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NANTUCKET MOR ADJUSTMENTS AND FLIGHT TESTS FOR THE EVALUATION PROGRAM

FOR LIMITED DISTRIBUTION

By

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Introduction

The Nantucket MOR has been operating regularly since July 1949, with two major shutdowns caused by the failure of the coupling transformers at two of the corner antennas. The station was retuned after each failure. During the station tune up by Technical Development and Evaluation Center engineers in July 1949, the tone-wheel pick-up units were set in accordance with an arbitrary standard which did not fix the variable and reference signals in-phase at true north.

A program for extensive evaluation of the MOR system has been set up whereby flight tests and long distance monitoring stations will be used to determine the range, accuracy, and reliability of the Nantucket MOR. Prior to this evaluation, it was essential that the station be rechecked and calibrated using the new type Radio Receptor Model RLB receivers.

During June 1950, Technical Development and Evaluation Center engineers returned to Nantucket to accomplish:

(1) checking the facility and making any readjustments necessary for correct operation, and (2) setting the tone-wheel pick-up unit of each equipment to produce plus and minus the same amount of error, i.e., to balance the station's error curve about the zero error line, as guided by receivers adjusted for in-phase at the north setting.

Station Tests and Adjustments

Immediately upon arrival at Nantucket, a flight calibration was made using equipment No. 1. Fig. 1 is a calibration of the No. 1 equipment made by flight test and with the station monitor. The two curves did not coincide, indicating that a theodolite calibration is necessary in calibrating MOR stations. The station monitor can be used only to check the stability of the station. This is the first weakness discovered in the monitoring equipment.

The parasitic currents in the center antenna, due to driving currents in the corner antennas, were found to be too large; namely, 120 milliamperes with 33 ohms in series, for the N - S pair; and 117 milliamperes, with 15 ohms in series for the E - W pair. By readjustment of the coupling controls at the corner towers, the minimum values of parasitic currents were obtained.

	Antenna Pair	Parasitic Current in Center Antenna ma.	Resistance in Series with Meter ohms
Final readings taken June 5, 1950	N - S	87	3
	E - W	54	6
Readings taken Feb. 10, 1950, following tune up	N - S	11	10
	E - W	16	0

These data show that the parasitic currents in the center antenna are approximately as low, after the final adjustments were made June 5, 1950, as they originally had been on February 10, 1950. Also, it appears that they must be measured and readjustments made periodically to maintain the minimum values.

The center antenna match had changed since the original tune up from 70 + j0 to 57.4 + jx ohms. The center antenna was rematched for 70 + j0 ohms. Fig. 2 compared with Fig. 1 shows the effect of these adjustments on the flight calibration curve. The tone-wheel pick up had been set prior to recording data for Fig. 2.

It was discovered at this time that the center antenna current was not properly sampled because an L-network was used for matching, thereby requiring the sampling of the shunt leg current instead of the true antenna current. A coupling transformer was installed in place of the shunt leg inductor, and a sample of the center antenna current was then obtained with the antenna matched to the transmission line.

Final calibration curves were taken. Fig. 3 shows station monitor curves, and Fig. 4 shows flight curves. The curves of Fig. 3 have been plotted to make them coincide as nearly as possible, but the ordinates are not coincident by five degrees. Yet, the curves of Fig. 4 show both equipments to be practically identical. This indicates a second weakness in the station monitor. The equipments (Nos. 1 and 2) appear to be different by five degrees to the station monitor, while they appear identical to the aircraft receiver. The station monitor probably picks up more stray signal from the No. 1 equipment than from the No. 2 equipment.

Fig. 5 is a plot of the flight calibration curve, F(θ), of the No. 1 equipment and the larger terms of an approximate Fourier analysis. Table I shows the magnitudes of the various terms and possible causes of error. The analysis indicates that the measured error curve is rather complex and is caused by a number of faults.

Flight Tests

The flight to Nantucket was made on May 31, 1950, in Airplane NC-181 for the purpose of checking the MOR facility, realigning the courses to the new zero standard, obtaining station calibration curves and securing more data on night effect during the return flight to Indianapolis. Take-off was made at 8 a.m., and while still over Indianapolis, signals from the Nantucket station were received on both the Radio Receptor Co. receiver, Type RLB, and on the RCA Type ARB receiver. A bearing of 66 degrees to the station was observed using the RLB receiver, with a measured course sensitivity of 12 degrees. Data observed during the flight is given in Table II. The large error between observed bearing and true bearing is due to the fact that the station was operating with the old zero setting, while the receiver was calibrated with the new zero setting.

Fluctuations of the course deviation indicator seemed to be the result of background noise superimposed on the weak signal, since the fluctuations diminished as signal strength from the station increased. This undesired movement of the deviation indicator occurred despite the use of a double section LC filter in series with the deviation indicator movement. When using a single 1250-microfarad wiggle filter across the deviation indicator, however, in place of the double section LC filter, the fluctuations increased from plus or minus two degrees to plus or minus 4.5 degrees indicating that a two to one improvement may be obtained by use of the LC filter.

On arrival at Nantucket, a flight calibration of the station was made immediately to determine how well the flight calibration of July 14, 1949 had held. These curves are shown in Fig. 6 for comparison.

A flight calibration made after rephasing the towers and reducing parasitic currents is shown in Fig. 2. One circle was flown with each of two RLB receivers to determine how well these receivers had been calibrated. An error curve published by Radio Receptor Co. for each of these receivers is included in the same illustration. Comparing these error curves it may be noted that at 120 degrees and at 310 degrees the receiver errors are the same. Since the flight calibrations, made an hour apart and using the same station equipment, show a difference of 1.75 degrees at an azimuth of 120 degrees; and since it is possible to repeat flight calibration data to within 0.5 degrees, it appears that the published calibration curves for RLB equipment may be in error by one degree under actual flight conditions.

After a new transformer had been installed in the center tower and the towers had been rephased again, two more flight calibration circles were made, one with each transmitter and goniometer. See Fig. 7. A final flight calibration of each equipment, after tone wheel adjustment was made on June 9, 1950, to bring the curves together, is shown in Fig. 4. This curve may be used to apply corrections to a bearing selector setting in the following manner:

For a bearing selector setting which will indicate a desired azimuth when the needle is centered, subtract (algebraically) the station error and published (FROM) receiver error at the desired azimuth from the reading of that azimuth.

Example - at 220 degrees. 220 - (-2)* - (-0.2)* = 222.2 degrees

To convert an indicated bearing to true azimuth, add (algebraically) the station error and published (FROM) receiver error to the indicated bearing.

Example - at 22.4 degrees: 22.4 + (-0.4)* + (-0.3)* = 21.7 degrees

The slight error introduced by using station error at 22.4 degrees instead of 21.7 degrees is negligible.

Corrections may be applied to a bearing TO the station by using the reciprocal station error and the published TO receiver error curve.

Example - at 40 degrees TO: 40 - (-2.0)** - (-0.35)*** = 42.35 degrees

*Figs. 2 and 3.
**Station error at 220 degrees.
***Not shown on Fig. 2.

On the night of June 9, 1950 the return flight to Indianapolis was made and the data obtained are shown in Table III. Several thunderstorms were encountered from a point east of Pittsburgh to Indianapolis and the general atmospheric noise level was quite high, making it difficult to obtain accurate course data from Pittsburgh for the remainder of the flight to Indianapolis.

TABLE I
Azimuthal Displacement in Degrees

n	Error in Degrees A_n	B_n	r_n	ϕ_n	Possible causes of error
0	------	+0.86	0.86	-----	Tone-wheel pick up adjustment
1	+0.069	+1.46	1.46	2.7	Cross modulation, E - W figure-of-eight off due to phasing of towers
2	+0.591	-1.27	1.40	155.0	
3	+0.05	0.0	0.05	90.0	
4	-0.274	-0.558	0.621	206.1	Tower spacing
5	-0.219	+0.04	0.222	280.3	
6	------	-0.025	-----	-----	

Where. $$F(\theta) = \frac{B_0}{2} + A_1 \sin \theta + A_2 \sin 2\theta + A_3 \sin 3\theta + A_4 \sin 4\theta + A_5 \sin 5\theta + B_1 \cos \theta + B_2 \cos 2\theta + B_3 \cos 3\theta + B_4 \cos 4\theta + B_5 \cos 5\theta + B_6 \cos 6\theta$$

$$= \frac{r_0}{2} + r_1 \cos(\theta - \phi_1) + r_2 \cos(2\theta - \phi_2) + r_3 \cos(3\theta - \phi_3) + r_4 \cos(4\theta - \phi_4) + r_5 \cos(5\theta - \phi_5).$$

TABLE II
Flight From Indianapolis To Nantucket

Date 1950	Distance from Station Statute Miles	Check Point	Observed Bearing To Station RLB #9 Rcvr. (Deg.)	True Bearing (Chart) (Deg.)	Station Error (Deg.)	Fluctuation of Course Deviation Indicator-Deg. (Deg.)	Remarks
May 31 0830	870	Over Indianapolis	66	88.0	+22.0	± 2.0	Period of oscillation 5 - 10 sec.
0850	783	Richmond, Indiana	67	88.0	+21.0	±2.0	
0930	692	Columbus, Ohio	---	---		---	Signal faded - Flag 1/2 up.
0945		-----------------	---	---		±1.5	Flag down
1005	520	Pittsburgh, Pa.	66	87.0	+21.0	±1.0	
1050	475	Flint Stone Marker NE of Cumberland, Md.	61	78.5	+17.5	±0.5	
1105	443	Martinsburgh, W. Va.	57	76.0	+19.0	±0.5	
1135	403	Washington National Airport	48	68.0	+20.0	±0.5	
1345	186	New Rochelle Marker	64	84.5	+20.5	None	
1355	138	Hartford, Conn.	80	105.0	+25.0		
1423	87	Boston Airport	125	151.0	+26.0		
June 2 0825	87	Boston Airport	126	151.0	+25.0		
0945	28	Mystic Beach	126	151.0	+25.0		

TABLE III
Flight From Nantucket To Indianapolis

Date Time EDT 1950	Distance from Station Statute Miles	Check Point	Observed Bearing From Station RLB #9 Rcvr. (Deg.)	True Bearing (Chart) (Deg.)	Station Error (Deg.)	Fluctuation* of Course Deviation Indicator-Deg. Rapid	Slow	Remarks
June 9								
2130	87	Providence Airport	300	299.0	-1.0	0.0	0.0	
2245	102	S. of New London, Conn.	272	272.0	0.0	±0.5	0.0	
2310	145	S. of New Haven, Conn.	271	270.0	-1.0	±0.5	0.0	
2326	190	Westchester County Airport	269	268.0	-1.0	±0.75	0.0	
June 10								
0005	280	Allentown VOR	265	263.5	-1.5	±1.5	±5.0	Atmospheric noise
0035	360	Sunbury VOR	265	264.5	-0.5	±1.5	±2.5	
0055	420	S. of Phillipsburgh VOR	260	265.0	+5.0	±2.7	±4.1	High Noise level
0115		-------------------	---	-----	----	----	-------	Rain Precipitation Static
0140	520	Pittsburgh, Pa.	260	267.0	+7.0	±5.0	Not evident	Noise level very high 50-degree course sensitivity
0200	575	-------------------	---	-----	----	----	-------	TO-FROM Needle in Red

*Average period of rapid fluctuation - (noise)

(a) LC filter:- 10 sec. - amplitude given in table above.

(b) 1250 microfarad wiggle filter:- 1 sec. - amplitude; two to three times as great as that given in the table above.

Average period of slow fluctuation - 2.5 min. - (Night effect)

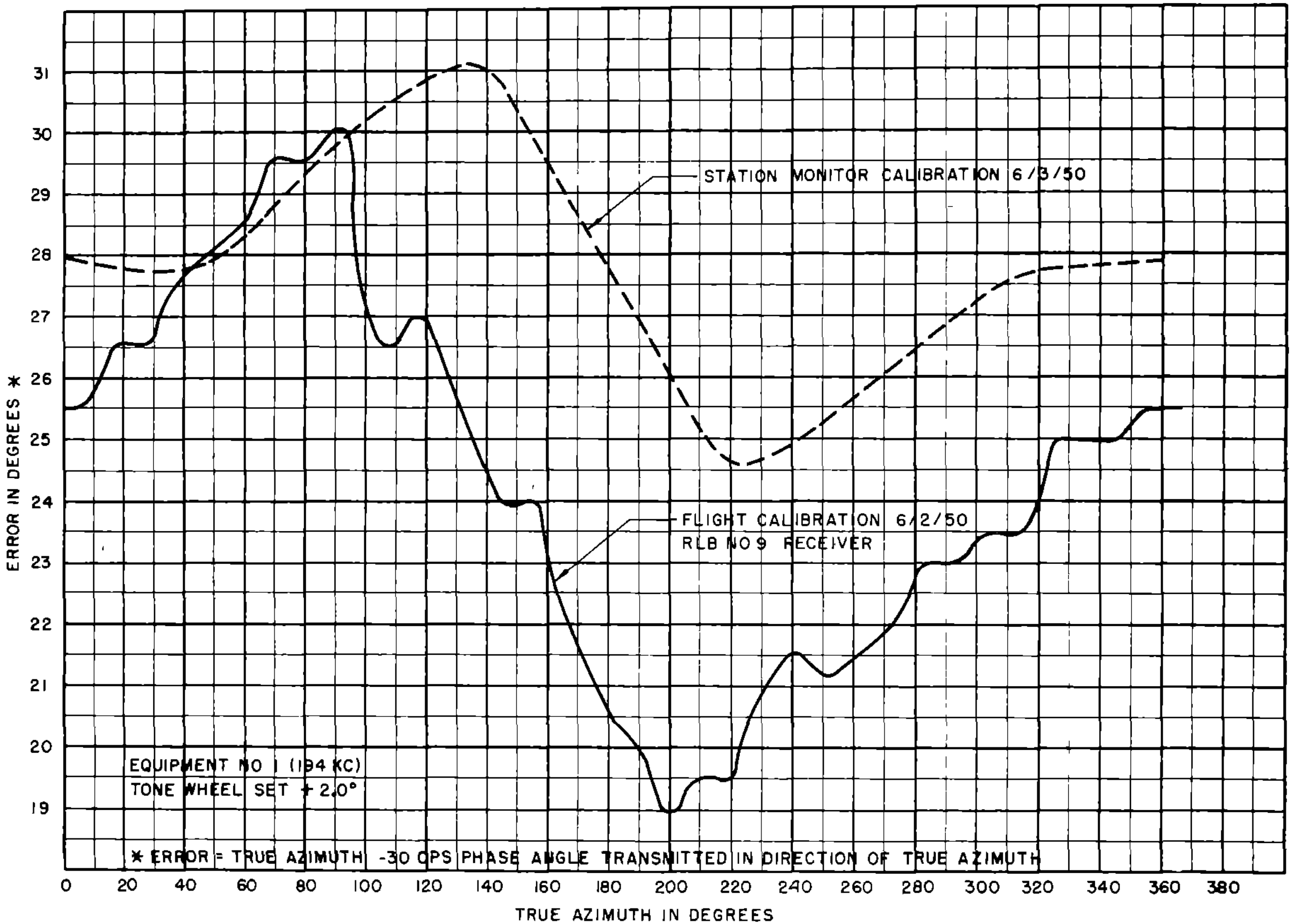

FIGURE 1 NANTUCKET MOR–MEASURED ERROR VERSUS TRUE AZIMUTH

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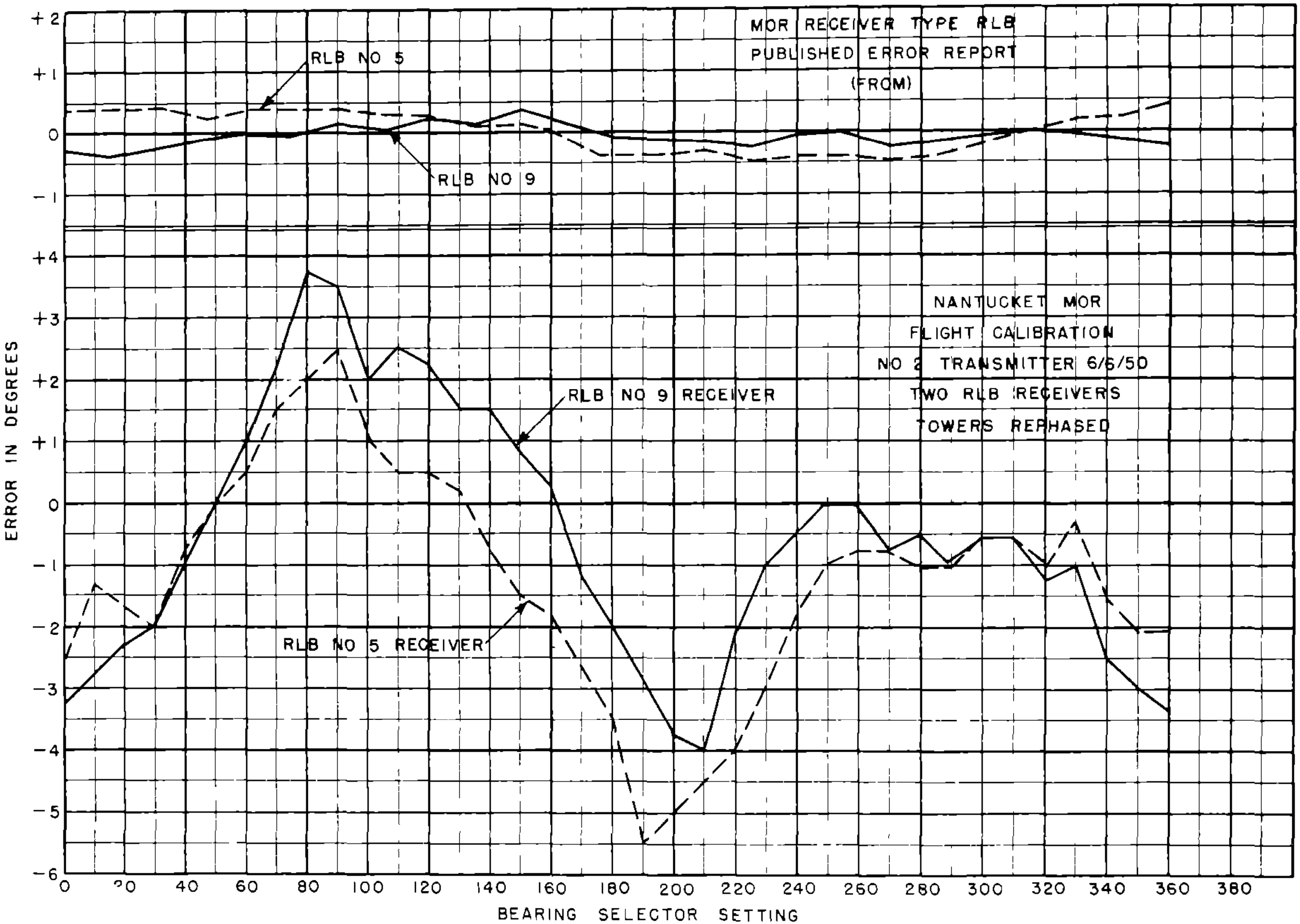

FIGURE 2 PUBLISHED ERROR CURVE AND NANTUCKET MOR FLIGHT CALIBRATION

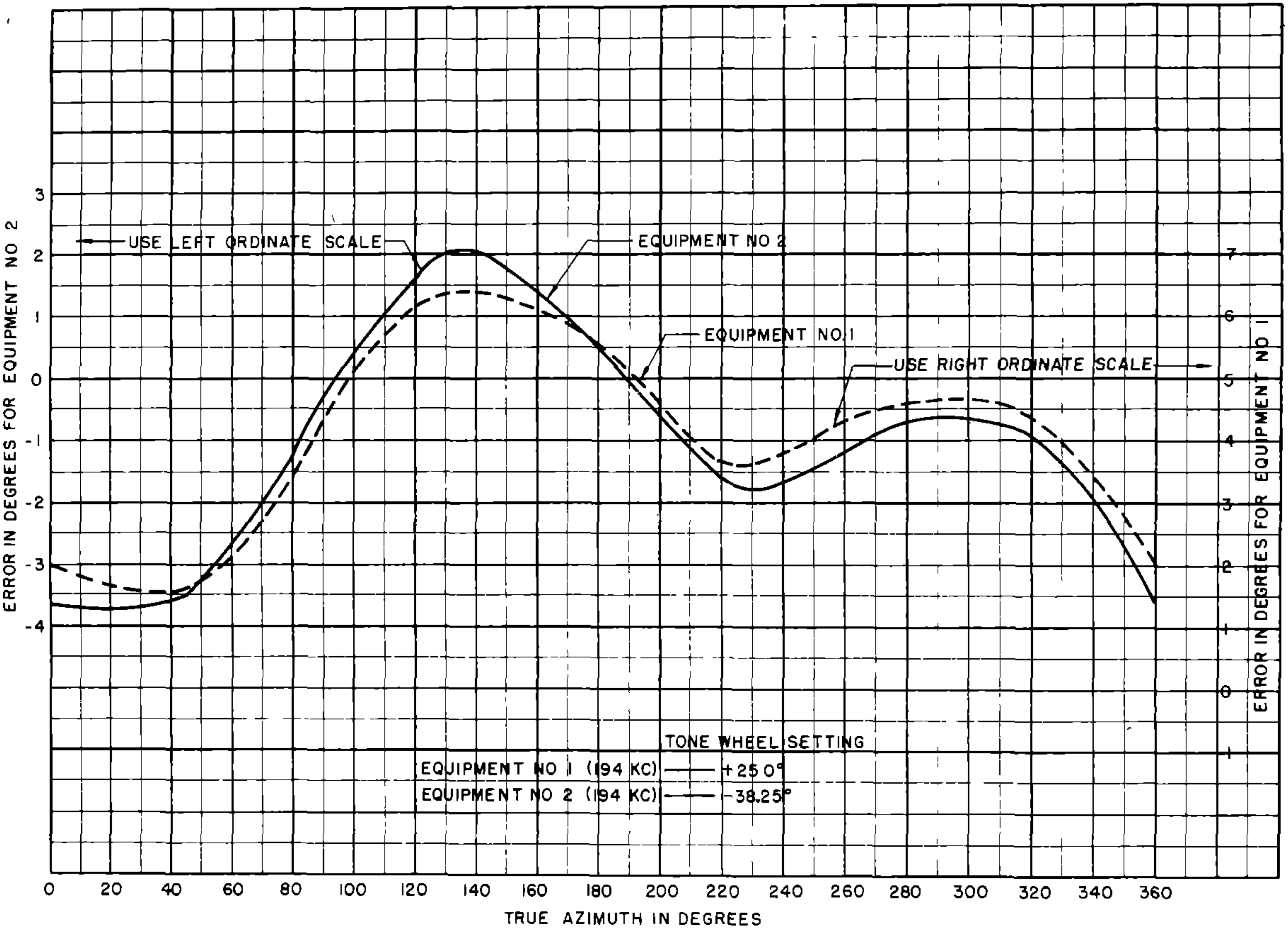

FIGURE 3 NANTUCKET MOR-STATION MONITOR
CALIBRATION OF STATION 6/9/50

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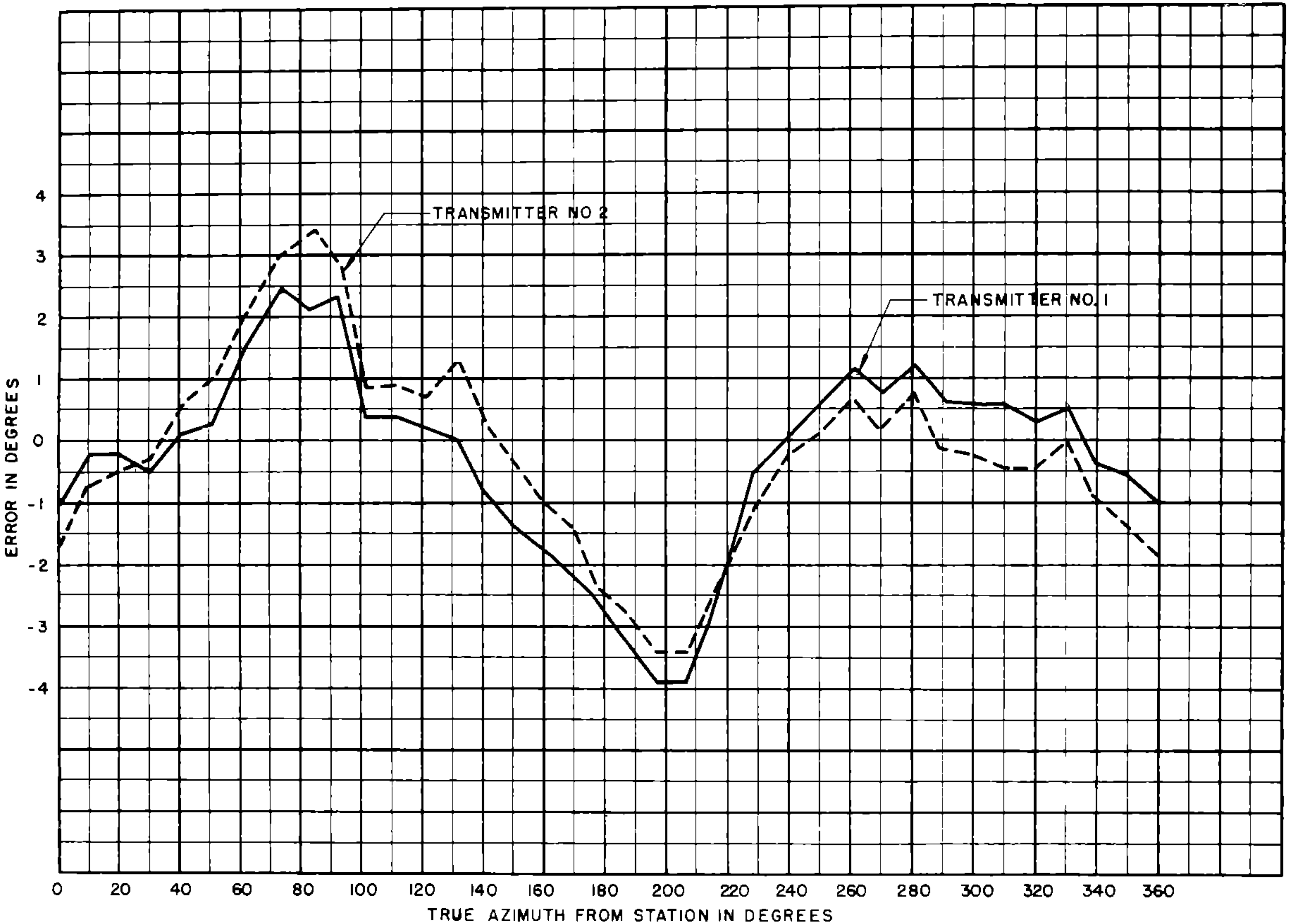

FIGURE 4 NANTUCKET MOR-STATION ERROR CURVE-PUBLISHED RECEIVER ERROR REMOVED-RLB NO 9 RECEIVER 6/9/50

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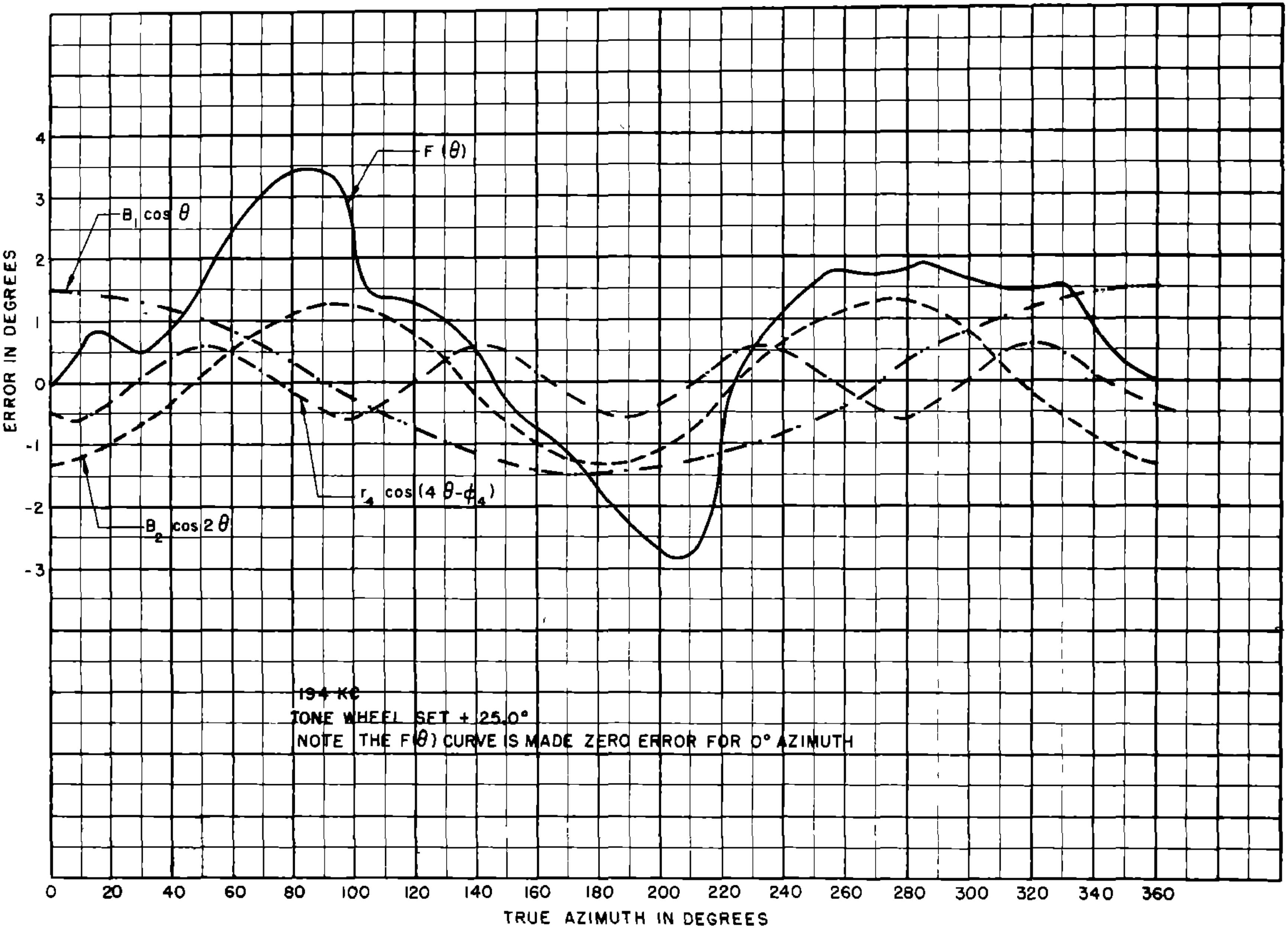

FIGURE 5 NANTUCKET MOR-EQUIPMENT NO I STATION ERROR CURVE AND SIGNIFICANT TERMS OF A FOURIER ANALYSIS OF STATION ERROR CURVE

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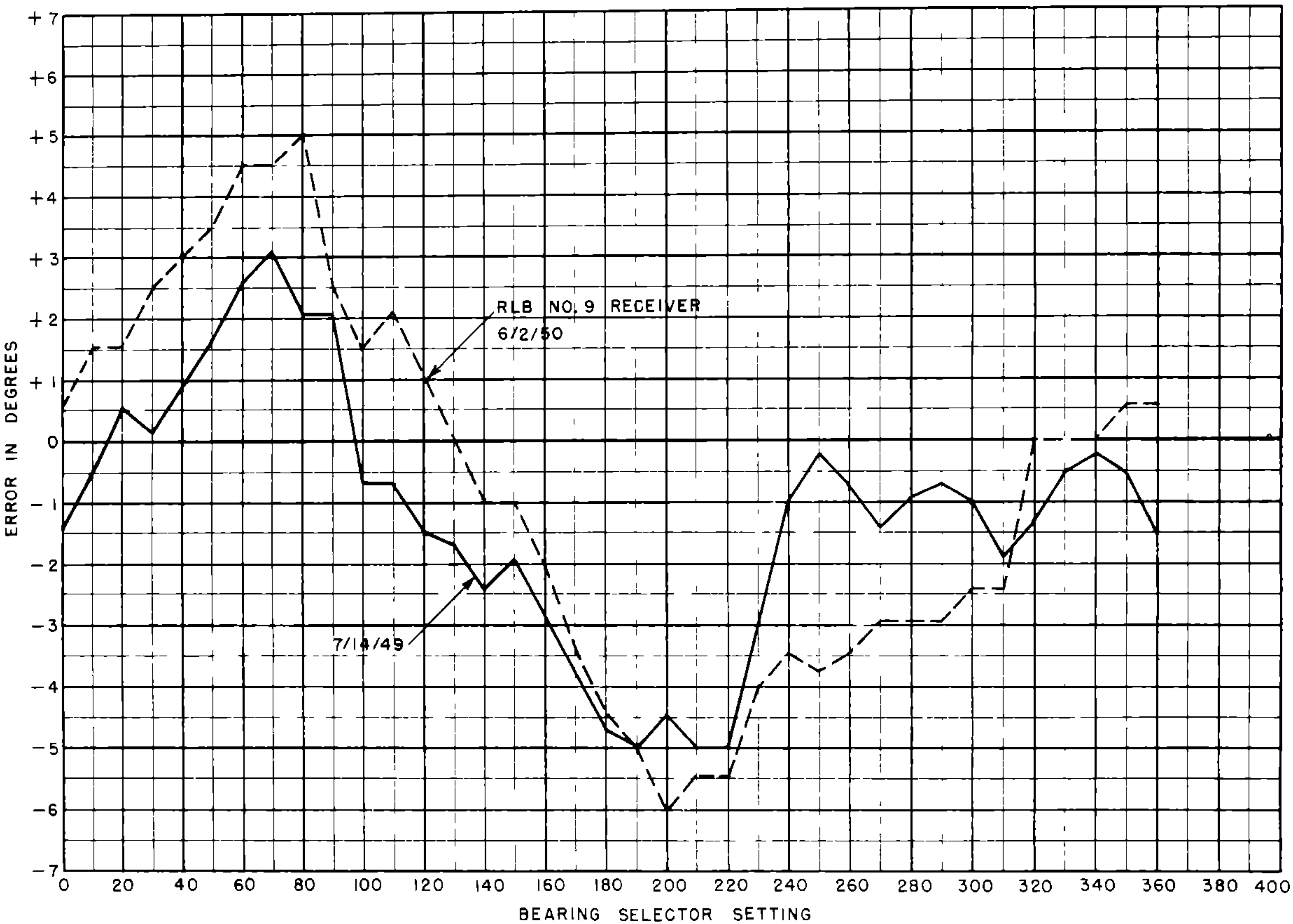

FIGURE 6 NANTUCKET MOR FLIGHT CALIBRATION

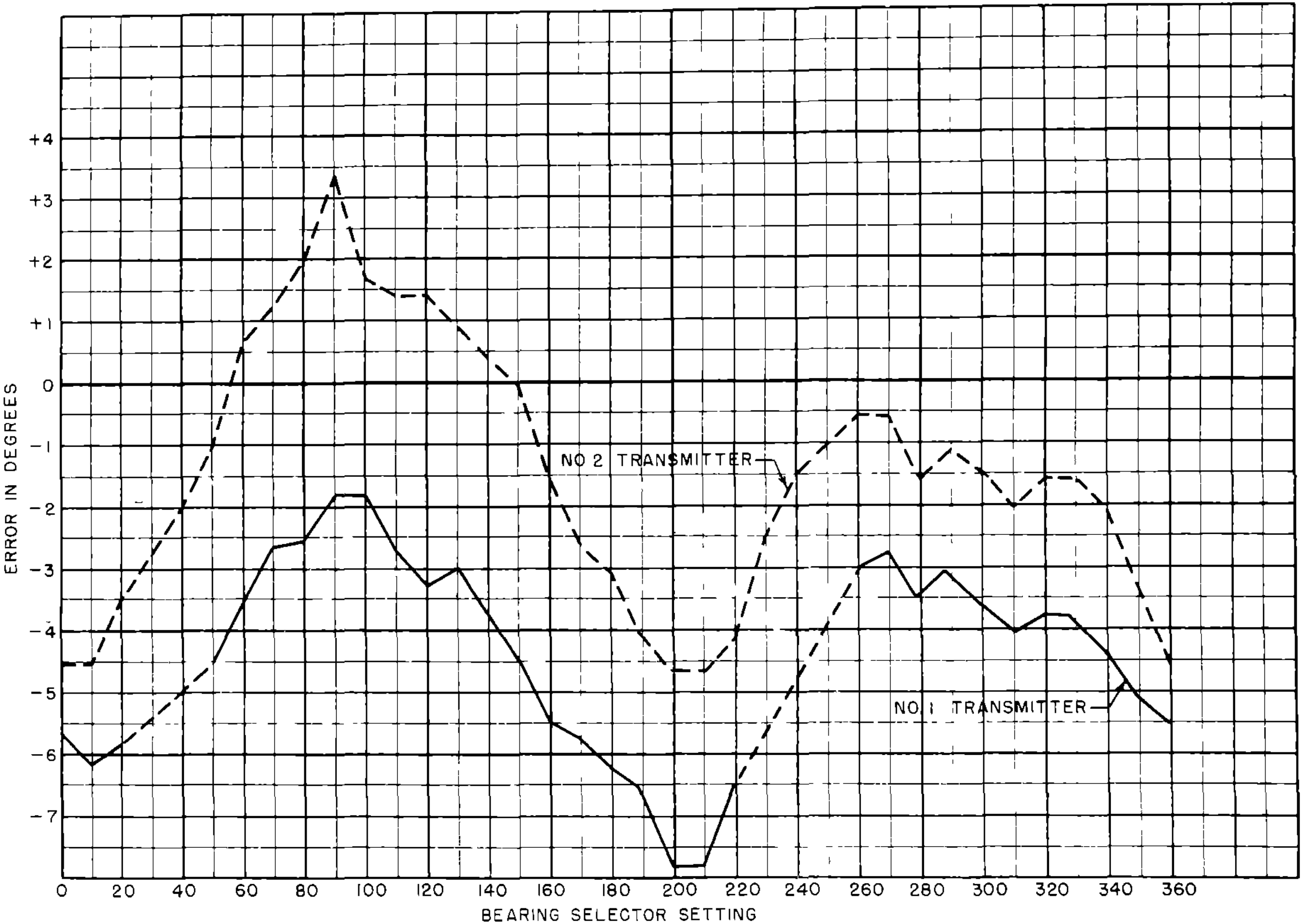

FIGURE 7 NANTUCKET MOR FLIGHT CALIBRATION
NEW CENTER TOWER TRANSFORMER
RLB NO 9 RECEIVER 6/8/50