TECHNICAL DEVELOPMENT REPORT NO. 204

OBSERVED VOR BEARING ERRORS CAUSED BY 30-CPS AMPLITUDE MODULATION ON THE 9.96-KC SUBCARRIER

FOR LIMITED DISTRIBUTION

by

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May 1953

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INDIANAPOLIS, INDIANA

W313

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Civil Aeronautics Administration
Technical Development
and Evaluation Center
P O. Box 5767
Indianapolis 21, Indiana

June 29, 1953

E R R A T A

Technical Development Report No 204

entitled

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Correction to TD Report No. 204 should be made as follows:

Change the title of the bottom scale of Fig. 18 to read "Per Cent Modulation" instead of "Bearing From Station (Degrees)"

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SUMMARY

This report presents the results of tests conducted at the Technical Development and Evaluation Center of the Civil Aeronautics Administration to determine the VOR bearing error, as indicated by different types of receivers and the monitor, when the amplitude of the 9960 cps modulation on the radio frequency carrier being fed to the goniometer is varied from 2 to 30 per cent.

It is concluded that the practical limit of residual modulation remaining on the rf carrier after passing through the modulation eliminator should not exceed 5 per cent Values of modulation greater than 5 per cent caused excessive bearing errors in some types of VOR receivers.

INTRODUCTION

A major problem in the establishment of reliable very high frequency omnirange facilities in the United States is the reduction of the number and length of time of station shut-down periods due to equipment failure or routine maintenance. One of the station components, namely, the modulation eliminator, requires considerable maintenance time in order to maintain less than 5 per cent residual modulation.

The function of the modulation eliminator is to remove the 9960 cps and voice amplitude modulation from the rf carrier that is being fed to the goniometer The 9960 cps modulation of the carrier going through the goniometer to the sideband loops causes an amplitude modulation on the transmitted 9960 cps subcarrier reference signal at a 30 cps rate. A 30 per cent modulation of 9960 cps on the carrier to the goniometer will result in 30 per cent amplitude modulation of the 9960 cps subcarrier transmitted signal at a 30 cps rate.

At the request of the Office of Federal Airways, an investigation was conducted to determine what the effect would be on the bearing accuracy, as indicated by the monitor and VOR receivers, if the 5 per cent limit of residual modulation were increased; and what maximum value of residual modulation can be tolerated.

EQUIPMENT AND TESTS

Tests were conducted on the Type CA-1277 station monitor and the following types of omnirange receivers that were available at this Center No effort was made to improve the VOR operation of these receivers

1. Collins Type 51R2

2 Bendix Type MN-85BA

3. Aircraft Radio Corp Model 15A.

4 National Aeronautical Corp Type VTR-1 (Omnigator).

The tests were conducted under the following conditions:

1. The carrier feeding the goniometer was modulated by the 9960 cps subcarrier to an amplitude equivalent to 2, 5, 10, 15, and 30 per cent

2. The station antenna array was rotated from 0° through 360° in increments of 45° at each of the above percentage modulations

3 The received signal level was adjusted to 50, 20, 10, and 5 microvolts at the receiver input for each of the modulation percentages and azimuth settings.

TEST SET-UP AND PROCEDURE

To measure the received signal levels a receiver was connected directly to the outside antenna and tuned to an omnirange station operating on 114.8 Mc A vacuum tube voltmeter (G.R. Type 1800A) was connected to the AVC circuit and the indicated voltage was recorded. The receiver was then disconnected from the antenna and connected to the omnitest equipment (consisting of a Collins Type 479S audio generator and a Boonton Type 211A rf signal generator) through a 6 db pad. The rf output from the Type 211A signal generator was adjusted to the same signal level as that obtained from the station, as indicated by the AVC level read on the vacuum tube voltmeter. This rf level (approximately 50 microvolts) was recorded as the receiver input signal level from the station The rf output from the signal generator was then adjusted for 20-, 10-, and 5-microvolt levels and the AVC voltage for each level was recorded The above AVC voltage calibration was made on each of the four receivers A block schematic diagram of the test set-up used in the receiver laboratory to measure the signals from the station is shown in Fig. 1

The following general test procedure was used to measure the error as indicated by the receivers operating under various test conditions·

The station first was adjusted for normal operation, that is, approximately 2 per cent modulation on the carrier signal fed into the goniometer. One of the receivers was connected directly to the antenna and the omnibearing selector adjusted for zero deflection of the course deviation indicator (CDI). The bearing as read on the OBS was recorded.

The antenna was then switched to incorporate the phaser and the 6 db pad in the antenna circuit. See Fig 1. The phaser, used as an attenuating stub, was adjusted to give the same AVC voltage as previously recorded on this receiver for the 20 microvolt level. The CDI deflection, as read on an external microammeter, and the course width were noted and recorded for this condition.

The phaser was next adjusted to obtain the same AVC voltage as recorded for the 10-microvolt level The CDI deflection and the course width were noted and recorded. The phaser was adjusted again to obtain the same AVC voltage as recorded for the 5-microvolt level. The CDI deflection and the course width were noted and recorded.

The above procedure was repeated on each of the other three receivers, and the CDI deflection and the course width for each receiver and input signal level were recorded

At the completion of the above tests on all of the receivers, the per cent modulation of the carrier fed into the goniometer was changed at the station from 2 per cent (normal operation) to 30 per cent (equivalent to the modulation eliminator not functioning), and all of the above tests on each receiver were repeated.

After the 30 per cent modulation tests at all input signal levels were completed, the percentage modulation was changed to 15, 10, and 5 per cent and all tests for each receiver were repeated for each modulation percentage.

The station antenna array was rotated through 360° in 45° increments and all of the above tests were conducted at each new bearing.

To measure the amplitude of the modulation on the carrier fed to the goniometer from the modulation eliminator, an oscilloscope was connected to the output of the modulation eliminator (Test Jack No. 2). The percentage modulation was measured with the station operating under normal conditions, and amounted to approximately 2 per cent. This value was used as the reference for all succeeding measurements. To obtain the various desired values of modulation amplitudes, the cathode resistance was varied and additional resistance added whenever necessary. The station was readjusted for proper modulation levels each time the modulation amplitude was changed.

TEST DATA

All of the following data were referenced to the 2 per cent modulation level (normal operation) at each bearing and input level. This was done to eliminate errors due to low signal input levels, station errors and inherent receiver errors. The data indicate only those errors caused by the change in percentage modulation of the 9960 cps on the carrier fed to the goniometer at each azimuth bearing and input signal level.

Receiver Course Sensitivity

It was noted during these tests that the course sensitivity of all of the receivers was not materially affected by changes in the percentage of modulation. However, the course sensitivity in the Narco and ARC type receivers was affected at the lower signal input levels. This is indicated in Table I.

TABLE I
Receiver Course Sensitivity

Signal Level (microvolts)	Narco (deg)	Bendix (deg)	Collins (deg)	ARC (deg)
50	32	18	15	26
30	32	18	15	28
20	34	18	15	44
10	36	19	15	-
5	52	21	17	-

Collins 51R2 Receiver

An analysis of Figs 2, 3, and 4 indicates that the percentage of modulation, up to a value of approximately 30 per cent, did not appreciably affect the accuracy of the bearing of the Collins 51R2 receiver at any azimuth setting.

Bendix MN-85BA

Figures 5, 6, and 7 indicate that 30 per cent modulation of the 9960 cps signal on the sideband caused a course error of approximately 1.5° at the 45° and 180° bearings on the Bendix MN-85BA receiver.

ARC-15A

It will be noted from the curves, Figs. 8, 9, and 10, that the ARC-15A receiver was sensitive to the difference in the percentage modulation. The course error due to the increase from 2 per cent (the reference line) to 5 per cent modulation was approximately 1.5° When the percentage modulation was increased to 30 per cent, the error was then increased to approximately 6°. It also should be noted that the error was dependent upon the signal input level and the azimuth from the station.

Narco VTR-1

The Narco VTR-1 receiver was found sensitive to a small change in the percentage of modulation, and showed an error of approximately 2° when the modulation was increased from 2 to 5 per cent. See Figs. 11, 12, and 13. When the percentage modulation was increased to 30 per cent, the error increased to approximately 15° at the low input signal level. It should be noted that the error was dependent upon the signal input level and the azimuth from the station.

Maximum Error

The curves in Figs 14, 15, and 16, show a comparison of the maximum error of all four receivers at various percentages of modulation and various signal input levels, and without regard to any particular azimuth setting of the antenna As seen in Fig. 15, an increase from 2 per cent to 5 per cent modulation caused an increase in error of 1.5° for the Narco and ARC type of receivers with a 20-microvolt input signal level With lower input levels, this error is increased. No data were obtained on the ARC receiver for the 5-microvolt input signal level due to the low sensitivity of the receiver available.

Monitor Error

Figure 17 shows that the error is dependent upon the station azimuth in relation to the location of the monitor pick-up head. The maximum error, as indicated by the monitor, would be at the 90° and 270° points The maximum error, as indicated by the monitor, is directly proportional to the percentage of residual modulation, as is shown in Fig. 18.

DISCUSSION

Airline Type Receivers

The bearing errors of the Bendix and Collins receivers were not materially affected when the percentage of modulation was increased from 2 per cent to 30 per cent This is attributed to the excellent limiting and discriminating circuitry used in these receivers.

Receivers Used in Executive Type Aircraft

The operation of the ARC Model 15A receiver often used in medium weight aircraft was found to be affected by the amplitude of the modulation fed to the goniometer The error caused by increasing the percentage modulation from 2 to 30 per cent was proportional to that increase. The amplitude of the error varied with the azimuth bearing from the station and the signal level.

Private Flyer Type Receiver

The Narco Omnigator receiver was used as a typical private flyer receiver. This receiver is very sensitive to any increase in the percentage modulation above 2 per cent The error caused by increasing the residual modulation is proportional to the increase in modulation and rises at a rate of approximately 1° error for an increase in 2.5 per cent modulation, with a 20-microvolt input signal level. Lower signal levels caused greater errors for the same per cent modulation.

Station Monitor

The error increases in proportion to the modulation amplitude The errors are affected by the location of the pick-up head in relation to the azimuth from the station. This is attributed to insufficient limiting circuitry in the Type CA-1277 monitors.

CONCLUSIONS

It is concluded that the several types of VOR receivers tested will have excessive bearing errors when the residual modulation on the rf carrier from the modulation eliminator exceeds a value of 5 per cent. The magnitude of error will vary with the different types of receivers and the percentage of residual modulation.

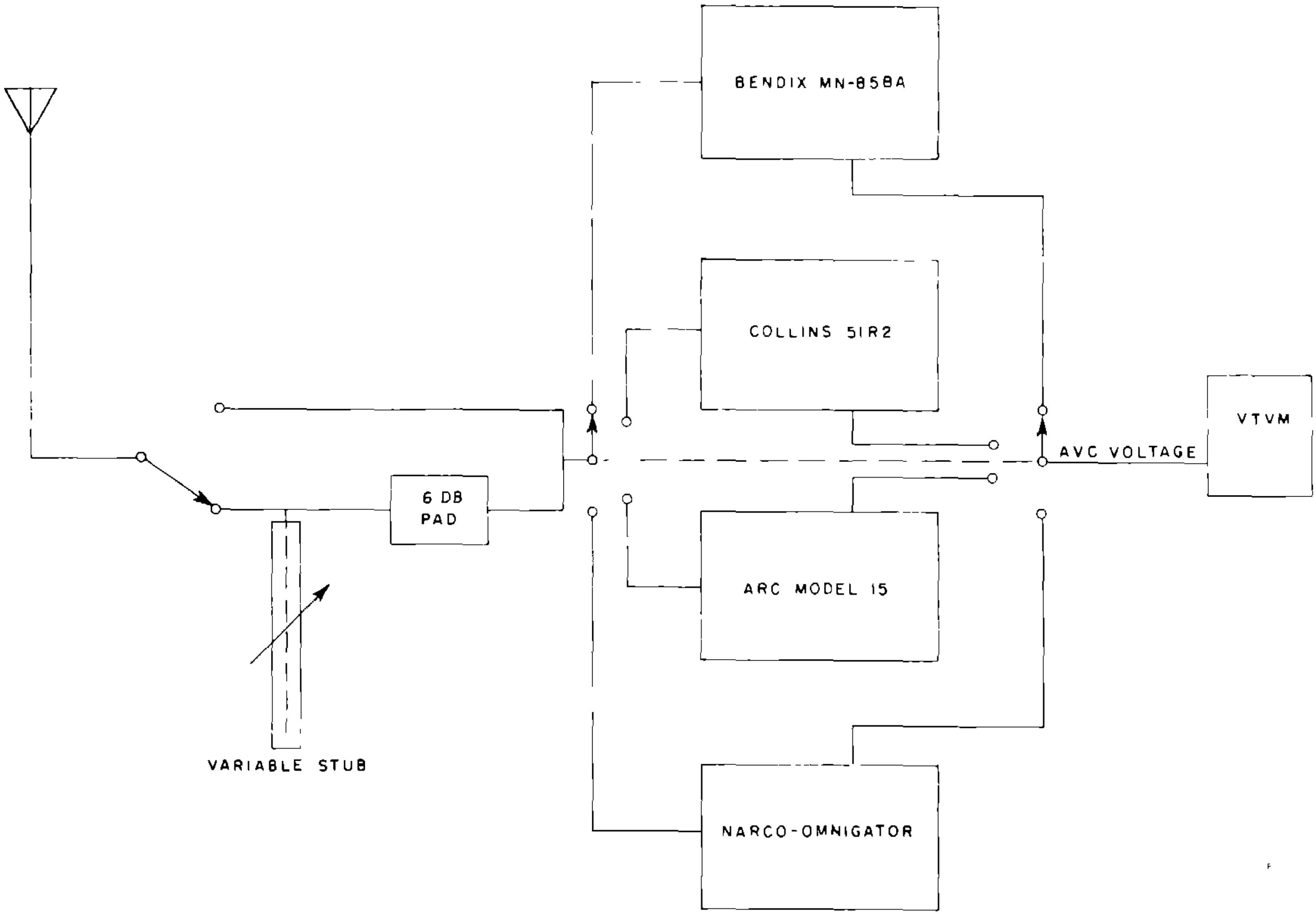

FIG I BLOCK SCHEMATIC DIAGRAM OF RECEIVER TEST SETUP AT TDEC

MARCH 20, 1953

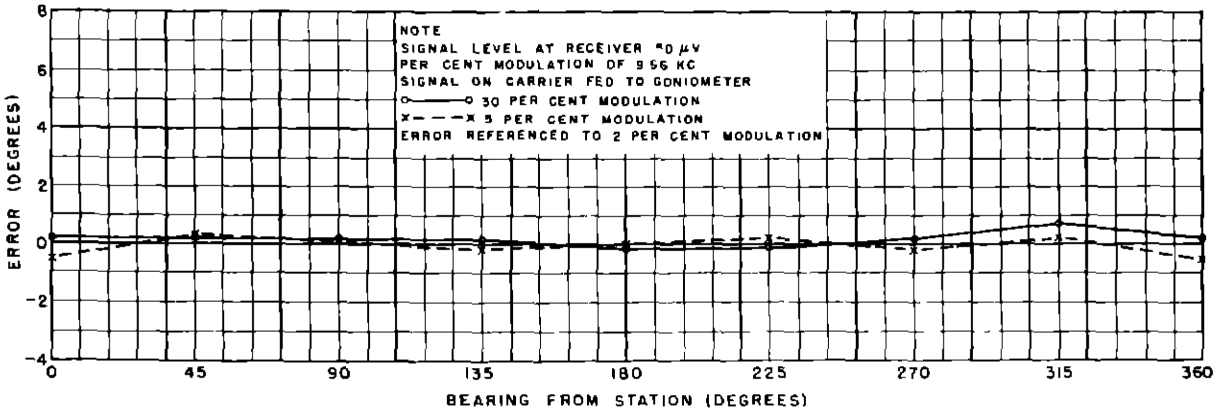

FIG 2 ERROR VS BEARING FROM STATION, COLLINS TYPE 51R2 RECEIVER

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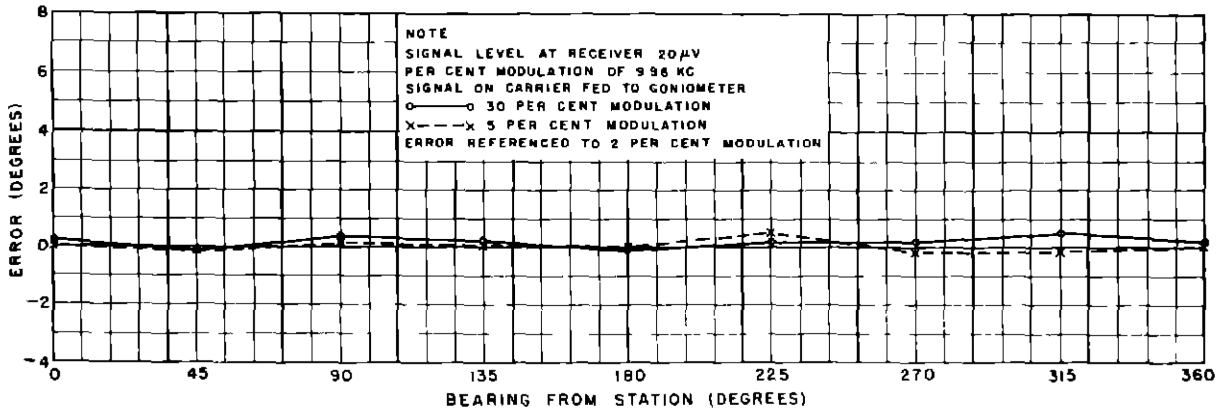

FIG 3 ERROR VS BEARING FROM STATION, COLLINS TYPE 51R2 RECEIVER

3/20/53

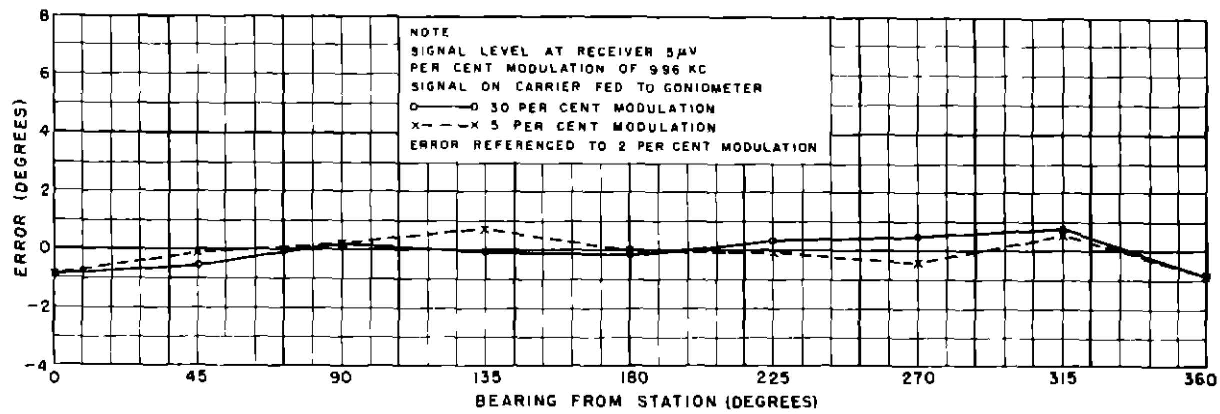

FIG 4 ERROR VS BEARING FROM STATION COLLINS TYPE 51R2 RECEIVER

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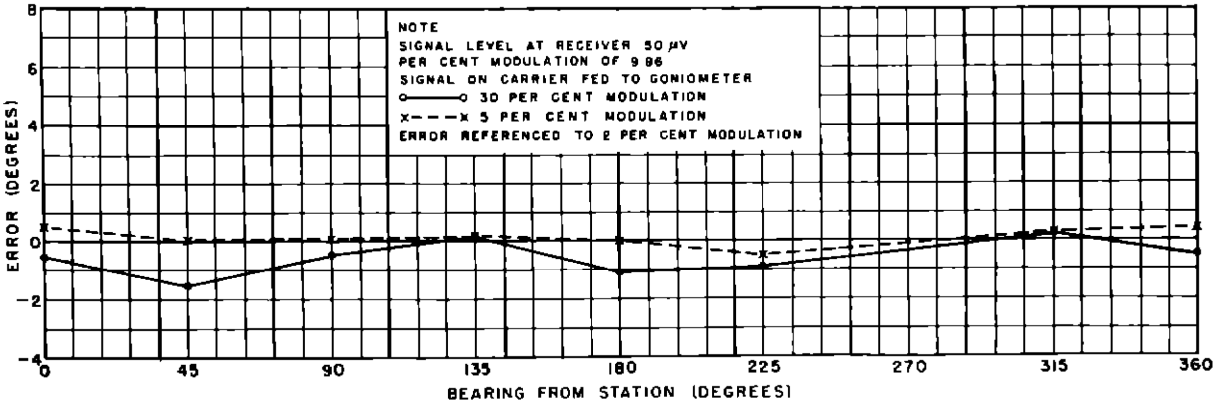

FIG 5 ERROR VS BEARING FROM STATION, BENDIX TYPE MN-85BA RECEIVER

3/20/53

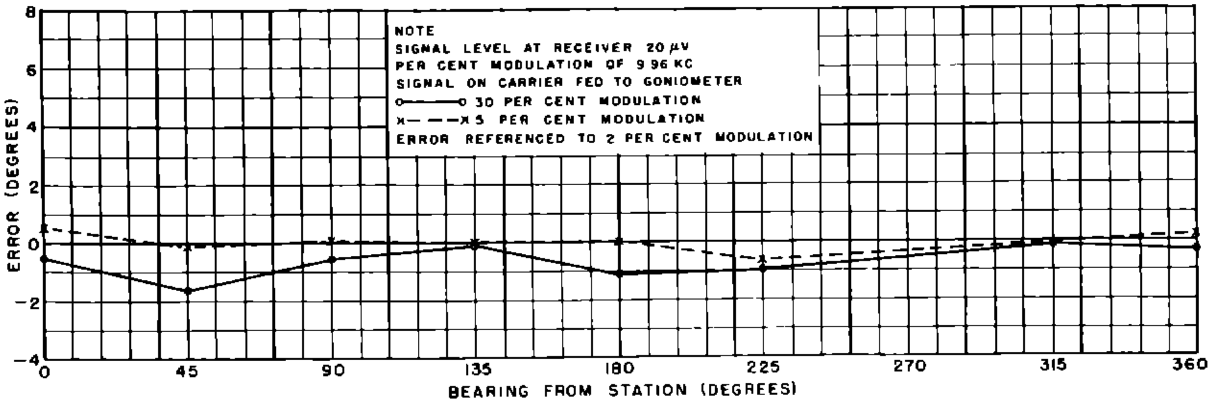

FIG 6 ERROR VS BEARING FROM STATION, BENDIX TYPE MN-85BA RECEIVER

3/20/53

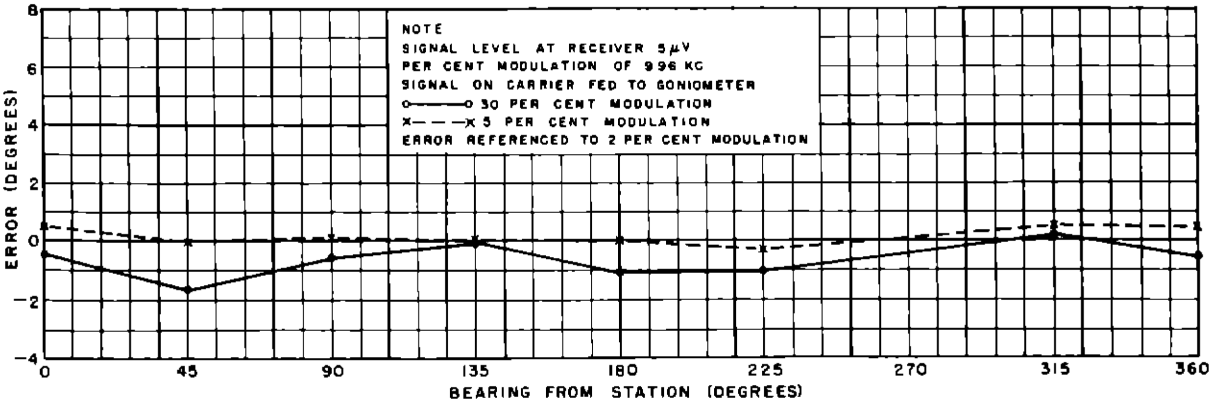

FIG 7 ERROR VS BEARING FROM STATION, BENDIX TYPE MN-85BA RECEIVER

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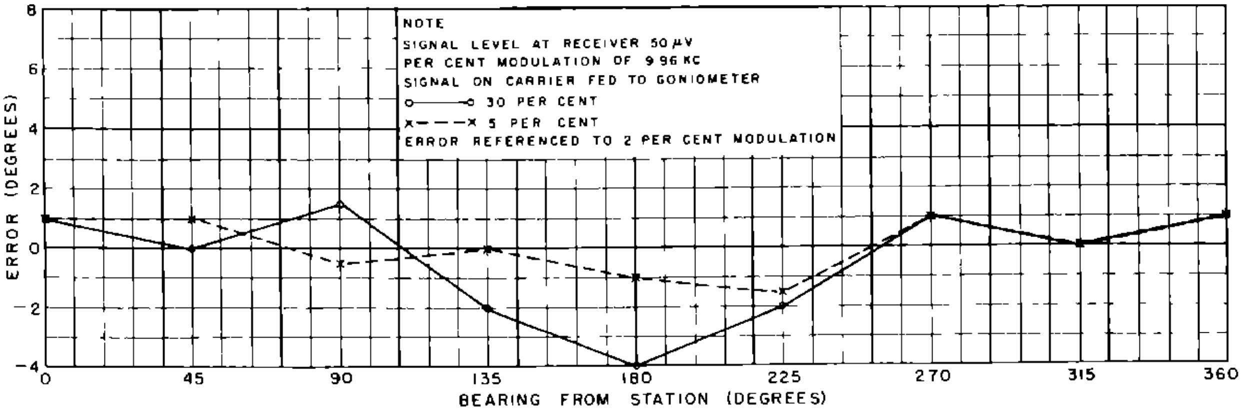

FIG 8 ERROR VS BEARING FROM STATION, ARC MODEL 15A RECEIVER

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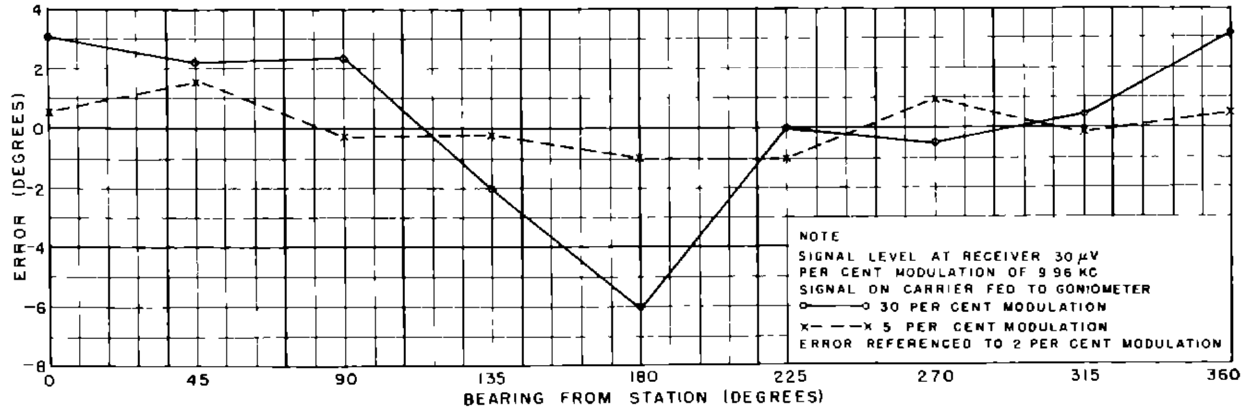

FIG 9 ERROR VS BEARING FROM STATION, ARC MODEL 15A RECEIVER

3/20/53

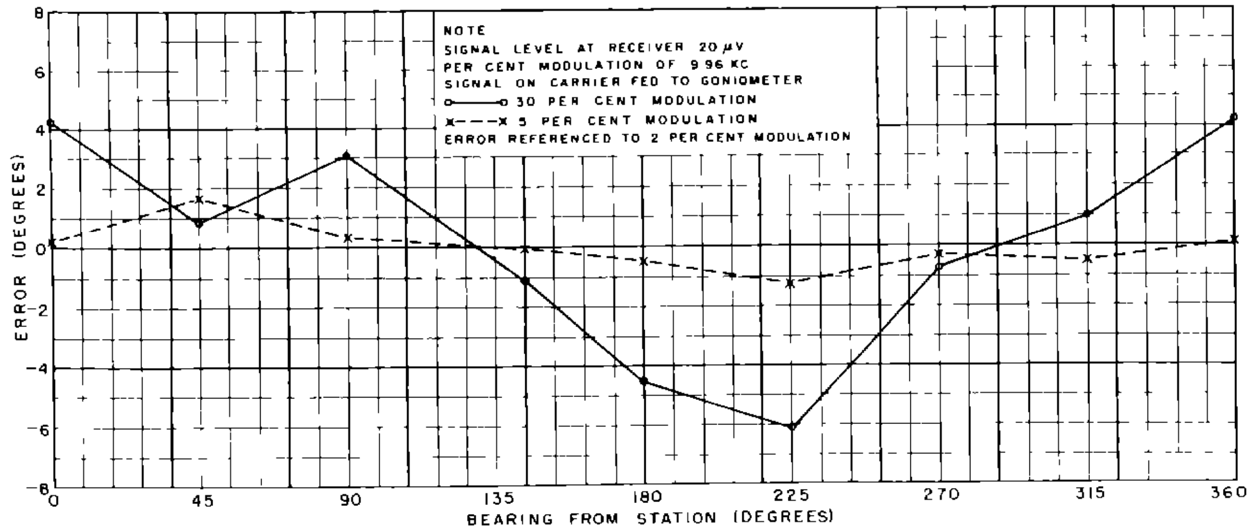

FIG 10 ERROR VS BEARING FROM STATION, ARC MODEL 15A RECEIVER

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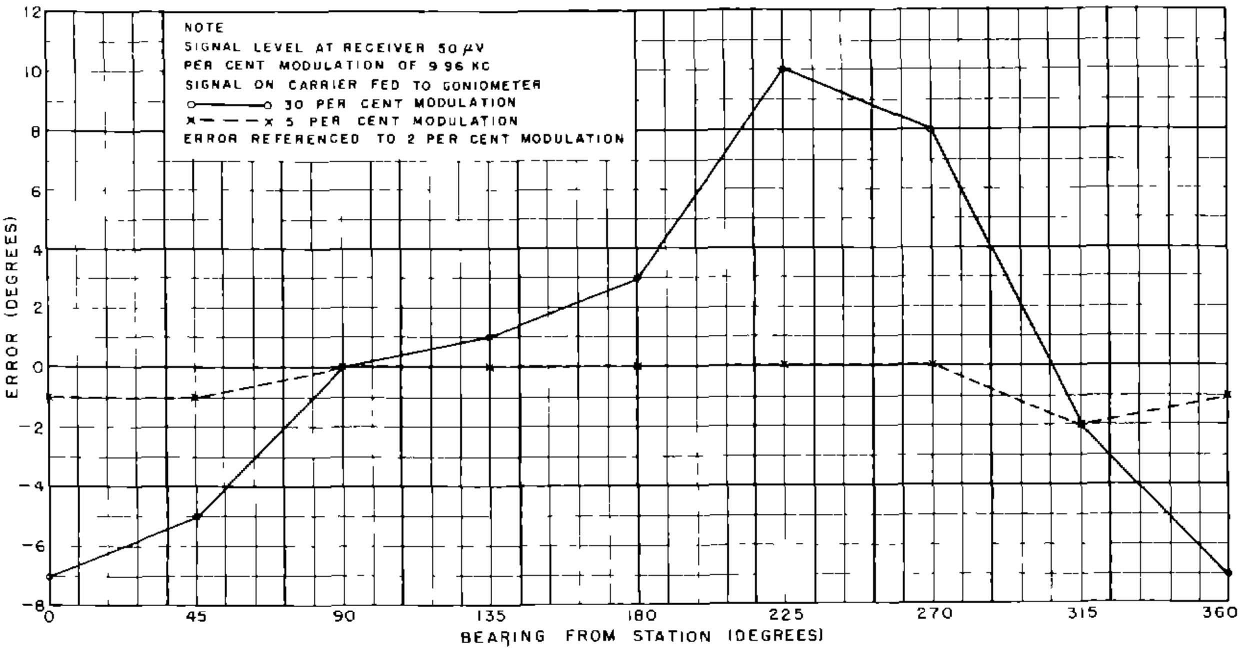

FIG 11 ERROR VS BEARING FROM STATION, NARCO-OMNIGATOR

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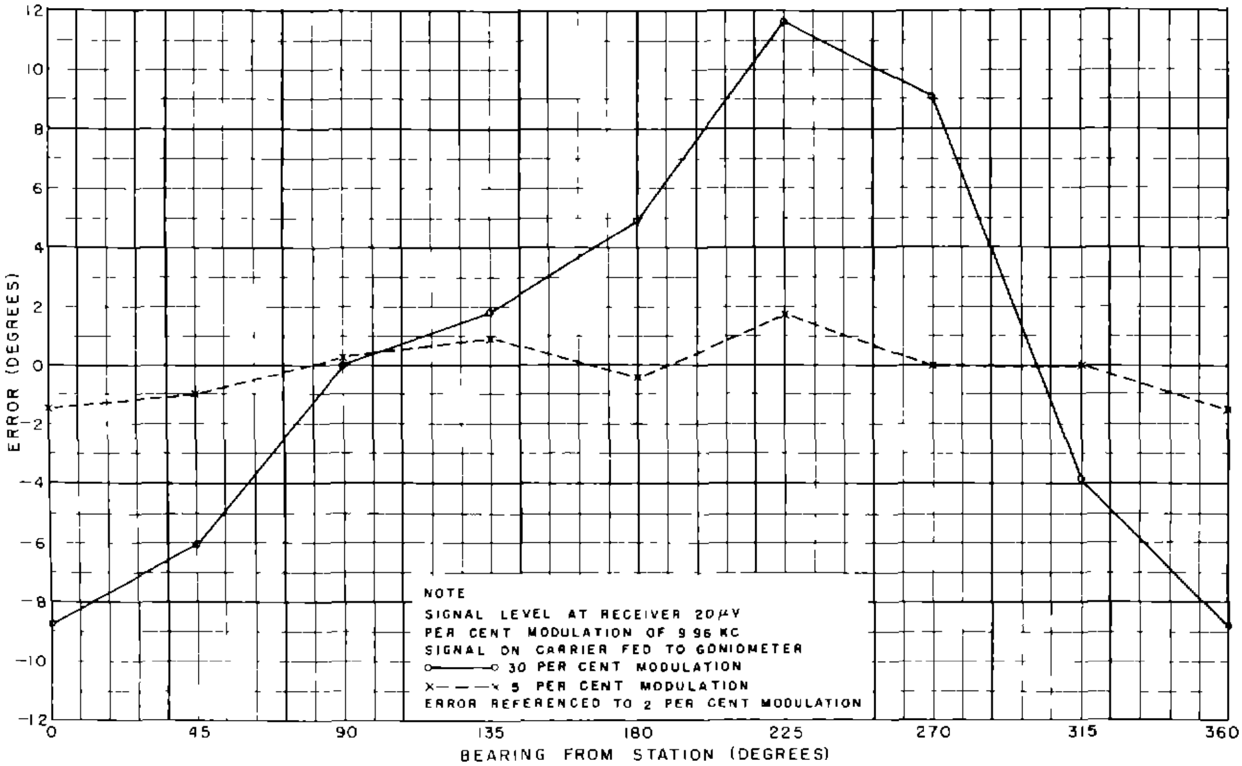

FIG 12 ERROR VS BEARING FROM STATION, NARCO-OMNIGATOR

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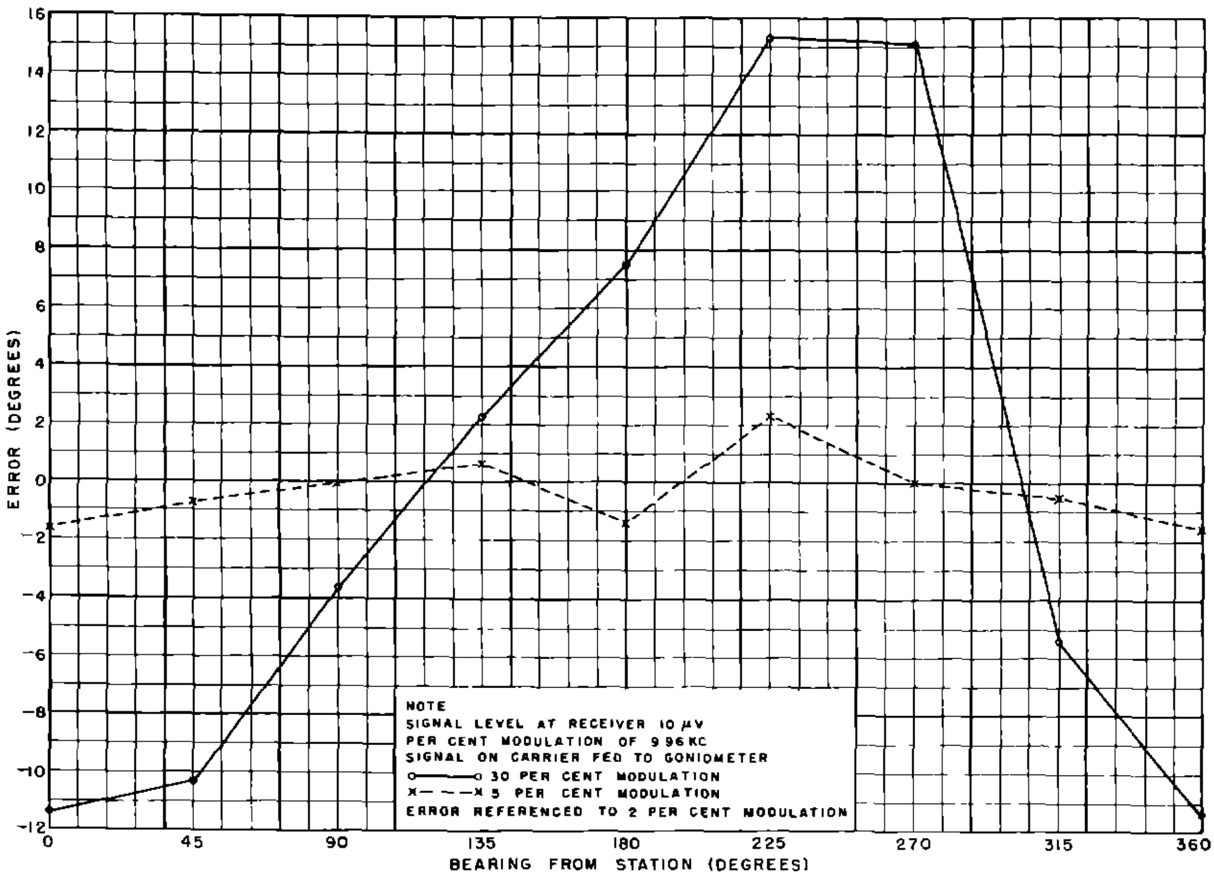

FIG 13 ERROR VS BEARING FROM STATION, NARCO-OMNIGATOR

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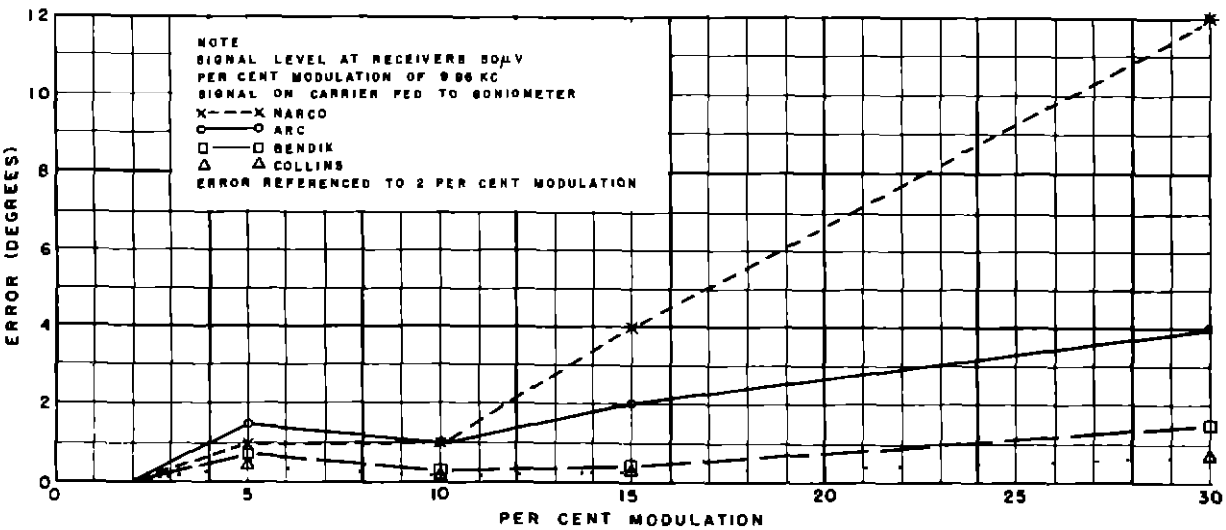

FIG 14 MAXIMUM ERROR VS PER CENT MODULATION

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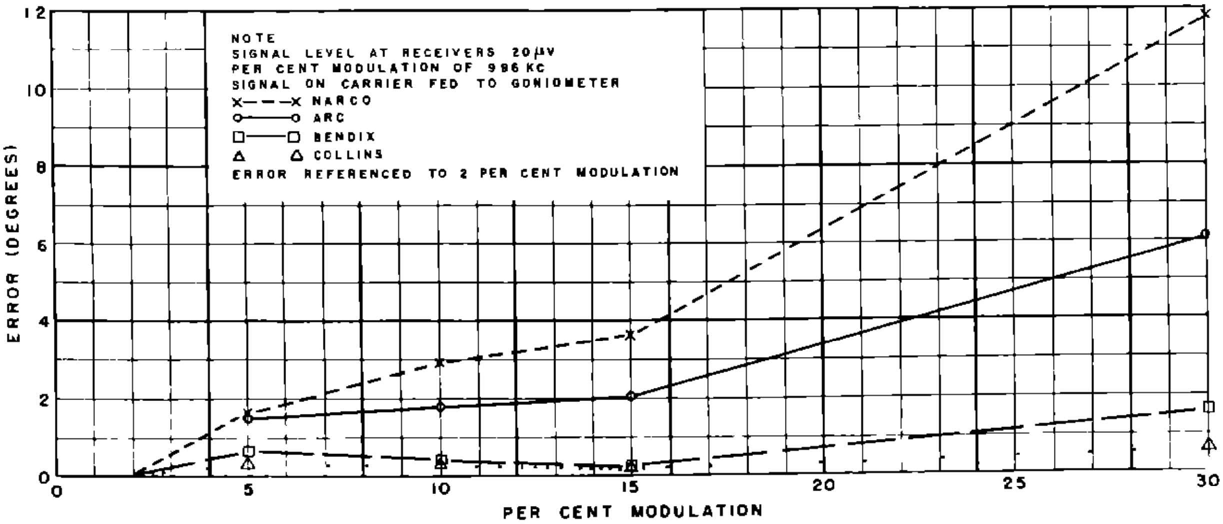

FIG 15 MAXIMUM ERROR VS PER CENT MODULATION

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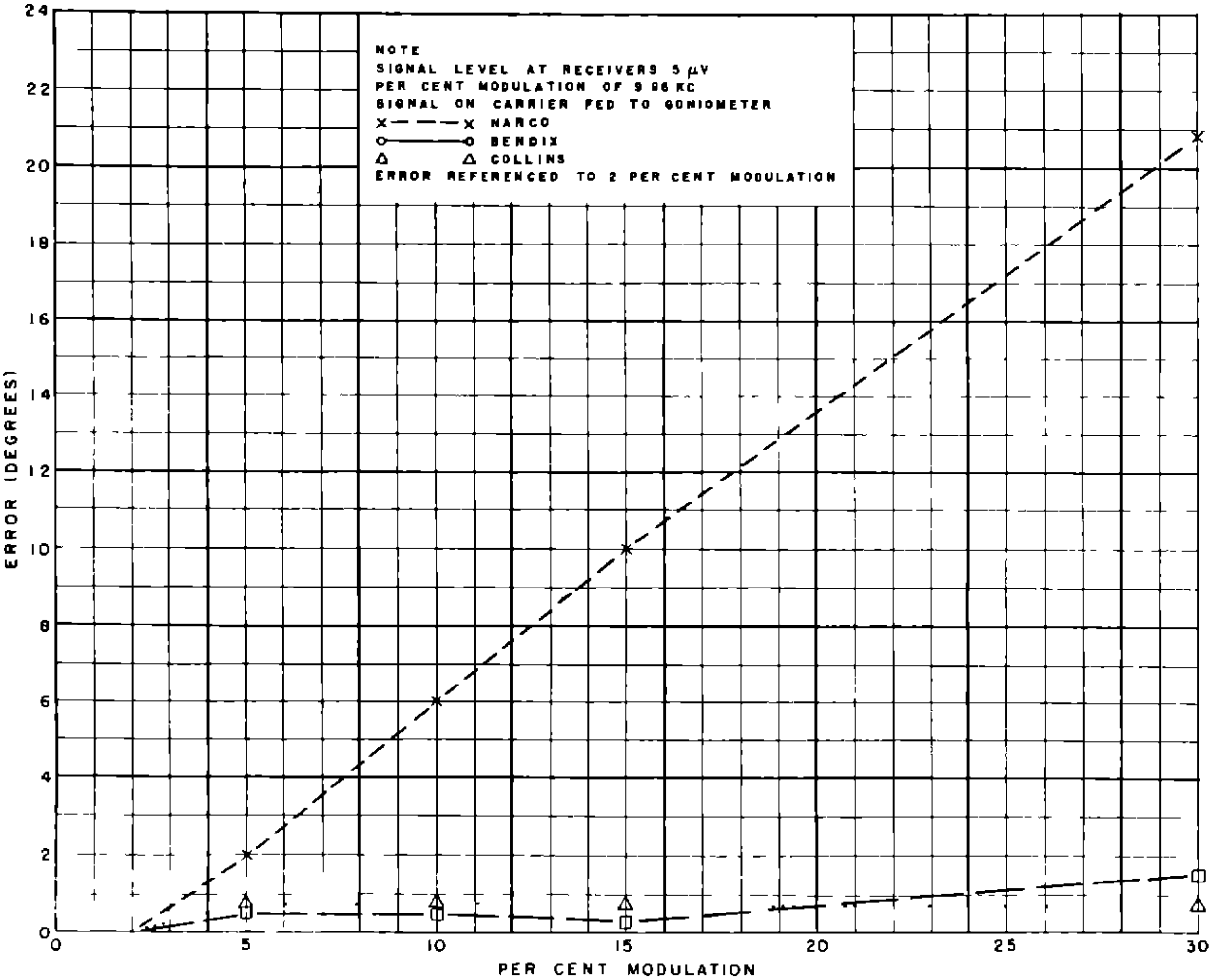

FIG 16 MAXIMUM ERROR VS PER CENT MODULATION

3/20/53

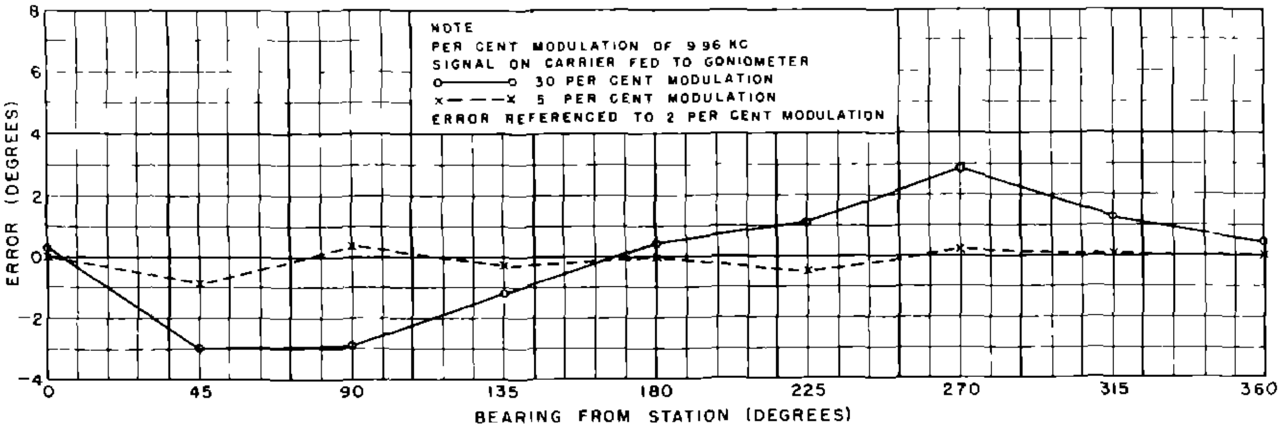

FIG 17 ERROR VS BEARING FROM STATION
STATION MONITOR—HOFFMAN

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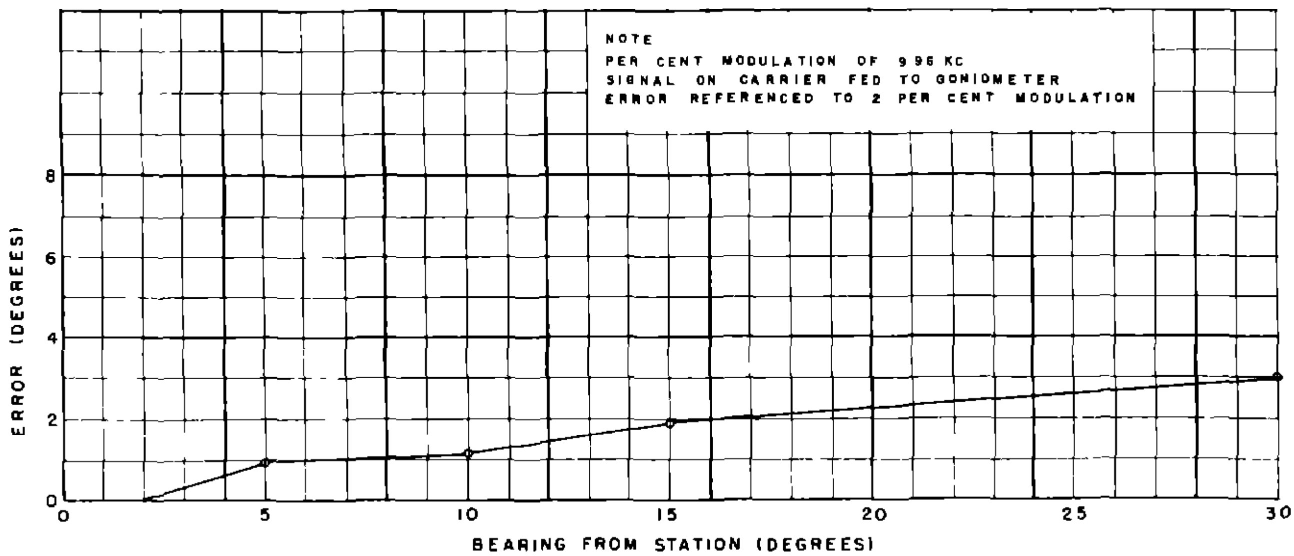

FIG 18 MAXIMUM ERROR VS PER CENT MODULATION
STATION MONITOR — HOFFMAN

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