VOR FLIGHT CALIBRATION WITH C45 AIRCRAFT

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SUMMARY

Flight calibration tests of VHF omniranges revealed the fact that results obtained in different types of aircraft were not in entire agreement The two most common aircraft in the use for calibrating omniranges are the Beechcraft C45 and the Douglas C47 It was observed that the results obtained in the Beechcraft C45 produced an error curve which indicated a greater over-all error when compared with the results obtained in a Douglas C47

This report deals with a problem encountered in the Beechcraft C45, in carrying out a precision measurement technique developed for a specific phase of the omnirange flight testing program

Attempts to improve the calibration characteristics of a C45 were unsuccessful until the fixed long wire 3105 kc antenna was removed After this antenna was removed, a dipole antenna placed on either the wing tip or on top of the fuselage above the pilot's compartment, produced calibration results substantially the same as those obtained in a C47

The final recommendations for antenna installation on a Beechcraft C45 include, (1) a dipole antenna on top of the fuselage over the pilot's compartment, (2) a V-109 antenna on top of the fuselage over the leading edge of the cabin entrance door, and (3) a trailing wire antenna, if desired, to be installed as far aft as possible

INTRODUCTION

The technique of calibrating an omnirange station has been in the process of development by engineers of Technical Development for a number of years This procedure was published as Technical Development Report No 69, entitled, "Flight Calibration of VHF Omnirange System"

Briefly, the method of calibrating a VOR consists of recording the movement of the course-deviation indicator in an aircraft as it circles the omnirange station at any radius from 7 to 15 miles The omnibearing selector is advanced in 10° steps to keep the course-deviation indicator on scale, and to present (at center scale) the indicated magnetic bearing from the station This indicated bearing is compared with magnetic bearing from the station, as measured by a theodolite operated on the ground at the omnirange station This process produces a series of exact differences between indicated and magnetic bearings, and these are obtained through the 360° around a range station These differences are plotted as a calibration or measured error curve

Following the development of the VOR flight calibration procedure, each of the CAA regions sent a flight inspection airplane, pilot and radio engineer to the Experimental Station at Indianapolis, Indiana, for a familiarization course and demonstration of VOR calibration Returning to their regions, a VOR flight calibration program was set in operation Two types of airplanes have been used in the flight calibration program They are the C45 Beechcraft and the Douglas C47 Later, reports were received that the calibration of a VOR station in two different types of aircraft produced two entirely different error curves In order to verify or disprove this claim, a thorough investigation of the problem was instigated

EQUIPMENT

Receiver

In order to eliminate as many variables as possible in this investigation, a complete ARC-15 omnirange receiver installation was set up in a portable case This unit could be transported from aircraft to aircraft during a series of flight tests and was completely self contained, with the exception of power source, antenna, and recording equipment The use of this portable unit eliminated the calibration differences which arise due to the individual characteristics of different receivers, course selectors, etc

Aircraft

Flight checks were made in the C45 Beechcraft and the C47 Douglas The flights in different airplanes were made in rapid succession One series of tests involving the two airplanes was completed as quickly as

possible, always in the same day, generally in four to six hours This increased control of the number of variables in the investigation

Antennas

Two separate C47 airplanes were used in these flight checks and in each case the antenna used was the V antenna located on the top of the vertical stabilizer On airplane NC-182 this is a type V-109 antenna On airplane NC-112 the antenna is a coaxial V antenna.

Since the investigation was the outgrowth of numerous individual reports of exaggerated error curves produced by calibrating in a C45, it was assumed the reports were well founded, and new antennas were constructed immediately to compare with the existing V antennas in the standard installation.

The ideal antenna for reception of omnirange information would be a dipole in free space properly oriented with respect to the range station In an attempt to reach this ideal condition two special antennas were constructed These antennas are of the dipole type The elements are constructed of three-eights inch tubing and are one-half wavelength at the mid-frequency of the omnirange band This balanced antenna is fed to an unbalanced transmission line by means of a quarter wave balun section mounted in the 18-inch pedestal One of these dipole antennas was mounted on the left wing tip of the Beechcraft, N-4, and the other mounted on a standard pedestal so that it could be interchanged with the hatch V antenna, normally mounted on the Beechcraft directly over the pilot's compartment This position on the Beechcraft corresponds to the position of the escape hatch on many airplanes including the C47 For the sake of simplicity, we shall refer to the position on top of the fuselage and directly over the pilot and co-pilot positions as the hatch position Thus, by referring to a Hatch V antenna, both type and location of antenna are denoted

A preliminary flight check with the dipole antenna proved that pushing and pulling did not exceed 1/2° when the antenna was oriented as much as 60° from a tangential position with respect to the omnirange Fig 1 is a view of the wing tip dipole antenna

FLIGHT CHECKS AT INDIANAPOLIS

Using the equipment described, the first series of flights consisted of four calibration circles around the Indianapolis omnirange The first two were made with the wing tip dipole and the hatch dipole in the Beechcraft C45. Upon landing after this flight, the receiving equipment was transferred to a Douglas C47 and one calibration circle made using a tail V antenna While this flight was in progress, the hatch dipole on the C45 was removed and the V antenna installed in its place At the conclusion of the flight in the C47, the receiving equipment was transferred back to the C45 and the fourth and final calibration circle was made using the C45 hatch V antenna These flights covered a 3-hour period

From previous experience, it was believed that the fixed long wire 3105 kc antenna was partially responsible for erratic calibration results in the Beechcraft The 3105 kc antenna consists of two wires in a V shape extending from the omnireceiving antenna, mounted on the hatch of the aircraft directly over the pilot's head, and extending to the top of each vertical stabilizer This antenna was removed for this series of flight tests The calibration conditions and results obtained are tabulated as follows

3105-kc Long Wire Antenna Removed From Beechcraft

Type of Aircraft	Antenna	Over-all Error Recorded (degrees)
C45	Wing tip Dipole	3 1/2
C45	Hatch Dipole	2 3/4
C45	Hatch V	4
C47	Tail V	3

The calibration results plotted in the form of error curves are presented in various combinations, in Figs 2, 3, 4, and 5.

FLIGHT CHECKS AT KANSAS CITY

The results of the flight checks at Indianapolis indicated that the maximum difference recorded in two types of planes in calibrating an omnirange, occurs at the rough points on the error curve In calibrating an omnirange which has little error and a fairly smooth error curve, small differences exist between the results obtained in a C45 Beechcraft and a Douglas C47

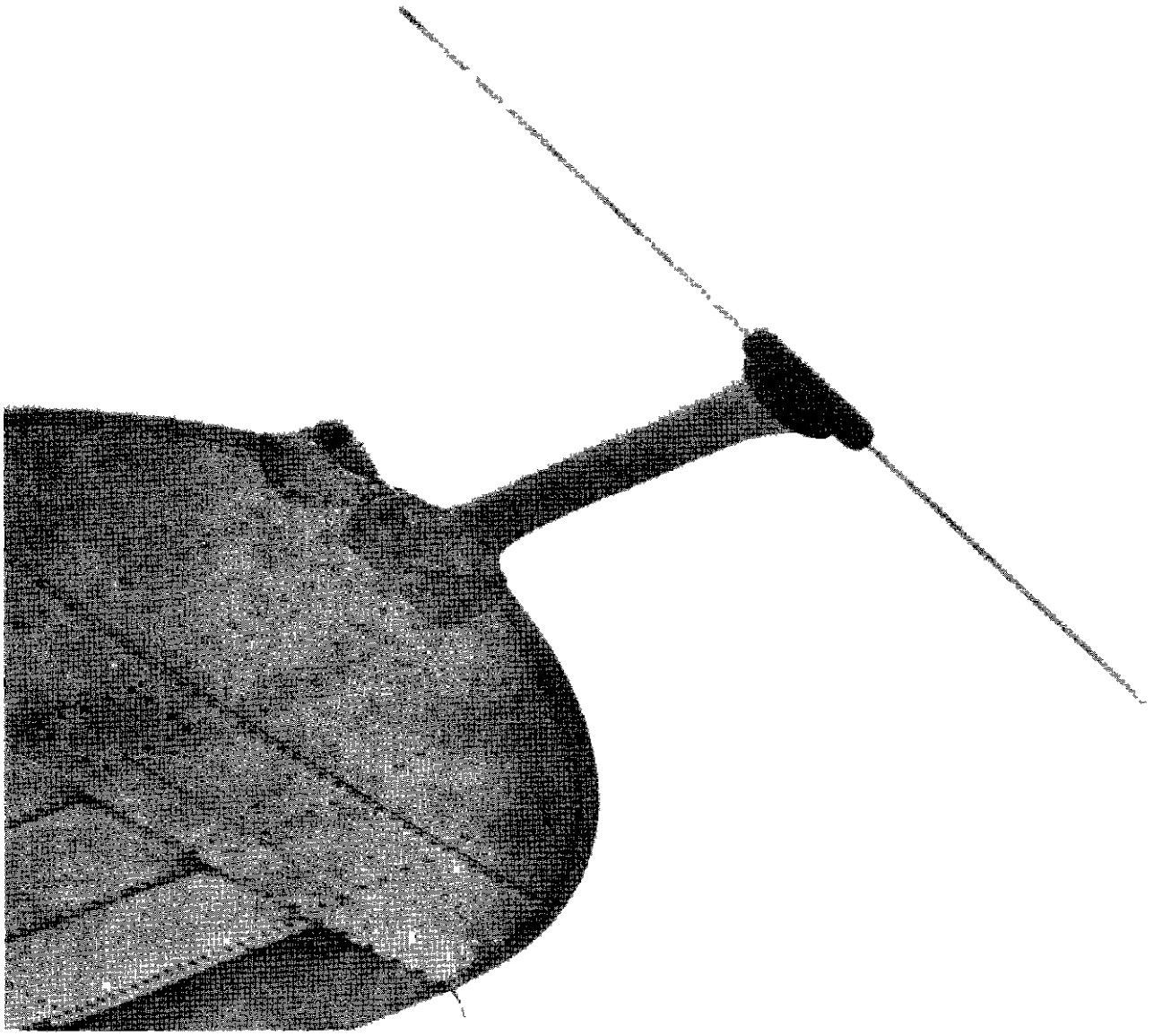

Fig 1 Wing Tip Dipole Antenna

Advice was received that calibration flights on the Kansas City omnirange would produce results more comparable to those experienced in the Regions The Beechcraft, N-4, with its calibrating equipment, was flown to Kansas City where seven calibration circles were flown Flights were made with and without the 3105 kc long wire antenna The calibration conditions and results obtained at Kansas City are tabulated as follows

3105-kc Long Wire Antenna Removed From Beechcraft

Type of Aircraft	Antenna	Over-all Error Recorded (degrees)
C45	Wing Tip Dipole	4 3/4
C45	Hatch Dipole	3 3/4
C45	Hatch V	6
C47	Tail V	4 1/4

ERROR CURVE KANSAS CITY OMNIRANGE
COMBINED TRANSMITTER AND RECEIVER ERROR
COMPARISON OF VARIOUS ANTENNAS ON C45 AND C47 AIRCRAFT
FEBRUARY 8, 1949

7 Mile Circle CCW
1500 Ft Above Ground

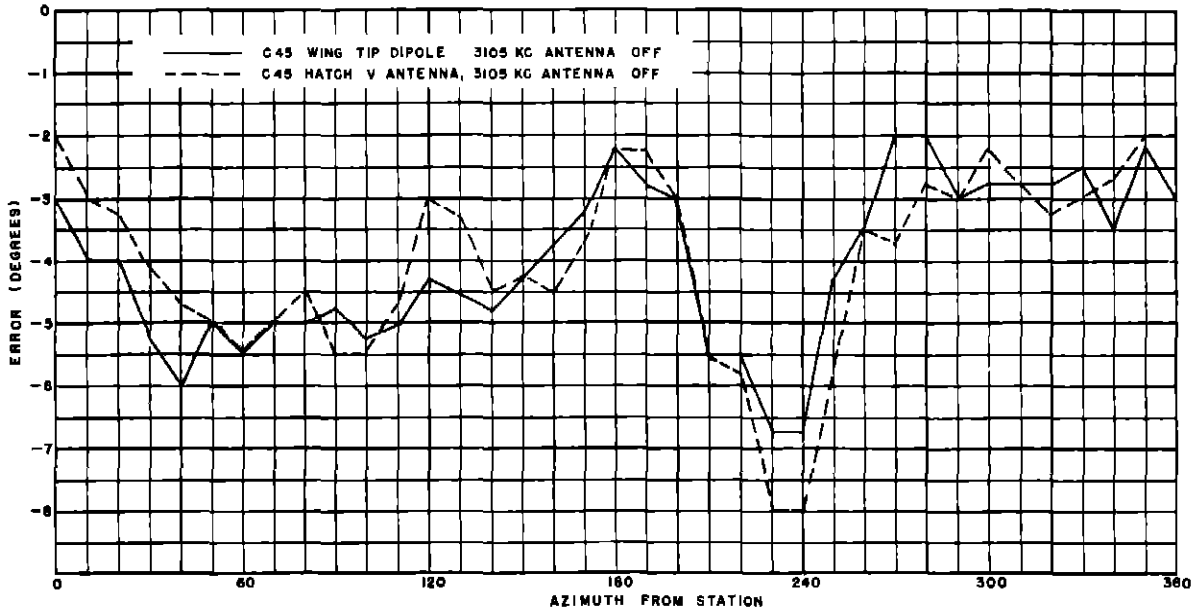

Fig 6 Error Curve C45 Wing Tip Dipole versus C45 Hatch V, Kansas City VOR

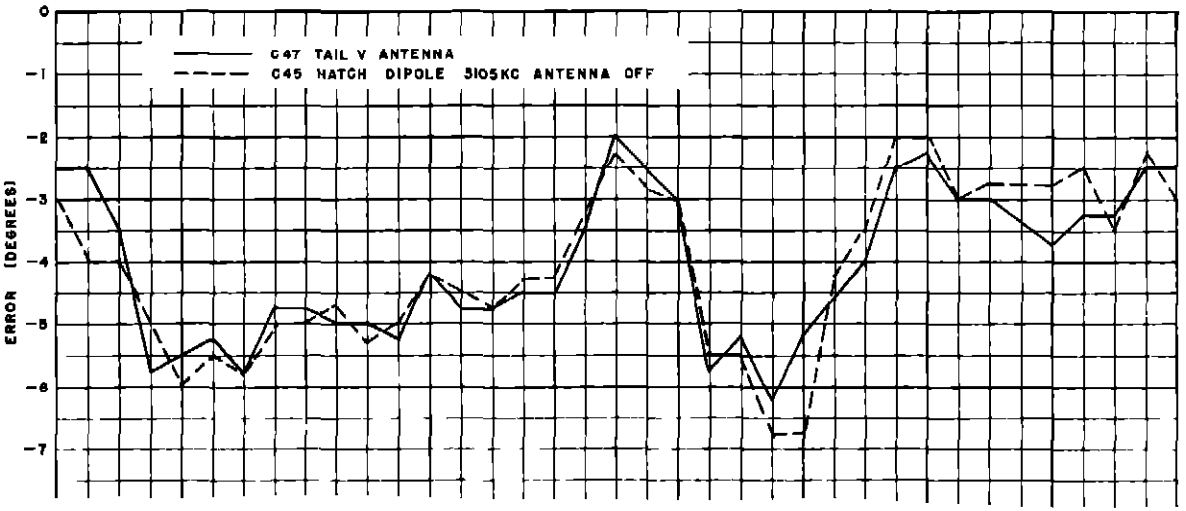

Fig. 7 Error Curve C47 Tail V versus C45 Hatch Dipole, Kansas City VOR

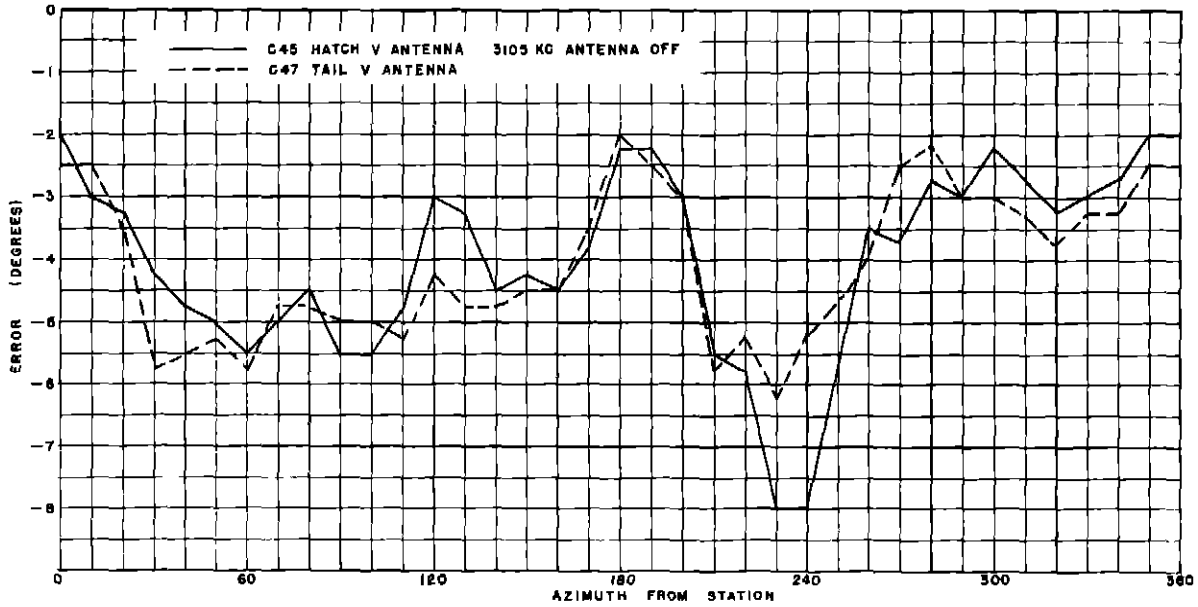

Fig 8 Error Curve C45 Hatch V versus C47 Tail V, Kansas City VOR

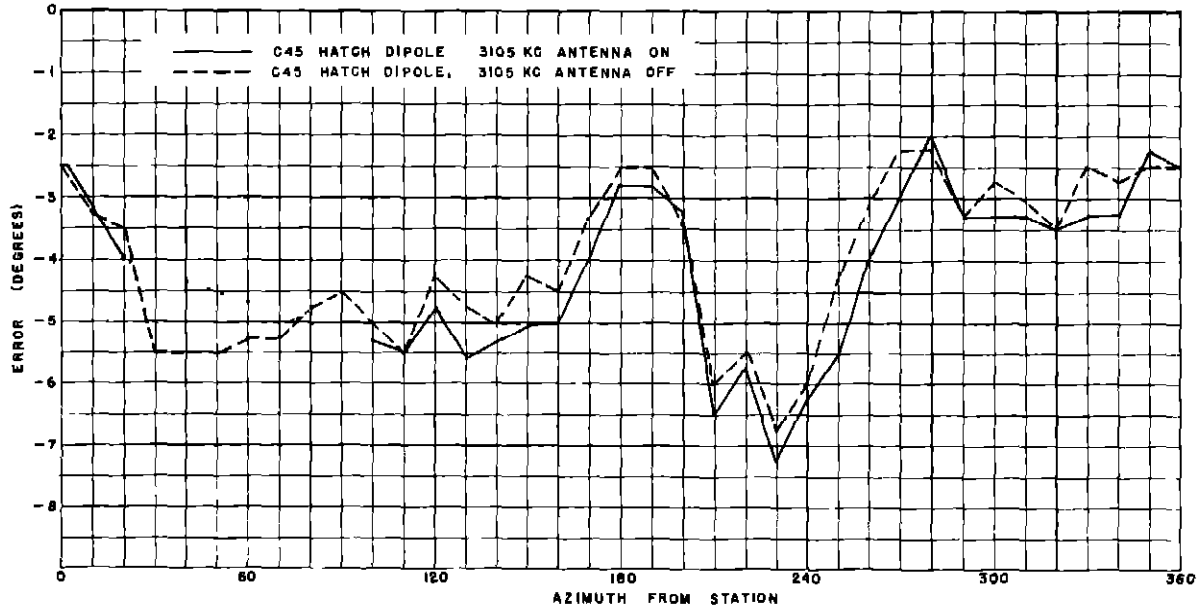

Fig 9 Error Curve C45 Hatch Dipole, 3105-kc Antenna On versus C45 Hatch Dipole, 3105-kc Antenna Off, Kansas City VOR

ERROR CURVE SOUTH OMNIRANGE
COMBINED TRANSMITTER AND RECEIVER ERROR
COMPARISON OF VARIOUS ANTENNAS ON C45 AND C47 TYPE AIRCRAFT
N-4 = C45 TYPE AIRCRAFT NC-182 = C47 TYPE AIRCRAFT
JANUARY 31, 1949

6 Mile Circle CCW
1500 Ft Above Ground
ARC-15 Receiver

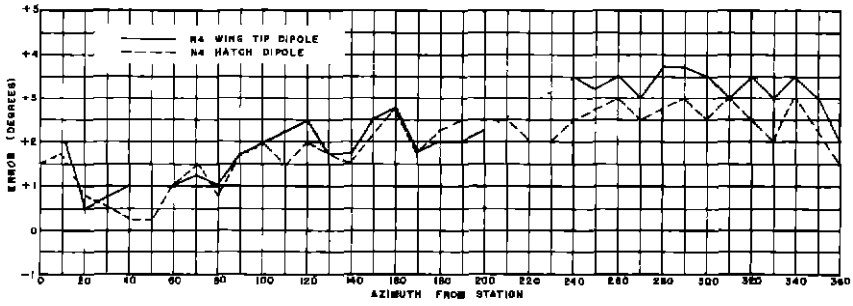

Fig 2 Error Curve N-4 Wing Tip Dipole versus N-4 Hatch Dipole, Indianapolis VOR

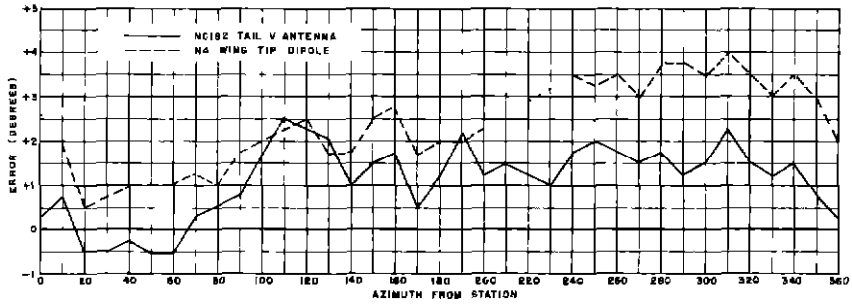

Fig 3 Error Curve NC-183 Tail V versus N-4 Wing Tip Dipole Indianapolis VOR

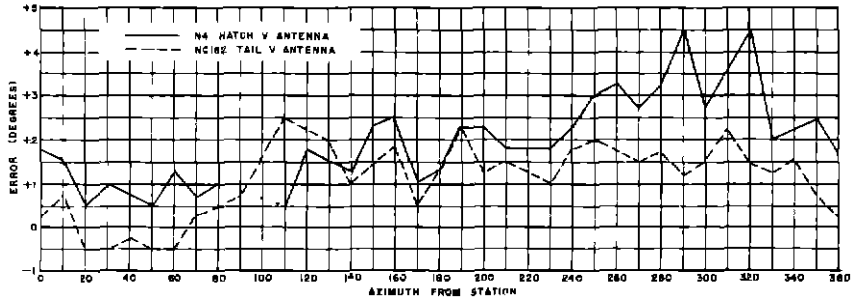

Fig 4 Error Curve N-4 Hatch V versus NC-182 Tail V, Indianapolis VOR

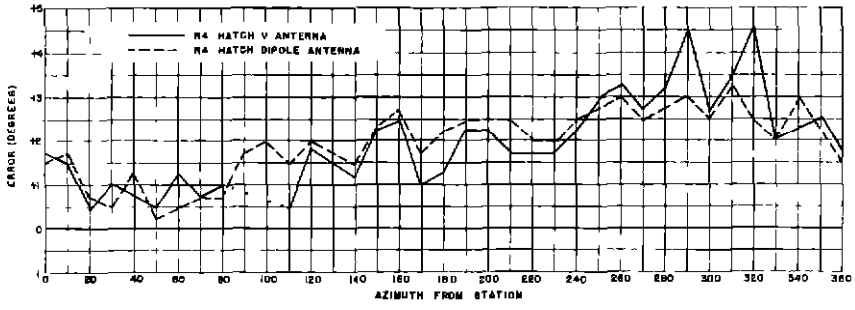

Fig 5 Error Curve N-4 Hatch V versus N-4 Hatch Dipole, Indianapolis VOR

3105-kc Long Wire Antenna Installed On Beechcraft

Type of Aircraft	Antenna	Over-all Error Recorded (degrees)
C45	Wing tip dipole	6
C45	Hatch dipole	5 1/4
C45	Hatch V	5 1/4

The calibration results plotted in the form of error curves are presented in various combinations in Figs 6, 7, 8, and 9

On each of the calibrating circles, checks were made to determine the extent of normal scalloping, propeller modulation, and attitude effect To check for propeller modulation, the engine rpm was varied in 50-rpm steps, from 1750 to 2000 in the Beechcraft, and from 1950 to 2300 rpm in the Douglas Attitude effect was checked by rocking the wings up and down to at least a 40° bank, while continuing the circle around the station. The maximum deflection of the course-deviation indicator is measured in degrees, and the results are tabulated herein

3105-kc Long Wire A itenna Installed On Beechcraft

Type of Aircraft	Antenna	Course-Deviation Indicator Variation-(degrees) Propeller Modulation	Scalloping	Attitude Check
C45	Wing tip dipole	2 1/2	1	0
C45	Hatch dipole	0	1	0
C45	Hatch V	3	1 1/2	3

DATA ANALYSIS

Examination of the data obtained at Indianapolis and Kansas City reveals several important facts

(1) The use of a hatch V antenna on a C45 Beechcraft will increase the over-all calibration error of an omnirange by an average of 2° when compared with the results obtained by a C47 using a tail V antenna

(2) All attempts to improve the calibration characteristics of a C45 were unsuccessful until the fixed long wire 3105 kc antenna was removed

(3) After the removal of the 3105 kc long wire antenna, a dipole antenna placed on the wing tips or hatch of a C45 produced calibration results substantially the same as those obtained in a C47

(4) The hatch dipole on a C45 is somewhat superior to a wing tip dipole The difference is small but the slightly inferior results combined with the work involved in reinforcing the wing tip recommends the use of the hatch dipole

FURTHER INVESTIGATION

Analysis of these facts reveals that the solution of the calibration problem in a C45 lies in the removal of the 3105 kc fixed long wire antenna, and the installation of a VHF dipole antenna This immediately brings forth two new problems

(1) The dipole antenna cannot be used when flying a radial omnirange course Since normal flight procedure is to check an omnirange for proper orientation with respect to magnetic north and then proceed with the calibration circle, it is apparent that two omnirange antennas are required

(2) The long wire low frequency antenna should not be removed from a C45 without offering a substitute Many patrol pilots fly over sparsely settled areas and removal of this antenna would constitute the loss of their most valuable radio aid in case of distress

The Beechcraft, N-4, was returned to Indianapolis where a V antenna was installed on top of the fuselage immediately over the cabin entrance door With the dipole antenna in the forward hatch position and the V antenna on the rear fuselage position, more flight checks were made about the Indianapolis omnirange. A photograph of N-4 with this antenna installation is shown in Fig 10

In order to solve the low frequency antenna problem, the Beechcraft, N-105, was flown to Indianapolis for flight tests This aircraft is equipped with a low frequency trailing wire antenna. Flight tests were conducted with this antenna in the extended and reeled in positions Results of these tests indicate, that a trailing wire antenna does not affect the calibration results in a Beechcraft

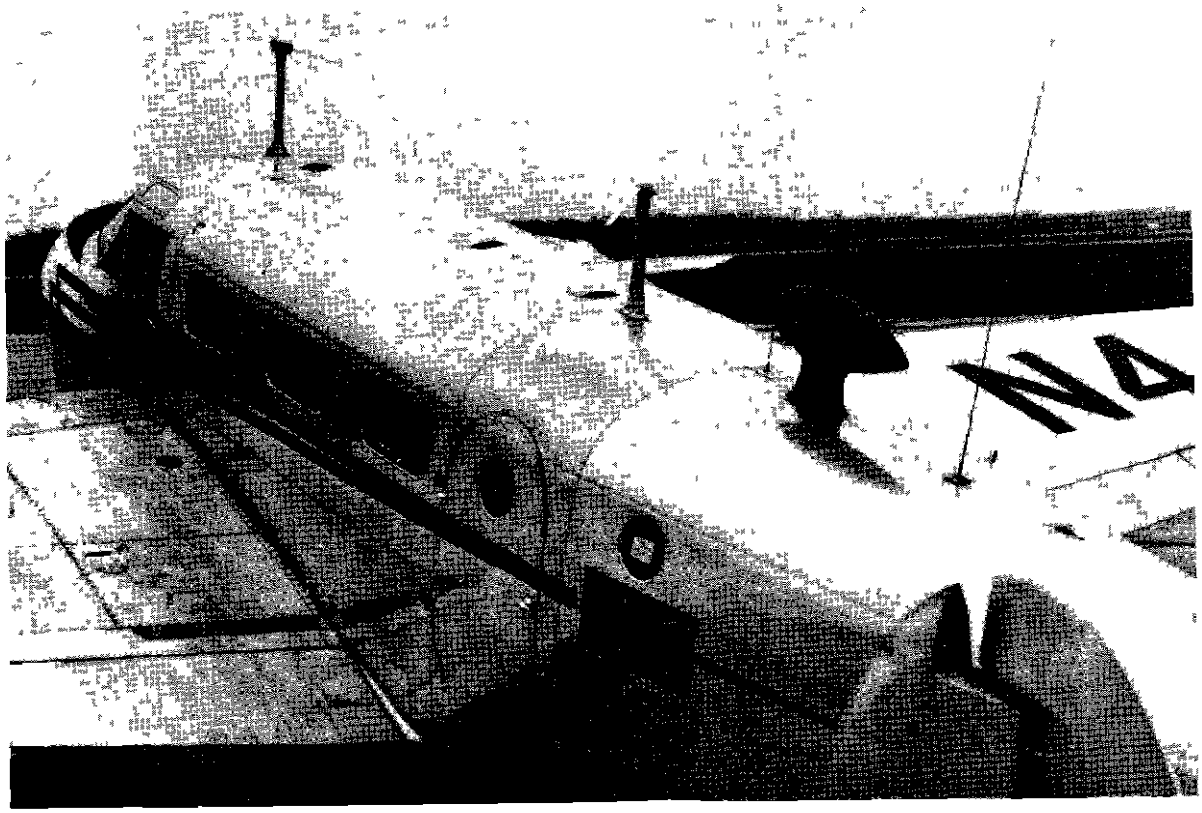

Fig 10 C45 Beechcraft N-4, Recommended Antenna Installation

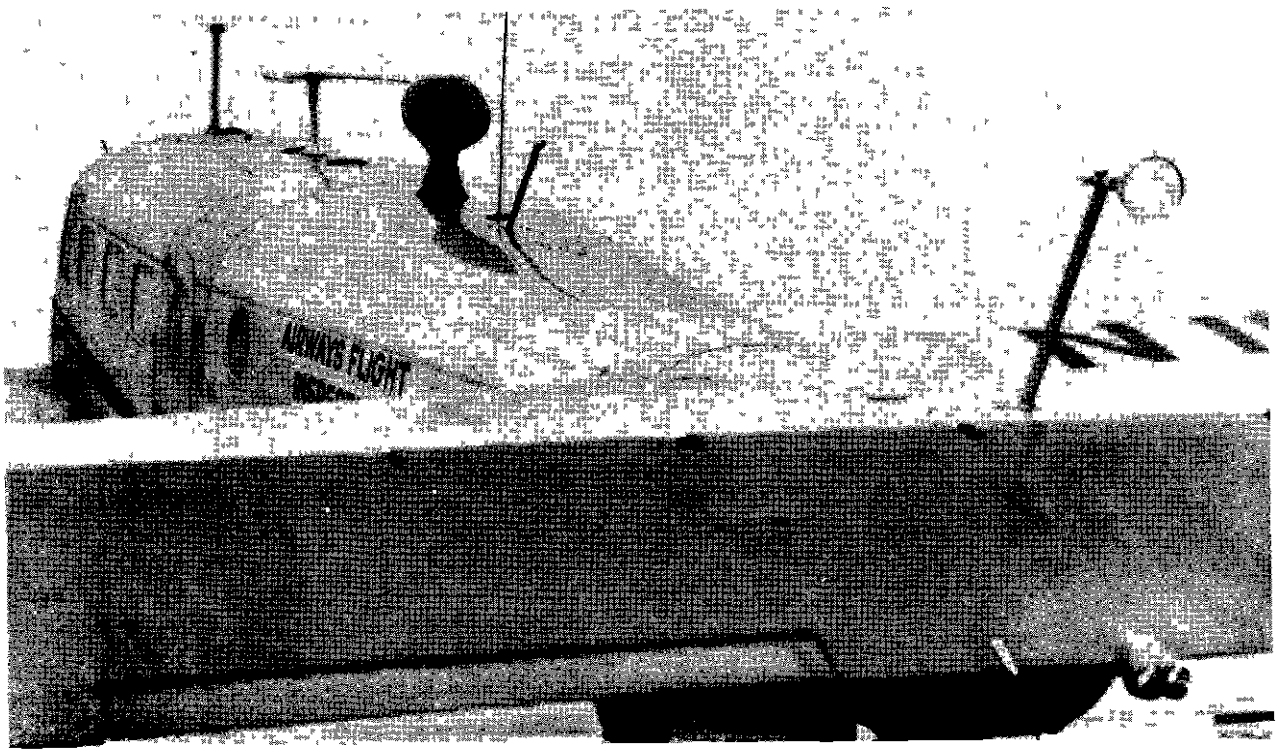

Fig 11 C45 Beechcraft N-104, Recommended Trailing Wire Installation

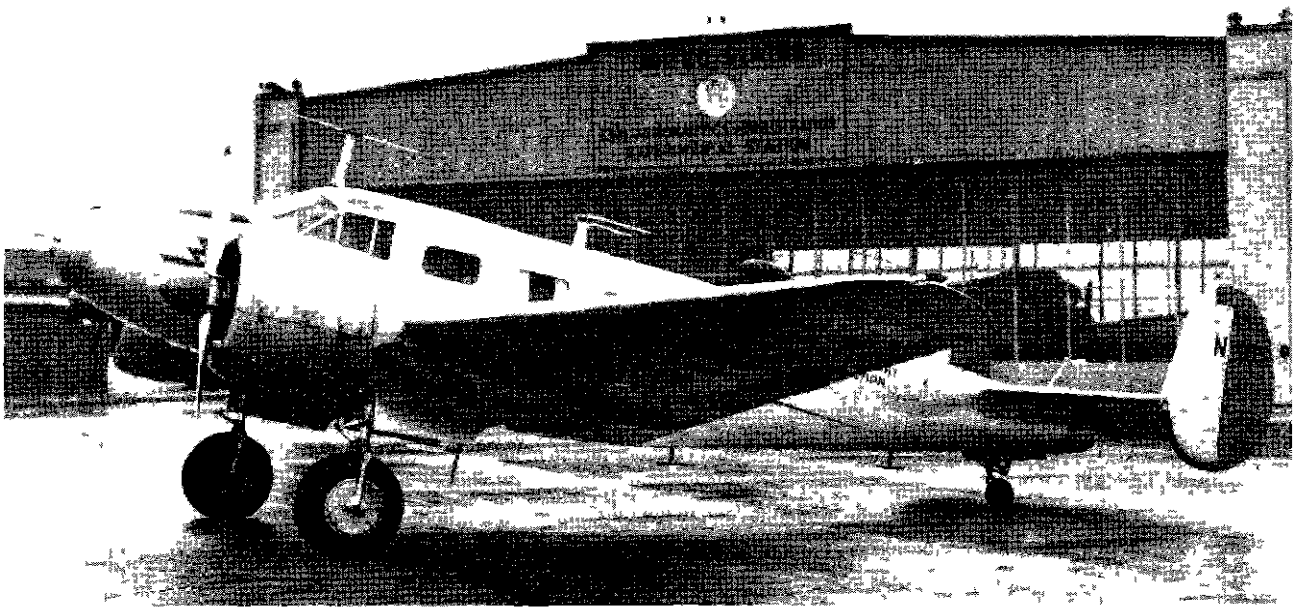

Fig 12 C45 Beechcraft N-105 Full View Recommended Antenna Installation

It is recommended however, that this antenna be reeled in during the theodolite calibration flight A proper installation of this type is shown in Fig. 11

CONCLUSIONS

The following recommendations are made for antenna installation on a Beechcraft C45 to be used in flight testing an omnirange

(1) A dipole antenna should be installed on top of the fuselage over the pilot's compartment, parallel to the longitudinal axis of the plane This antenna is to be used only on the calibration flight around the omnirange station

(2) A V-109 receiving antenna should be installed on top of the fuselage over the leading edge of the cabin entrance door This antenna is to be used in flying radials and for omnirange navigation

(3) The 3105 kc fixed antenna should be removed If a 3105 kc antenna is required, a trailing wire, reel-in antenna should be installed as far aft as possible Calibration should be done with antenna reeled in Maximum exposed antenna in reeled-in position should not exceed eight feet

(4) Beechcraft C45 aircraft should be operated with the engines indicating 2000 rpm when checking a station for magnetic north orientation and when flying a theodolite calibration circle

A C45 aircraft with antenna installations made in accordance with the recommendations of this report is shown in Fig 12

It should be emphasized that omnirange navigation in a Beechcraft C45 is entirely satisfactory The special antennas described in this report are necessary in the specialized case of omnirange flight testing

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