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RECENT OMNI RANGE IMPROVEMENTS AND STATUS OF PROGRAM

by

Radio Development Division

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CIVIL AERONAUTICS ADMINISTRATION
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SUMMARY

The performance of the VHF omni range has been demonstrated to exceed by a good margin the specified requirements of the COT division of ICAO. All electrical and mechanical problems encountered in its development have been satisfactorily solved. Siting of stations remains the major installation problem, but it has been found that satisfactory operation can be secured on the basis of clearing a 700-foot radius for obstacles 30 feet high, and by using a large dish-shaped counterpoise in rough terrain where clearing is not practical.

Independent tests made by the Collins Radio Company on ten omni ranges selected at random showed that course variations were less than two degrees for 99.25 percent of the flight time of 14 hours 43 minutes devoted to such measurements.

Initial flight tests have been made on a course line computer developed for CAA by the Minneapolis-Honeywell Regulator Company, using the omni range and DME installed at Indianapolis. Parallel tracks over distances of 120 miles were flown with an accuracy of better than two miles. Distance to an arbitrarily selected way point was also indicated with an accuracy of two miles.

To meet the need of private flyers for a combined navigation and communication receiver, negotiations are under way for a development contract, intended to establish facilities for quantity production at low cost.

Among improvements effected in the omni range system during the past year and a half are the following:

1) A circular antenna shelter has been devised which eliminates errors found to be caused by the unsymmetrical configuration of previously used shelters.

2) Resistance cloth has been installed around the antenna supporting pedestals to reduce errors caused by the emission of vertically polarized energy.

3) The aircraft antenna has been improved in design and location.

4) Improved clipper circuits have been developed and applied to eliminate the possibility of course reversal, and also to reduce errors introduced by the receiving equipment when the action of the limiter circuit in the reference channel is inadequate.

5) A new commercial design goniometer has been adopted which has an r-f efficiency of 90 percent, compared with 30 percent for earlier models. A tone wheel on the goniometer shaft has replaced the pilot generator and ten-kilocycle FM oscillator, which were previously used, improving stability and simplifying maintenance.

6) Progress has been made in the development of a spinning transmitting antenna which may eventually replace the present five-loop array and goniometer.

7) Laboratory test facilities have been established which are capable of precision determination of omni receiver and converter characteristics.

RECENT OMNI RANGE IMPROVEMENTS
AND STATUS OF PROGRAM

Introduction

During the past one and one-half years, considerable effort has been made to improve the accuracy and reliability of the VHF omni range system. At this time substantial improvements have been accomplished, and the purpose of this memorandum is to summarize these improvements and indicate the status of the omni range program.

Reduction of Errors Caused By House

At the time of the PICAO demonstration at the Experimental Station, a house eight feet square was installed around the antenna array of the south omni station. The station was calibrated by personnel from the Electronics Subdivision of Wright Field, Ohio, and from the Experimental Station. The over-all accuracy of the system, including the receiver, was found to be ±2.1 degrees. The receiver was an RC-103 type which was modified by the Experimental Station. As a result of commitments made at PICAO, the monitor was moved from a point northeast of the station to a point having a magnetic bearing of north from the station, and the antenna array was rotated 45 degrees to restore the monitor on-course indication. Calibration measurements showed that the over-all error was slightly greater than ±3 degrees. This error was ±1 degree greater than before the antenna array was rotated. The reason for the increase in error was not understood at first, and a series of tests were made to determine the optimum rotation of the house with respect to the loops for minimum error. It was found that the minimum error of ±2.1 degrees was obtained when the vertical planes through the diagonal loops were parallel to the sides of the house. This corresponded to the condition existing during the PICAO demonstration, except that the house and loop array had both been rotated 45 degrees.

In order to determine the optimum orientation with a standard 12-foot Federal Airways house similar to those used at all omni range stations, one was obtained from the Third Region and installed. It was found that this larger house increased the error with optimum house rotation to ±3 degrees. Furthermore, the optimum orientation of the loop array was found to be reversed from the optimum orientation for the smaller house since the over-all error was smaller when the loop diagonals made an angle of 45 degrees with the sides of the house. The attached Figs. 1, 2, and 3 show the errors observed during flight tests without the house installed and with the larger house installed. Without the house, the over-all error was approximately ±2 degrees. With the house installed and loop array oriented so that the diagonals of the array formed an angle of 45 degrees with the sides of the house, the over-all error was ±3 degrees. With the loop array rotated so that the diagonals of the array were parallel to the sides of the house, the over-all error was ±4 degrees. Fig. 4 shows that rotation of the house alone about the fixed antenna array caused approximately ±1.5 degrees variation in on-course indications during observations using an Aircraft Radio Corporation Type 15 receiving equipment at the Experimental Station laboratory.

Fig. 5 shows the errors observed without the house when the transmitter antenna array was rotated and an ARC-15 receiving equipment was used at the Experimental Station. Figs. 6 and 7 show the errors observed under the same conditions, except that the house had been installed and the house and antenna array were rotated simultaneously. The orientation of the house with respect to the antenna array is indicated on the figures.

The results of all the work at this stage indicated that a circular house was necessary to eliminate errors due to house configuration. Accordingly, a circular house having a diameter of eight feet and constructed of masonite material was installed and its effect investigated.

Flight tests were made using the same ARC-15 receiving equipment as before, and the over-all error was found to be ±2.1 degrees and was approximately one degree less than that obtained for optimum orientation of the loop array with the large square house installed. A calibration test was also made with the aircraft at a fixed point on the ground by rotating the loop array through 360 degrees. The over-all error was ±2.2 degrees, and the shape of the error curve was very much like that of the flight-test error curve indicating that the round house did not contribute noticeable errors. For the first time good correlation between flight and ground calibration was obtained. Figs. 8 and 9 showing the above error curves are attached.

Recent Measurements of Station Error

Fig. 10 shows the measured error of the transmitting station with circular house installed. This was obtained by measuring the variation in phase of the 30-cycle transmitter modulation at the output of the second detector of a receiver located at a fixed point as the loop array at the station was rotated 360 degrees with the frequency modulated subcarrier modulation removed from the center loop. The error was found to be ±0.9 degree. The phase of the output of the phase discriminator, with the frequency modulated subcarrier modulation restored to the center loop and the goniometer terminated in a dummy load instead of the outer loops, did not vary as the loop array was rotated.

On December 3, 1947, a ground calibration of the station was made using a receiver developed by Federal Telecommunication Laboratories installed in the Air Transport Association aircraft. An over-all error of ±1.0 degree was obtained when using the radial converter indicator. This is shown in Fig. 11. When the bearing selector was used, an error of ±2.25 degrees was obtained and is shown in Fig. 12. The error was greater when the bearing selector was used, and this was attributed to unbalance in the bearing selector circuit. These tests and the measurements of the errors in the variable phase signal indicate that the omni station, exclusive of receiver, has an accuracy of approximately ±1 degree.

In comparing the error curves on Figs. 9 and 11 it should be noted that the error obtained using the ARC-15 receiver is ±2.2 degrees, while the error obtained using the FTL receiver is only ±1.0 degree. The difference in over-all error is attributed to larger errors in the ARC-15 receiver and to different error distribution in the ARC and FTL receivers. Receivers of improved design are on order, and when these receivers are obtained, the over-all accuracy should be equal to that of Fig. 11.

Black Moshannon Station Error

The Black Moshannon omni range is located in the most rugged and mountainous terrain of the Appalachian Mountains. A calibration of this station was made on December 18, 1947, by Experimental Station personnel. The calibration curve obtained is shown in Fig. 13 and indicates an over-all error of ±2 1/2 degrees. It is believed that replacing the square house now installed with a circular house will substantially reduce the errors observed.

Reduction of Polarization Errors

Recently, considerable effort has been made to reduce the magnitude of the vertically polarized energy radiated from the antennas in order to reduce errors noticed when flying the aircraft at different headings over a fixed point and to reduce aircraft attitude errors.

For several years the errors due to changing the aircraft heading were checked by flying the aircraft over a specific point towards and away from the station and in both directions normal to the radial through the point. This same procedure was followed over points at different azimuths from the station. The errors were approximately ±1 degree. During the period from October 15 to October 17, 1947, the ATA made a series of flights over several points at eight different headings. Some of the tests made by the ATA were repeated immediately by the Experimental Station, and it was found that errors of +2 to -4 degrees were obtained using the tail V antenna when the aircraft heading was equal to the bearing of aircraft to station ±45 degrees. The results of this test are shown in Fig. 14. When using the forward V antenna, errors from +2.5 degrees to -2 degrees were obtained as shown by the dashed curve of Fig. 15.

Numerous methods were tried to reduce the errors due to the vertically polarized component. It was determined that the best practical solution was to rotate the phase angle of the vertical component so that it had a phase angle of 90 degrees with respect to the horizontal component. In addition the amplitude of the vertical component was reduced 10 percent.. This was accomplished by using resistance cloth wrapped around the four outside loop pedestals in the form of a square. A single layer of this cloth was wrapped around the top and bottom of the four outside loop supporting pedestals as a group. The top and bottom layers overlapped for a distance of two feet at the center portion of each pedestal. The pedestals were not wrapped individually. This cloth had a rated resistance of 377 ohms per square, although the measured resistance was 500 ohms per square.

The final results as shown on Fig. 16 indicates that the errors at different headings vary from +0.1 to -0.8 degree when using the tail V antenna and +1.6 to -1.4 degrees when using the forward V antenna. These results indicate that a substantial improvement has been made, especially when the tail V antenna is used, and that the tail V antenna location is superior to the forward V antenna location which is just aft of the hatch in the pilot's compartment.

Flight tests on December 8, 1947, made before and after the resistance cloth was installed showed that the installation of the cloth decreased the attitude errors. The following table lists the maximum errors noted during 360-degree turns at a 30-degree bank at various distances east of the station during a flight in aircraft NC-181 using ARC-15 receiving equipment and the tail V antenna.

Distance From Station (miles)	Maximum Error	
	With Cloth Installed (degrees)	Without Cloth Installed (degrees)
13.75	±1.5	±2.25
23	±1.75	±3.4
38	±2.1	±3.1

A comparison was made of attitude errors when using the tail V antenna and using the forward V antenna. The resistance cloth was used during all these tests made in NC-182 and using another ARC-15 receiver.

Distance From Station (miles)	Maximum Error	
	Tail V Antenna (degrees)	Forward V Antenna (degrees)
13.75	±1.75	±2.0
23	±1.85	±1.8
38	±1.75	±1.25

Stability of Omni Range Courses

During the PICAO demonstration and prior to this period, the center loop and sideband loops were fed from a common source of r-f energy. A clipper was inserted between the source (output of the transmitter) and the goniometer input. The results obtained with this arrangement were excellent in that the courses were always found in the same position.

After the PICAO demonstration, it was decided to investigate a different method of feeding the antennas. This method consisted of feeding the center loop antenna from the power amplifier plate circuit and the goniometer from either the I.P.A. plate circuit or the power amplifier grid circuit. These tests disclosed that slight variations in course positions occurred and it was difficult to maintain constant percentage variable phase modulation. Variations in the phase of the voltage fed to the outer loops with respect to that fed to the center loop caused a variation in course width and a marked increase in course bends. It has also been observed that an open grid of one of the power amplifier tubes caused a shift in phase which reversed all courses

180 degrees even though the station continued to operate and transmit an apparently normal signal as observed in the airplane.

Reversal of courses without other apparent malfunctioning is very serious and must be prevented. The use of signals from a station with such a defect could easily result in disaster. The stations must be monitored in a manner such that the station will be made inoperative immediately should course reversal occur. Course reversal could occur unnoticed for a period of time if the station is not monitored constantly, or if the monitor is defective. For this reason it is deemed necessary that the goniometer be fed from a clipper circuit connected to the output circuit of the power amplifier to insure constant phase displacement of the energy fed to the goniometer with respect to that fed to the center loop for any condition which might prevail at the transmitter.

The effectiveness of the clipper circuit, described in the publication "The CAA VHF Omni-directional Radio Range With Simultaneous Voice" distributed at the PICAO demonstration, has been improved by using a VHF bridge and superior diode tubes. Also, the unit housing the tubes has been greatly improved both from the standpoint of maintenance and construction. Fig. 17 shows a block diagram of the omni transmitting equipment including the clipper, VHF bridge, and associated parts. The oscillograms on Fig. 18 show the envelopes of the voltage appearing in the transmitter output and clipper output. The original clipper reduced the ten-kilocycle modulation from 25 percent to approximately five percent, the latest clipper reduces the ten-kilocycle modulation from 30 percent to a negligible percentage and similar to that shown in the oscillograms. Fig. 19 is a schematic diagram of the "clipper" shown in Fig. 17.

Steps are now being taken to install clipper circuits at all VHF omni range stations. This will eliminate the difficulties outlined above when supplying the antenna array from two r-f sources which can vary in phase. The use of clipper circuits will also reduce errors introduced by the receiving equipment when the action of the limiter circuit in the reference channel is inadequate.

The Goniometer and Tone Wheel

The goniometer, pilot generator, and ten-kilocycle FM oscillator used during the PICAO demonstration has been replaced by superior equipment. The new goniometer unit is much smaller and is driven by a 1/20-horsepower synchronous motor, whereas a 1/2-horsepower synchronous motor was required to drive the old unit. The r-f efficiency of the new goniometer is approximately 90 percent, while that of the old goniometer was 30 percent.

Also driven by the 1/20-horsepower synchronous motor is a tone wheel which takes the place of the pilot generator and ten-kilocycle FM oscillator. The tone wheel greatly improves the stability and simplifies the installation and maintenance of the station. Fig. 20 is a photograph of the CAA Type 1231 capacity goniometer and tone wheel unit.

Spinning Antenna Development

The spinning dipole type antenna has been replaced by the spinning double-loop antenna shown in Fig. 21. The spinning dipole antenna was not satisfactory because of errors introduced by vertical polarization. The new spinning antenna is made of magnesium, rotates at 1800 rpm, and theoretically only horizontally polarized energy will be radiated. The carrier is radiated from a loop antenna placed either above or below the spinning antenna. Tests are being made at the present time to determine the characteristics of the new antenna.

Method of Setting Up and Monitoring Omni Ranges

PICAO standards have been set up which establish the direction of rotation of the figure-of-eight pattern as clockwise. In order to check the direction of rotation of the figure-of-eight pattern the carrier energy to the center antenna is removed. A check is made of the position of one of the nulls of the figure-of-eight pattern with a field meter when the goniometer is stopped. The goniometer is rotated 45 degrees manually in the same direction as during normal operation, and the position of the figure-of-eight null is again observed. If the null has moved in a clockwise direction, the direction of figure-of-eight rotation is in accordance with PICAO standards. If the rotation of the figure-of-eight pattern is found to be counterclockwise, the r-f cables feeding the two pairs of sideband loops are interchanged at the goniometer.

In order to insure uniform alignment of all stations with respect to magnetic north and to provide a means of monitoring the station course alignment, a monitor has been developed. A schematic diagram of the monitor is shown in Fig. 22. A remote pick-up is located on a pole at magnetic north and approximately 200 feet from the station, and the monitor is used to determine whether the 30-cycle modulation voltages from the variable and reference phase signals are in phase.

When the CAL-MON switch is in the CAL position, the only signal fed into the monitor phase comparison circuits is the signal from the tone wheel. The 30-cycle output voltage of the frequency discriminator circuit which is designed for zero phase shift is fed to the variable phase channel consisting of a 30-cycle pass filter and amplifier. The discriminator output voltage is also fed to the remaining portion of the reference phase channel which consists of 30-cycle amplifiers and bearing selector. The bearing selector is adjusted to the setting that will center the the course deviation indicator needle and provide clockwise motion of the needle when the bearing selector is moved in a clockwise direction. This adjustment is made to obtain on-course indication of the course deviation indicator when the 30-cycle variable phase modulation voltage and the 30-cycle reference phase modulation voltage are in phase. When the CAL-MON switch is in the MON position, the variable and reference phase voltages from the detector in the remote pick-up are fed into the monitor variable and reference phase channels, respectively.

If the course deviation indicator remains centered, the phase relationship of the modulations of the transmitted signal are in phase or 180 degrees out of phase. If the indicator does not remain centered, the tone wheel pick-up coil should be rotated to center the indicator.

In order to determine that the reference and variable phase voltages are in phase instead of 180 degrees out of phase, the bearing selector is moved in a clockwise direction. If the voltages are in phase, the course deviation indicator needle will also move clockwise. If the needle should move in the counterclockwise direction, the antenna array should be rotated 180 degrees.

Laboratory Test Facilities for VHF Omni Range Receiving Equipment

Laboratory test facilities that provide signals simulating those from the VHF omni ranges have been developed. These facilities have been used to determine the performance characteristics of VHF omni range receiving equipments. Heretofore, satisfactory test equipment has not been available commercially, although it is anticipated that test equipment suitable for over-all performance measurements will be made available by Collins Radio Company in a few months.

A block diagram of the test facility components developed at the Experimental Station is shown in Fig. 23, and schematic diagrams of the r-f modulator unit, frequency modulated 9960-cps oscillator and VHF converter in Fig. 24. The ten-megacycle signal from the signal generator is unmodulated and is fed to the modulator unit where it is amplitude modulated by the 30-cps signal from the variable phase alternator and also by the frequency modulated 9960-cps signal. The modulated ten-megacycle signal is fed to the VHF converter consisting of an oscillator operating at a frequency of 125 megacycles, a mixer, and an amplifier. The receiver is tuned to the 115-megacycle signal which contains the same modulation as the ten-megacycle signal. If desired, voice modulation may be introduced by means of the microphone and voice amplifier connected to the modulator unit.

The VHF converter may be removed and the output of the modulator connected directly to the intermediate frequency amplifier stages in the receiver if it is desired to make tests involving only the intermediate frequency and audio stages.

If desired, the frequency modulated tone wheel assembly may be substituted for the frequency modulated 9960-cps oscillator. The tone wheel assembly is identical to that used at the omni range station; however, the oscillator is used for development purposes since the frequency and frequency deviation can be varied to study the characteristics of the frequency discriminator in the receiver. Also, provision is made for amplitude modulating the frequency modulated signal for the purpose of determining the effectiveness of the limiter circuits preceding the frequency discriminator.

To simulate the effects of propeller modulation audio signals in the frequency range of 30- to 90-cps are applied from the variable frequency audio oscillator to the grid circuit of the 6AC7 amplifier tube in the VHF converter.

When determining the effect of power line frequency variation at the transmitter upon the receiving equipment accuracy, the tone wheel assembly is substituted for the 9960-cps oscillator. The synchronous motors of the tone wheel assembly and 30-cps alternators are operated from a variable frequency alternator which is driven by a d-c motor. By varying the voltage applied to the direct current motor, the motor speed and alternator output frequency is varied.

To determine the bearing accuracy of the receiver the stator of the variable phase alternator is rotated in desired angular increments, and the corresponding readings of the receiving equipment bearing selector are noted and compared with the settings of the variable phase alternator stator. Accuracy and course sensitivity tests may be made at different signal levels and at different signal frequencies by adjusting the signal generator output attenuator and frequency of the VHF converter oscillator. Fig. 25 shows the error curve of an Aircraft Radio Corporation Type 15 receiving equipment which was recently modified to reduce errors. Flight tests will be made to determine the over-all accuracy of the system using this receiver.

Improvement of Aircraft Receiving Antenna

In the omni range system it is important that the aircraft receiving antenna has satisfactory electrical and mechanical characteristics. In addition to being weather resistant and having good aerodynamic design, the field pattern, sensitivity, and attenuation of vertically polarized signals should be satisfactory over the band of frequencies from 108 to 122 megacycles.

An improved model of the pedestal type of coaxial V antenna has been constructed using cast magnesium parts and is shown in Fig. 26. The model weighs four pounds ten ounces, and is eighteen inches over all in height. The electrical characteristics are shown in Figs. 27 and 28. Both the standing wave ratios and the radiation pattern were taken under free space conditions which are similar to those encountered when the V antenna is mounted six inches above the vertical stabilizer of a DC-3 aircraft as shown in Fig. 29. This location is the most efficient mounting position from the standpoint of sensitivity and freedom from propeller modulation interference. Polarization effects are also reduced by locating the receiving antenna on the vertical stabilizer when resistance cloth is not used at the omni range station. The second choice in location is just forward of the astrodome and 18 inches above the skin of the aircraft. With twin-tailed aircraft, this has been found to be the best location. In this location the service range is essentially equivalent to the tail V when headed toward the omni station, however, the service range is reduced approximately 20 percent when headed away from the omni station. Furthermore, the propeller modulation is increased approximately 200 percent.

Since the present model is intended for use with RG 8/U, 52-ohm coaxial transmission line instead of the balanced RG 22/U line formerly used, a balanced to unbalanced bazooka matching section has been built into the pedestal. This adds 12 ounces to the weight of the unit and permits the use of a line which is mechanically more reliable and has considerably less attenuation.

Coaxial V antennas have been used on various types of aircraft for the past two years with very satisfactory results.

Course Line Computers Using Information From Omni Range and DME

In addition to the omni range installation program nine distance measuring equipment ground beacons are now undergoing factory tests. These units will be installed early this spring for exhaustive field tests.

Extensive flight tests have been made on the experimental model of the course line computer developed by the Minneapolis-Honeywell Regulator Company for the Civil Aeronautics Administration. The omni range and DME facilities at the Experimental Station were used for these tests. Results of tests consisting of flights over parallel ground tracks 120 miles long indicate that tracks can be flown with an accuracy better than ±2 miles. A map showing an actual flight track and a recording of course deviation indicator deflections is shown on Fig. 30. These data show that the accuracy of the computer is acceptable. The course width, however, is too sharp and in future tests five dots on the course deviation indicator will be made to represent six miles instead of 2 1/2 miles. This computer also indicates distance to a selected destination on the chosen track. This indication is also accurate within two miles. Automatic radio flights have been made on the present computer; however, the control is somewhat rough because of the periodic variation shown in the right-hand end of the recording of Fig. 30. Smoothing of automatic flight will require the utilization of new long-time integrating techniques which have recently become available.

In order to determine the characteristics of other types of computers, arrangements are being made to obtain computers from Collins Radio Company and Bendix Radio. Also, an improved model has been designed by the Experimental Station and is now under construction.

VOR Flight Tests and Laboratory Measurements by Collins Radio Co.

The Collins Radio Company conducted flight tests of ten omni range stations in October, 1947, and reported the results in a 27-page report. The flight tests were made in a DC-3 aircraft using a tail V antenna and the Collins 51-R navigation receiver together with recording equipment. The following gives the pertinent data contained in the report.

An analysis of flight recordings obtained by flying various courses of the ten stations showed the variation in on-course indications produced by course bends as follows·

	Minutes	Percentage
Total time when deflection exceeded ±3 degrees	1 1/2	1/4
Total time when deflection exceeded ±2 degrees	6 4/10	3/4
Total time when deflection was less than ±2 degrees	875	99 1/4

The 6 4/10 minutes where the deflection exceeded two degrees were made up of a number of intervals each of short duration. Cone effects were excluded in this analysis.

The course width on all stations was found to be between 20 and 23 degrees. All stations were found to deliver a usable signal out to and somewhat beyond the optical line of sight. Reciprocal course error obtained by flying straight tracks over the station was found to be less than two degrees (or less than one degree on any given radial). The orientation of the stations with respect to magnetic north or "indexing error" was found to be less than could readily be ascertained from the limited chart data available on the position of the stations.

At various times during the flight tests, the propeller speed was varied to make residual propeller effect show up on the recordings. Occasionally, with certain critical headings, an oscillation in indication as high as ±1/2 degree was experienced having a period corresponding to the difference between the propeller frequency and 60 cycles. In general, propeller modulation produced no observable effect on the course indications.

Some of the major over-all performance characteristics of the Type 51R navigation receiver developed by the Collins Radio Company to comply with the Aeronautical Radio, Incorporated, specifications are shown on Figs. 31 to 38, inclusive. These figures were drawn from graphs furnished by courtesy of the Collins Radio Company.

Existing Problems of Omni Range System

Experience obtained to date both in the development and installation of VHF omni ranges has indicated that there are no insurmountable problems. All electrical and mechanical problems have been satisfactorily solved, however, it is conceded that siting of the omni stations is the major problem in connection with the installation of facilities. Summarized briefly, it has been found that in flat terrain in the vicinity of trees and obstacles 30 feet high the installation should be made at a site which is cleared to a radius of at least 700 feet. If the trees or obstacles are 60 feet high, the radius of the cleared area should be at least 1400 feet. If the obstacles are 90 feet high, the radius should be at least 2100 feet. In mountainous terrain it has been found desirable to locate omni ranges on top of high ground which is as level as possible in the vicinity of the station. It has also been found desirable to use counterpoises which are 15 feet high in lieu of the 30-foot counterpoises when the ranges are located on hills or mountains. In sites which have been located in rough terrain it has been found that a very considerable improvement in the elimination of course bends has been made by erecting dish-shaped counterpoises 85 feet in radius which decrease the magnitude of the reflected wave that reflects off the rugged slopes. In locations where the ground is abnormally rough, or in the vicinity of trees which cannot be removed, a major improvement can be made by utilizing this technique. It is planned to make more extensive tests of siting problems, and it is confidently felt that a satisfactory solution will be found.

Tests have been made where the power line frequency at the omni station was varied between 57 and 63 cps and bearing observations were made using an early model ARC-15 omni receiver which produced the results plotted in Fig. 39. The Collins receiver, a later and more improved omni receiver, produced the small errors shown on Fig. 34 for power frequency variation, excluding the phase splitting circuit. Theoretically the phase splitting circuit should produce one degree per cycle variation at 60 cycles. Tests will be conducted on this receiver during the next few weeks to determine its error with line frequency variation.

While most commercial power companies maintain their frequency to within ±1/10 cps of 60 cps, a local stabilized oscillator has been developed and is available to supply power for the goniometer and tone wheel synchronous motor in the localities where the power frequency is not satisfactory.

Status of CAA Omni Range Program

As of October 31, 1947, the latest date for which complete information is available, the status of the VHF omni range installations is as follows; it is planned to install 394 VHF omni range stations, 34 of which are already in operation, and 211 are in the process of construction and installation.

In order to promote commercial interst in the development and production of a low cost private flyer's navigation receiver, approximately 12 commercial concerns were contacted for the purpose of determining the possibility of producing a low cost receiver having performance characteristics suitable for the private flyer. As a result of these discussions, a specification containing minimum essential performance requirements was prepared. Negotiations are now being made to obtain a quantity of these receivers through a development contract intended to establish facilities for production at low cost.

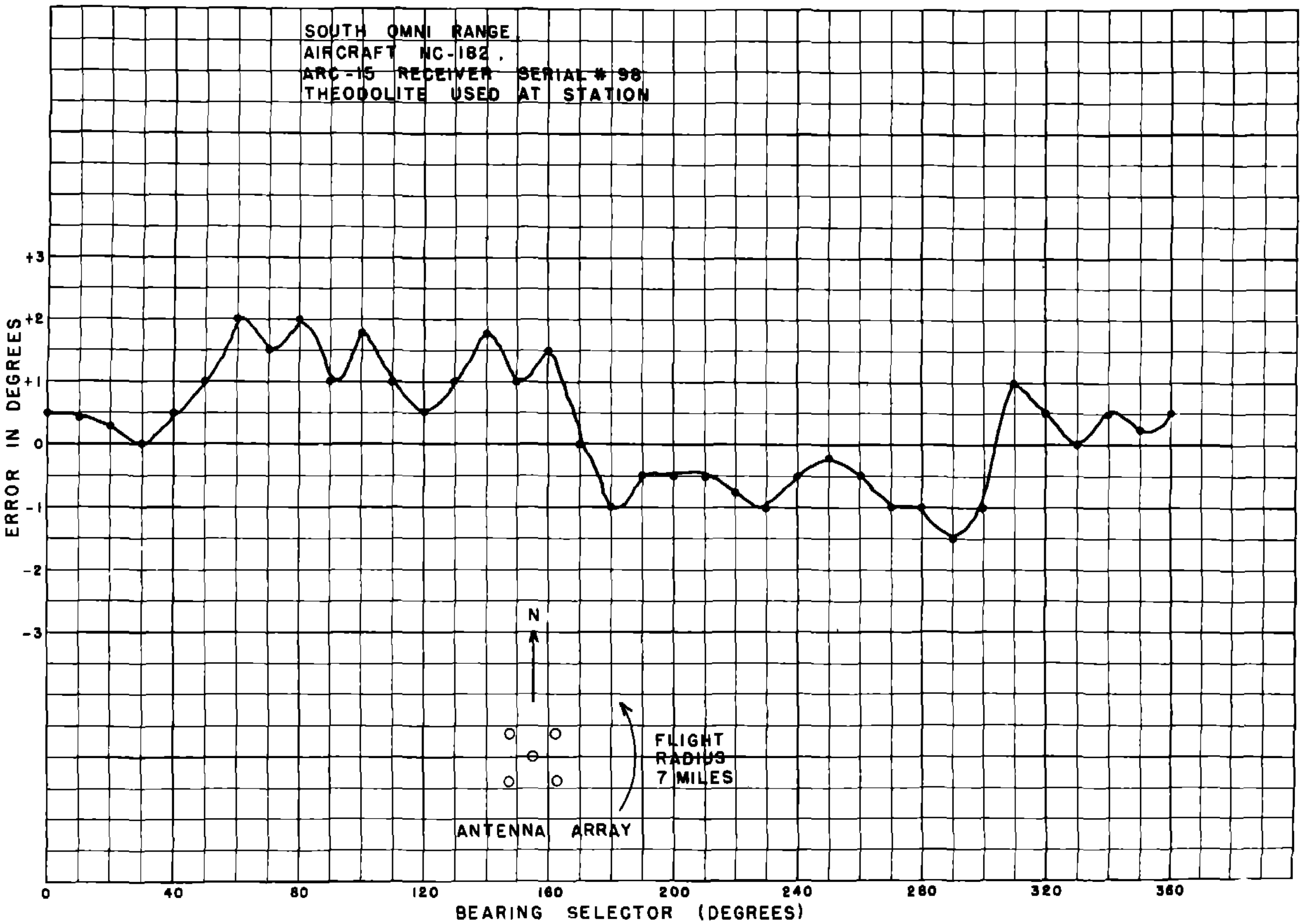


FIGURE I FLIGHT CALIBRATION WITH NO HOUSE INSTALLED

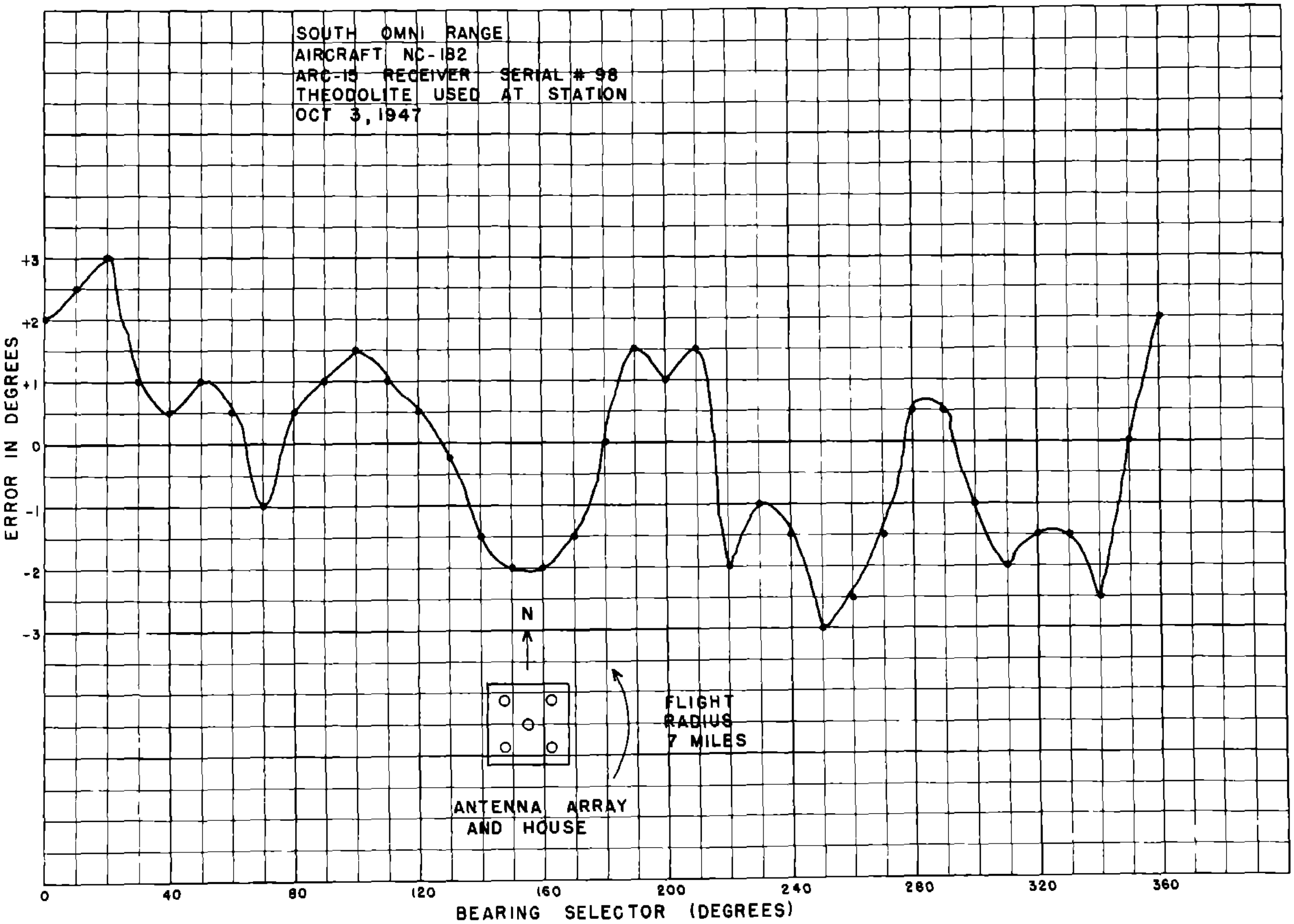


FIGURE 2 FLIGHT CALIBRATION WITH SQUARE HOUSE INSTALLED

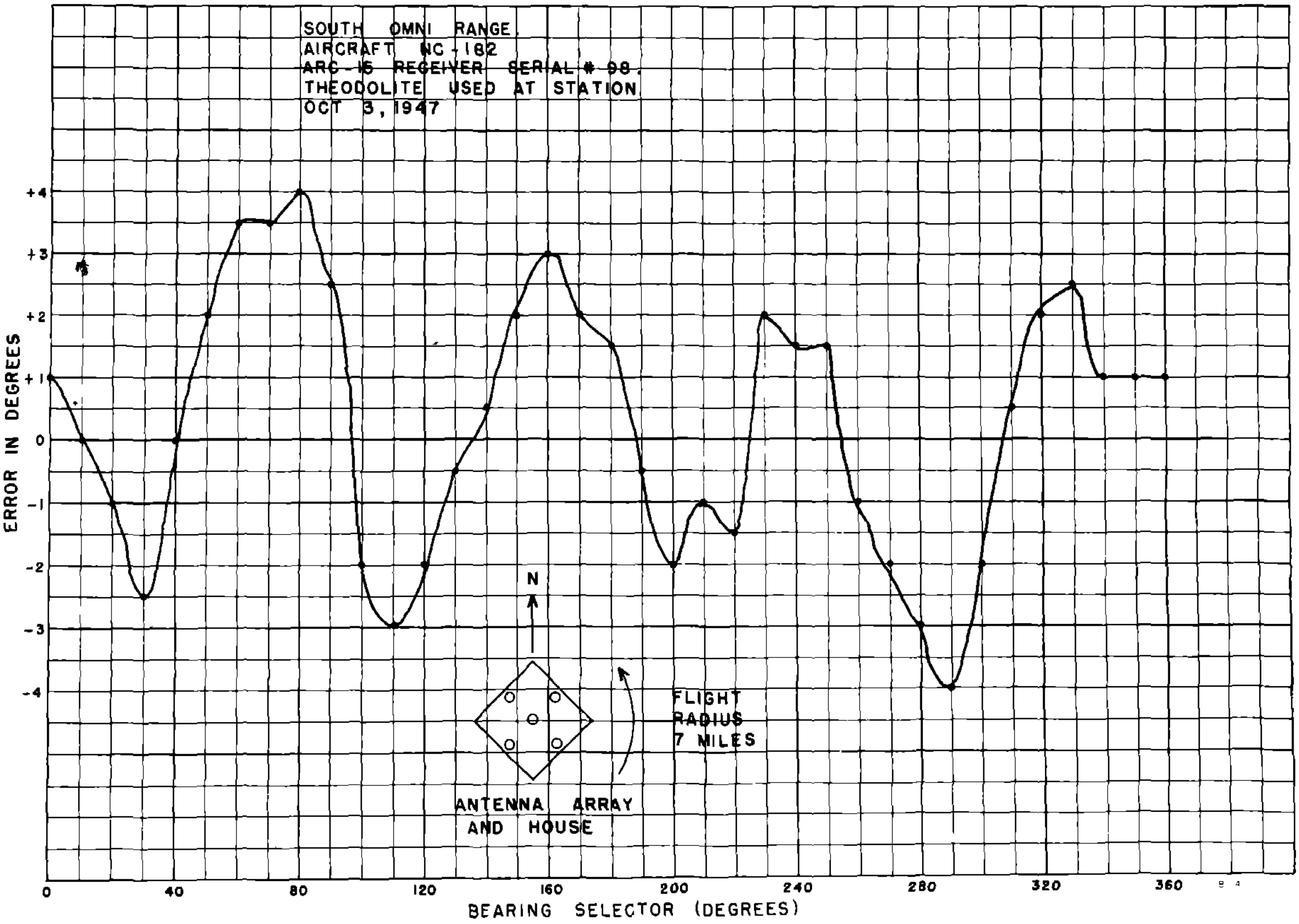


FIGURE 3 FLIGHT CALIBRATION WITH SQUARE HOUSE INSTALLED

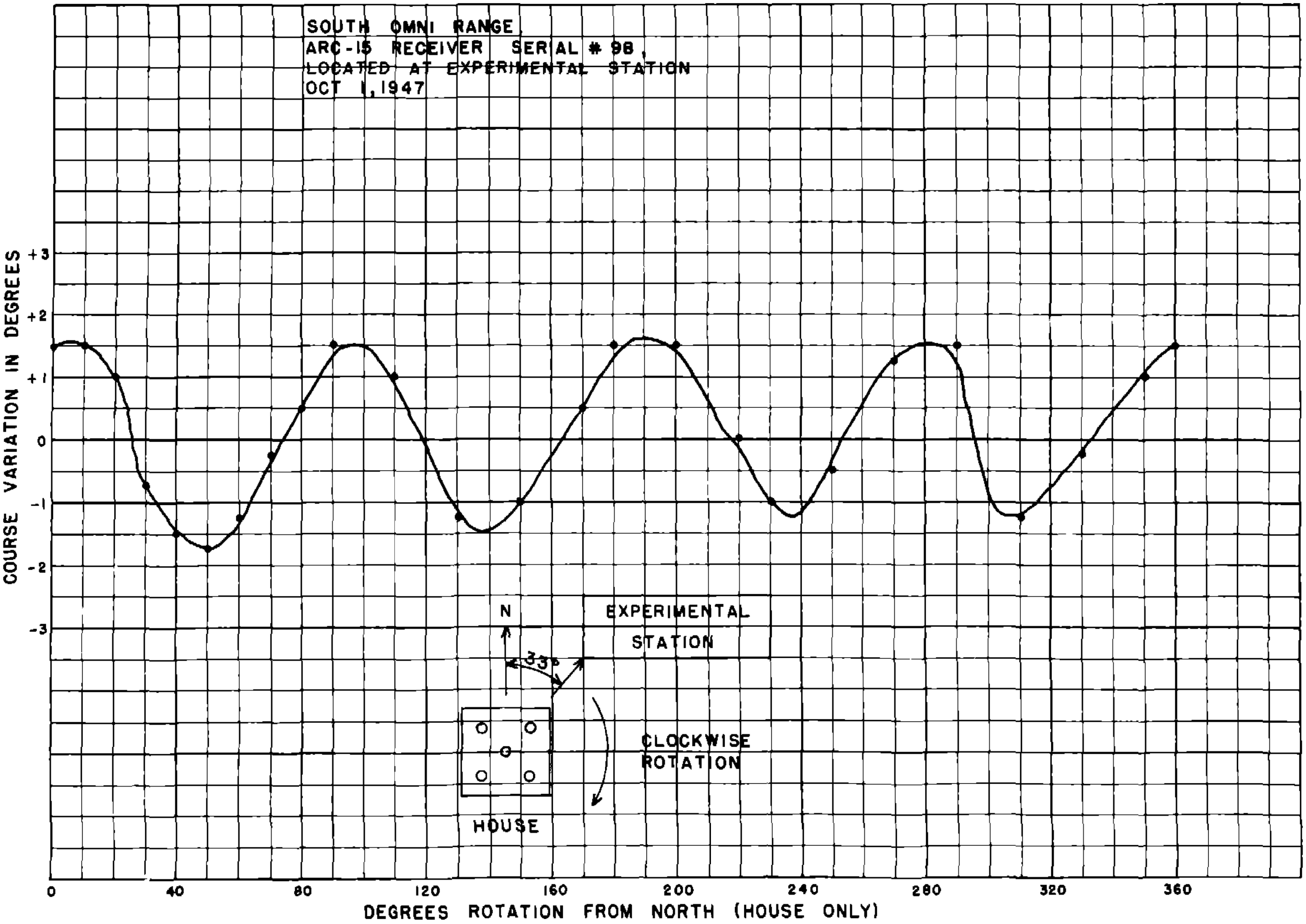


FIGURE 4 COURSE VARIATION VERSUS ROTATION OF HOUSE

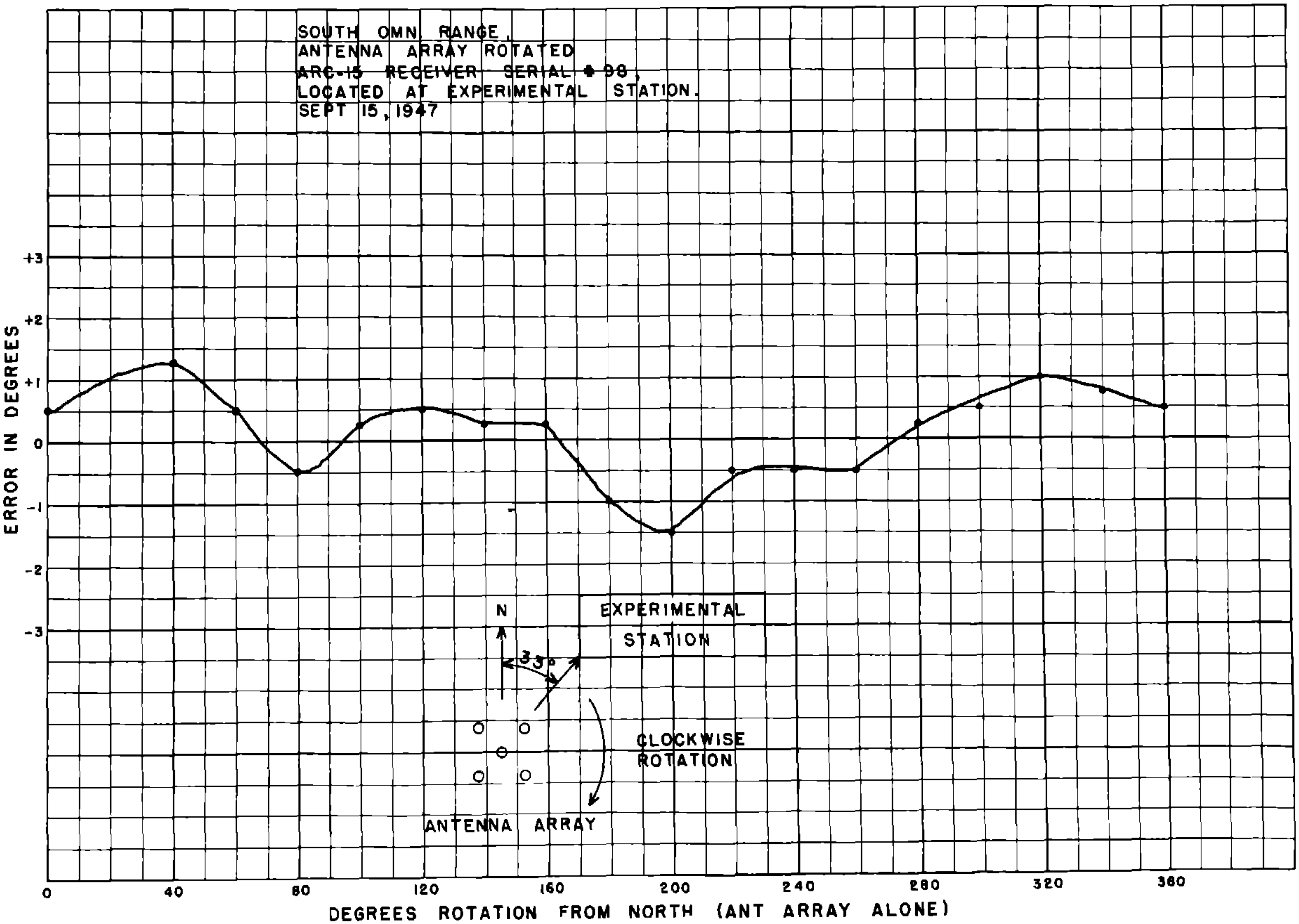


FIGURE 5 GROUND CALIBRATION WITH NO HOUSE INSTALLED

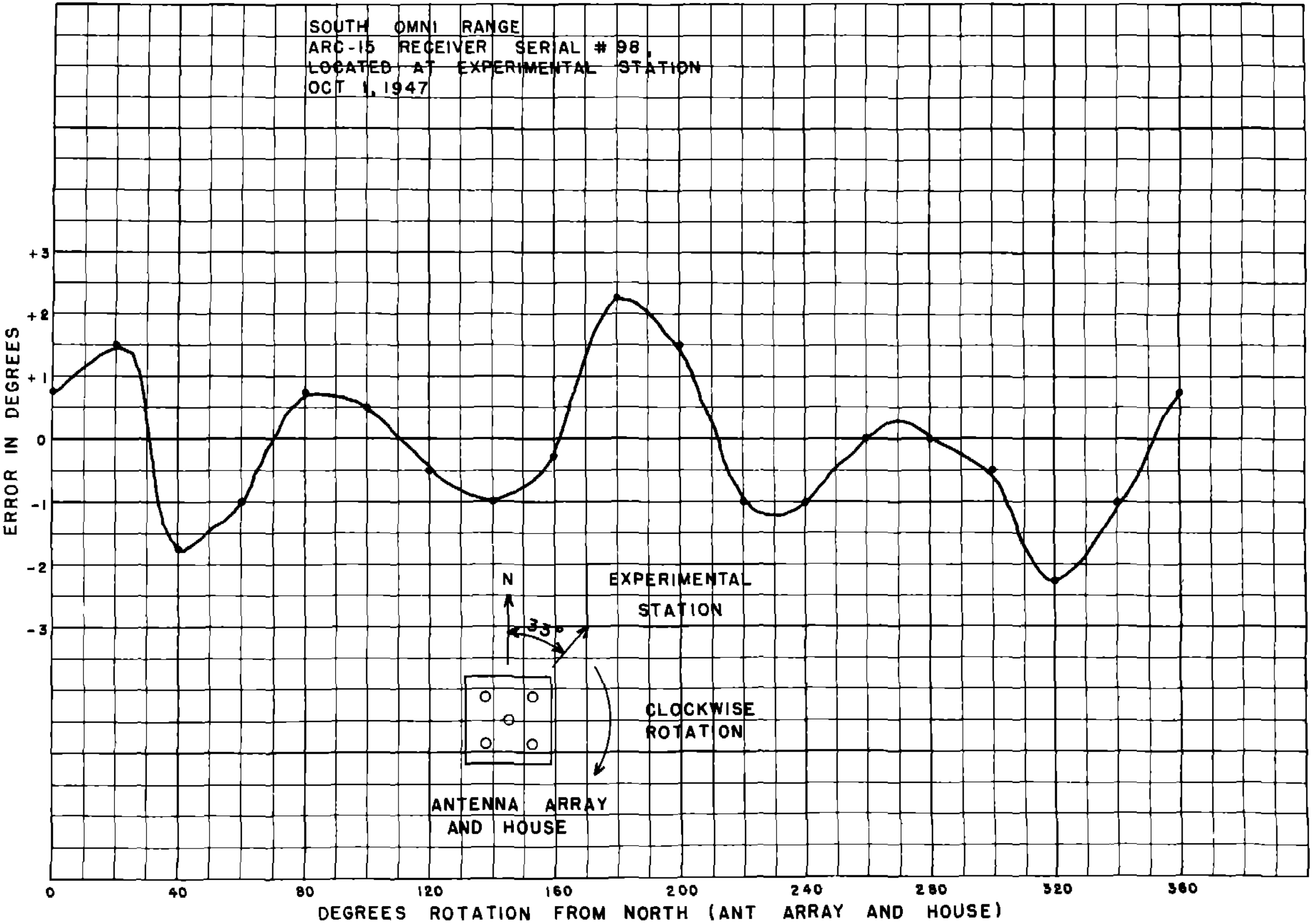


FIGURE 6 GROUND CALIBRATION BY ROTATING ANTENNA ARRAY AND HOUSE

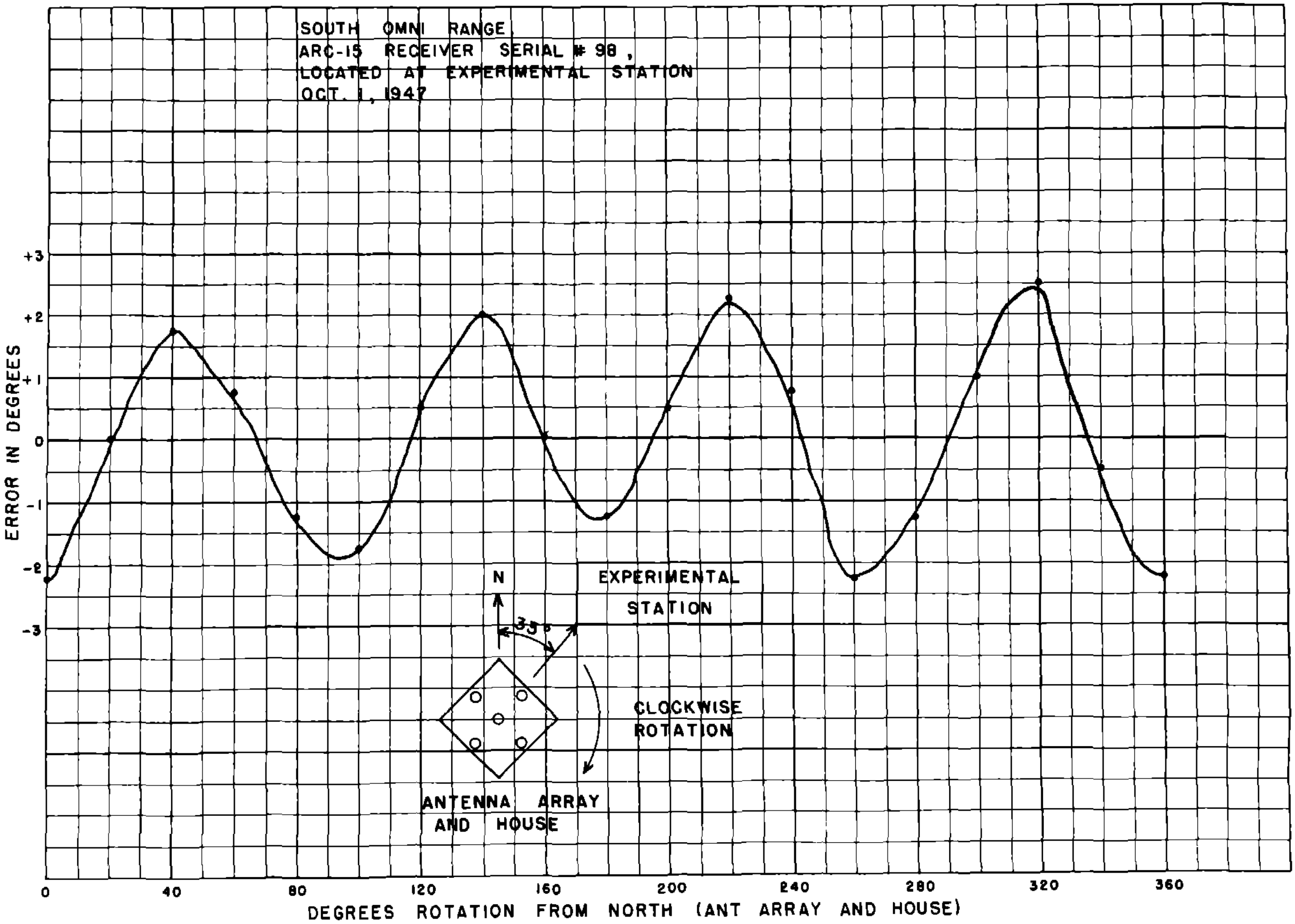


FIGURE 7 GROUND CALIBRATION BY ROTATING ANTENNA ARRAY AND HOUSE

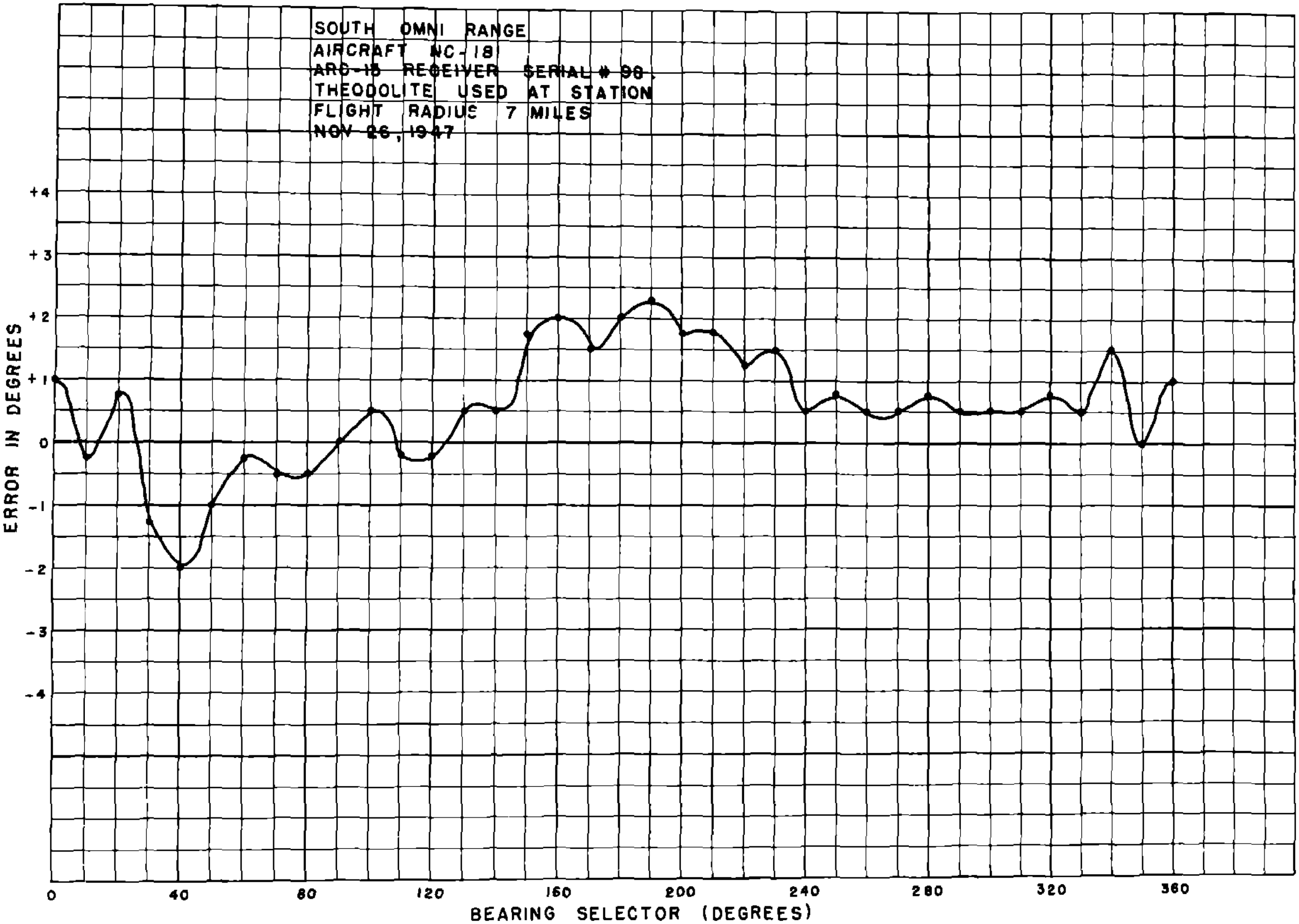


FIGURE 8 FLIGHT CALIBRATION WITH CIRCULAR HOUSE INSTALLED

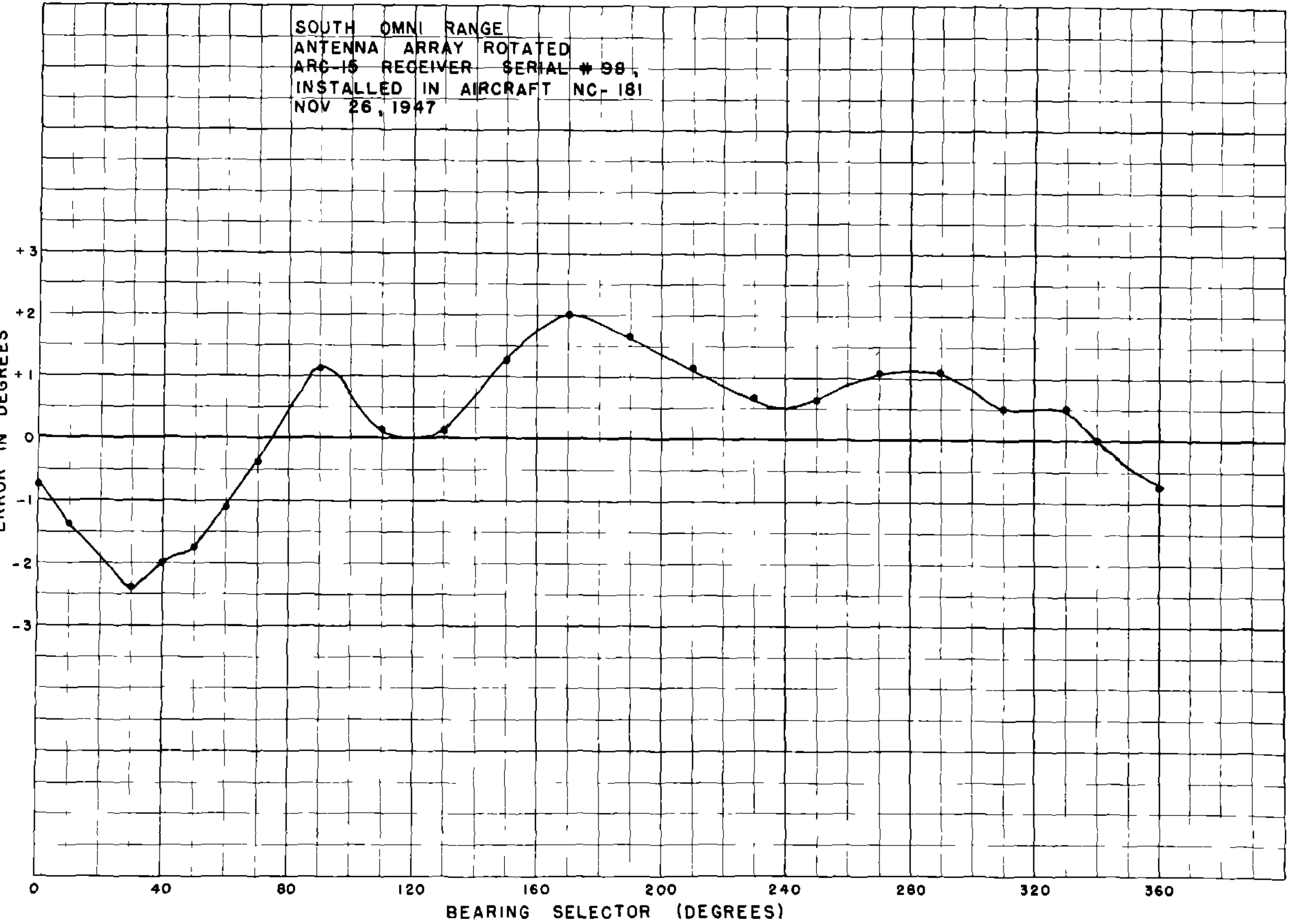


FIGURE 9 GROUND CALIBRATION WITH CIRCULAR HOUSE INSTALLED

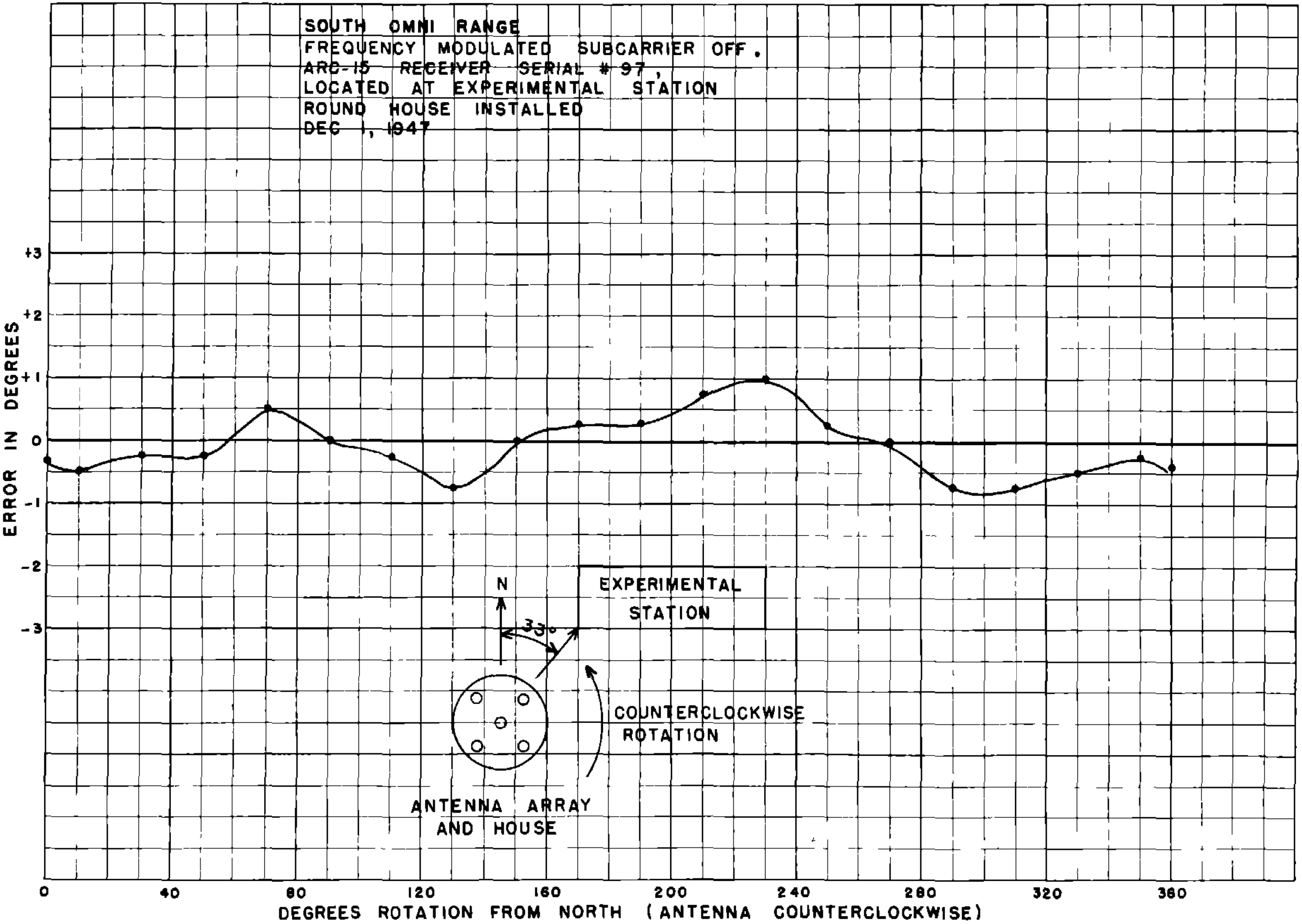


FIGURE 10 GROUND CALIBRATION OF VARIABLE PHASE SIGNAL BY ROTATING ANTENNA ARRAY

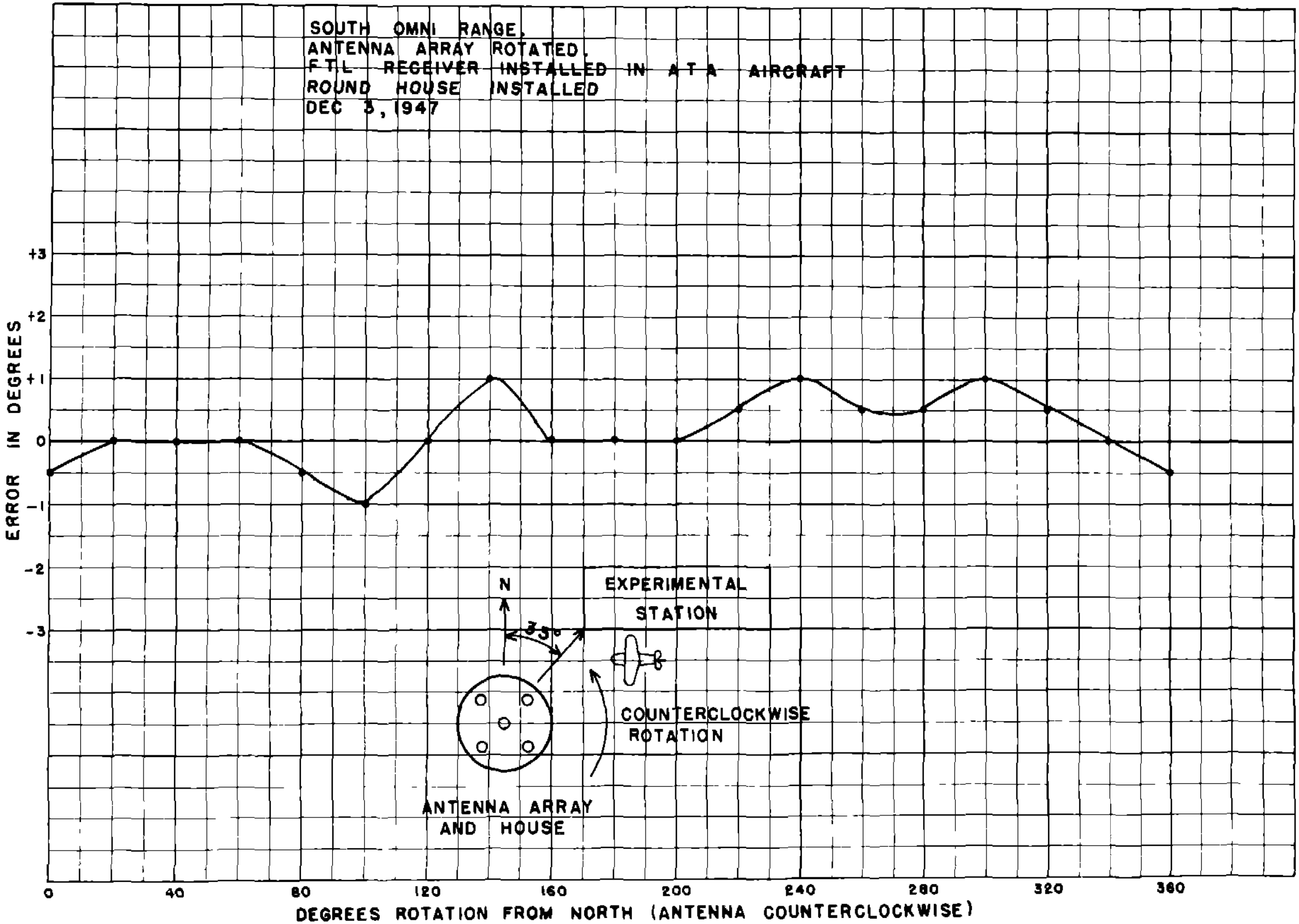


FIGURE 11 GROUND CALIBRATION USING F T L RECEIVER AND RADIAL CONVERTER INDICATOR

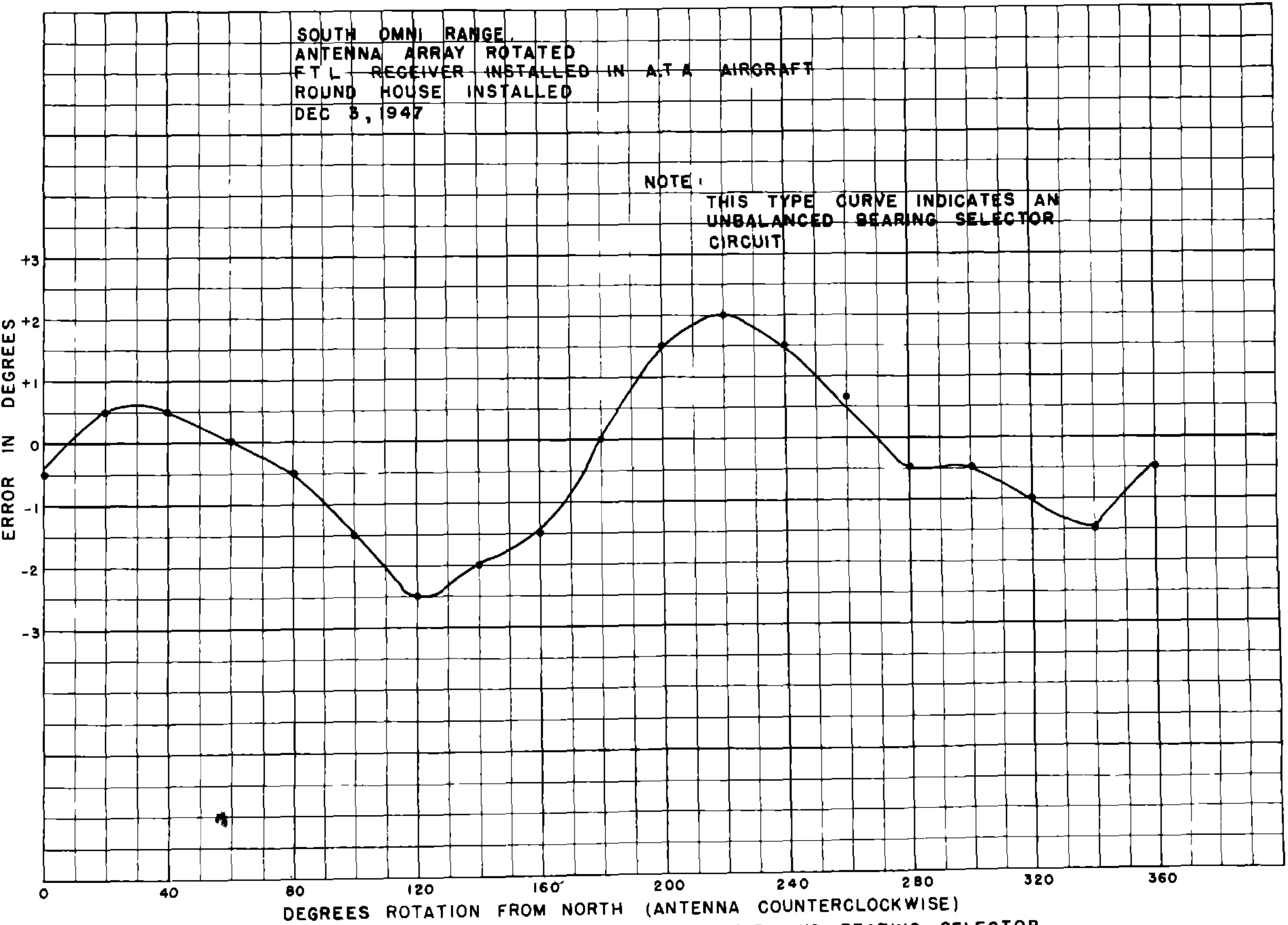


FIGURE 12 GROUND CALIBRATION USING F T L RECEIVER AND BEARING SELECTOR

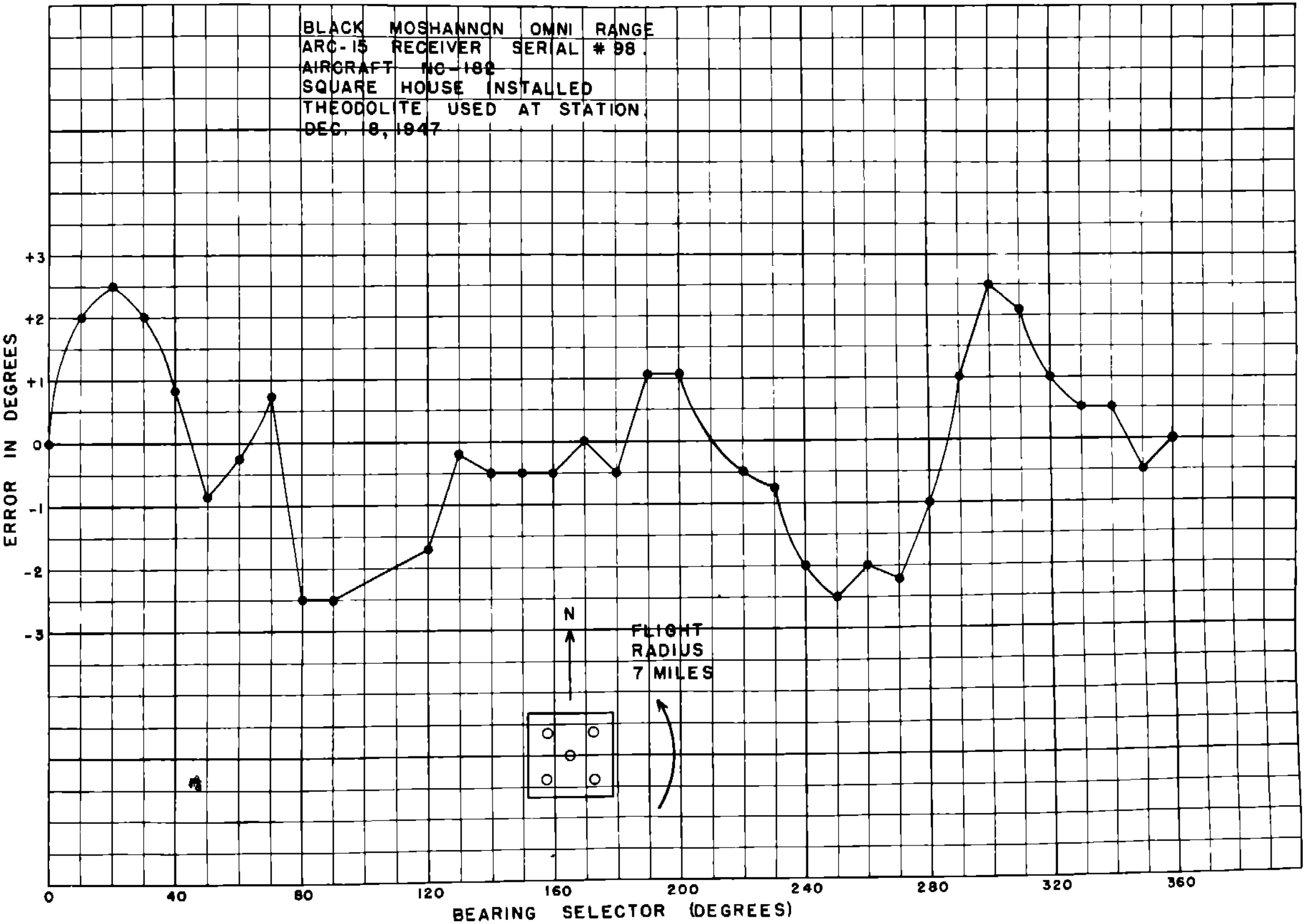


FIGURE 13 FLIGHT CALIBRATION OF BLACK MOSHANNON OMNI RANGE

SOUTH OMNI RANGE
ARC-15 RECEIVER SERIAL # 97
AIRCRAFT NC-181
POINT 20 MILES NORTH OF STATION
ALTITUDE 2300' ABOVE GROUND
TAIL V ANTENNA
NO RESISTANCE CLOTH ON PEDESTALS
OCT 17, 1947

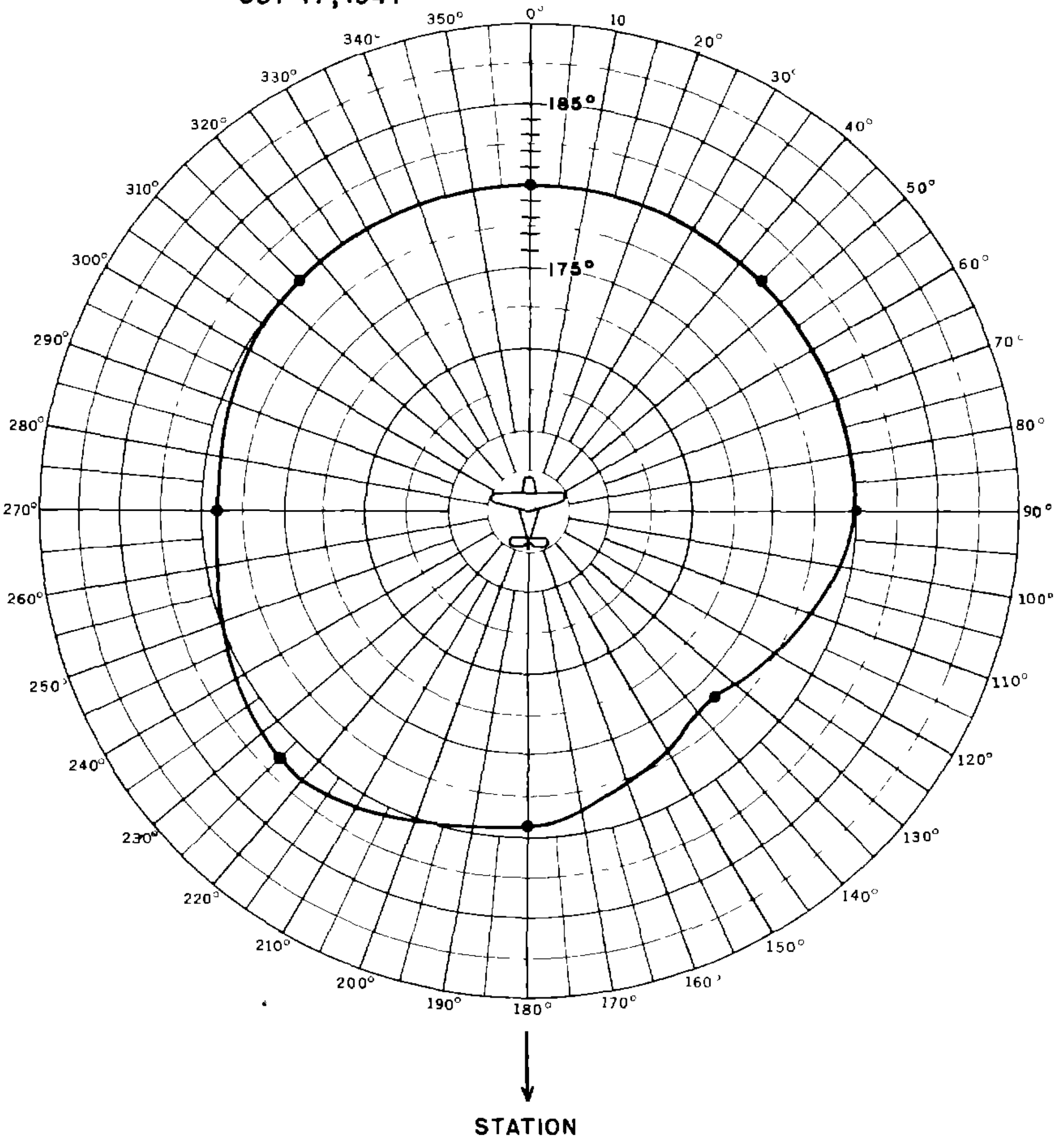
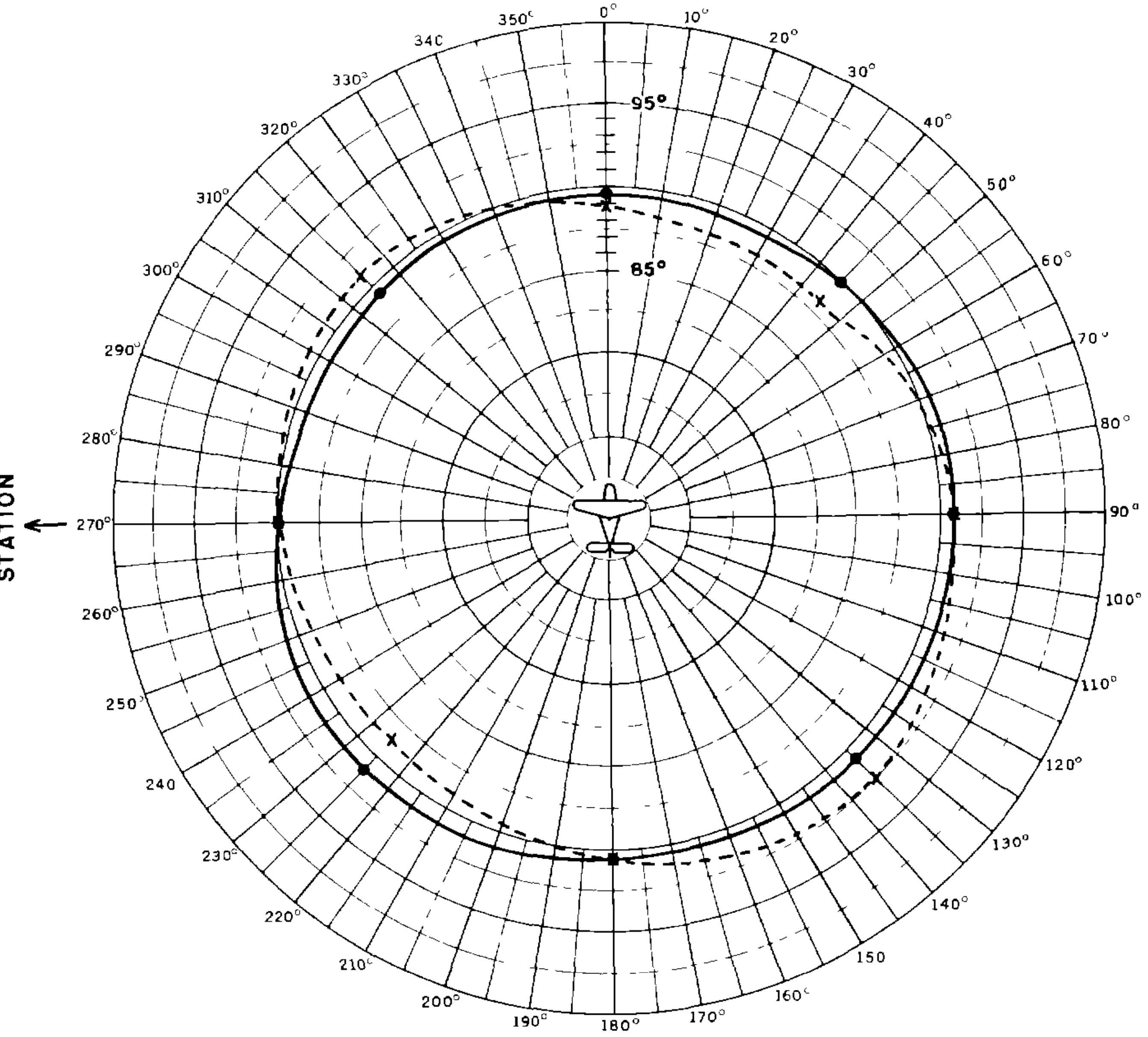


FIGURE 14 BEARING SELECTOR READING VERSUS AIRCRAFT MAGNETIC HEADING

SOUTH OMNI RANGE
ARC-15 RECEIVER SERIAL # 98
AIRCRAFT NC-181
POINT 23 MILES EAST OF STATION
ALTITUDE 1000' ABOVE GROUND
FOWARD V ANTENNA
DEC 1, 1947



x-----x-----x NO RESISTANCE CLOTH ON PEDESTALS
●———●———● RESISTANCE CLOTH ON PEDESTALS

FIGURE 15 BEARING SELECTOR READING VERSUS AIRCRAFT MAGNETIC HEADING

SOUTH OMNI RANGE
ARC-15 RECEIVER SERIAL # 97
AIRCRAFT NC-181
POINT 20 MILES NORTH OF STATION
ALTITUDE 2500' ABOVE GROUND
RESISTANCE CLOTH ON PEDESTALS
NOV 20, 1947

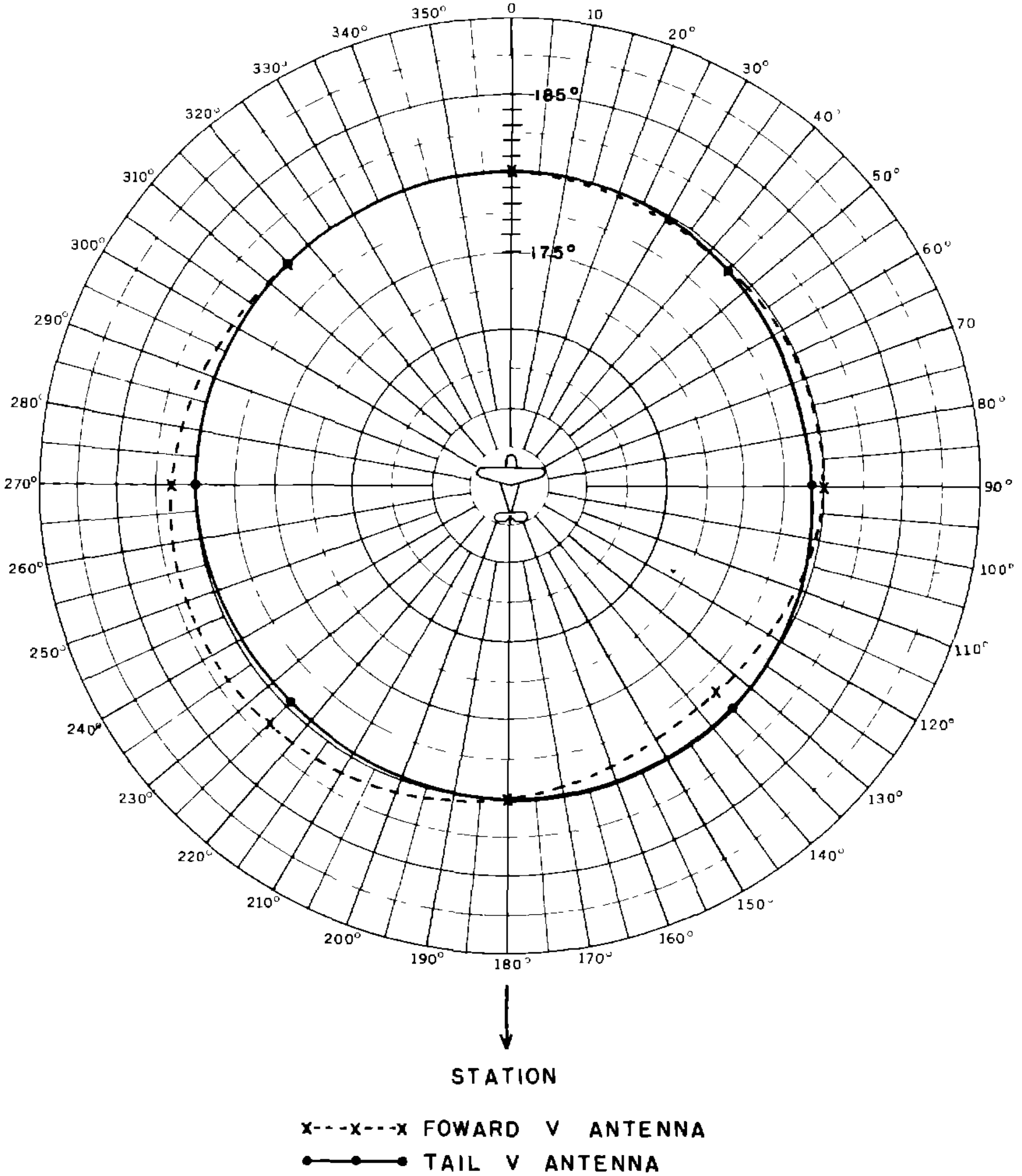


FIGURE 16 BEARING SELECTOR READING VERSUS AIRCRAFT MAGNETIC HEADING

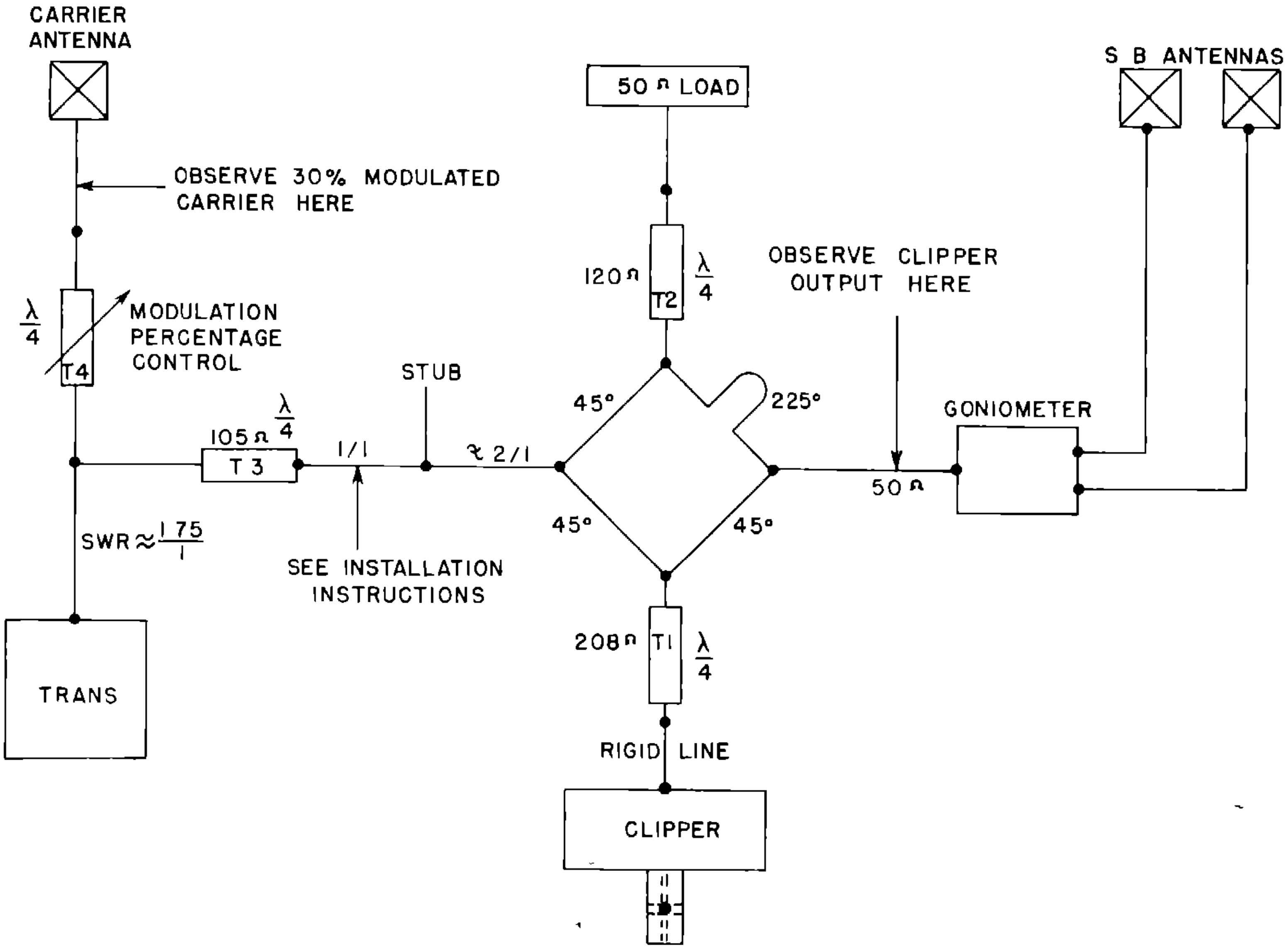


FIGURE 17 BLOCK DIAGRAM OF TRANSMITTING EQUIPMENT

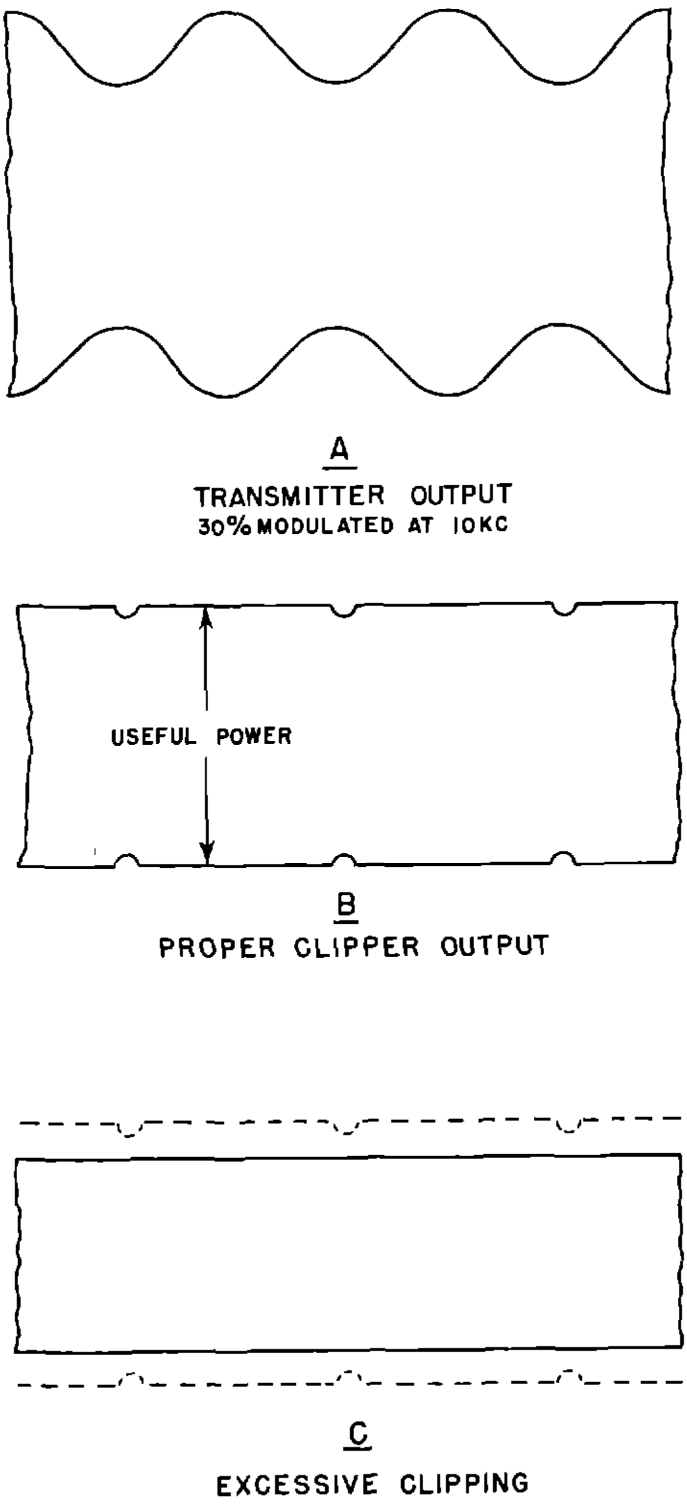


FIGURE 18 WAVE FORM PATTERNS USING CLIPPER

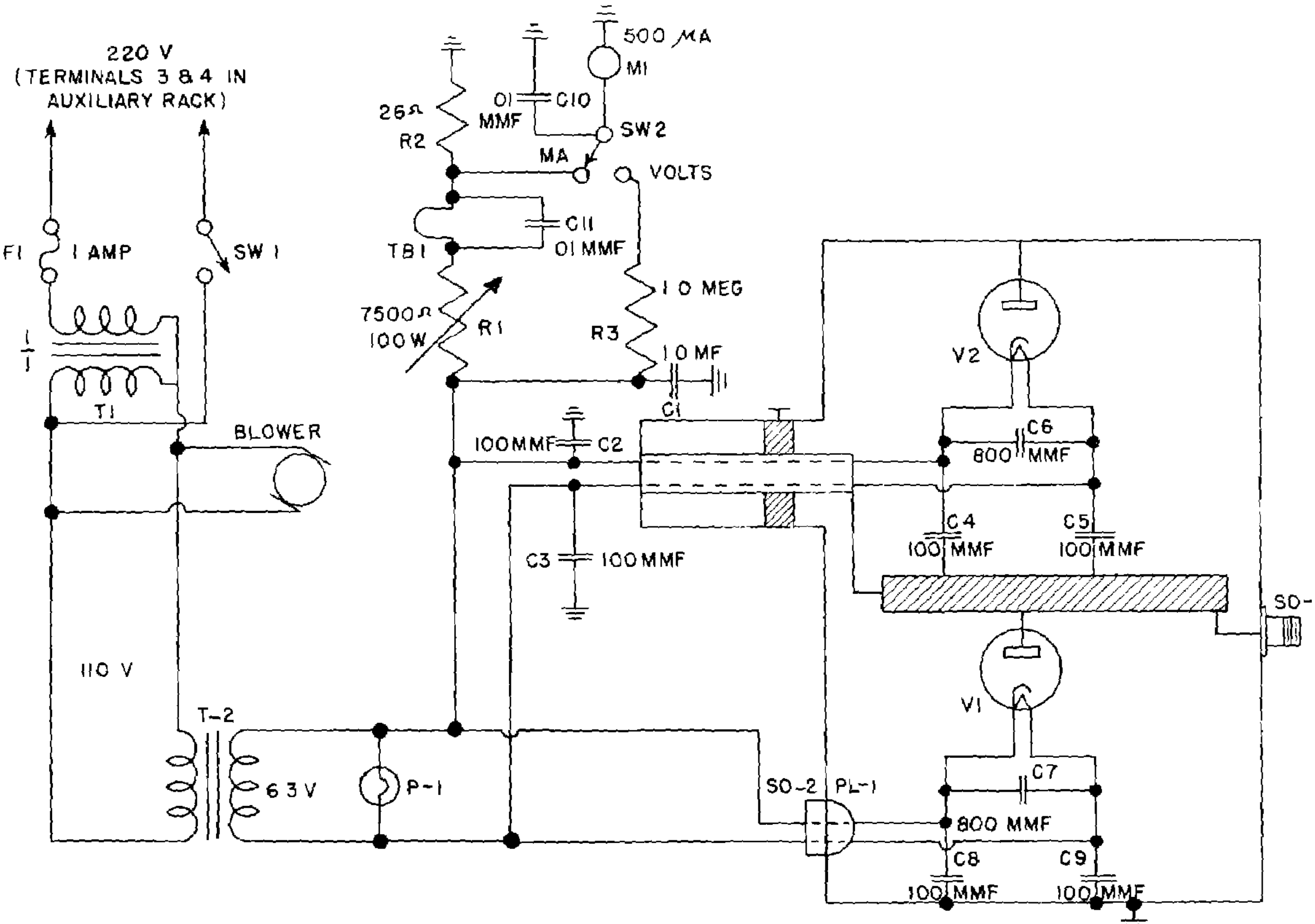


FIGURE 19 SCHEMATIC DIAGRAM OF CLIPPER

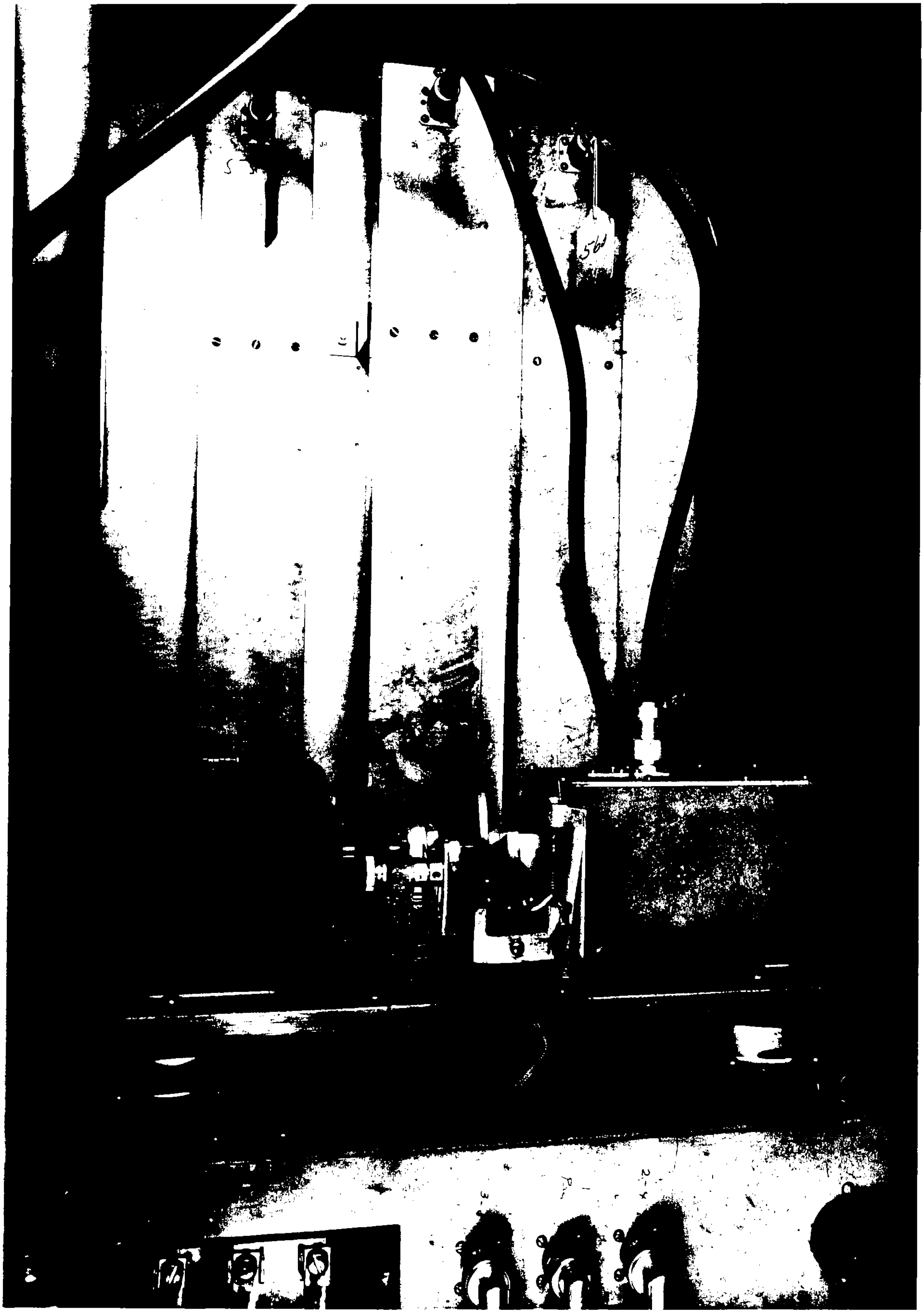


FIGURE 20. CAA TYPE 1231 CAPACITY GONIOMETER AND TONE WHEEL

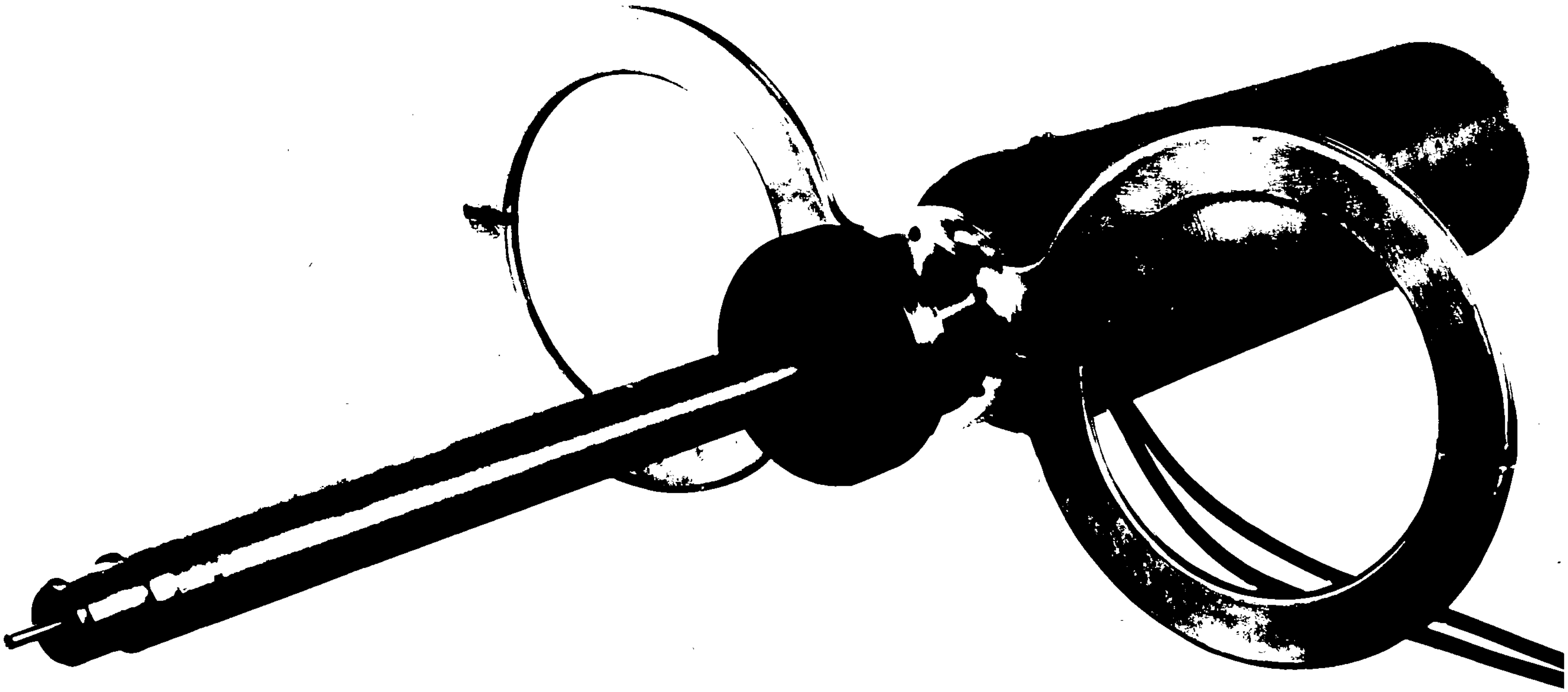


FIGURE 21. OMNI RANGE SPINNING ANTENNA

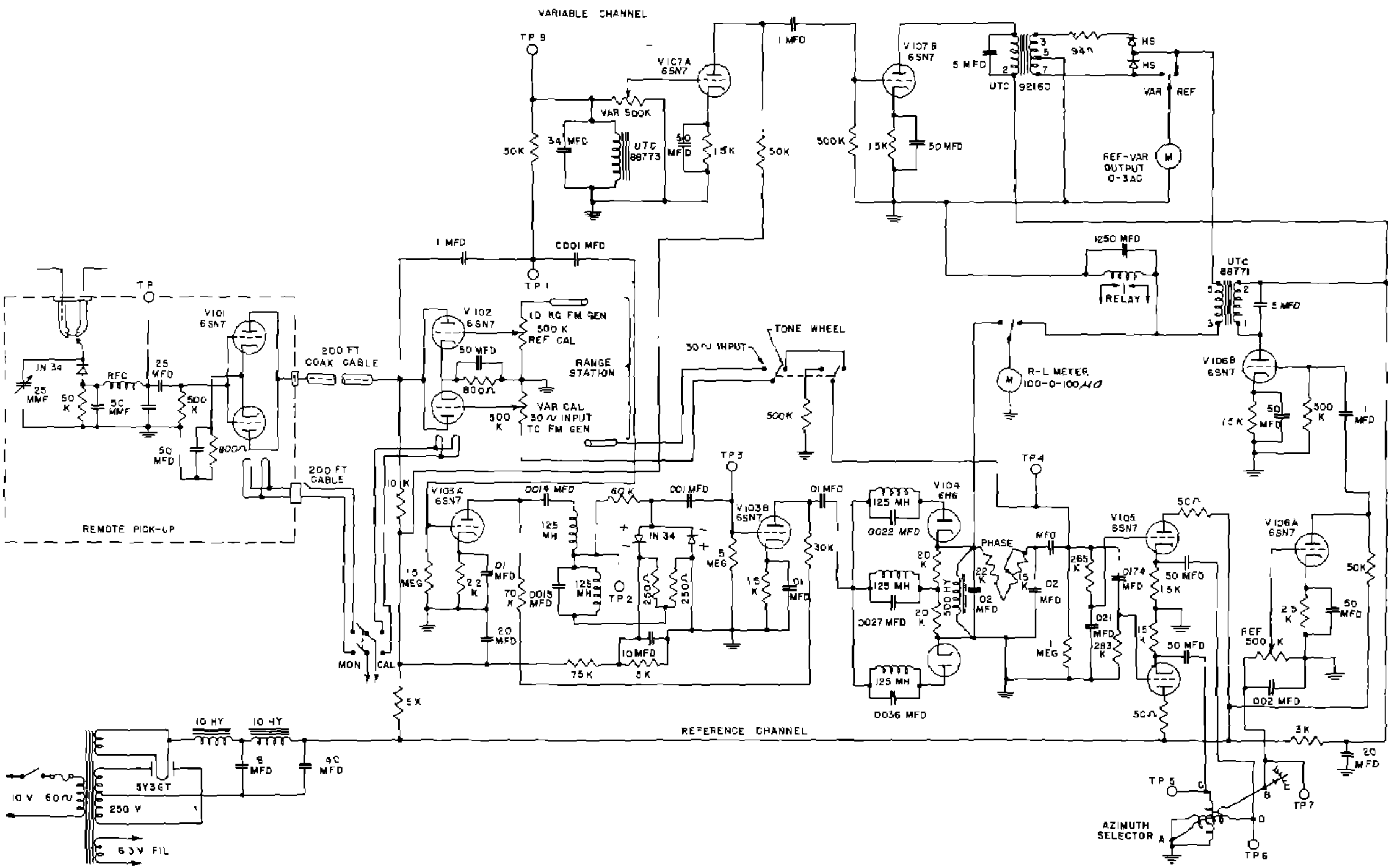


FIGURE 22 SCHEMATIC DIAGRAM OF OMNI RANGE MONITOR

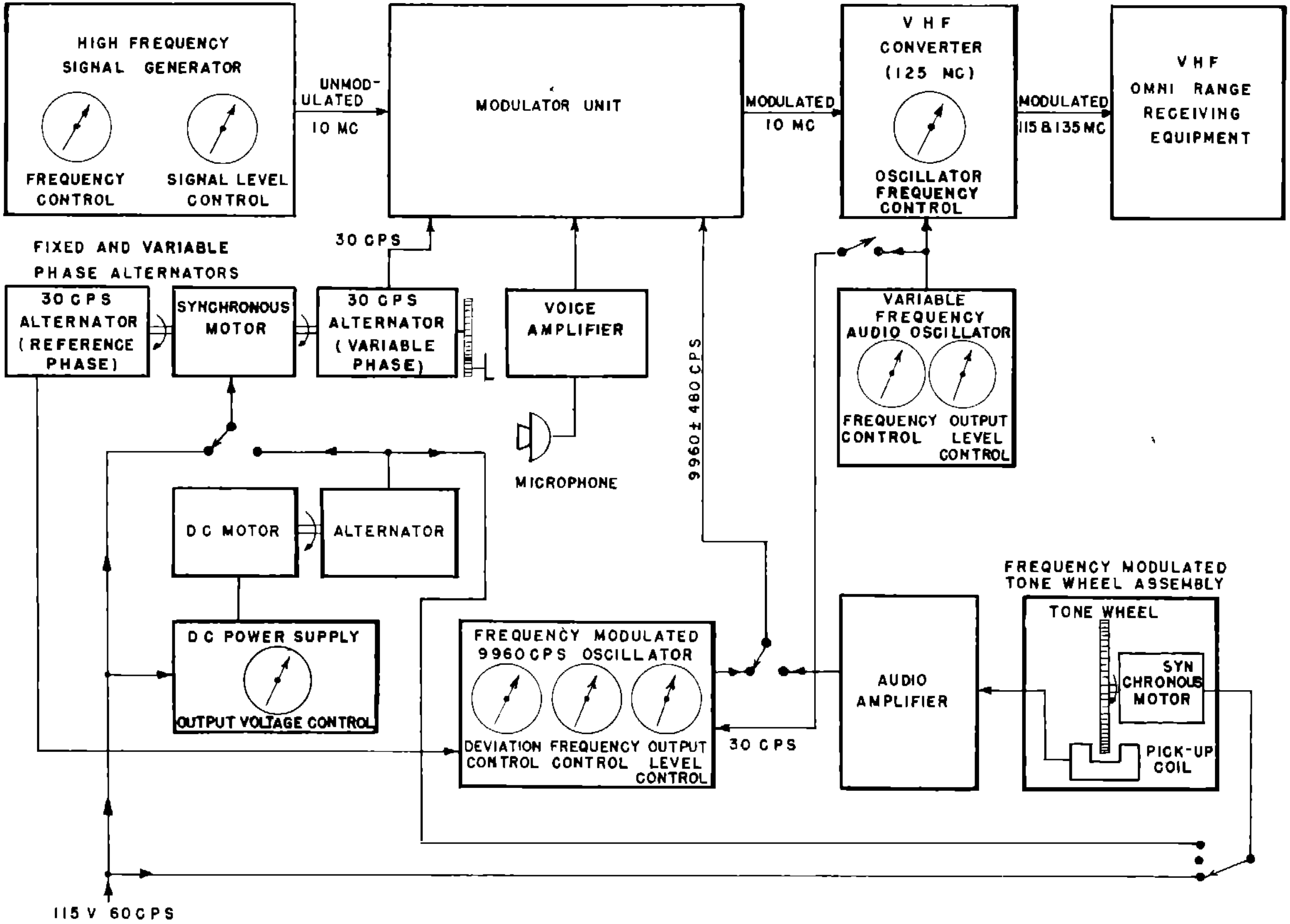
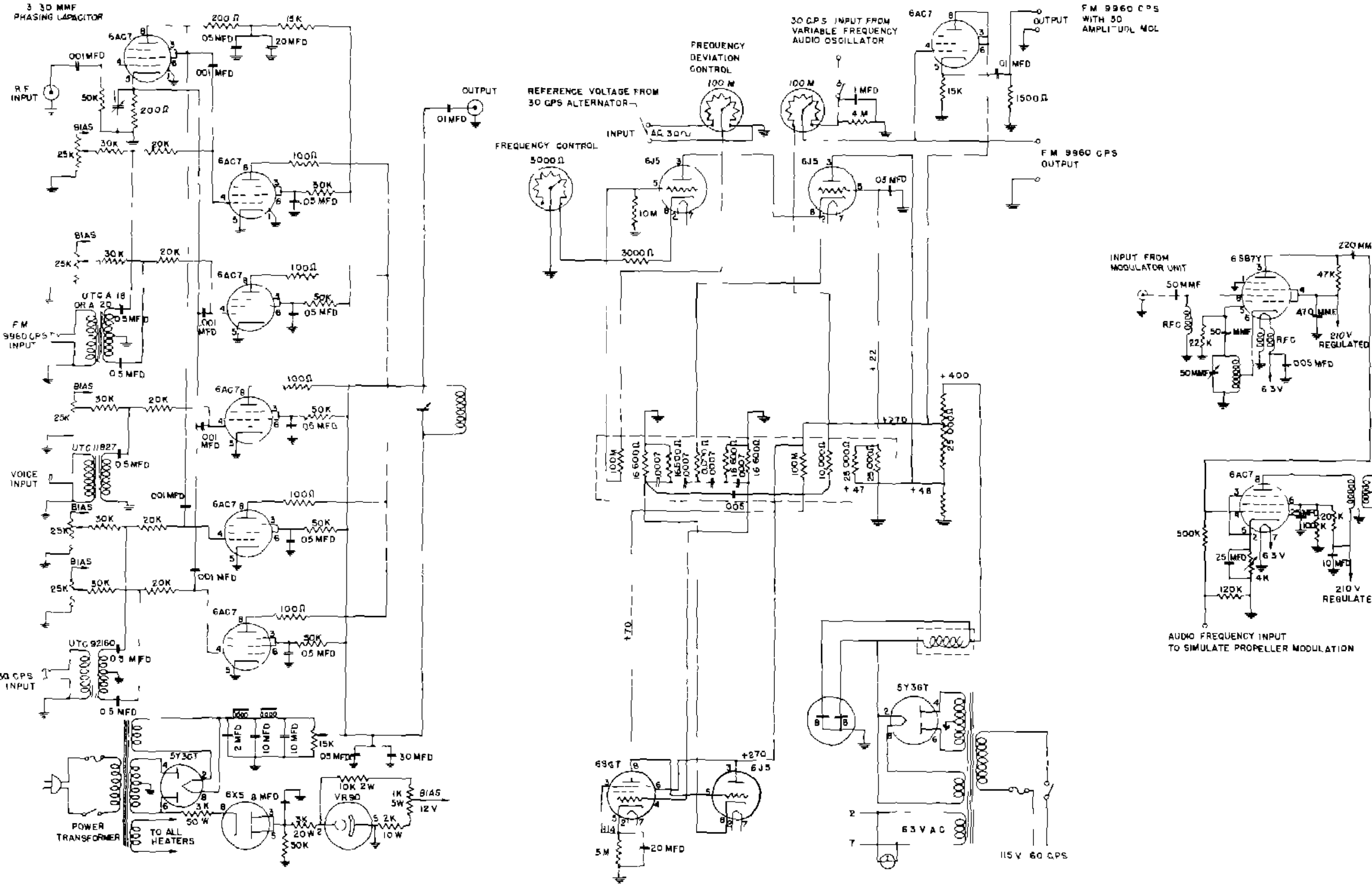


FIGURE 23 BLOCK DIAGRAM OF OMNI RANGE RECEIVER TEST EQUIPMENT



MODULATION UNIT FOR SIMULATION OF OMNI RANGE SIGNALS — F M 9960 CPS OSCILLATOR — V H F CONVERTER

FIGURE 24 SCHEMATIC DIAGRAM OF SPECIAL TEST EQUIPMENT FOR OMNI RANGE RECEIVERS

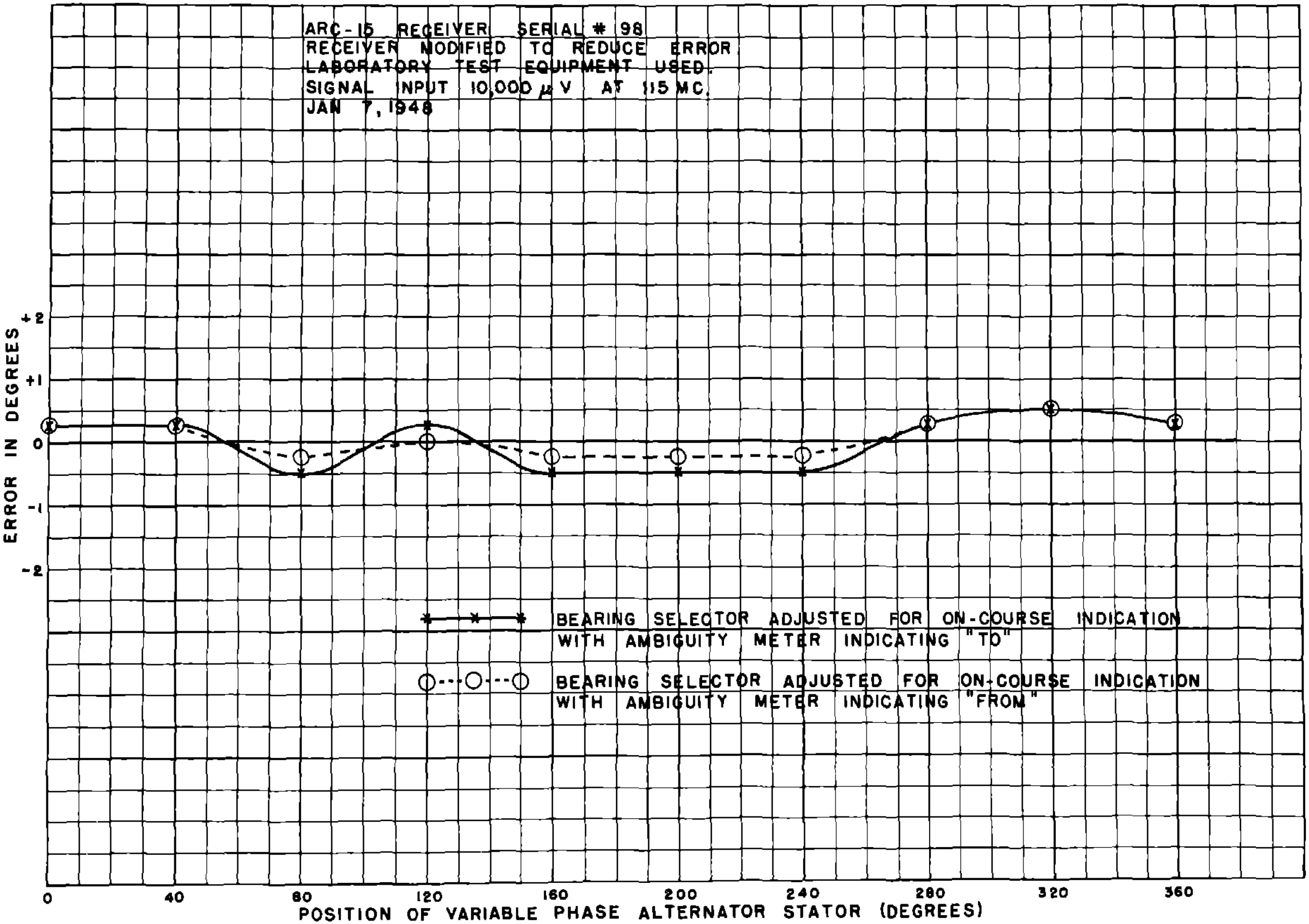


FIGURE 25 LABORATORY CALIBRATION OF ARC-15 RECEIVER

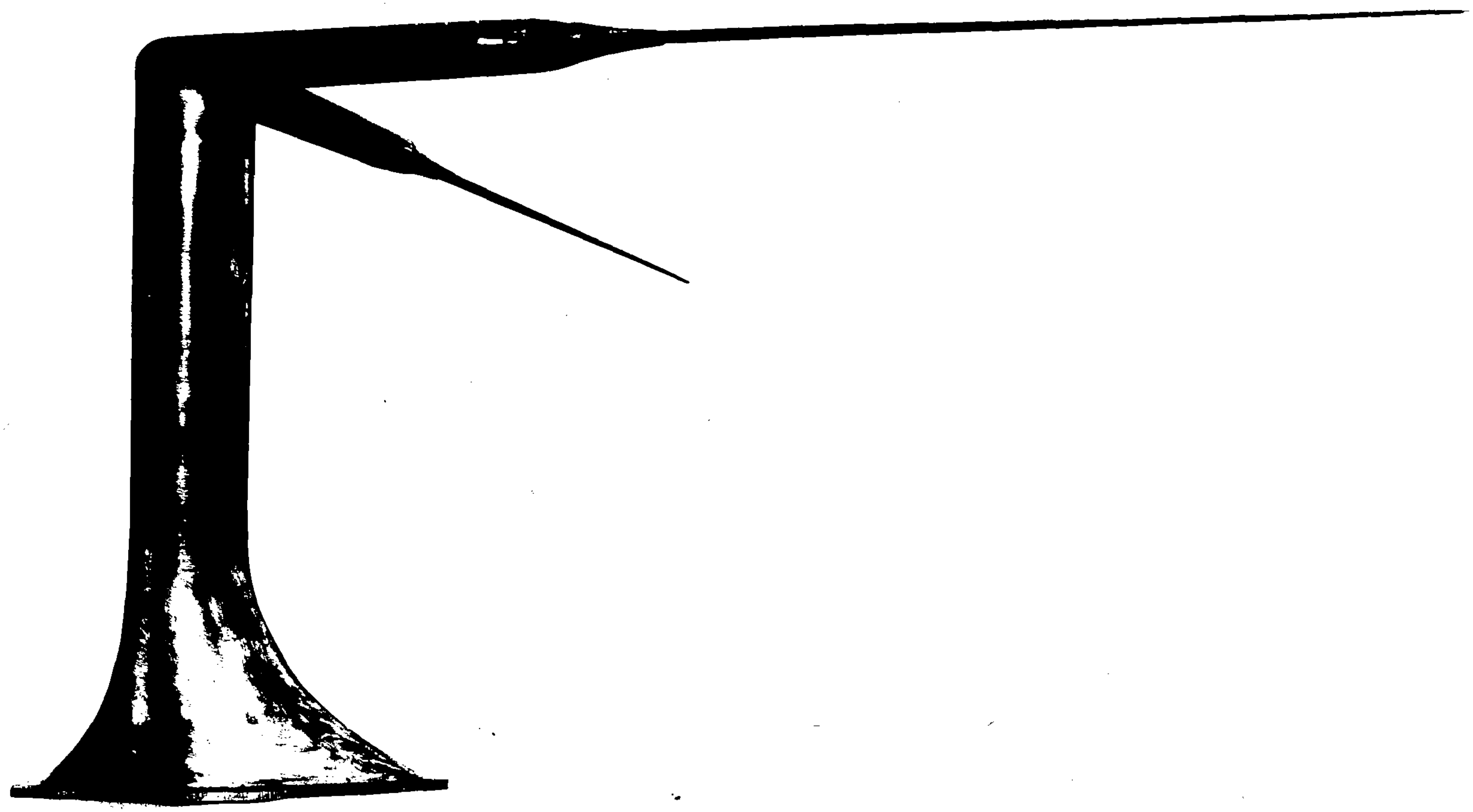


FIGURE 26. VHF V ANTENNA MODEL V-106

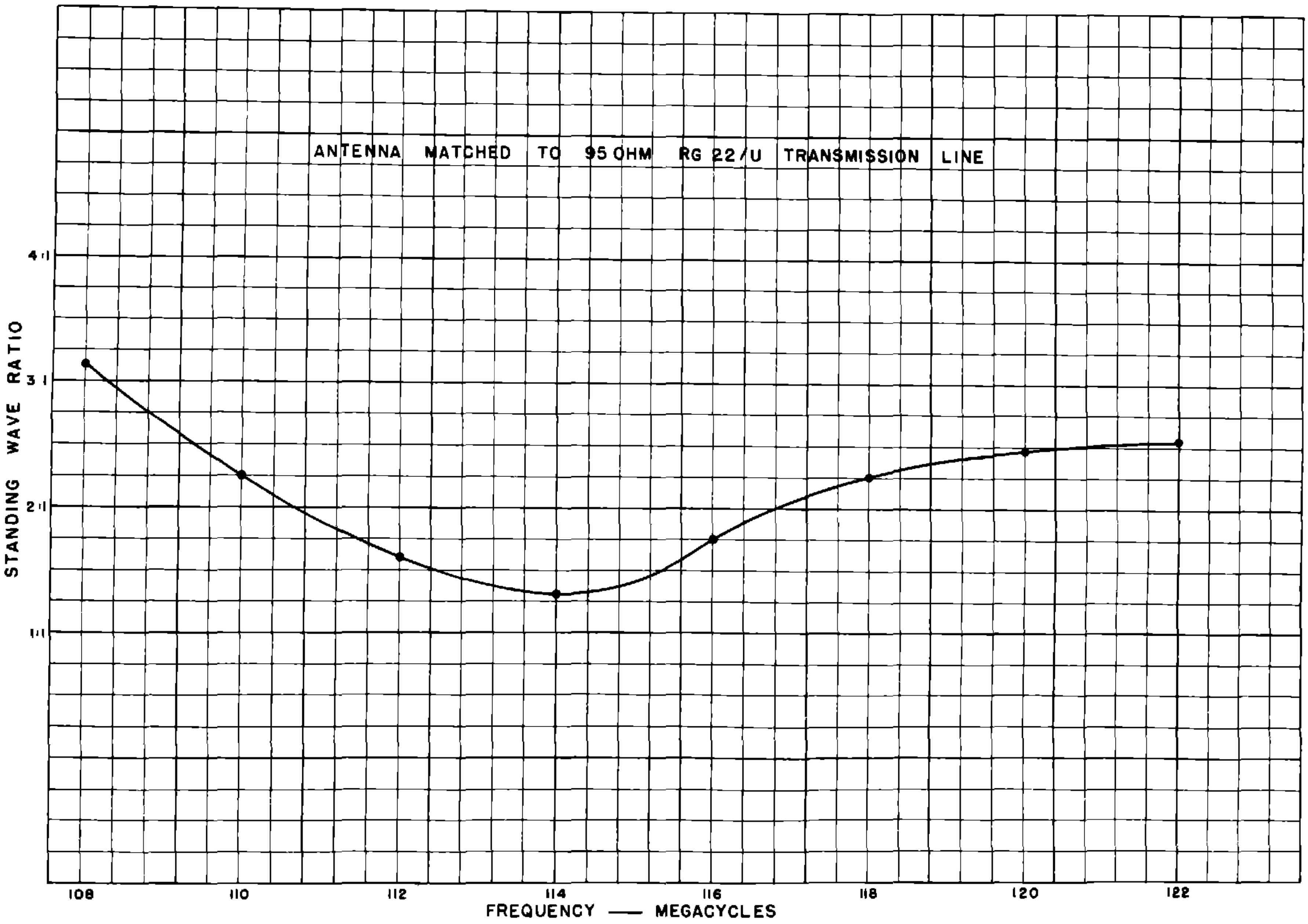


FIGURE 27 V H F V ANTENNA MODEL V-106 STANDING WAVE RATIO VERSUS FREQUENCY

RECEIVING ANTENNA ROTATED THROUGH 360°
DISTANCE 200' FROM TRANSMITTER

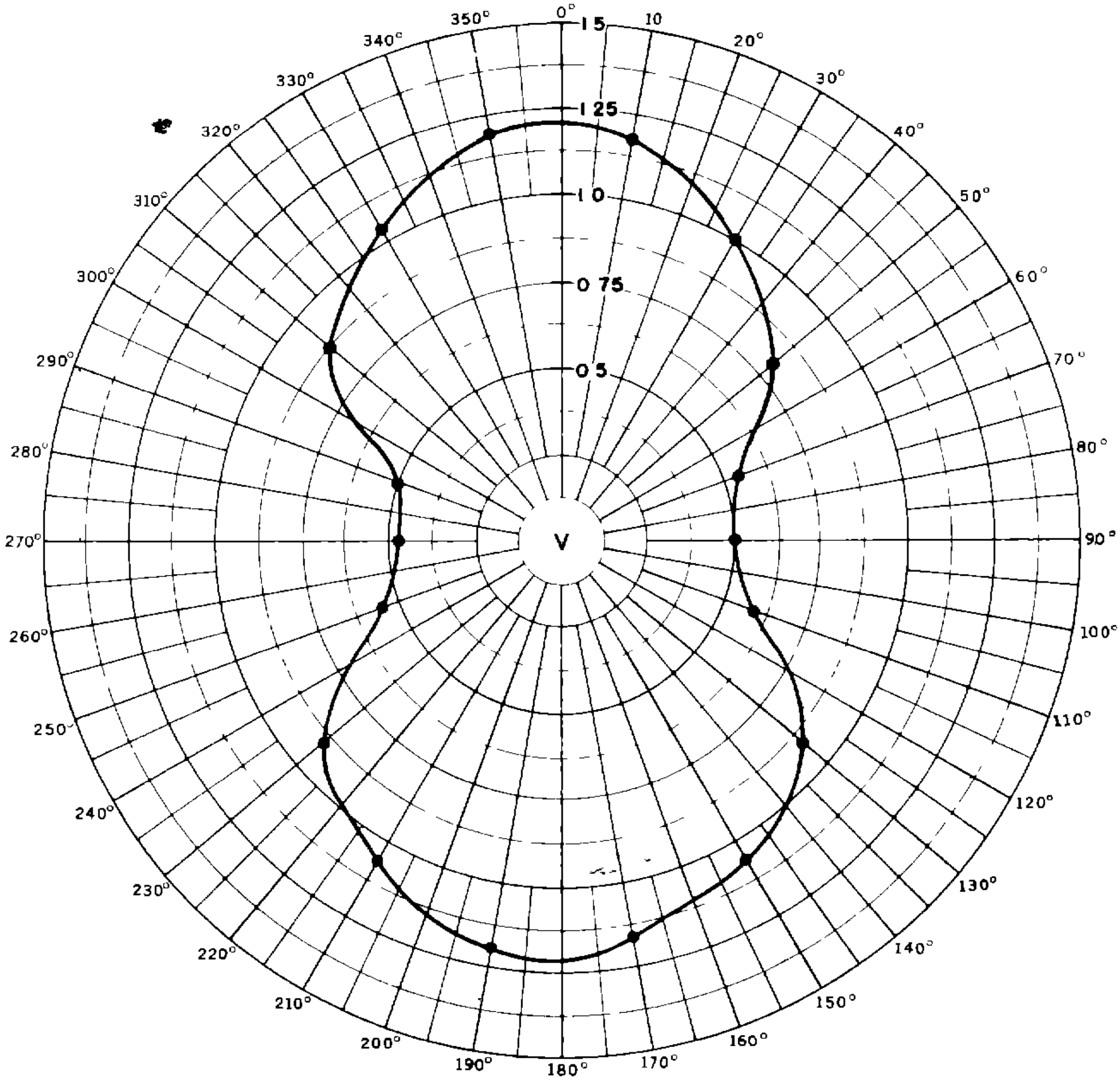


FIGURE 28 VHF V ANTENNA MODEL V-106 — FIELD PATTERN

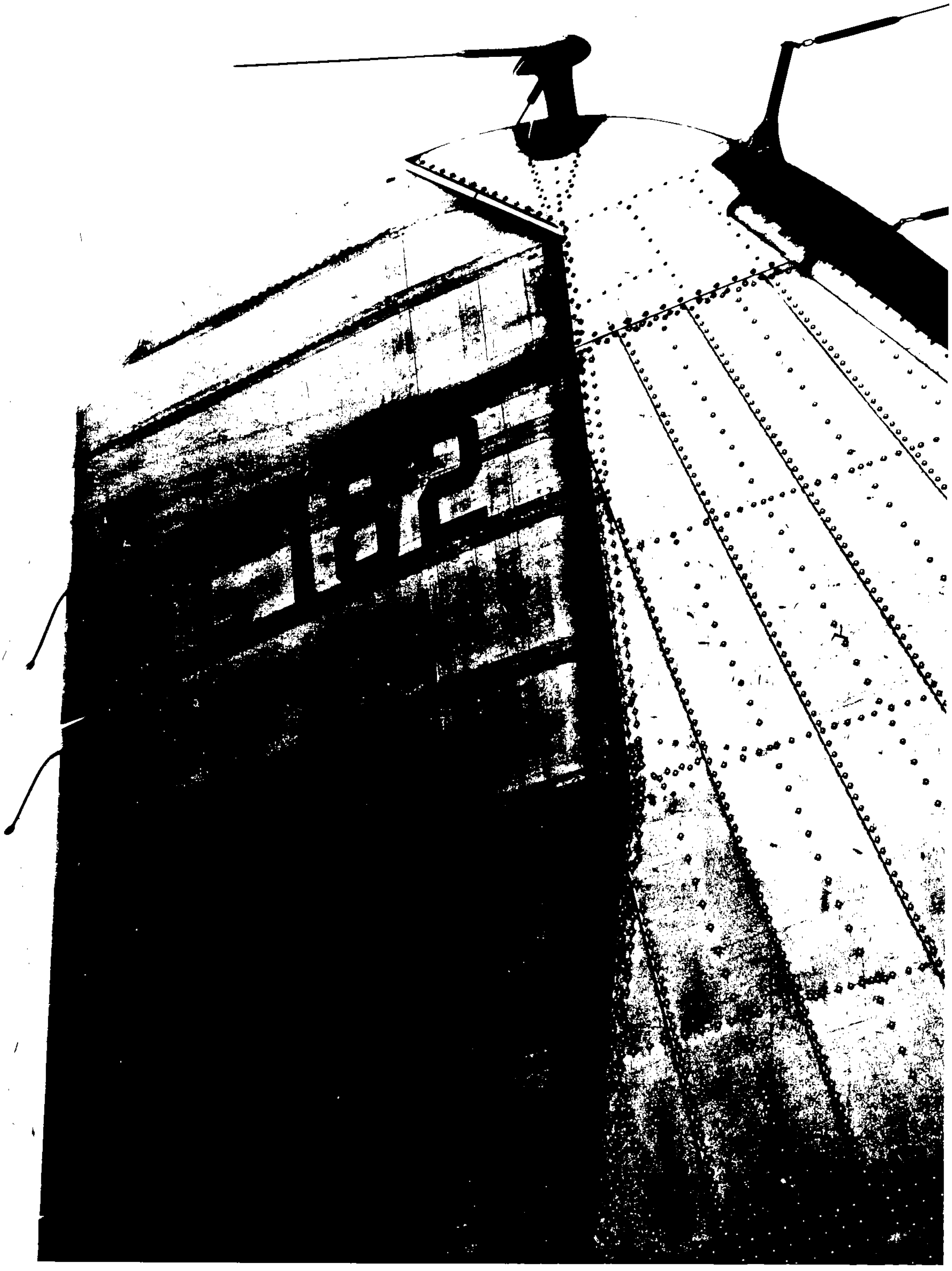


FIGURE 29. RECEIVING TAIL V ANTENNA

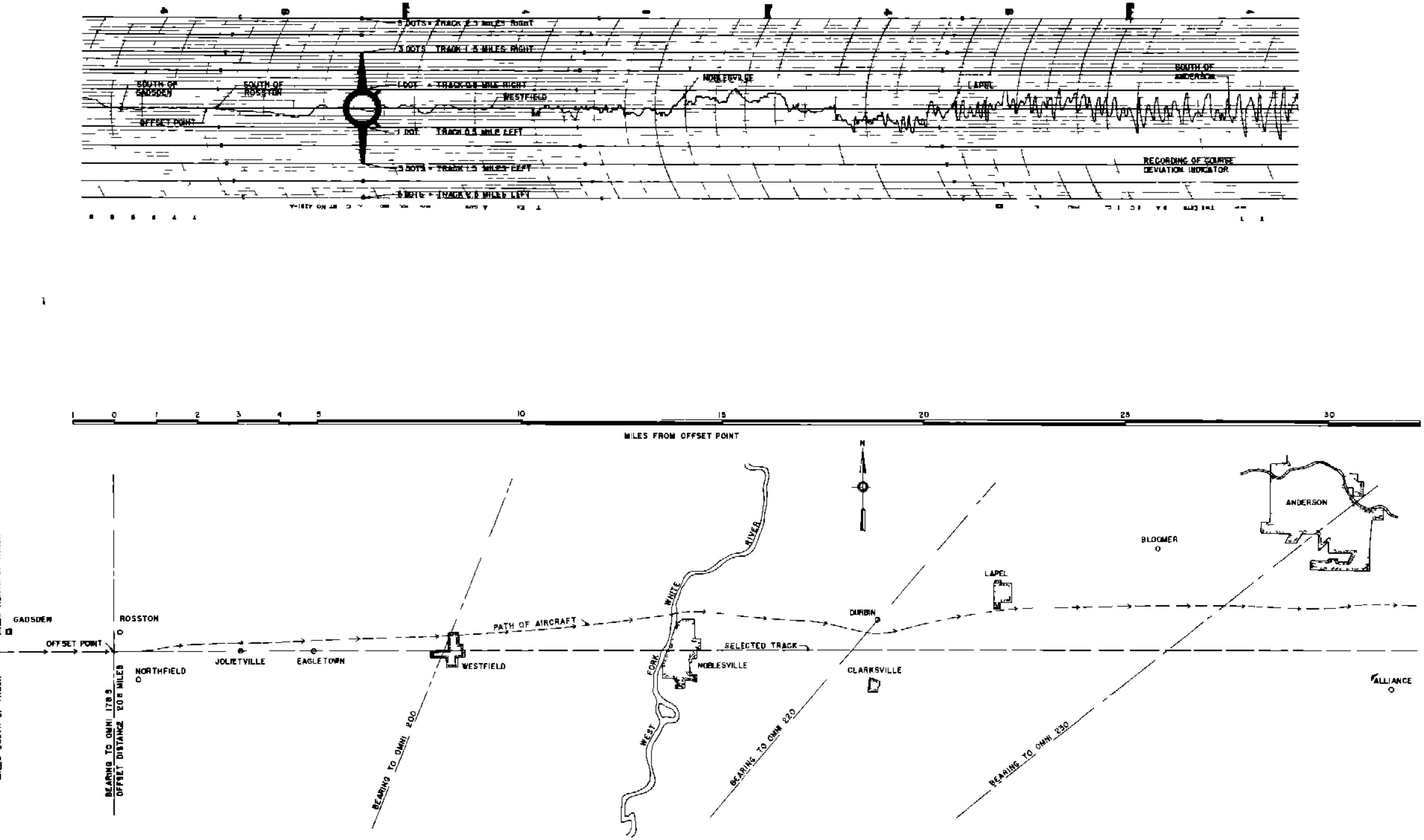


FIGURE 30 COMPUTER FLIGHT ON PORTION C OF TRACK 1819 SETTINGS: COURSE 88.5 OFFSET 20.6 MILES ALONG TRACK COORDINATE 0 OMNI BEARING DISTANCE STATION AT SITE 26

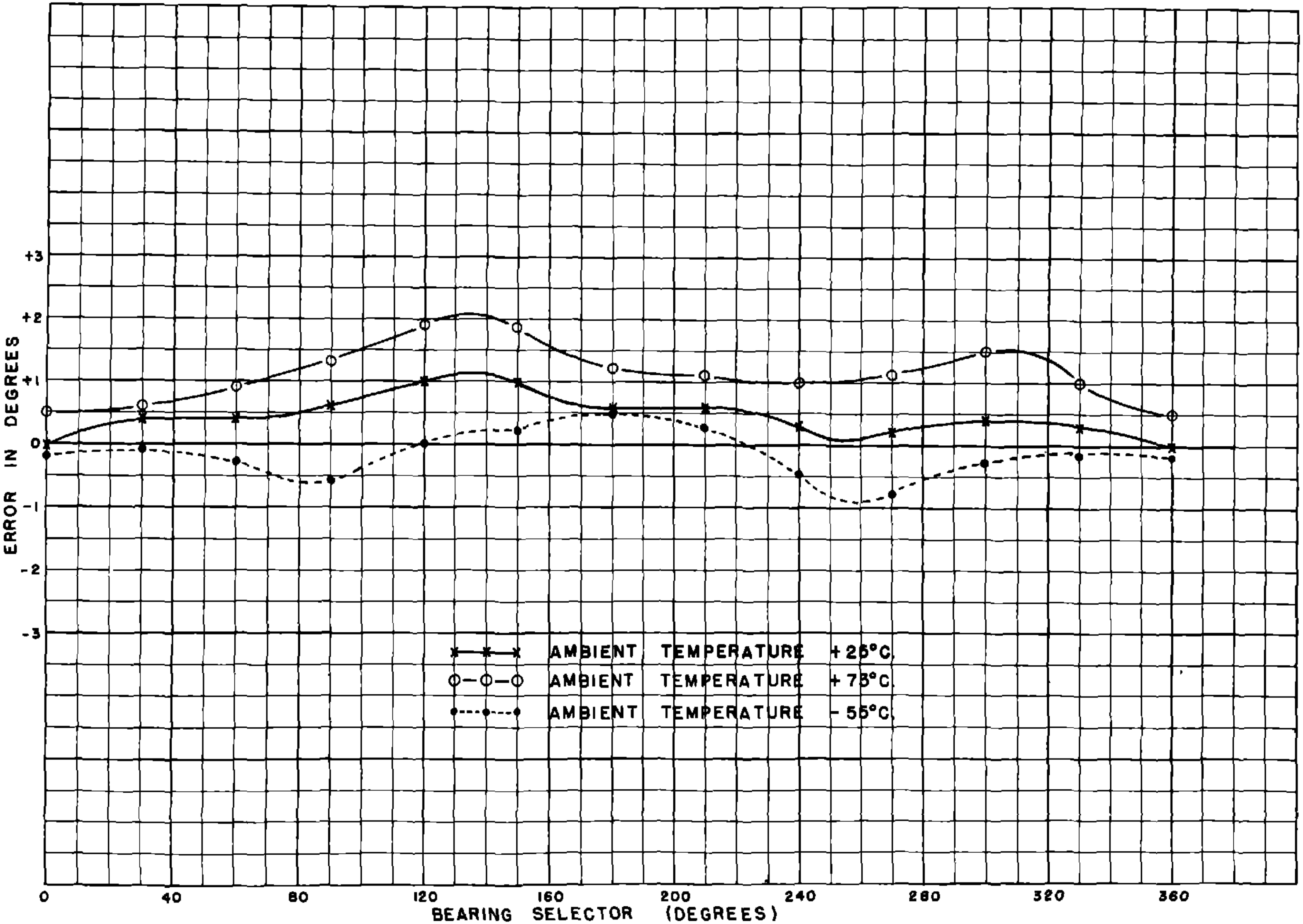


FIGURE 31 COLLINS-51R RECEIVER LABORATORY CALIBRATION AT VARIOUS TEMPERATURES
(COURTESY OF COLLINS RADIO CO)

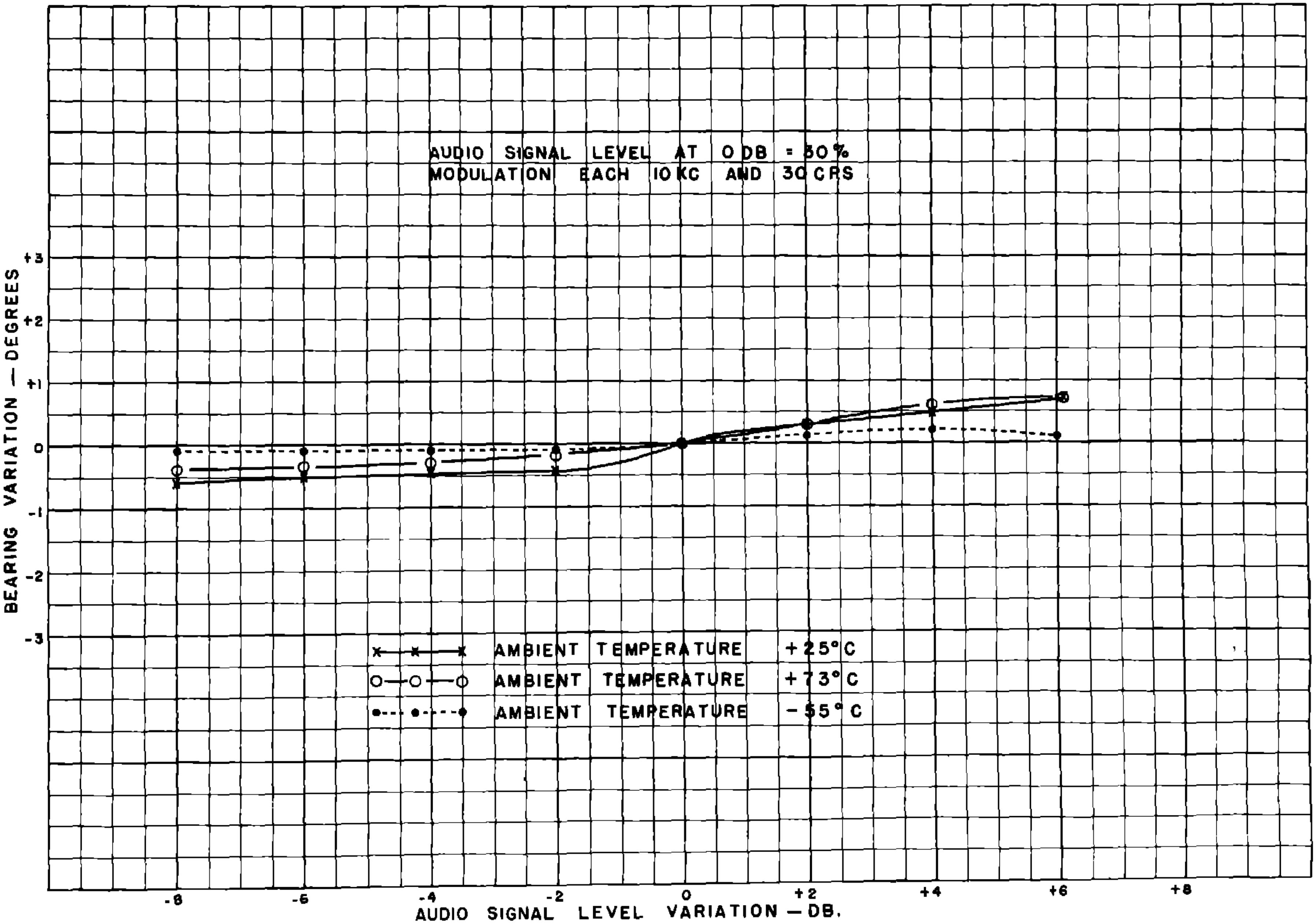


FIGURE 32 COLLINS-51R RECEIVER BEARING VARIATION VERSUS AUDIO SIGNAL LEVEL
(COURTESY OF COLLINS RADIO CO.)

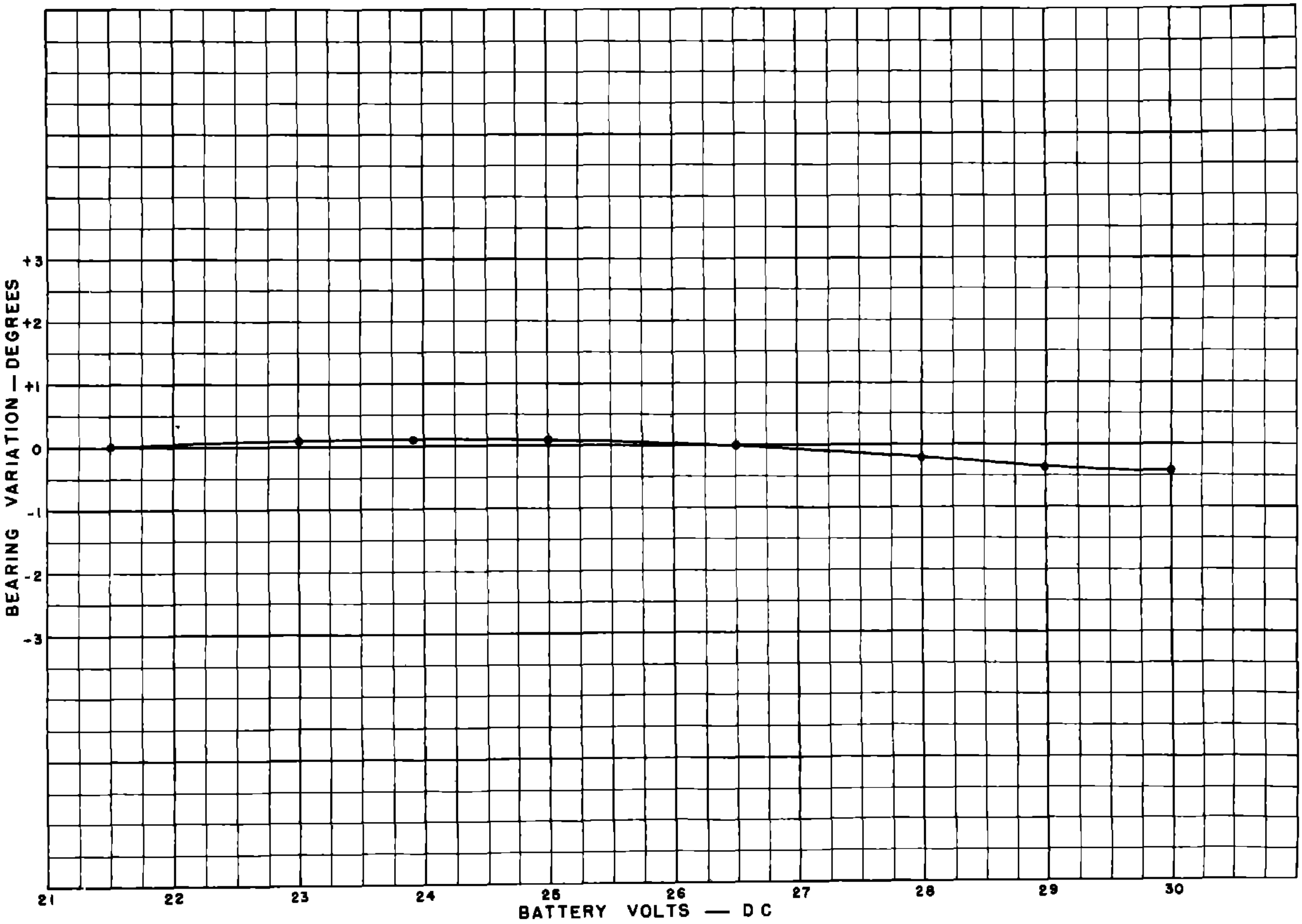


FIGURE 33 COLLINS-51R RECEIVER BEARING VARIATION VERSUS BATTERY VOLTAGE
(COURTESY OF COLLINS RADIO CO)

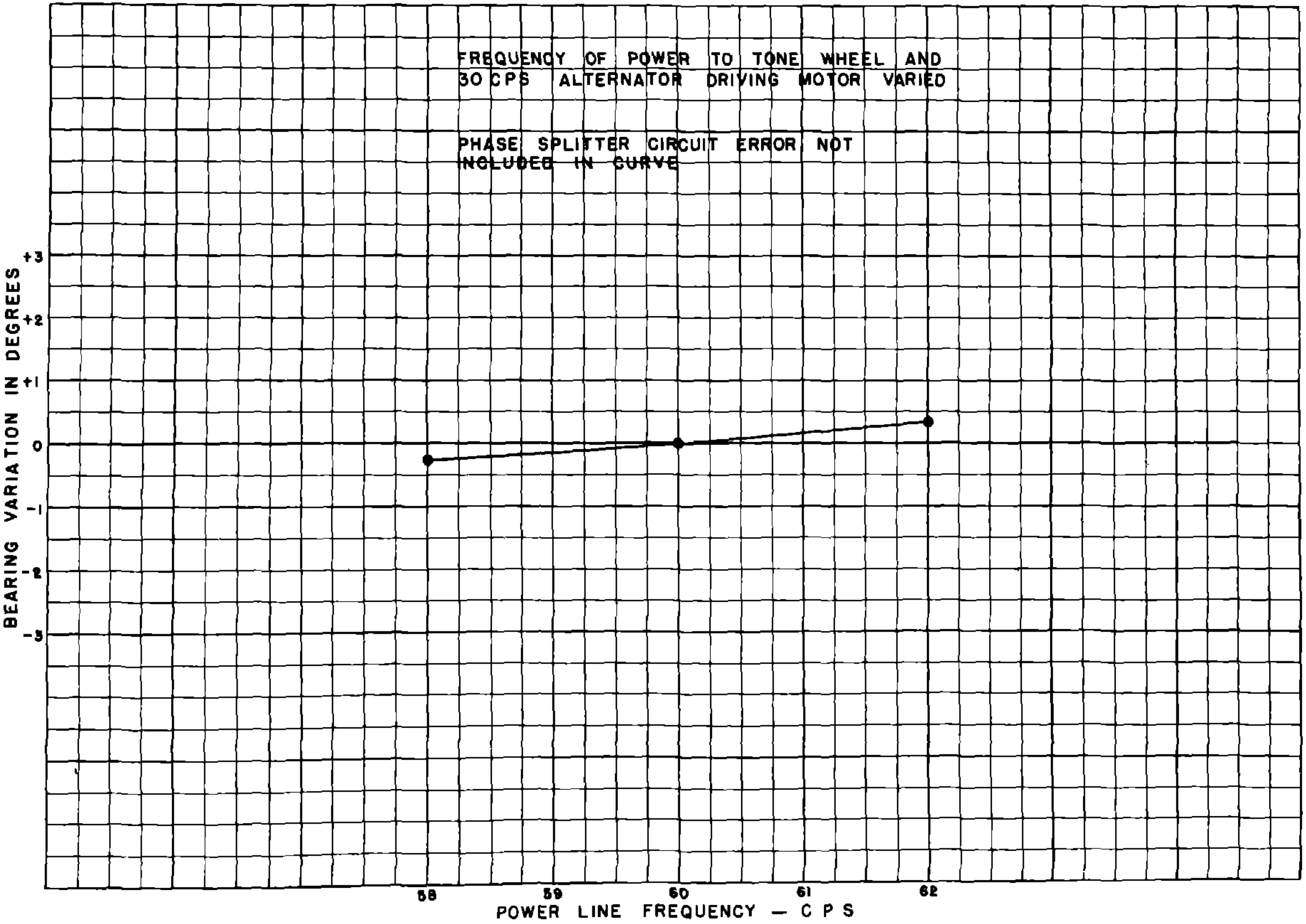


FIGURE 34 COLLINS-51R RECEIVER BEARING VARIATION VERSUS POWER LINE FREQUENCY
(COURTESY OF COLLINS RADIO CO)

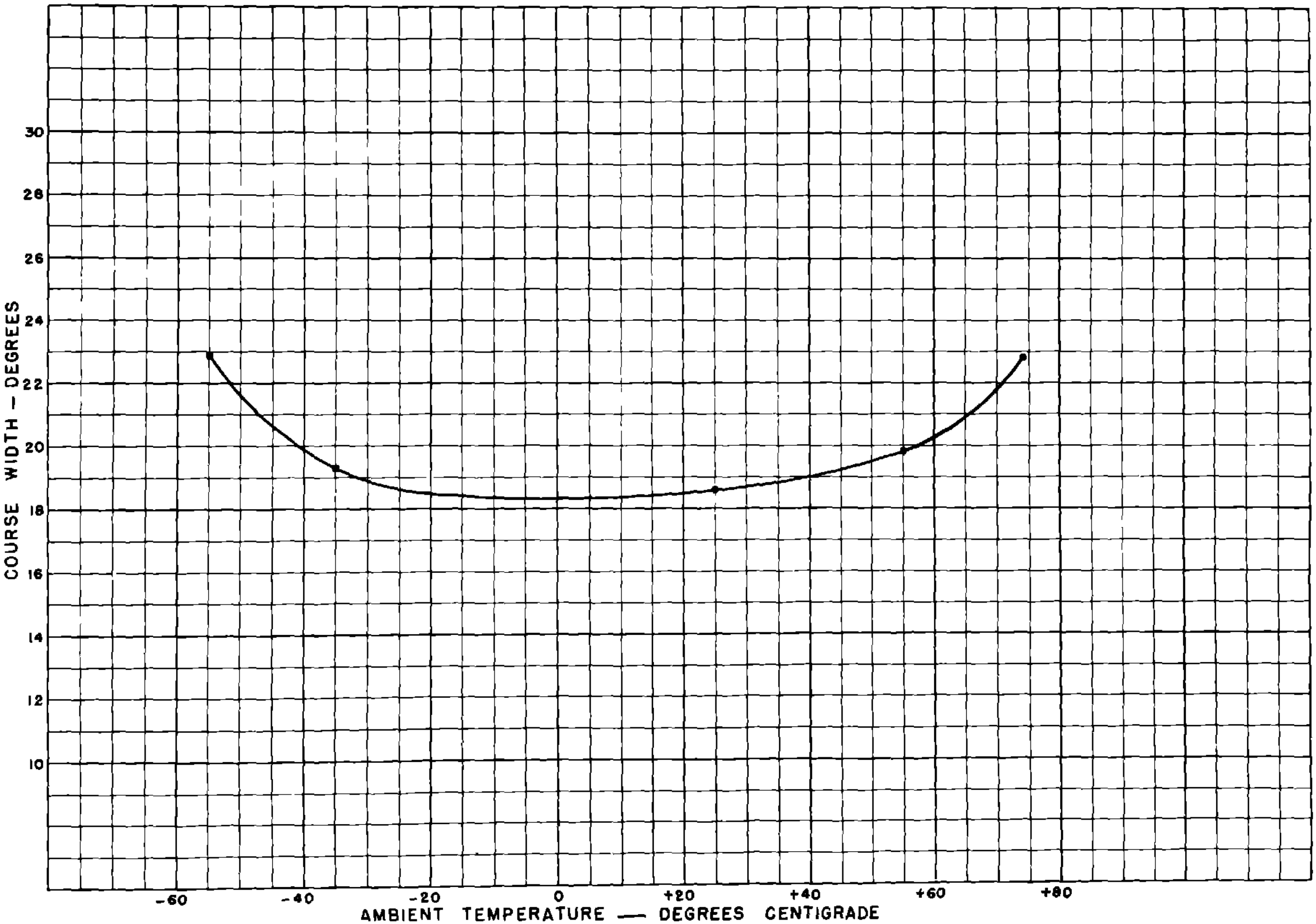


FIGURE 35 COLLINS-51R RECEIVER COURSE WIDTH VERSUS TEMPERATURE
(COURTESY OF COLLINS RADIO CO)

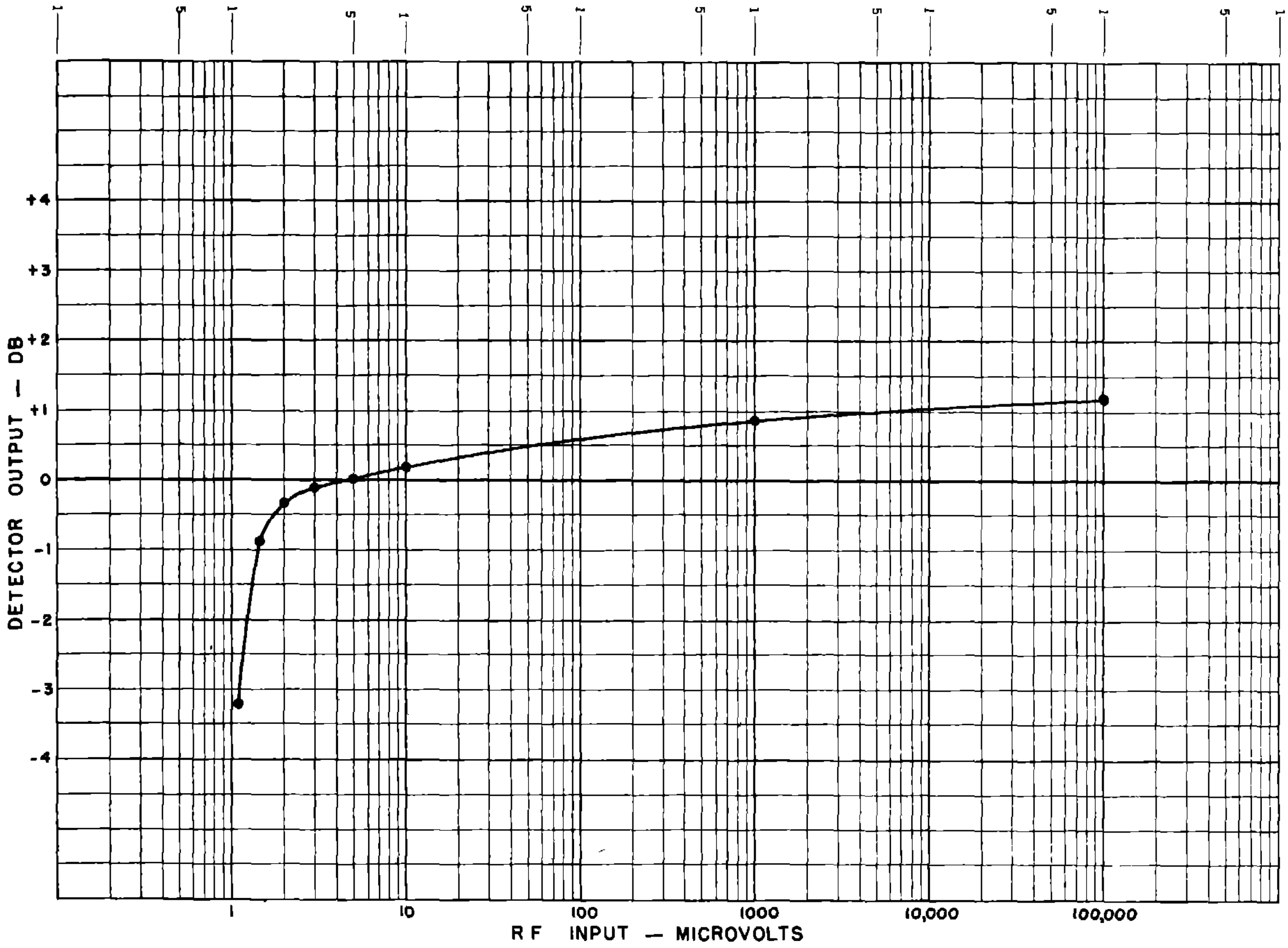


FIGURE 36 COLLINS - 51R RECEIVER A V C. CHARACTERISTICS
(COU TE Y OF COLLI R [illegible])

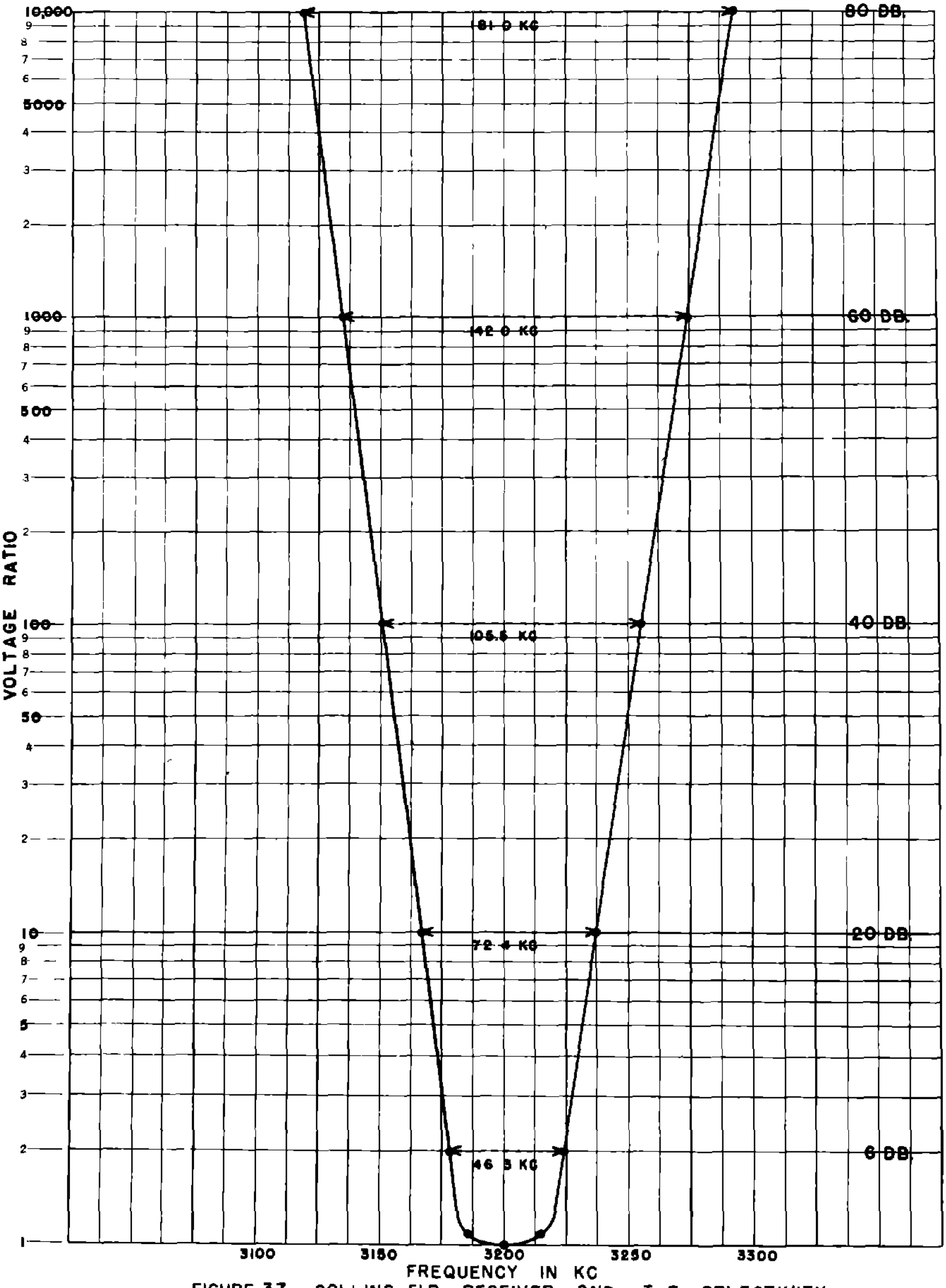


FIGURE 37 COLLINS-51R RECEIVER 2ND I-F SELECTIVITY
(COURTESY OF COLLINS RADIO CO)

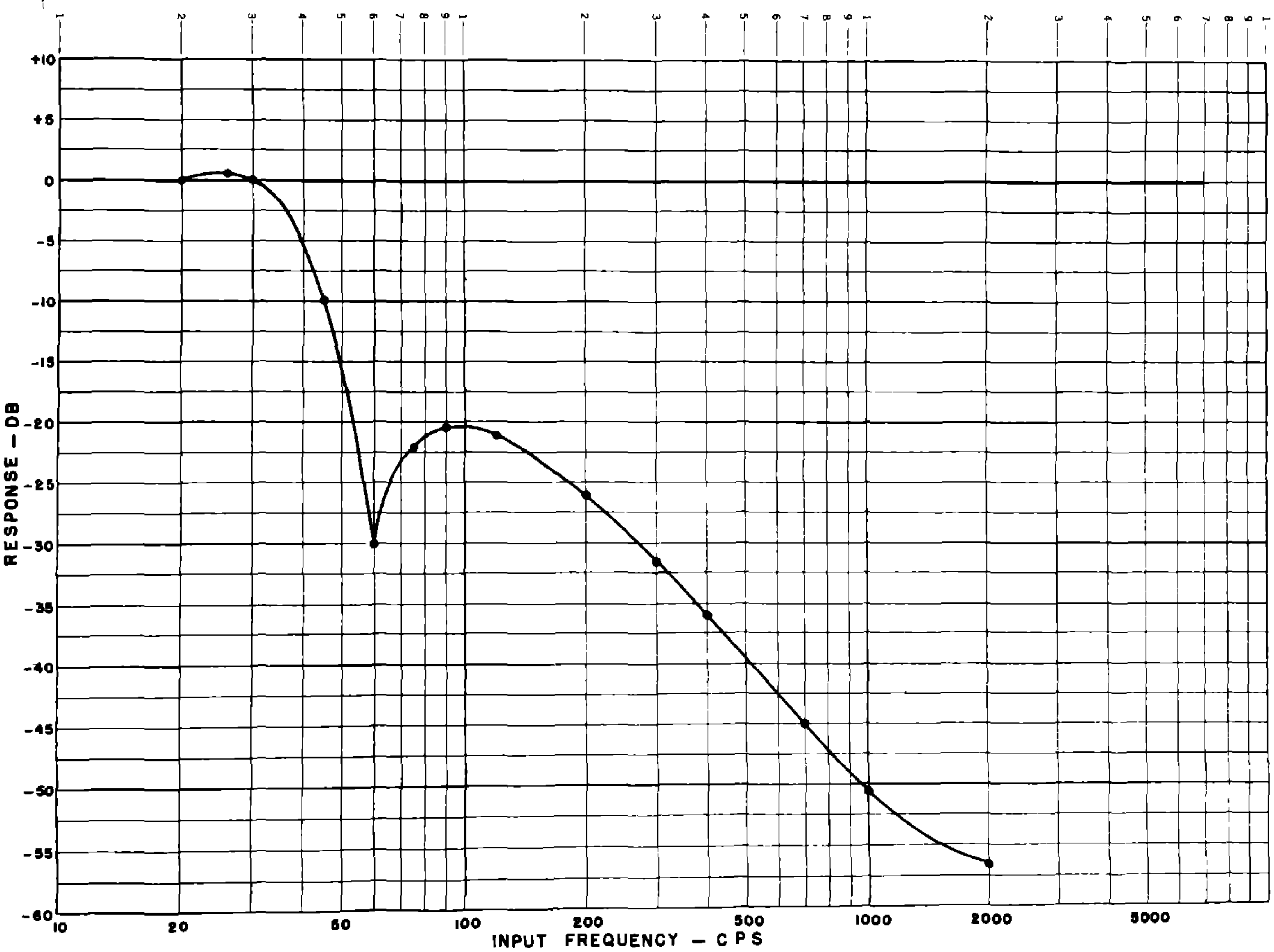


FIGURE 38 COLLINS-51R RECEIVER VARIABLE PHASE CHANNEL FREQUENCY RESPONSE
(COURTESY OF COLLINS RADIO CO)

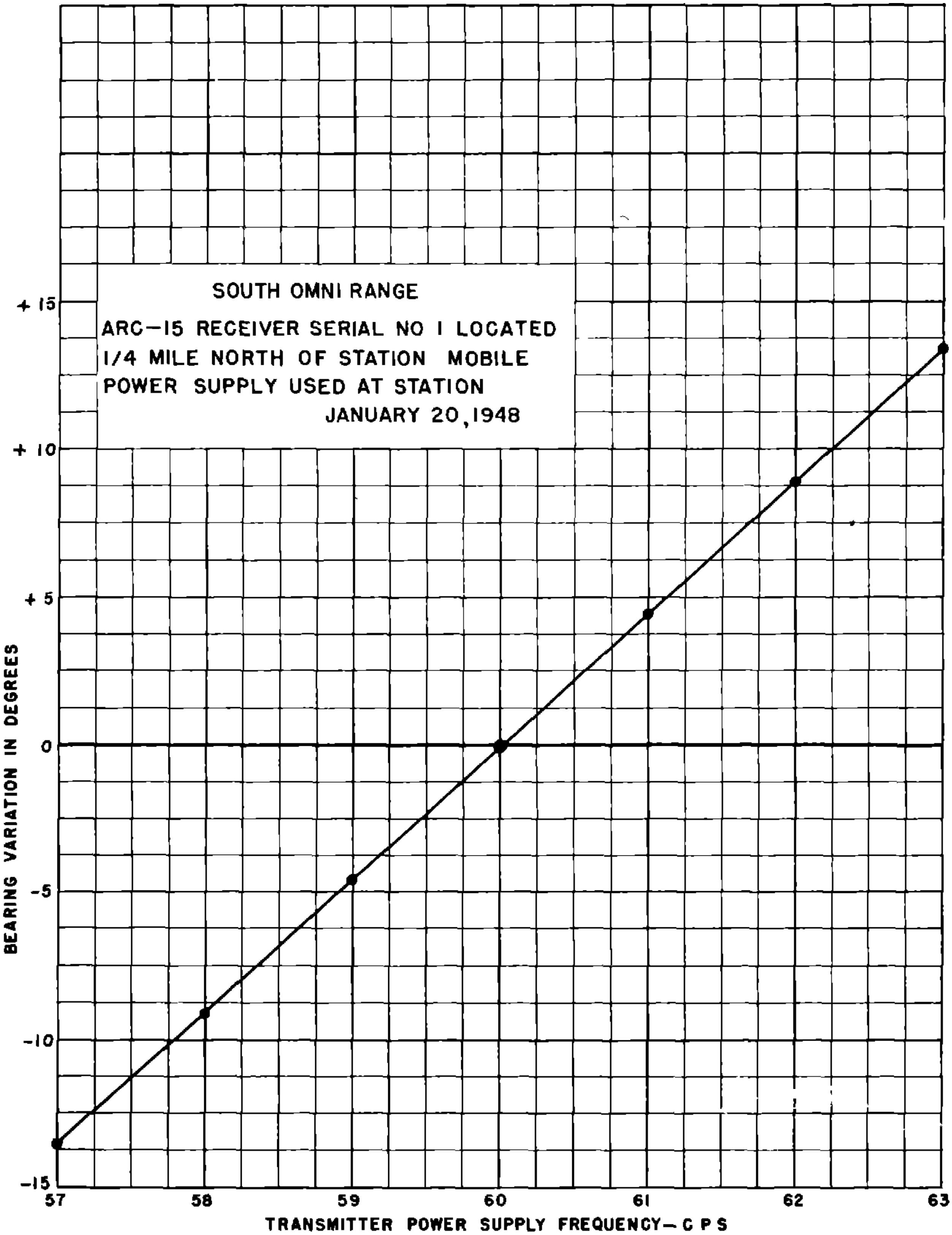


FIGURE 39 ARC—15 RECEIVER BEARING SELECTOR VARIATION VERSUS POWER LINE FREQUENCY