THE PHASE COMPARISON LOCALIZER

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TABLE OF CONTENTS

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SUMMARY

This report covers the development of the phase comparison localizer, first tested in August, 1945, at the CAA Technical Development and Evaluation Center, Indianapolis, Indiana In this system, the difference in phase between two voltages of the same frequency is measured rather than the difference in amplitude between two voltages of different frequencies as in the equisignal localizer The phase comparison system for localizers operates on a principle similar to that of the omnirange and uses identical transmitting equipment The same receiver is used for reception of both the phase comparison localizer and the VHF omnirange Stability of course-width and position is assured by taking energy for both the carrier loops and sideband loops from the plate circuit of the power amplifier stage Flight tests indicate that the courses of the localizer are clearly defined and sharp Clearance is excellent at all bearings from the localizer on either side of the two courses

INTRODUCTION

In 1938, the first instrument landing system was installed at Indianapolis, Indiana One of the essential components of the instrument landing system (ILS) is the localizer which provides lateral guidance for an aircraft approaching a runway Present localizers, of which there are now approximately 100 installations in the United States and about 40 in other parts of the world, are of the familiar equisignal, or amplitude comparison, type

After a careful study of the phase comparison principles used in the omnirange, and early in the development of the range, it was decided by the Office of Technical Development that the same principles might be applied to the ILS localizer and certain advantages gained thereby These are, (1) use of a common receiver for both VHF omnirange and ILS localizer navigation, eliminating the need for a 90 - 150 cps filter-rectifier unit, and (2) simplification of transmitting equipment by using essentially the same components and requiring the same type of maintenance as in the omnirange

The purpose of this report is to describe the phase comparison localizer and to point out some of its advantages over the equisignal type

THE EQUISIGNAL LOCALIZER

Before proceeding with a discussion of the phase comparison localizer, we shall review briefly the operation of the 90 - 150 cps equisignal localizer presently in use

In the equisignal localizer, the course is defined by the intersection of two highly directive overlapping field patterns The overlapping, or equisignal zone, is aligned with the runway Referring to Fig 1, the CAA localizer antenna consists of a broadside array of eight loops, the two central loops, CL and CR, radiate carrier signals modulated at both 90 and 150 cps (and incidentally at 1,020 cps and voice for station identification) The remaining six loops, 1SL, 2SL, 3SL, 1SR, 2SR, and 3SR, radiate 90 and 150 cps sideband signals only.

The radiated field patterns of (A) the carrier loops, (B) the sideband loops, and (C) the resultant pattern are illustrated in Figs 2A, 2B, and 2C It will be noted, Fig 2B, that the radiation from the sideband loops is zero along the line of the course, and that the 90 and 150 cps major lobes of the sideband antenna pattern are opposite in phase with respect to each other Phase relationship between the sidebands from the two groups of antennas is such that 150-cps energy predominates on the right when facing the antenna system from the runway The relative sideband currents in the four pairs of sideband antennas are indicated in Fig 1

The received signals are detected in a superheterodyne receiver shown diagrammatically in Fig 3 The 90 and 150 cps components of the received signal are separated by means of bandpass filters The outputs of the filters are rectified and the difference in

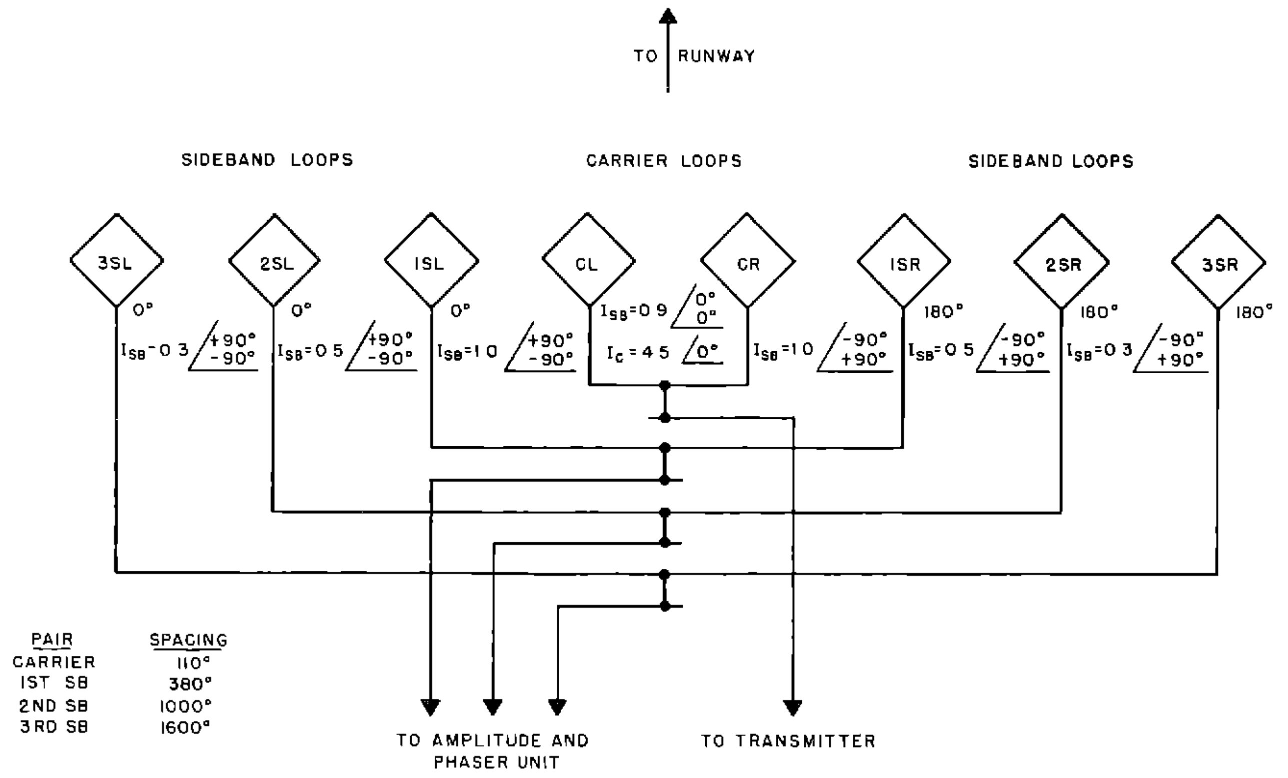


Fig. 1 Standard CAA Localizer Antenna Array

voltage is indicated on a zero-center instrument [1]

THE PHASE COMPARISON LOCALIZER

To convert the equisignal localizer to phase comparison operation, it is necessary to radiate an essentially non-directive modulated carrier from the carrier loops CL and CR, Fig 2A This comprises the "reference phase" signal since it is radiated without phase change due to direction of transmission The "variable phase" signal is comprised of sideband energy only, radiated from the sideband loops, Fig 2B. In space, the carrier and sidebands combine to produce a modulated signal, the modulation frequency components of which are in either 0° or 180° phase with respect to each other, by virtue of the inherent 180° phase displacement between the two major lobes of the sideband field pattern, Fig 2C The localizer course is defined and fixed by the null of the sideband space pattern along the line of phase change from 0° to 180° The same antenna array may be used for either the equisignal or phase comparison localizer With a given antenna assembly, the pattern shapes are the same for both localizers

In order that the reference and variable phase signals may be conveniently separated in the receiver without cross-modulation between these two channels, the reference phase voltage is superimposed on a subcarrier of 10 kc by frequency modulation The frequency modulated subcarrier in turn modulates the rf carrier radiated by the carrier loops

Fig 4A is a block diagram of the equisignal localizer equipment, and Fig 4B is a block diagram of the first phase comparison localizer converted from equisignal operation at the Technical Development and Evaluation Center in August, 1945 It will be observed that the 90 - 150 cps motor-alternator set, Fig 4A, was dis-

[1] For a more thorough description of the localizer, the reader is referred to "The CAA Instrument Landing System," by P Caporale, published in "Electronics" February and March, 1945

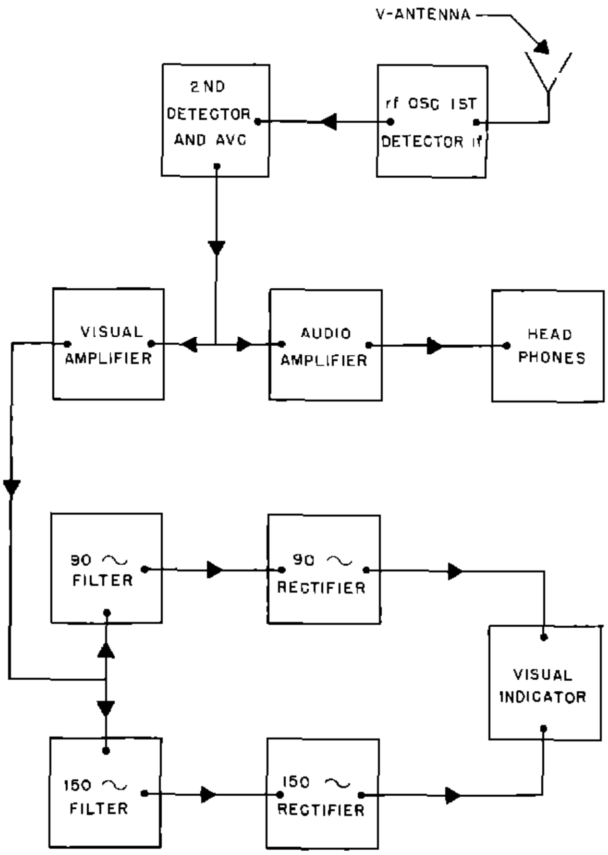


Fig 3 Equisignal Localizer Receiver

connected and that the hybrid unit (no longer necessary as such) served as a power transformer A 10 kc FM subcarrier generator was added The modulating voltage at 60 cps was derived from the commercial power mains The frequency deviation ratio was set at eight and the subcarrier level was adjusted to modulate the rf carrier at approximately 30 per cent The voice modulation level also was set to an average value of 30 per cent The entire process of conversion was accomplished in a little over one hour

For reception, a Type RC-103 receiver, with certain modifications, was used The receiver modifications consisted of removing the 90 - 150 cps bandpass filters and rectifiers, substituting a 10 kc FM demodulator and installing a wattmeter indicator circuit

Referring to Fig 5, the indicator circuit operates as follows When the receiver is located to the left of the course, position A, the voltage across rectifier X_1 is equal to the sum of Ev and Er Hence, I_1 is greater than I_2, and the instrument pointer deflects to the right When the receiver is on the right side of the course, position B, I_1 is less than I_2, since the voltage across rectifier X_1 now is the difference between Ev and Er, and the instrument pointer deflects to the left When the receiver is on course, position C, Er is zero and I_1 is equal to I_2 The voltages appearing across the rectifiers are equal and opposite, hence the resultant current through the indicating instrument is zero and the pointer indicates "on course"

The receiving equipment was installed in airplane NC-11, a Boeing 247D, and connected to a tail V receiving antenna In this form, the new type localizer was first demonstrated to the delegates of PICAO (Provisional International Civil Aviation Organization), during the CAA demonstrations of radio aids to air navigation in October, 1946

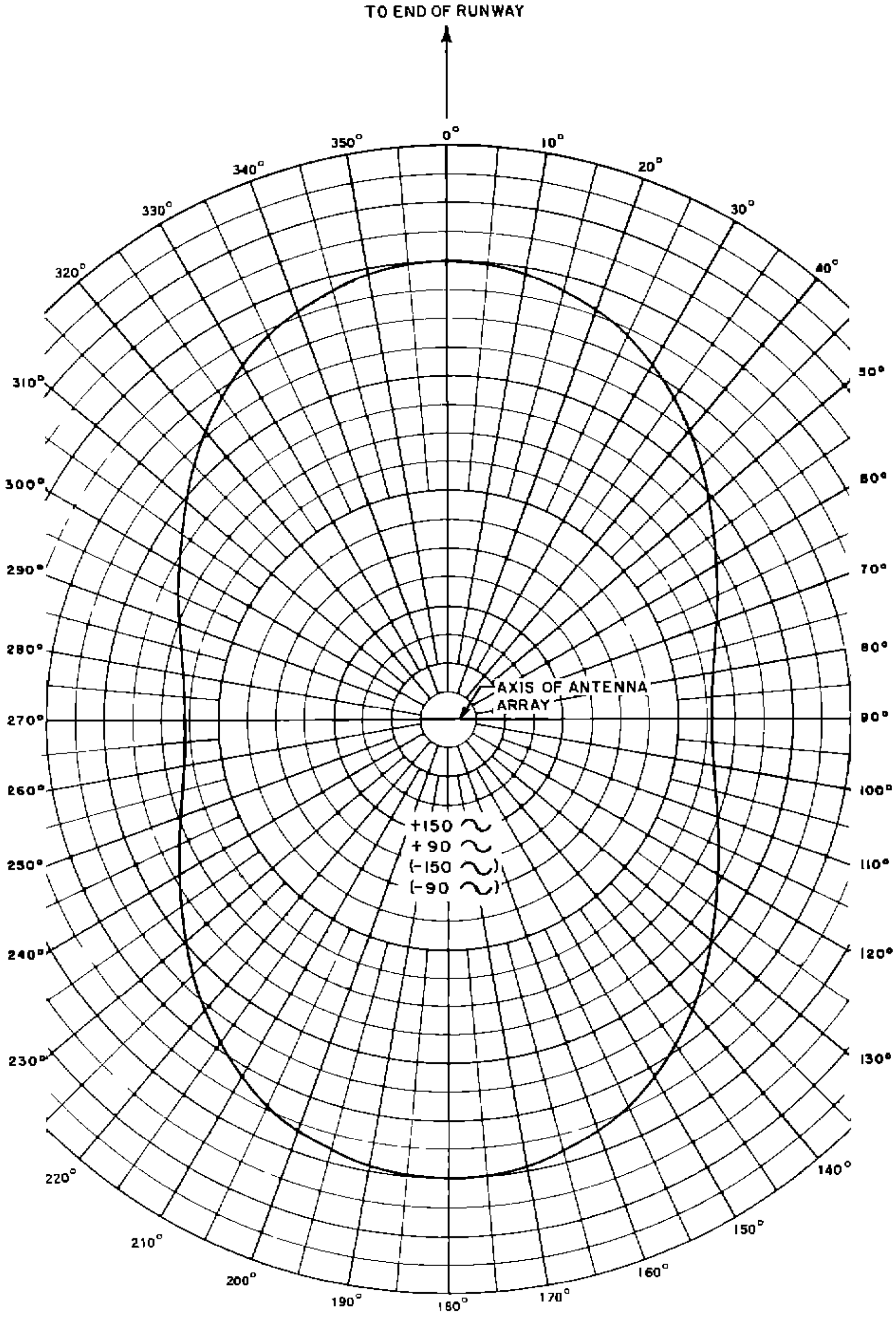
Soon after the PICAO demonstrations, the modulation frequency of the omnirange and phase comparison localizer was changed from 60-cps to 30-cps in order to minimize the effects of propeller modulation[2] on the airborne equipment A further simplification of the ground equipment was made at this time The electronic sideband generator was replaced by a 30-cps capacity type goniometer of the type used in the omnirange[3] The hybrid unit, which had merely been used as a transformer to supply 60-cps voltage to the screens and plates of the tubes used in the sideband generator, was no longer needed and was discarded

A synchronous motor was used to drive the goniometer which was mounted on a shaft common to the motor, goniometer, and a frequency modulated tone wheel The mean frequency of the tone wheel was 9,960-cps, modulated plus and minus 480-cps at a modulation frequency of 30-cps The frequency modulated tone wheel was used to replace the 60-cps frequency modulated oscillator previously used

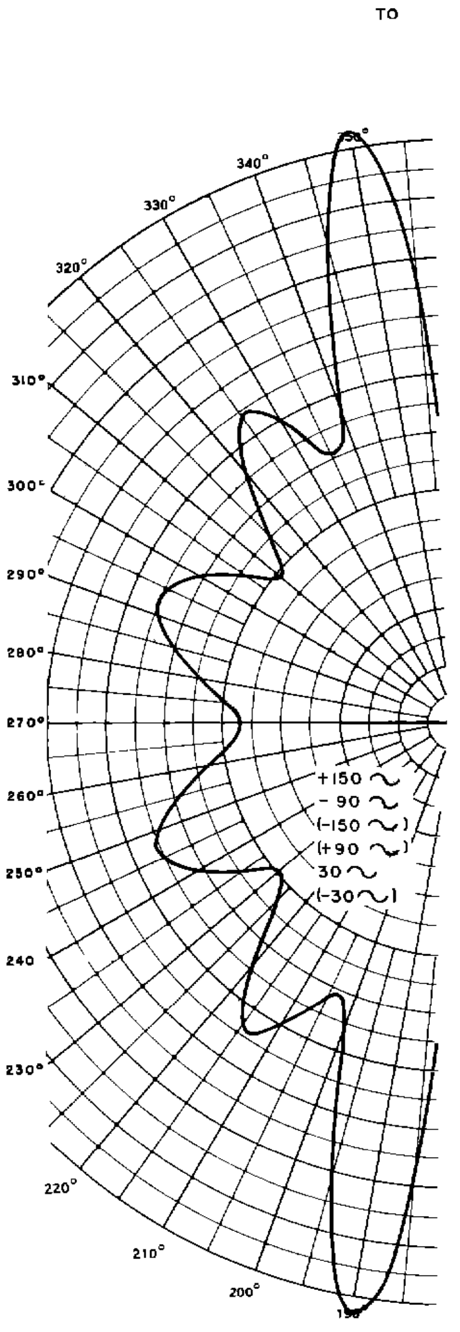
When the goniometer was first installed, input power was derived from the plate cir-

[2] H C Hurley, S R Anderson and H F Keary, "The CAA VHF Omnirange," Technical Development Report No 113, June 1950

[3] See footnote 2

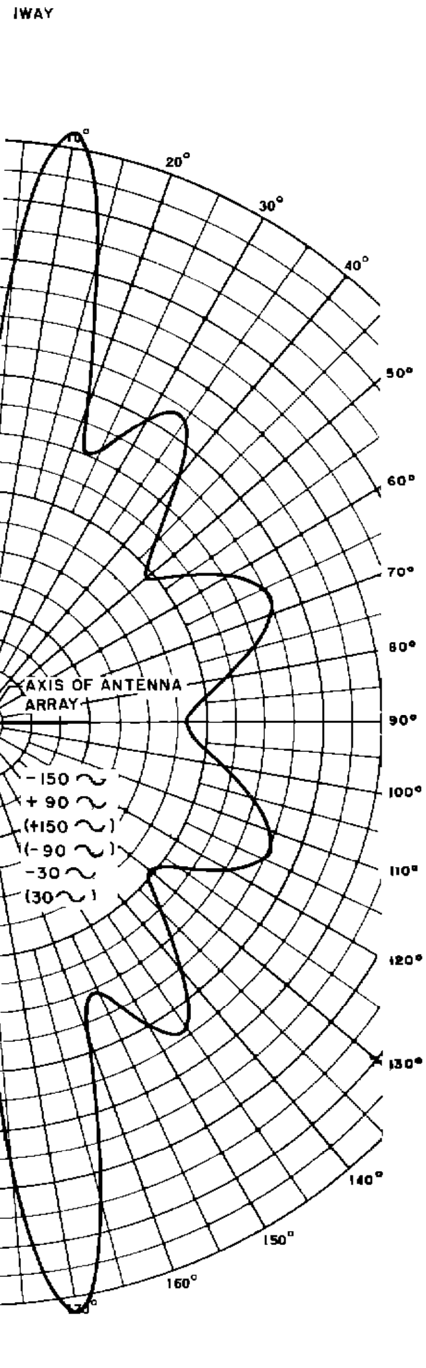


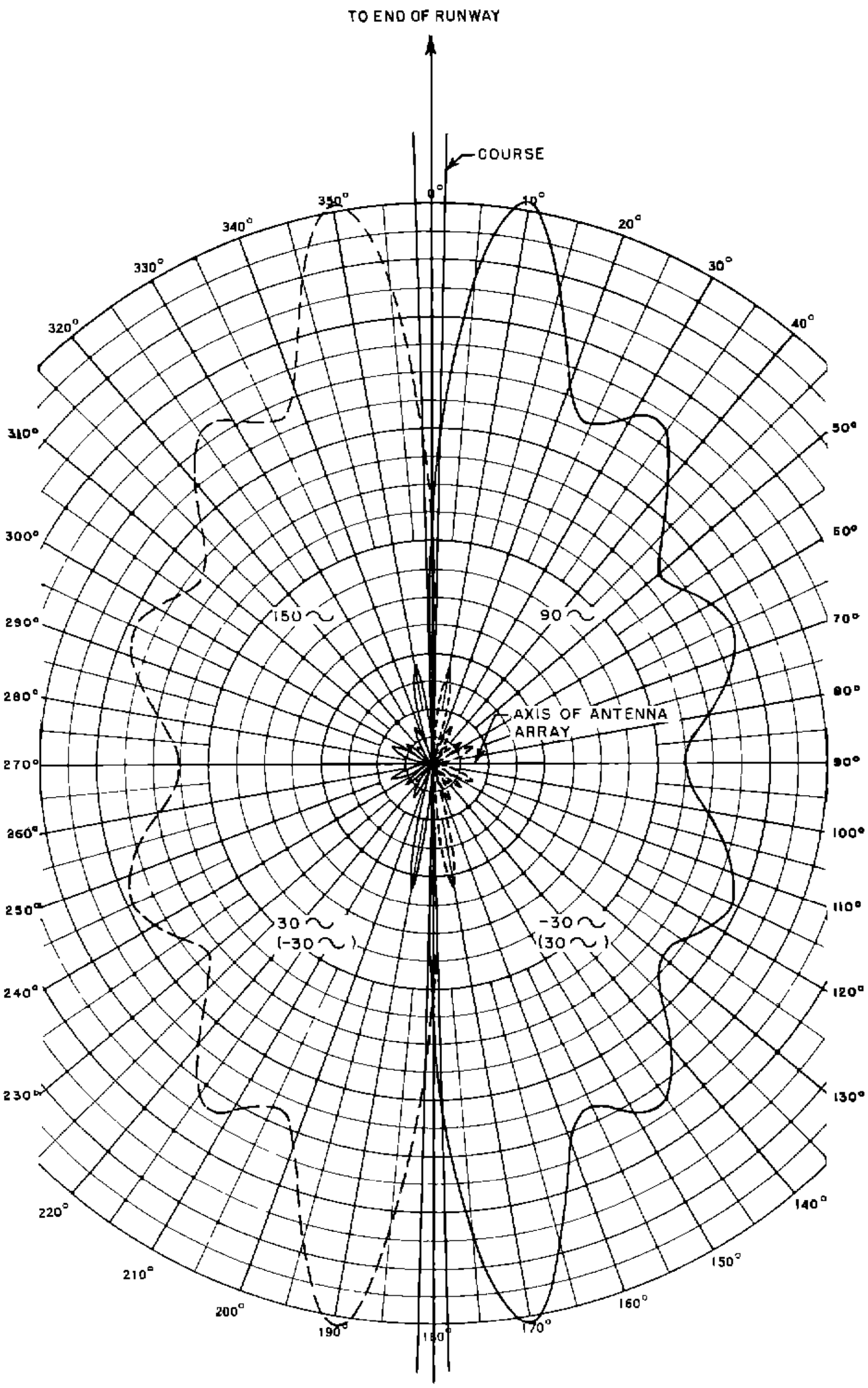
(A) CARRIER ANTENNA



(B) SI

Fig 2 Equisignal and Phase Comp





(C) SIDEBAND FIELD STRENGTH, ALL LOOPS EXCITED

on Localizer Field Strength Patterns

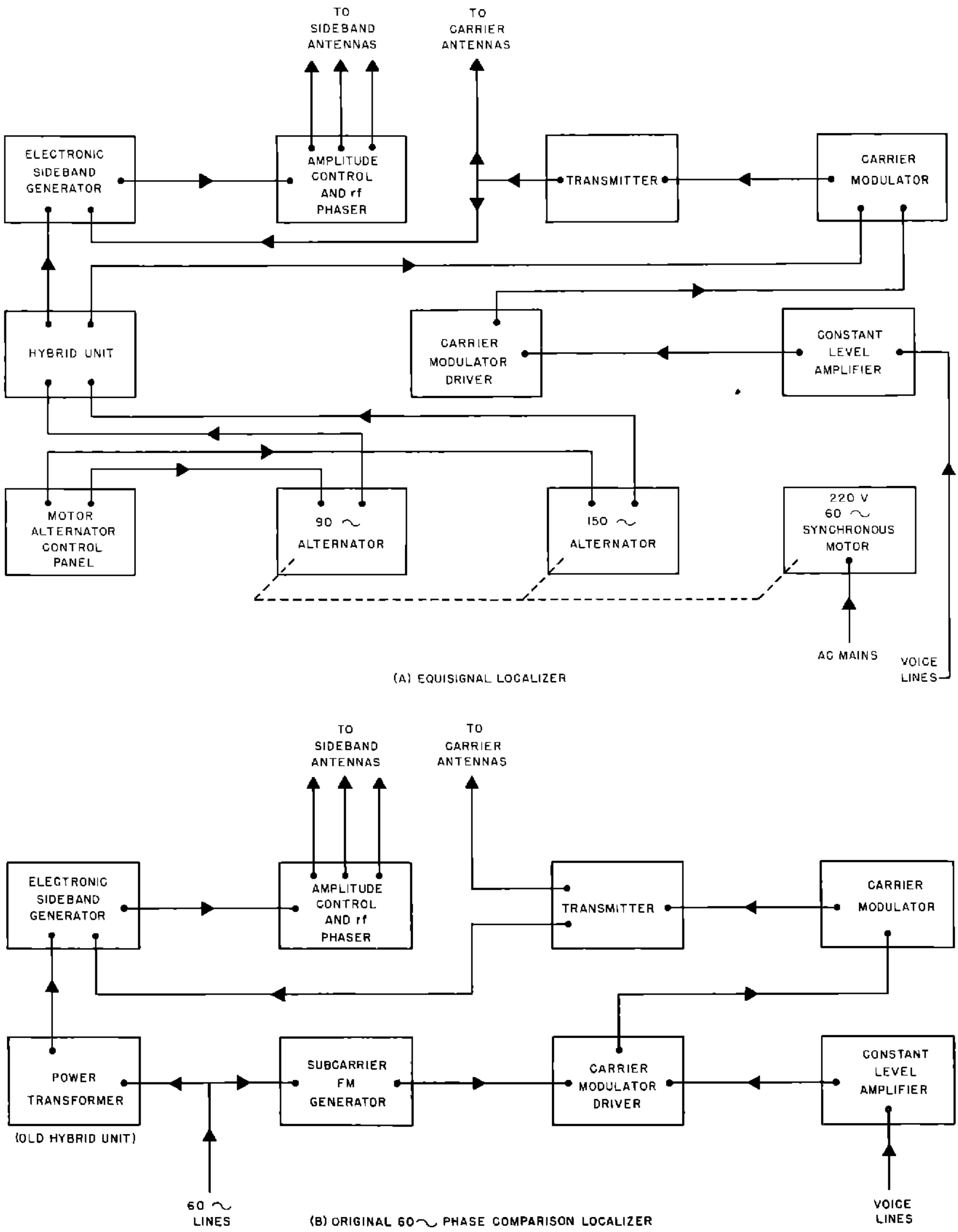
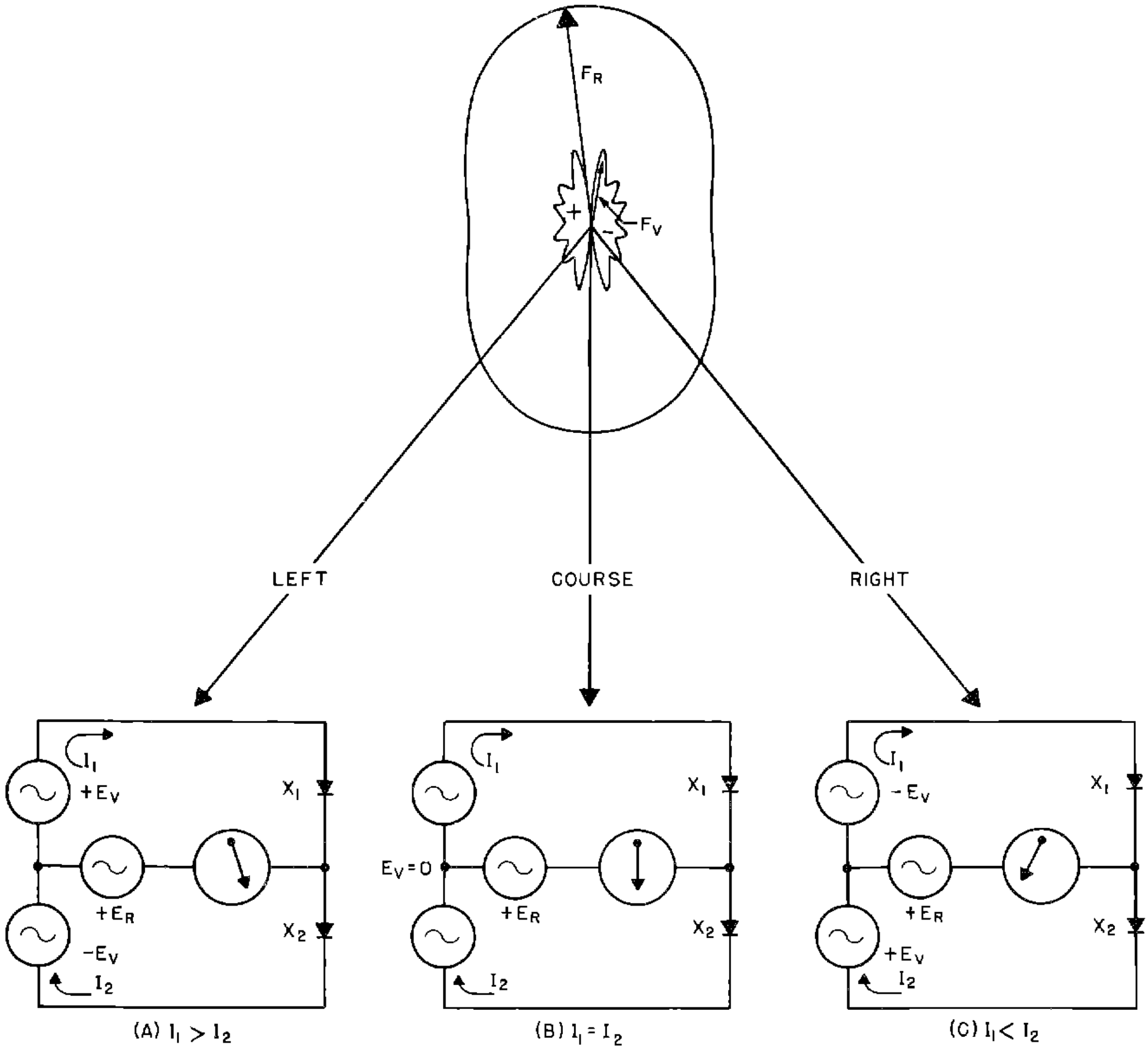


Fig 4 Localizer Ground Stations



F_R = FIELD INTENSITY OF REFERENCE PHASE

F_V = FIELD INTENSITY OF VARIABLE PHASE

E_R = REFERENCE PHASE VOLTAGE

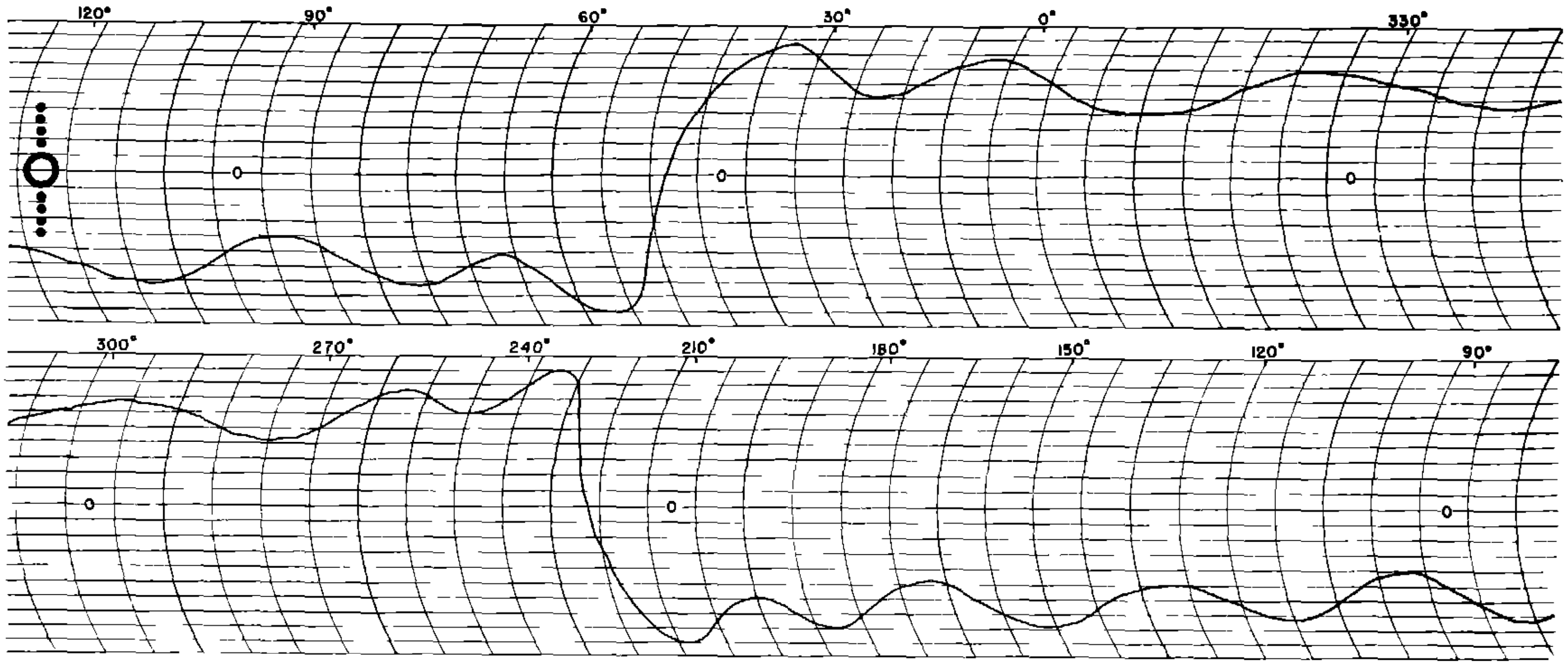
E_V = VARIABLE PHASE VOLTAGE

I_1 AND I_2 = DC COMPONENTS OF CIRCUIT CURRENTS PRODUCED BY $\pm E_V + E_R$,

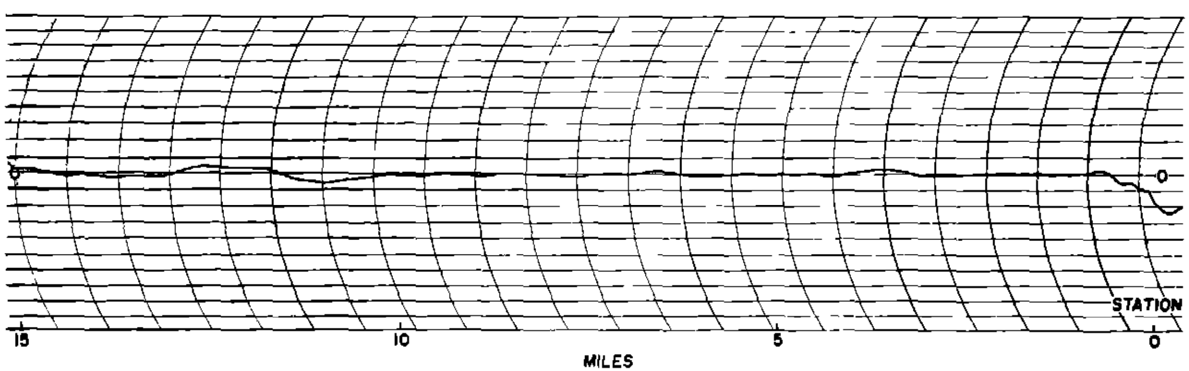
X_1 AND X_2 ARE SELENIUM RECTIFIER UNITS

Fig. 5 Operation of Indicator Circuit, Combined Omnirange and Phase Comparison Localizer Receiver

cuit of the power amplifier driver stage of the transmitter Later tests showed this method of obtaining rf power to be unsatisfactory Course-width variations and reversals of course-sensing, due to improper adjustment of tuning controls or failure of a transmitting tube, are definite possibilities when the goniometer is excited with rf energy taken from



RECORDING WHILE CIRCLING STATION AT A SIX MILE RADIUS, 1,000 FEET ABOVE THE GROUND AT 150 TO 160 MPH TAIL V RECEIVING ANTENNA USED ON DC 3 AIRCRAFT, NC 182, JAN 21, 1949



RECORDING OF LOW APPROACH TO STATION

Fig 6 Recording of Flight Test of Phase Comparison Localizer

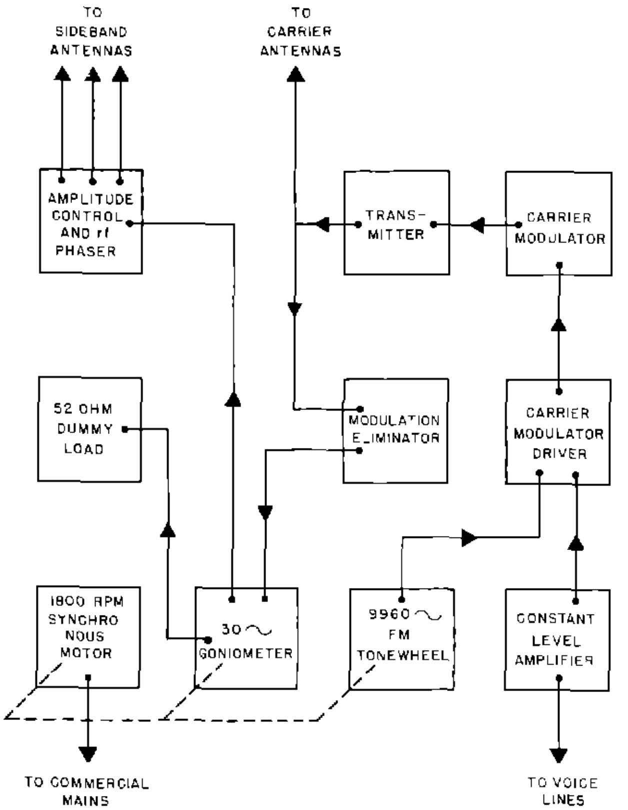


Fig. 7 Thirty Cycle Phase Comparison Localizer

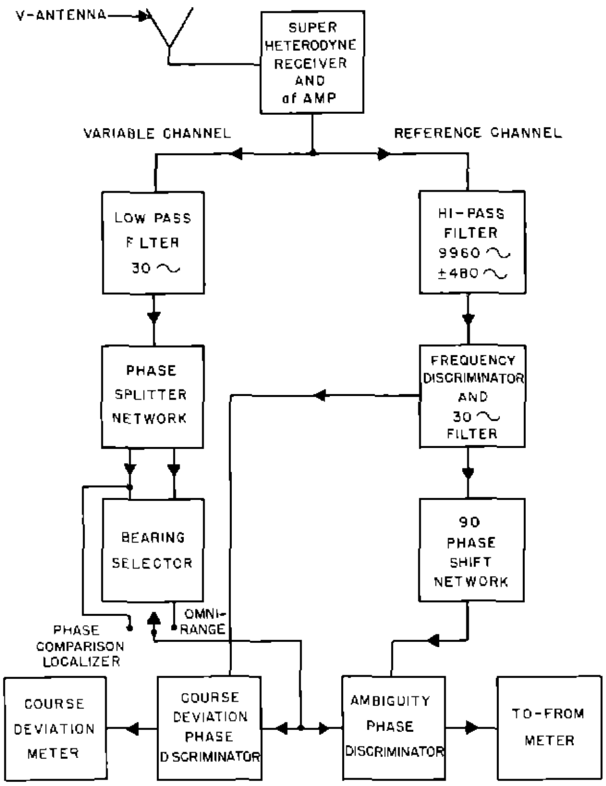


Fig. 8 Combined Omnirange and Phase Comparison Localizer Receiver

either the plate circuit of the driver stage or the grid circuit of the power amplifier stage of the transmitter These possibilities may be avoided by taking rf energy for the goniometer from the plate circuit of the power amplifier stage When this method of supplying energy to the goniometer is used, a means of removing the modulation from this energy must be provided. This is accomplished by using a modulation eliminator similar to that provided in the omnirange[4]

TEST RESULTS

A recording, reproduced in Fig 6, was made with the components of the ground station of the phase comparison localizer arranged as shown in Fig 7 The receiving equipment shown diagrammatically in Fig 8, was designed for reception of both the omnirange and the phase comparison localizer In making the aforementioned recording, the airplane circled the station at a distance of ten miles and at an altitude of 1,000 feet above ground It will be noted that the change in direction of deflection of the crosspointer meter was smooth as the aircraft flew across the two courses, moreover, at no point on either side of the courses was the deflection of the crosspointer meter less than full scale This indicates that the clearance was excellent in all directions from the station It should be mentioned that the equisignal type localizer, formerly installed at the same site and using the same antenna system, gave clearance values about 20 per cent lower in any given direction from the station when adjusted to the normal course-width of 5° Exhaustive flight tests over a period of nearly four years have shown the course is exceptionally straight and easy to fly

A chart of course deviation based on readings taken at irregular intervals over a period of six months is shown in Fig 9 The known wide limits between which modulation

[4]See footnote 2

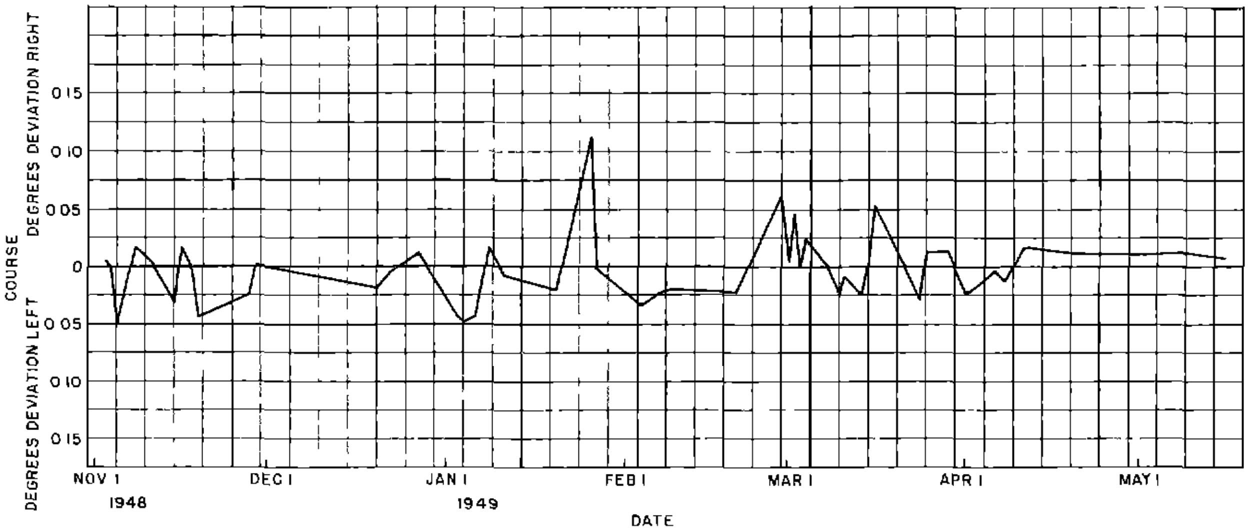


Fig. 9 Course Stability of Phase Comparison Localizer

percentages and power output of the transmitter varied are not reflected in the chart On January 25, 1949, power to the monitor was interrupted for 16 hours The large deviation of course position indicated for January 26 is probably erroneous because only a short time was allowed for the monitor to stabilize before meter readings were recorded The monitor with which the data in Fig 9 was obtained had formerly been used at one of the VHF omnirange sites The pick-up head of the monitor was placed on-course Controls were then adjusted so that a deviation of one-quarter degree in either direction of the course position would cause full scale deflection of the indicating meter

CONCLUSIONS

Although the first consideration in developing the phase comparison localizer was to complement the omnirange and to simplify receiving equipment, a localizer superior to the equisignal type in several respects was developed

Because the course established by the phase comparison localizer is determined by the null of the antenna space pattern, variations in modulation amplitude do not alter its position In the case of the equisignal localizer, the relative amplitudes of the 90 and 150 cps modulating voltages directly affect the course position Variations in amplitude of either of the two modulating voltages will cause an appreciable shift in the course, likewise, any unbalance due to changes in characteristics of the 90 - 150 cps bandpass filters and the rectifiers used in the receiving equipment will cause an apparent shift of the localizer course Hence, the phase comparison localizer is inherently more stable than the equisignal localizer

An outstanding advantage of the phase comparison localizer lies in the simplification of the receiver The same receiver may be used for both omnirange and localizer facilities Further, the elimination of the balanced 90 - 150 cps filters results in a lower cost receiver and a reduction of about 5 lbs in weight

Tests have shown that the quality of voice transmission from the phase comparison localizer is greatly superior to that from an equisignal localizer The 9,960-cps FM modulation of the carrier and the 30-cps sideband energy are present in only a small quantity in the af channel of the receiver, whereas the 90 and 150 cps modulation, together with the sum and difference frequencies, add materially to the background noise when receiving voice from an equisignal localizer This effect is particularly noticeable when flying more than 5° to either side of the course

Of considerable significance is the fact that the transmitting equipment of the phase comparison localizer is common and interchangeable with that of the omnirange which simplifies procurement and maintenance of the facilities

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