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EVALUATION OF THE FOUR-LOOP OMNIRANGE ANTENNA

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INTRODUCTION

This report presents the results of the evaluation of the 4-loop omnirange antenna developed at the Technical Development and Evaluation Center. The 4-loop antenna was installed at the north omnirange site at the west edge of Weir Cook Municipal Airport, Indianapolis, Indiana, at the same site where the evaluation of the 5-loop antenna with Uskon cloth and the FTL rotating antenna[1] had been conducted previously. The results of those evaluation tests are included in this report for comparison purposes. During the evaluation of the 4-loop antenna, Uskon cloth was not used since previous tests indicated that no advantages were to be gained by its use.

DESCRIPTION OF THE FOUR-LOOP ANTENNA

This antenna is composed of 4-loop radiators mounted at the corners of a square. Each diagonal pair of loops is driven from an output of a goniometer and produces a figure-of-eight pattern in space, which rotates at a rate of 30 rps. All four loops are simultaneously driven in-phase with carrier frequency currents. Modulating this carrier is the conventional 9,960-cps subcarrier, which in turn is frequency modulated with a 30-cps signal. In order to feed the four loops simultaneously from two separate generators, a double bridge circuit is employed. This permits isolation of one generator from the other.

FLIGHT TESTS

The flight tests conducted included polarization checks, distance range checks, theodolite orbits to measure indicated azimuth accuracy, and cone measurements.

Polarization Flight Checks

Three polarization tests were conducted. These tests were made approximately 20 miles from the VOR station at an altitude of 1,000 feet above ground in a Douglas C-47 aircraft using a Collins 51R-1 receiver and a tail-mounted V-109 antenna. A description and results of the tests performed follow.

(1) 30-degree Wing Rock. Headed toward the station the aircraft was banked ±30 degrees. The nose of the airplane was held "on the point"

[1]Thomas S. Wonnell, "Evaluation of Federal Telecommunication Laboratories Omnirange Antenna," Technical Development Report No. 111, May 1950.

during this maneuver. The course deviation indicator current was recorded and converted to degrees of course displacement. This polarization flight check was performed on four different radials around the VOR, and the results are given in Table I.

TABLE I

Bearing From VOR (degs.)	4-loop Antenna (degs.)	5-loop Antenna (degs.)	FTL Antenna (degs.)
0	±1.25	±0.75	±0.25
45	±1.25	±0 75	+0 5
180	±2.00	±0.87	±0.37
270	±2.00	±0.62	±0.5

(2) Eight Ways Over a Ground Check Point. Recording the course deviation indicator current, the aircraft was flown on eight different headings ("Daisy" pattern crossing a point at every 45-degree heading) over a specific ground check point. The recording was marked as the plane crossed the check point, and the indicated bearing was compared with the magnetic bearing. The zero reference point in each case was taken on the heading to the station. The results are given in Table II.

TABLE II

Check Point 20 Miles From VOR (degs.)	Aircraft Heading Over Check Point (degs.) E	W	N	S	SE	SW	NE	NW	Total Heading Effect (degs.)
				4-loop Antenna					
0	0	+1/2	0	0	+1 1/4	-1	0	0	±1 1/8
45	-1/4	+3/4	0	-1	0	0	0	0	±5/8
180	-1/4	-1/4	0	+1/2	+1/4	0	+1	-1 1/4	±7/8
270	0	+3/4	+1 1/4	0	+2	+3/4	+1	+1/4	±1.0
				5-loop Antenna					
0	+1	-1/2	0	0	+1/4	+1/2	+1/2	0	±3/4
45	+3/4	+3/4	0	0	+1/2	0	+1/2	-3/4	±3/4
180	+3/4	-1	0	-1	0	-1/4	-1	+1/2	±7/8
270	0	-3/4	-1	+1/4	-1/2	-1/4	-1/4	-3/4	±5/8
				FTL Antenna					
0	-1/2	-1	-3/4	0	-1/4	-3/4	-1/2	-1/4	±1/2
45	-1/4	+1/2	+1/2	-1	0	0	-1/4	-1/2	±3/4
180	+1/4	+1/4	0	+1/2	0	+1/4	+1/4	0	±1/4
270	0	+3/4	+1/4	+1/4	+3/4	+1/2	+1/4	+1/4	±3/8

(3) 360-degree Circle. Headed toward the station and starting from a ground check point, a 360-degree circle was flown at a constant 30-

degree bank. The course deviation indicator current was recorded during this circle and converted into degrees of error from the azimuth course being flown at the beginning of the circle. Since the aircraft in the 360-degree circle was changing azimuth with respect to the VOR, this deviation was computed in degrees and subtracted from the course deviation indicated error, resulting in the numerical value of polarization error, following the removal of the receiver error. This polarization test was conducted at an altitude of 1,000 feet above ground at a distance of approximately 20 miles from the VOR. The results obtained on four different azimuth bearings from the station are shown in Table III.

TABLE III

Bearing From VOR (degs.)	Polarization Error (degs.)		
	4-loop Antenna	5-loop Antenna	FTL Antenna
0	±1.5	±2.25	----
45	±1.85	±2.05	±0.5
90	----	----	±0.5
180	±1.9	±2.0	----
270	±2.3	±2.2	±1.0
315	----	----	±0.75

Distance Range Flight Check

The distance range of a VOR is defined as the distance in statute miles from a VOR at which the course width in degrees becomes double the course width measured at ten miles from the VOR. This test is conducted at an altitude of 1,000 feet above ground. The distance range flight checks were conducted on the zero radial of the north omnirange site and are shown in Table IV.

TABLE IV

Antenna	Distance Range (miles)	
	Headed North	Headed South
4-loop	50.1	51.0
5-loop	62.6	60 8
FTL	45.4	45.5

Theodolite Flight Calibration

The theodolite flight calibration is a process wherein a series of exact differences between indicated and magnetic bearings is obtained through the 360-degree circle around a range station. These differences are plotted as a calibration or measured error curve. Flights were made in both clockwise and counterclockwise directions at a 6-mile radius.

Fig. 1 shows the error curves of the 4-loop antenna. Table V shows the error spread in degrees resulting from theodolite flight calibration on the three antenna systems.

TABLE V

	Error in Degrees	
Antenna	Clockwise Circle	Counterclockwise Circle
4-loop	±2.12	±2.75
5-loop	±1.25	±1.5
FTL	±1.25	±0.8

Cone Measurements

Cone measurements were made on radial flights across the VOR by recording the currents of the course deviation indicator and the TO-FROM indicator of a Collins 51R-1 receiver. Two methods of measuring the cone were used in these tests.

The course deviation indicator is graduated in equally spaced "dots" across the face of the instrument When the indicator deviates beyond one dot, and this deviation (as observed on the recording) is due to the normal course disturbances encountered above a VOR, the cone is considered to begin at the point where the indicator deflection exceeds one dot from the center position. Similarly, the cone ends at the one dot deflection point, as the straight-line course indication is resumed on the other side of the cone. When measuring a cone in this manner, the results are referred to as a course deviation indicator (CDI) cone measurement.

The second method of cone measurement consists of recording the current of the TO-FROM indicator. The cone is considered to begin at the point where the TO-FROM indicator deviates from the normal TO indication position; and this deviation (as observed on the recording) is due to the normal change from a TO indication to a FROM indication as a result of passing over the VOR. The cone ends at the point where the transition from TO to FROM is completed. A cone angle measured by this method is referred to as a TO-FROM cone measurement. In measuring the cone by the TO-FROM method, the course deviation indicator recording must be available in order to verify the fact that the radial flown passed directly over the VOR station.

The results of the cone measurement flight tests on the 4-loop antenna, together with the measurements recorded on the 5-loop and FTL antennas are given in Table VI.

TABLE VI

	Aircraft Altitude Above Ground (feet)	Type Measurement	Cone Angle Above Ground (degs.)
4-loop Antenna			
	2,000	CDI	73.9
	2,000	CDI	77.0
	2,000	TO-FROM	86.4
	2,000	TO-FROM	87.0

TABLE VI (continued)

	Aircraft Altitude Above Ground (feet)	Type Measurement	Cone Angle Above Ground (degs.)
5-loop Antenna			
	2,000	TO-FROM	49.4
	2,000	TO-FROM	49.8
	2,000	CDI	49.8
	2,000	CDI	51.3
FTL Antenna			
	2,000	TO-FROM	69.2
	2,000	TO-FROM	69.9
	2,000	CDI	71.7
	2,000	TO-FROM	75.7
	2,000	CDI	71.6
	2,000	CDI	75.2
	10,000	TO-FROM	75.2
	10,000	CDI	77.3

GROUND TESTS

Polarization Error Measurements

The polarization error of the antenna was measured in accordance with the latest procedure devised at the Center. The procedure is equivalent to tilting a dipole ±45 degrees from the horizontal position, but with the added advantage of being able to change the radio-frequency phase between the vertical pickup as compared with the horizontal pickup. The receiving test antenna was located at a distance of approximately 1,000 feet and at zero degree elevation. The 4-loop antenna was rotated in 20-degree steps and the resulting polarization error is shown in Fig. 2.

Listed below in Table VII are the polarization error extremes of the three antenna systems:

TABLE VII

Antenna	Error Extremes (degs.)	
4-loop	-1.5	+2.0
5-loop	-3.0	+3.0
FTL	-0.75	+1.4

CONCLUSIONS

The improvements in VOR performance desired in the development of the 4-loop antenna were a narrower cone and reduced polarization error. The cone characteristics of the 4-loop antenna are very good. The action of the TO-FROM indicator on passing over the cone is excellent. The TO-FROM meter

makes one very sharp cross over from the TO position to the FROM position. This results in a very accurate position fix directly over the VOR station.

The polarization error of the 4-loop antenna without Uskon cloth is approximately the same as the standard 5-loop antenna with Uskon cloth now in use by the CAA; however, it does not provide the over-all improvement desired.

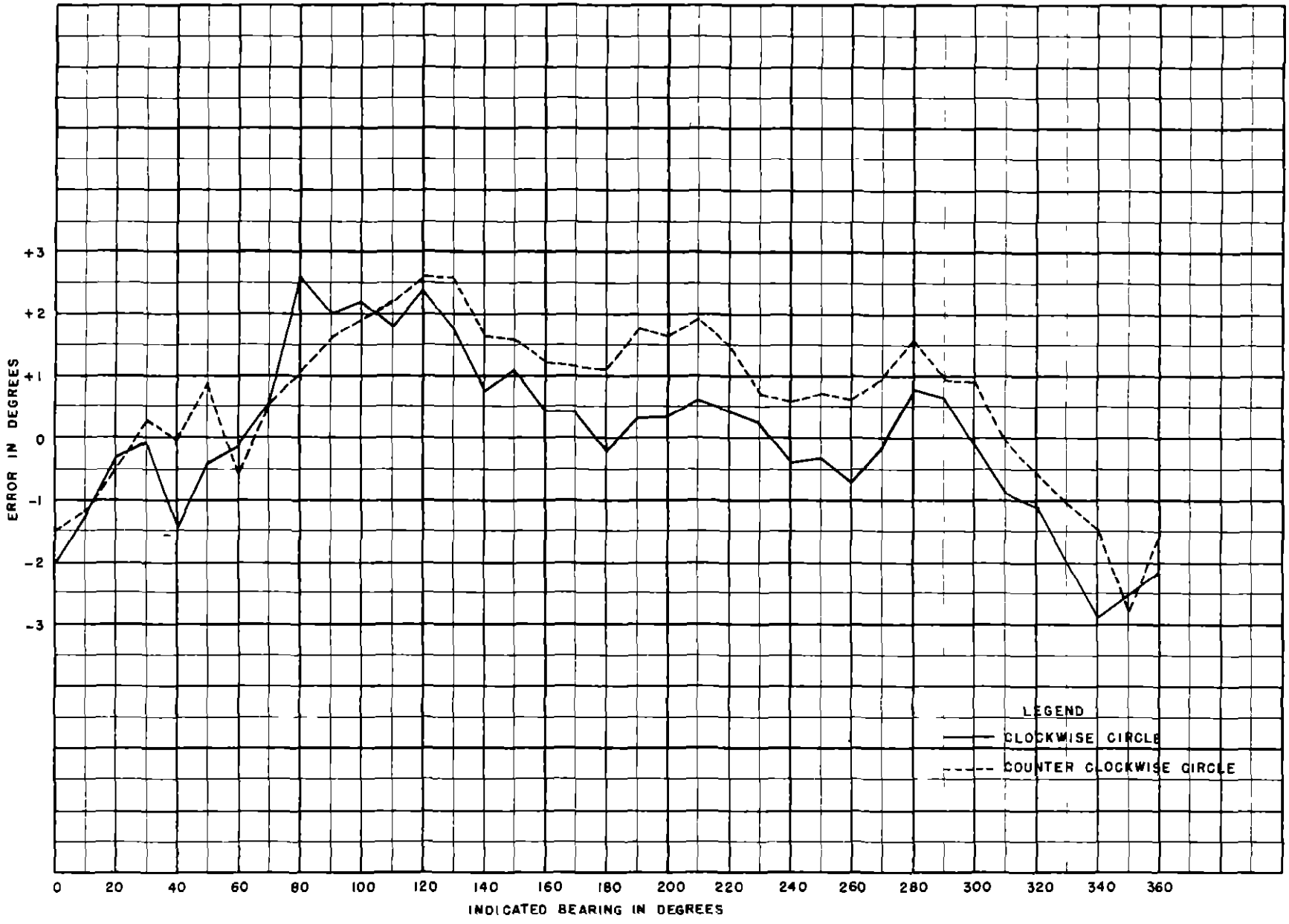

FIG 1 THEODOLITE FLIGHT CALIBRATION ERROR CURVE OF 4 LOOP OMNIRANGE TRANSMITTING ANTENNA (RECEIVER ERROR REMOVED)

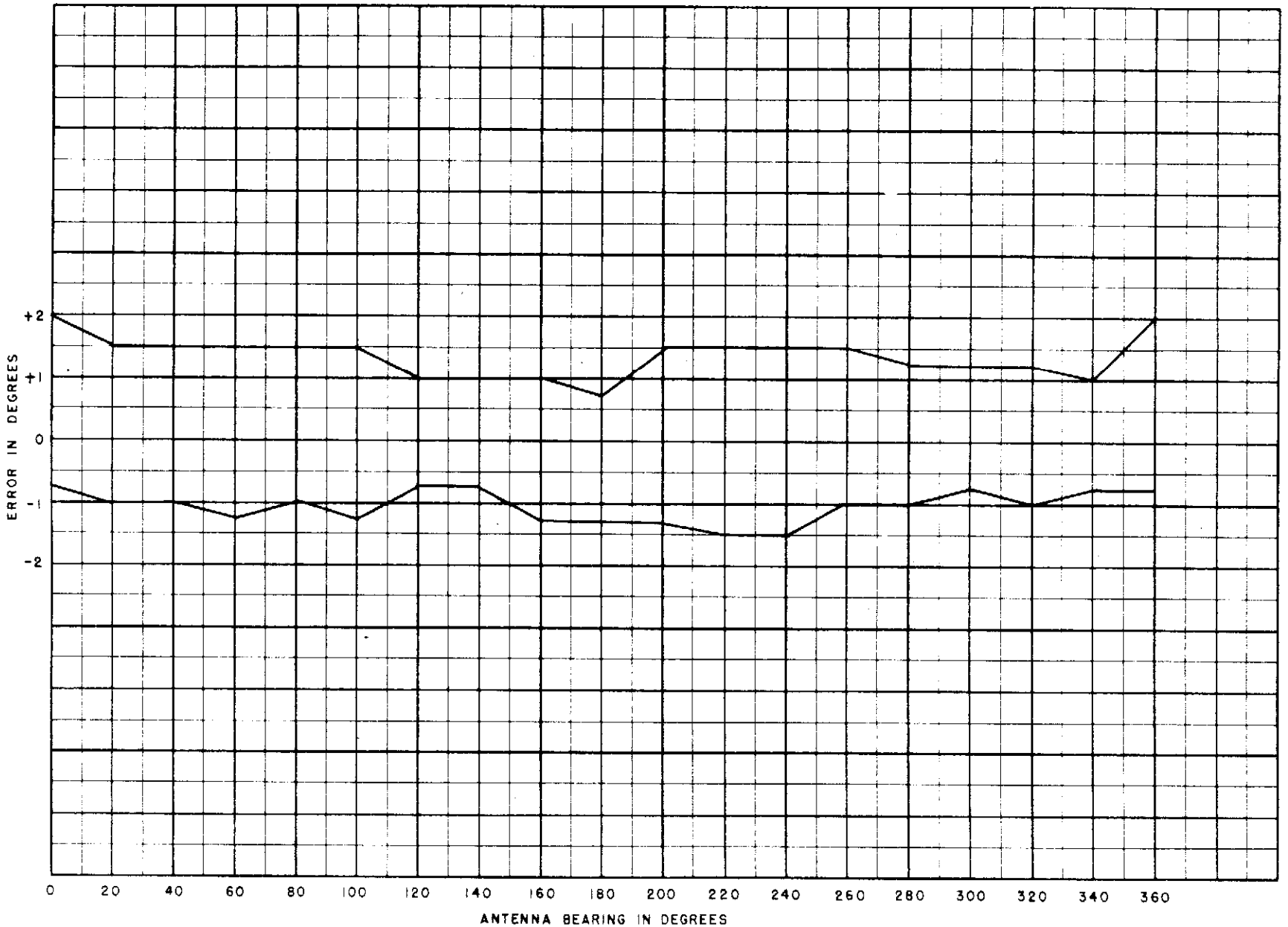

FIG. 2 POLARIZATION ERROR CURVE 4 LOOP
OMNIRANGE ANTENNA, GROUND CHECK