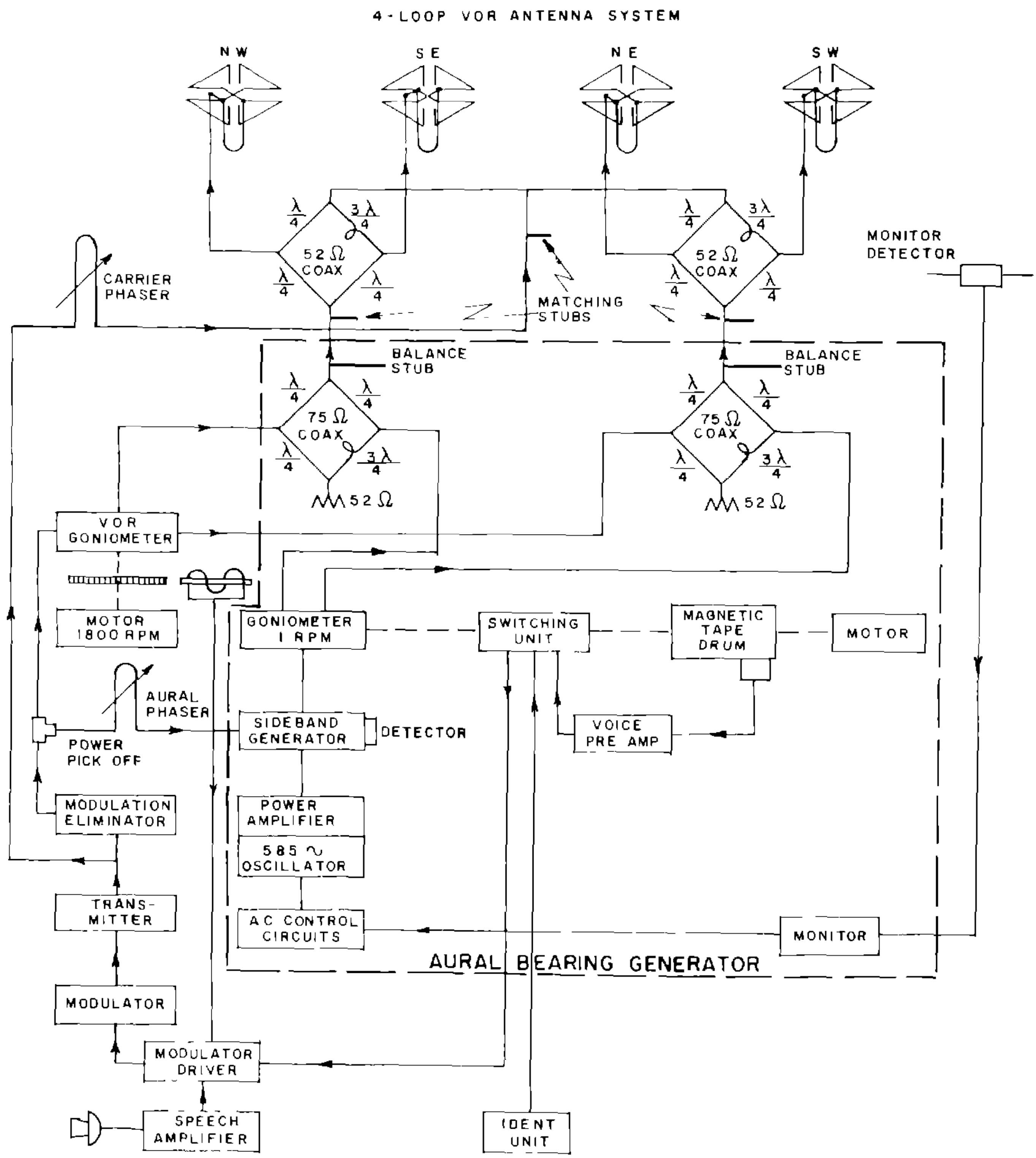

FIG 4 BLOCK DIAGRAM OF VAOR

NOTE RECORDING MADE WITH COLLINS 51 R2 RECEIVER AT RECEIVER LABORATORY
10 MILES FROM VOR AT 115 DEGREES AZIMUTH

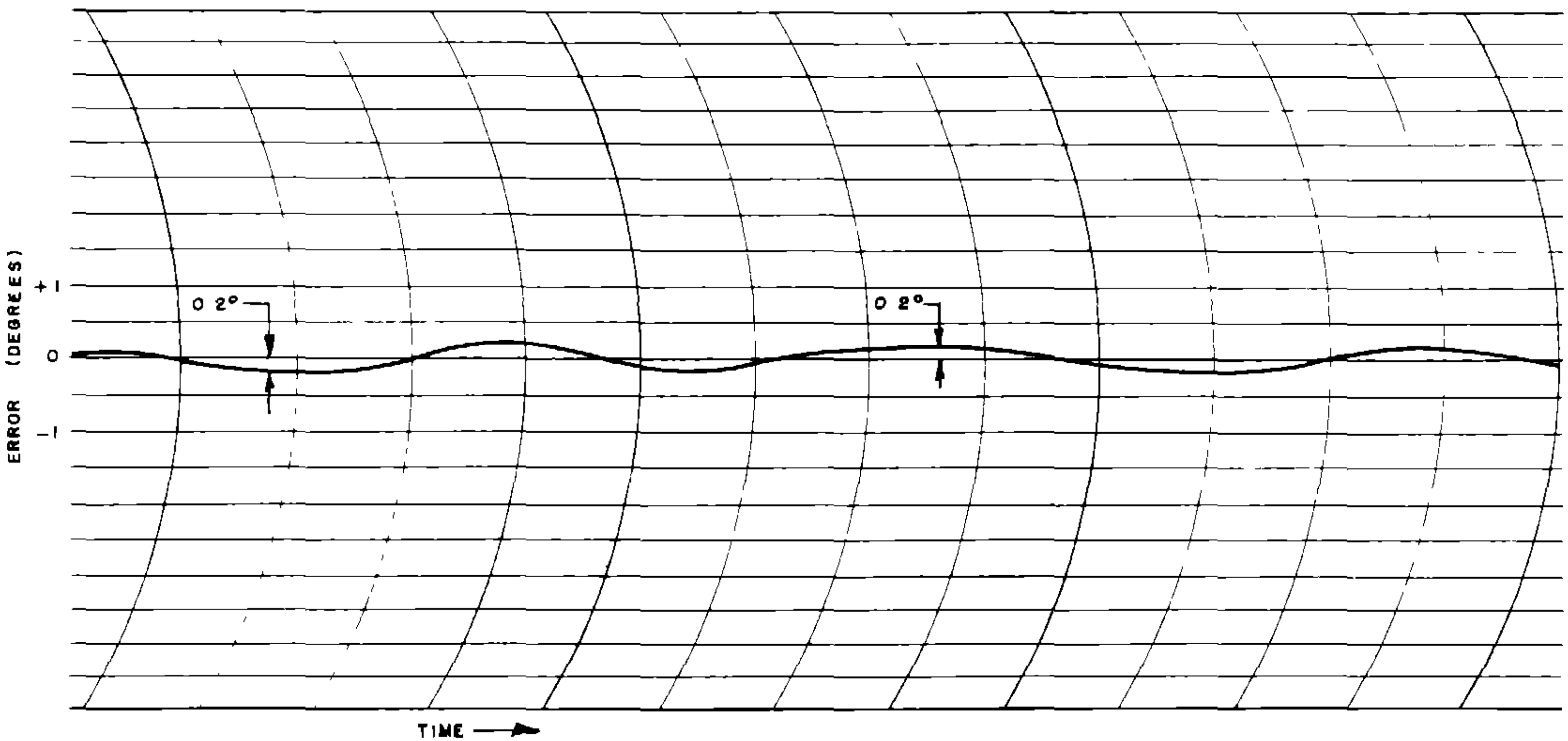

FIG 5 COURSE VARIATION CAUSED BY AURAL GONIOMETER

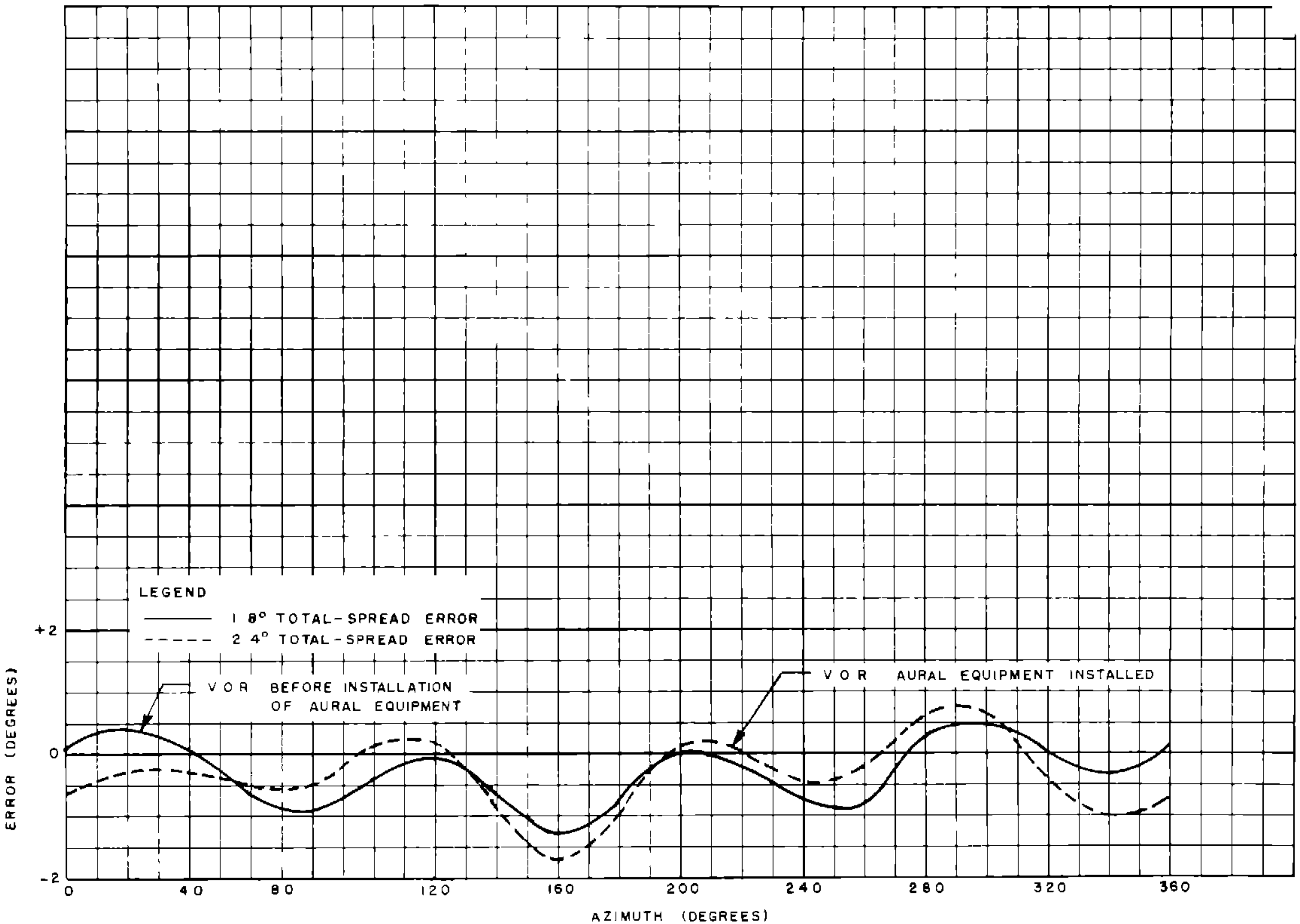

FIG 6 BEARING-ERROR CURVES OF STATION BEFORE AND AFTER INSTALLATION OF AURAL EQUIPMENT

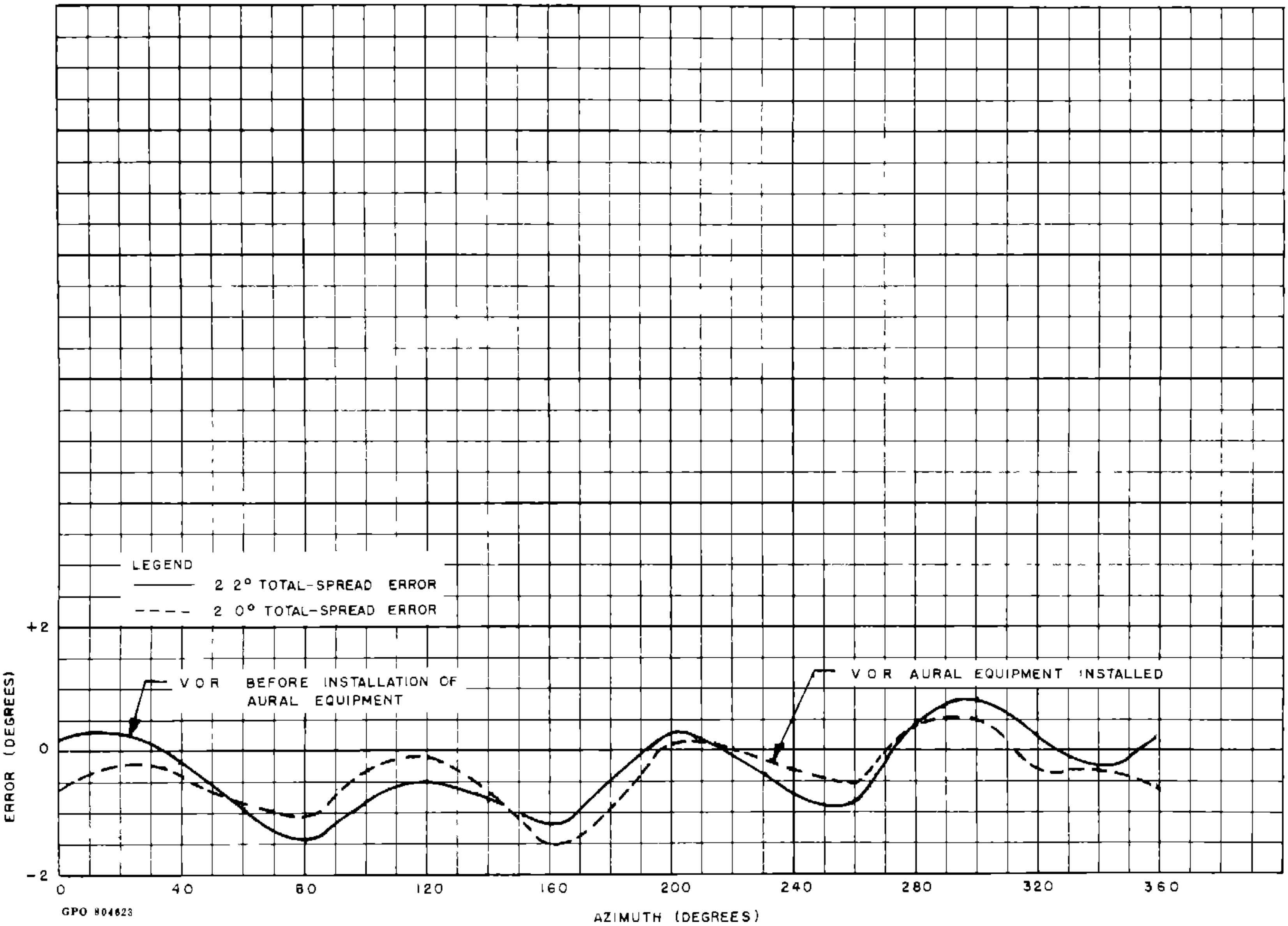

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FIG 7 BEARING-ERROR CURVES OF STATION RETURNED TO NORMAL AFTER THREE WEEKS OPERATION AND WITH AURAL EQUIPMENT REINSTALLED

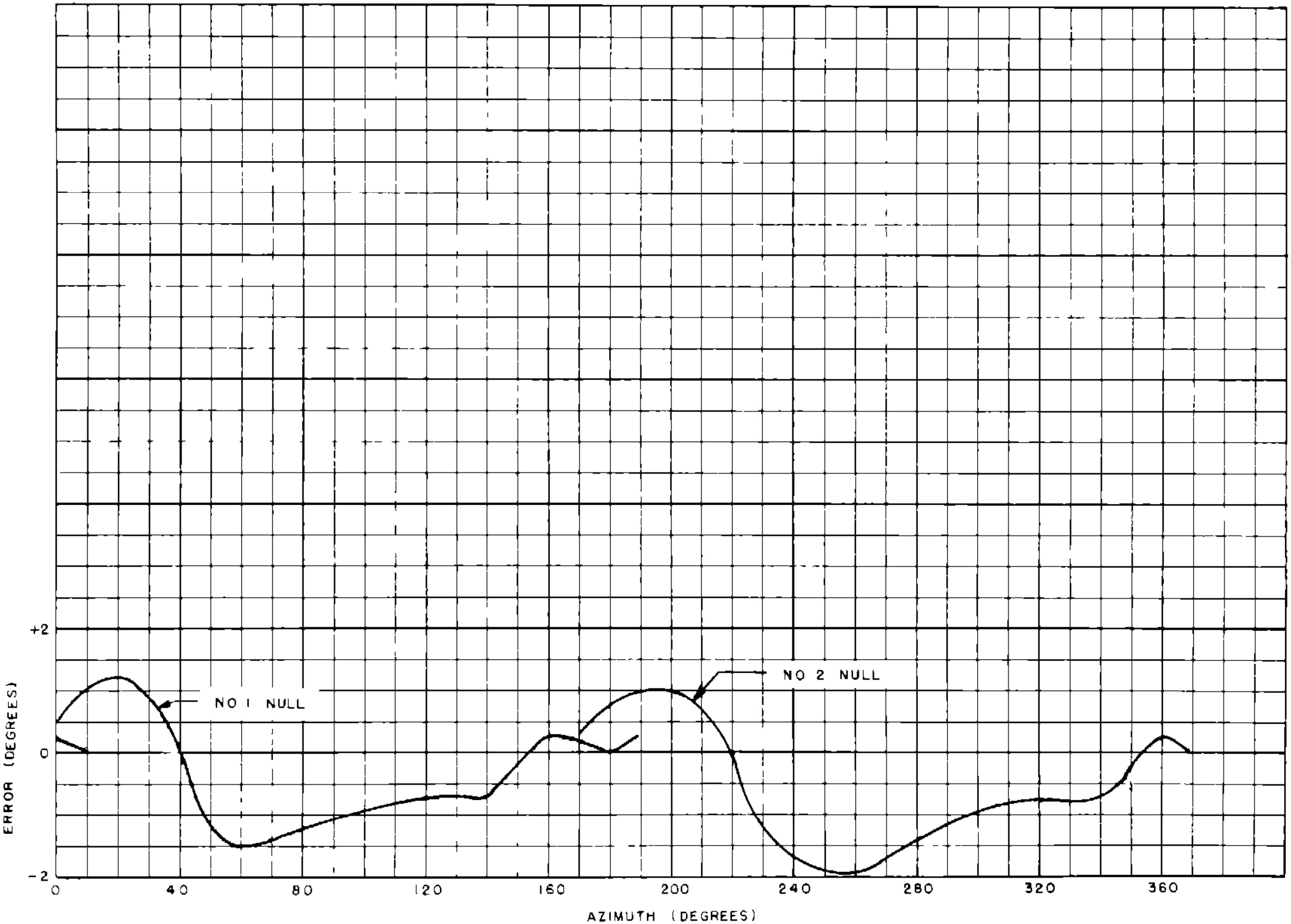

FIG 8 ERROR CURVES OF THE NULLS PRODUCED BY THE ROTATION OF THE AURAL FIGURE-OF-EIGHT PATTERN

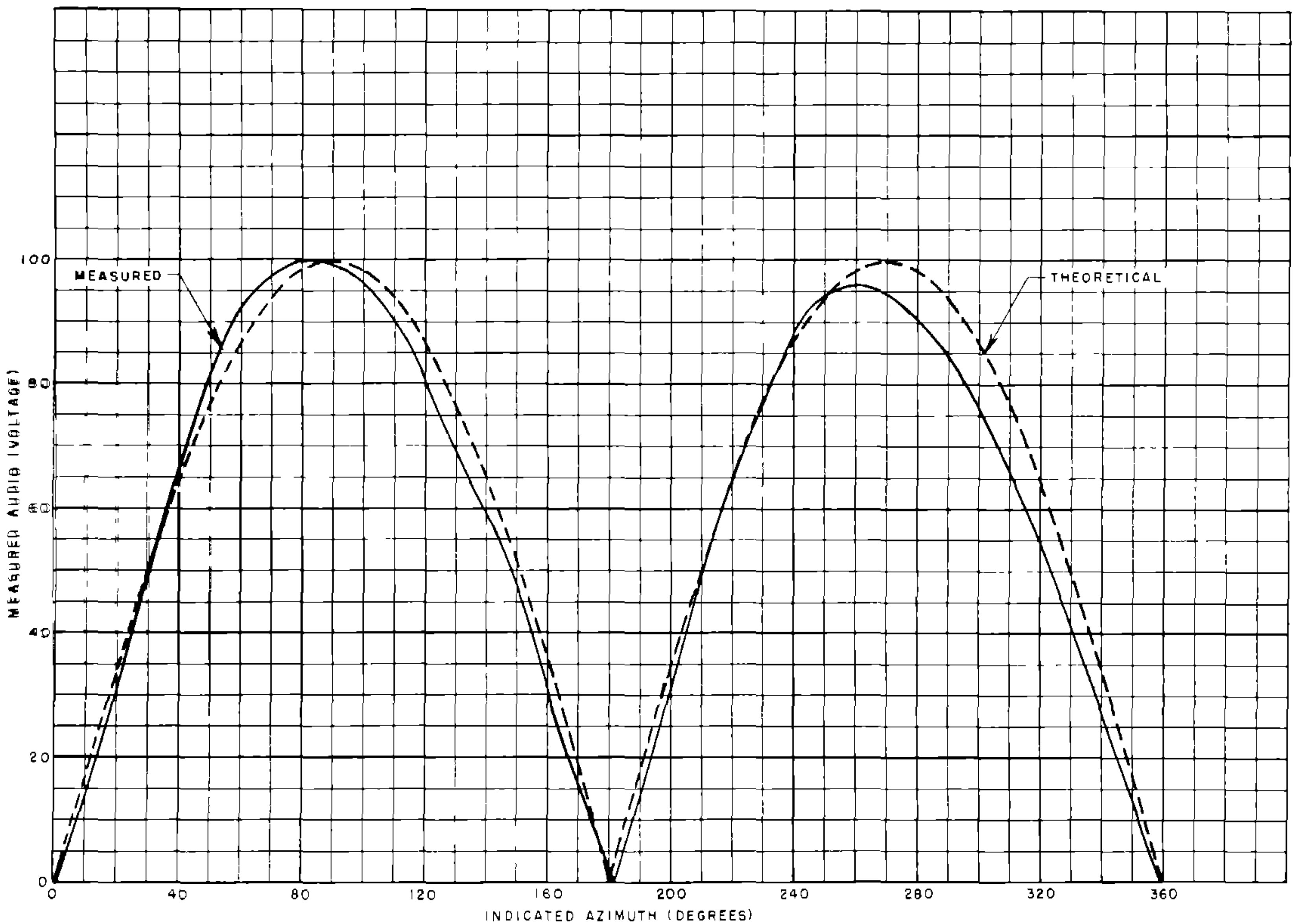

FIG 9 AURAL BEARING-GENERATOR FIGURE-OF-EIGHT HORIZONTAL-PLANE PATTERN

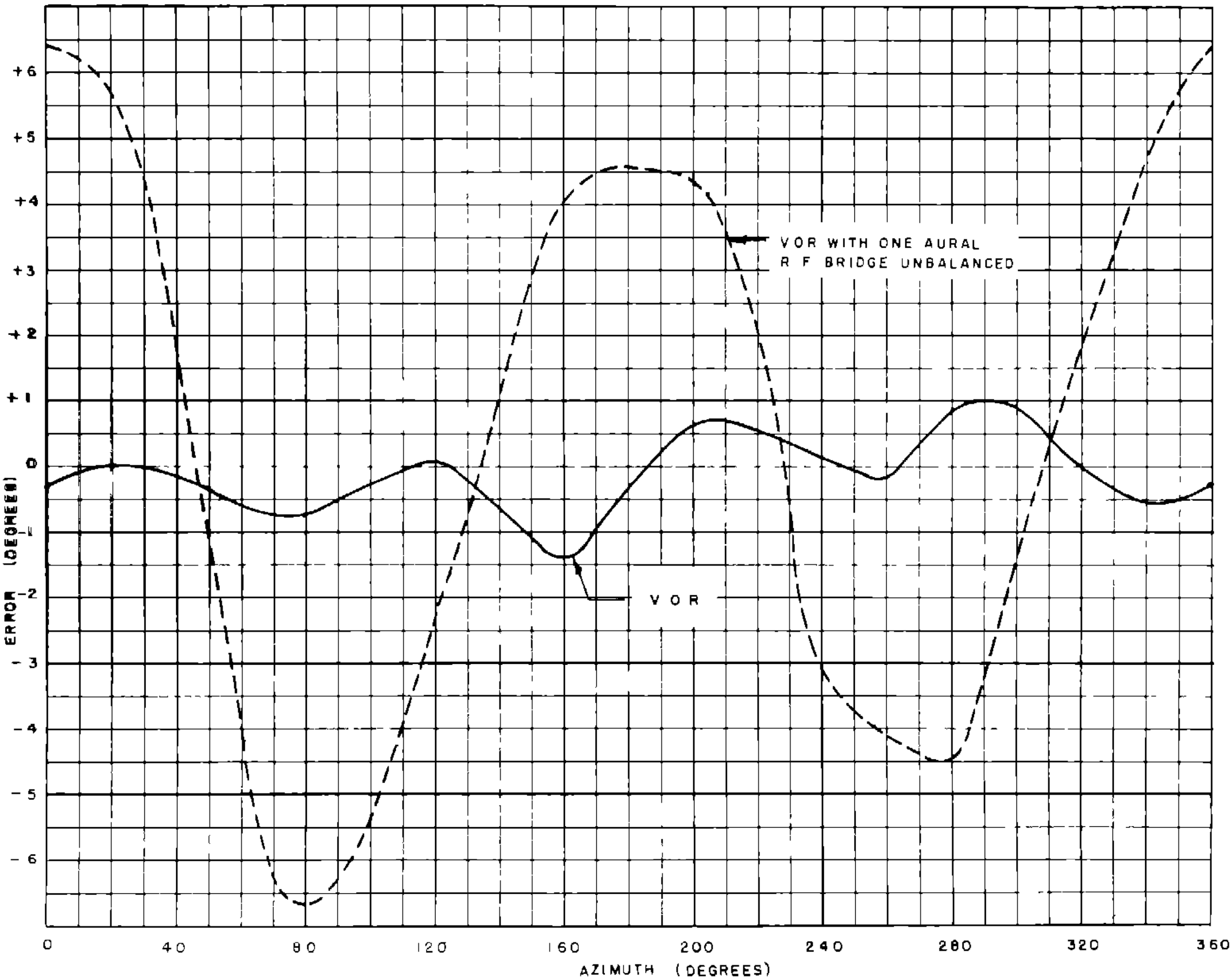

FIG. 10 BEARING ERROR CURVES WITH NORMAL OPERATION AND WITH ONE AURAL R-F BRIDGE UNBALANCED

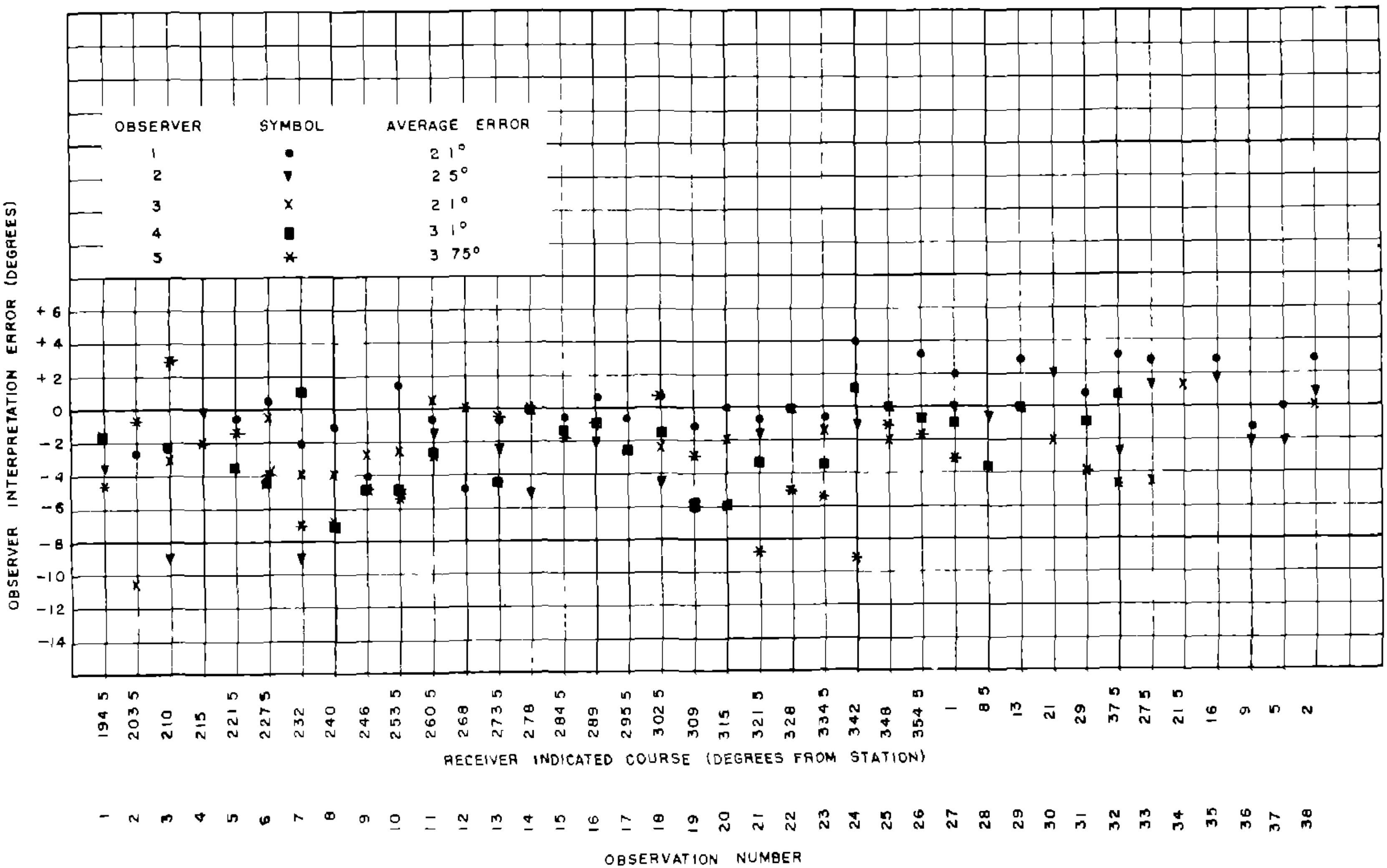

FIG 11 OBSERVER INTERPRETATION OF AURAL BEARINGS