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Report on

Calibration Analyses of First Naval District

Shore Direction Finder Stations

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by

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NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
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ABSTRACT

This report deals with the calibration analyses of the First District Shore Navigation Direction Finder Stations. The importance of coast line and local conditions on deviations as reported by other investigators is reviewed, discussed and summarized. Following this, an analysis is made of the deviation and balance curves from each of the six shore stations, from which evidence is obtained pointing to the most probable cause of the more serious and frequently the more unstable deviation influences. Of considerable assistance in analyzing the data has been the Polar Method of plotting the normal deviation curves and the "Station Layout" on the same sheet.

A new method for extending and simplifying the Polar Method of analysis is reported. The improvement is due to the manner in which the balancer curve is converted into a proportional and somewhat fictitious balancer deviation curve. When the latter is superimposed upon the normal deviation curve, a <u>shaded</u> <u>area</u> between them is obtained whose sign, magnitude, shape and displacement uniquely define the deviation and balancer calibration data. Since such areas can be obtained for each frequency of calibration, their family can be plotted on the polar coordinate curve sheet containing the "Station Layout." The consolidation of the balancer, deviation and "Station Layout" data on a single curve sheet results in a summarized or "Polar Composite Calibration Chart" (e.g., see Plate 1) from which it is possible to obtain a simplified and concise picture of the station's coordinated physical and electrical characteristics. Use of the "Polar Composite Calibration Chart" allows a more natural correlation to be noted between the abnormal behavior of the shaded areas and the structure, coast line or other component of the "Station Layout" most likely responsible.

[redacted]

No serious harmonic analysis investigation is reported, since in an attempt to make such analyses of the calibration data an unwarrantable amount of time and effort was required (to obtain, then plot in proper phase and magnitude, the several components of each deviation and balancer curve) for the amount of correlation information contributed.

[redacted]

Table of Contents

Appendices

Radio Direction Finder Stations

Calibration Analysis of:

Polar Composite Chart

Polar Deviation Charts

[redacted]

AUTHORIZATION

1. This report was written in response to Bureau of Engineering letter C-NX/ND1 (1-26-R2-28), Serial C-R2-13 of 8 February 1939 to the Chief of Naval Operations, via Naval Research Laboratory, requesting comments on enclosure (A), (blueprints of deviation and balance curves with attached letter* of discussion), pertaining to the multiple frequency calibrations of all First Naval District Shore Direction Finder Stations.

STATEMENT OF PROBLEM

2. The object of this investigation was:

(a) to study the calibration curves of the various shore direction finder stations,

(b) to attempt a correlation between the deviations and the "layout" of particular shore direction finder stations in order to locate the possible causes of the more serious and more irregular deviations, and

(c) to recommend procedures that will increase the ease and accuracy of analyzing such calibration data.

3. In many cases there are large and serious irregularities between the deviation curves of successive frequencies of a particular direction finder station. This makes it difficult and sometimes impossible to interpolate between them accurately. These inconsistencies often indicate unstable deviation influences, such as absorptions and reradiations from lines, metallic structures and other obstructions close to the direction finder. Such lines and structures have deviation influences which are dependent upon their electrical constants. Since switching and other load or structure changes may abruptly alter their deviation versus frequency characteristics, they may introduce variable errors whose presence may go undetected. If it were possible to determine and locate these deviation and unstable influences, corrective steps could be initiated to reduce their effects. The analyses given in this report attempt to determine the cause and the location of these influences; also reported are those methods of plotting and analyzing the deviation and balance curves which have been of great assistance in this work.

KNOWN FACTS BEARING ON THE PROBLEM

4. The Radio Research Board of England has published Special Reports No. 1 to 5, inclusive, covering their extensive investigations into the causes of direction finder deviations. The conclusions they(a) and others(b) have reached on the principal types of deviations may be classified and summarized as follows:

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* See Bibliography (j).

[redacted]

(a) Coastal Deviations. Direction finder deviations have been encountered whenever radio waves cross a coast line at very acute angles. At Orford, England, coastal deviations of 3° to 4° were experienced on 450 and 600 meters when the path of transmission was within 20° of the coast line. Increasing the wave length from 500 to 600 meters decreased the corresponding deviation from 3.2 to 1.4°. At higher wave lengths the coastal deviation was less than 1°. In all instances of waves passing from sea to land, the direction of the deviation indicated a bending of the land wave toward the normal to the coast line.

These experimenta confirm earlier observations made by T. L. Eckersley(c) and by Baümler and Zenneck(d). More recently, confirmation has been reported by the U. S. Army Signal Corps(k) in connection with aircraft transmission tests to a portable direction finder. These tests showed that maximum coastal deviations were obtained whenever the line of flight approached a tangent with the coast line and that this deviation approached zero whenever the line of flight became normal to the coast line. The results of the various investigations are in general agreement with respect to the magnitude and direction of coastal deviation for waves passing from sea to land.

(b) Local Condition Deviations. Experiments carried out to ascertain the effects of local conditions on direction finder deviations showed that deviations up to 22° can be produced by the proximity of metalwork, overhead wires, trees, etc. Very few direction finder sites could be found where the maximum deviations due to local conditions were less than 2°. In general, local condition deviations are made up of several contributing causes which may be superimposed upon one another. Among the more important of these contributions may be listed the following:

(1) Deviations due to Terrain. Hills(l) and mountainous terrain as well as sudden changes in the nature of the ground surface, e.g., a line of rocks(m) or shifting sand dunes(n) may produce fixed as well as unstable deviations. Direction finder sites within one wave length of the edge of cliffs or inland rocks may be expected to give deviations under such conditions which vary with the wave length and the wave azimuth.

(2) Deviations due to Sub-Strata. Concentrated areas of dry or poorly conducting as well as concentrated areas of wet soil accentuate the irregular deviation effects of non-uniformly distributed conducting strata under the direction finder loop. This is due to the dependence of the intensity and angle of the reflected wave upon the direction of the arriving wave.

(3) Deviations due to Buried Conductors. Buried conducting materials such as cables, conduit, pipes, etc., particularly those close to the direction finder, should be avoided. In the case of the Aberdeen, Scotland, station, bearings(e) taken with a loop direction finder at scale points only 50° apart were subjected to +16° and -12° deviations due to buried supports of a sewer duct beneath the direction finder.

(4) Deviations due to Surface Obstructions. An open plain, with the nearest buildings, trees, and other obstructions more than one wave length away, may be considered as approaching an ideal direction finder site. Some common departures from the ideal site are:

[redacted]

Buildings. Limited direction finder areas, nearby buildings, and other obstructions one wave length away from the direction finder loop may be expected to cause deviations. Eckersley(f) interpreted the effects of such obstructions in the terms of the solid angles they subtend at the direction finder and has concluded that 2 to 3° appears to be the maximum permissible angle.

Metallic Lines. Aside from concentrated conductors or semi-conductors such as buildings and trees, there are telephone lines, power transmission lines, railroads, and wire fencing which may cause deviations due to such lines acting as distorters to the radio field or as Beverage Antennas(i). Deviations obtained with a portable direction finder at different distances from a set of telephone wires have been reported. These deviations(g) varied from 70°, when the loop was beneath the telephone wires, to a few degrees at 120 feet distance. At times these deviations varied from instant to instant and were attributed to changes or switchings of the telephone circuit.

Railroad Tracks. Deviations as much as 10° have been reported when railroad tracks make an acute angle with the direction of the approaching wave. At the College Park Bureau of Standards Radio Range System(h), distortion of the equi-signal course is quite marked when the railroad tracks come close to the radio course.

(5) Deviations due to Resonance Effect. Metallic objects such as aerials, cables, towers, tall chimney stacks, etc., may have natural periods close to that at which the direction finder is operating. Under such conditions, they may reradiate strongly and cause abrupt changes in deviation when the direction finder frequency of operation and the direction of arrival of the wave are varied. It is usually more difficult to study resonance or partial resonance effects because of the great variations in polarization of such waves. Nearby receiving or transmitting aerials may be a particular source of unstable deviations in view of the intentional and varied tuning to which they are subjected. Forbes(o) has shown instances where a resonant receiving antenna as remote as 1 mile or more from a receiver or direction finder can distort the field of transmitters whose bearings are being taken; in a striking test, a microphone placed in the antenna circuit of this remote resonant receiving antenna was capable of modulating the field received by the direction finder, from the distant transmitter.

[redacted]

(6) Deviations due to Transmitter Station on Direction Finder Site. Transmitting aerials must be particularly watched as a source of unstable deviation because of their frequent great length and height tending to make them act as directive or Beverage(i) Antennas in addition to their possibility of acting as resonant reradiators. Transmitting aerials must be disconnected at the lead-in point before taking bearings in order to avoid their extraneous coupling (via high leakage capacity to walls and earth) causing wave deviation and distortion effects.

(7) Deviation and Blurred Minima due to Electrical Interference. Aside from the deviation they may cause as overhead or buried conductors, power mains are frequently a source of interference. Since power mains are subjected to load changes, they may be responsible for variable deviations and at times may couple inductive interference effects into the direction finder loop, often causing uncorrectable blurring of the minimum and consequent bearing indefiniteness.

NARRATIVE OF ORIGINAL WORK DONE AT THIS LABORATORY

5. Having noted from the references and the summarized discussion above how important the various possible errors at coastal radio direction finder stations can be, analyses have been made of the First District station's multiple frequency calibration curves with the following results:

(a) Evidence has been presented pointing to the cause and location of the more serious deviation influences at each of the radio direction finder stations.

(b) Methods of analyzing the calibration data are given that simplify the obtaining of such evidence.

METHODS OF ANALYSIS

6. Polar Method

(a) In this method the deviation curves of the original calibration data are plotted on a large polar coordinate curve sheet and a zero deviation circle is chosen in such a manner as to allow (1) the worst deviation curve to be plotted about this reference circle, and (2) an appreciably clear area at the center of the curve sheet.

The radial lines are used as observed bearing azimuths starting with zero azimuth at the top and increasing clockwise. In the centrally clear area the various lines, metallic structures, coast line and other possible contributors to deviations are correctly drawn to scale and azimuthal orientations, using the direction finder loop as a center. This results in a more or less bird's-eye view of the direction finder station "layout" and permits the eye to glance along any radius or azimuth traveled by a radio wave and note the coast line, communication line or other structural lines the wave encounteres in its travel toward the direction finder loop.

[redacted]

(b) In general, it is difficult to segregate the deviations caused by the separate influencing factors. This is due to the simultaneous contributions from several such causes that are often present and to the lack of accurate dimension and orientation data of the "Station Layout." It has been possible, however, to resolve the probable causes and locations of the more serious deviations at most of these stations. Although Mare Island Navy Yard(p) has used the Polar Method as early as 1920 and the Boston Navy Yard(q) in 1921 shows a plot of the soil as well as the structure layout of the station on the same polar curve sheet as the deviations, there is no information available, however, which reports on the analyses made by these means.

(c) Quadrature Effect.

(1) As early as 1919 Navy shipboard tests(r)(s)(t) have disclosed definite deviation and balancer characteristics that could in part be identified with particular fixed metallic structures coupling to the direction finder loop. In particular, quadrantal error (i.e., the two cycle deviation characteristic obtained during one cycle of loop rotation) introduced by certain ship structures acting as a closed loop or short circuited turn and reradiating to the direction finder loop was not only known, but its use as a means for deviation compensation was often employed(v)(w).

(2) In general, metallic structures in the vicinity of a direction finder loop are energized by the electromagnetic wave field, F_1, common to both. Since such a structure is not necessarily resonant with the received wave, its reradiation field F_2 will have a random phase with respect to F_1. Near the direction finder loop the resultant field F will be elliptic in character and may be resolved as follows:

Possible Components of a Resultant Field
in Vicinity of a Direction Finder

Component		Bearing Relative to F_1	Phase Relative to F_1
No.	Field		
1	F_1 (Desired)	Correct	0°
2	F_2 (Undesired)	Incorrect	0°
3	F_2 (Undesired)	Incorrect	90° or 270°

Components 1 and 2 combine to produce a deviation in the direction finder bearing while component 3 acts as a quadrature field to produce an indefinite or blurred loop minimum. The balancer condenser functions to introduce a quadrature component of F_1 and F_2 (generally derived from an auxiliary antenna) which will just balance out component 3. Mesny(y)(z) and Horton(aa) treat these elliptic fields at great length.

(3) This Laboratory has often suggested that harmonic analyses (see par. 7) be made of calibration data as a method for finding evidence of these characteristics in the various harmonic components of the calibration data. This is true particularly since it has been possible to

[redacted]

identify structures acting as non-directional (e.g., vertical antenna) and as directional antenna (e.g., closed loops) from the respective semicircular* and quadrantal** characteristic components of shipboard direction finder calibration data.

7. Harmonic Analysis Method. Paragraph 11 of reference letter(j) also suggests that the Naval Research Laboratory make a harmonic analysis of the North Truro and Surfside deviation curves as a possible step in arriving at a solution to the causes responsible for such deviations. Accordingly, a "Mader Harmonic Analyzer" (a mechanical type) was set up and such analyses were made for some of the North Truro deviation curves. Plate 4 shows the fundamental and harmonic components (with proper phase relationships) which were obtained for the North Truro 375 kilocycle deviation curve. It will be noted that these components were plotted in polar form similar to the normal deviation curves plotted for the North Truro direction finder station (Plate 7), in an attempt to correlate the harmonic components with the "layout" of the station. Not much additional correlation beyond that already shown in Plate 7, however, could be observed. Because of this lack of additional correlation and due to the considerable time and effort required in determining and plotting at least four harmonic components (in proper phase relationship#) for each deviation and balancer curve for which a frequency calibration had been made, no further investigation was made of this method.

8. Polar Composite Method. From the analyses of the deviation curves shown in Plates 2 to 8, inclusive, it has been possible to observe substantial correlation between the deviation curves and the "layout" of the station. In most instances, a similar type of balance curve correlation could also be observed with the station "Layout." Often the irregularities of the deviation and the balance curves would occur at the same azimuths. An attempt was therefore made to superimpose the balance curve on its corresponding deviation curve. Plate 1 shows a composite form of such combined curves and "Station Layout," which were plotted for the Cape Elizabeth Radio Direction Finder Station. It will be noticed that every balance curve is plotted as if it were a fictitious deviation curve (using the actual deviation curve as reference) and the area between them is shaded. This was done in order to visualize the balancer setting in terms of its more basic electrical role. That is:

> If the balancer function were not present (e.g., equivalent to its zero setting) it would no longer "buck out" the quadrature voltage generally existing when bearings are taken. This would destroy the desired sharp minimum and give instead, a certain amount of bearing indefiniteness.## The balancer setting or the amount of balancing condenser required, therefore, compensates for and corresponds to the magnitude of the undesired quadrature voltage.

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* A single sinusoidal cycle per single revolution of the direction finder loop.
** Two sinusoidal cycles per single revolution of the direction finder loop.
\# To determine the phase of each harmonic component, each scanning operation of the mechanical analyzer must be repeated.
\## Often called blurred minima.

[redacted]

The solid lines or deviation curves plotted in Plate 1 are identical (except for the deviation scale) to those plotted in Plate 2 for the same station. The dotted curves indicate the proportion of quadrature voltage or bearing indefiniteness that would have been obtained if no balancer compensation were used. The sign, shape, magnitude and displacement of the shaded area between these curves makes it convenient to follow the magnitude of quadrature voltage or bearing spread simultaneously with the deviation curve. Plate 1 thus gives a compact picture of the station's "layout" and its calibration behavior. This results in a concise and simplified coordination of the station's physical and electrical characteristics. The increased ease and accuracy with which it is possible to correlate the bearing spread and deviation effects with respect to the station "layout" has shown it to be a most effective way of determining the cause and location of deviation influences.

DATA OBTAINED

9. The analyses made of the First District Radio Direction Finder Station's calibrations are given in Appendices I to VI, inclusive, Tables 1 and 2, and Plates 1 to 8, inclusive.

DISCUSSION OF PROBABLE ERRORS

10. The analyses as given are in the nature of compiling evidence pointing toward the most probable cause influencing the deviation and balance curves over particular sectors of a given direction finder station. More accurate analyses would require that more complete and more precise station "layout" information (dimensions and orientations of structures, etc.) be submitted with the calibration curves, larger polar coordinate curve sheets, and more suitable division of the polar coordinates to allow rapid plotting and interpolation of the shaded areas; i.e., the deviation and balancer deviation curves. Since all the polar charts of this report have the calibration data plotted against observed bearings or azimuths, some error may be introduced in locating a reradiating structure when its maximum disturbing effects are solely relied upon for this purpose. This is due to the observed bearings then being at maximum difference from the true bearing. This possibility of error is practically eliminated when the minimum coupling positions are employed to locate the disturbing structure since under these conditions, the observed and true bearings approach one another.

DISCUSSION OF RESULTS OF ANALYSES

11. The data and results of the radio direction finder station calibration analyses are stated in Appeneices I to VI and the most probable causes of disturbing influences are pointed out.

12. It has been observed that in general there are two kinds of deviation and balance influences, namely, smooth and irregular types. The smooth type may be termed the non-resonant effect which includes maximum coupling and coastal effects. The irregular types may be called minimum coupling and resonant effects. These types are discussed in the next paragraphs.

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13. Minimum Coupling and Resonant Effects. Usually it is possible to distinguish between the resonant and non-resonant effects, since from the tables and we may note that for the former:

(a) The balancer curves are markedly disturbed within a particular sector without appreciably disturbing the deviation curves, and

(b) The irregularities are evident in one or more curves extending over a narrow frequency band with the balance curve of one particular frequency being much more irregular than those of the adjacent frequencies.

These irregularities will often possess a polarity reversal of the balance curve. Generally it is possible to correlate the maximum of these eccentricities with some structure having an appreciable active length and maximum coupling to the loop taking bearings within this sector. It is to be noted that the frequency and angular position of such a structure appears so closely related with the frequency and coupling position for which the deviation and balance curves have the greatest irregularities, that an apparent approach to natural resonance of this structure is indicated. Since the electrical load and constants as well as the length of the structure alter its frequency of resonance, such structures may undergo electrical and physical changes beyond the knowledge or control of the direction finder operator and thus can cause severe changes in the station calibration near the old and the new resonance frequencies. A specific instance of control lines having such variable deviation effect is reported in paragraph 10 of reference letter(j) from which the following is quoted:

> "As a test upon the effects of variation of coupling between the D.F. and underground cables at Cape Elizabeth, the control lines terminating on the south side of the compass house and the Coast Guard telephone line terminating on the north or opposite side were bonded together by a temporary jumper for intervals of a few seconds during each frequency calibration while the target ship was bearing along an axis of maximum deviation. On all the calibrated frequencies during the above test, there was a decided fluctuation in the deviation of varying amounts, ranging between minus three to plus thirty degrees. These observations did not rise nor fall uniformly with increase of frequency but were erratic and of haphazard values."

There is a need, therefore, to note which structures are so critical and to investigate methods of either reducing their influence or means for keeping a constant check on those calibrations influenced by these structures.*

* Since it is believed that there is a receiver at most direction finder stations continuously guarding 500 kilocycle transmissions, proper precautions should be taken to prevent the receiving antenna from causing unnecessary influence on the direction finder calibration.

[redacted]

14. <u>Maximum Coupling and Non-Resonant Effects</u>. These effects are generally much more stable and their presence, as indicated in Tables 1 and 2, is not nearly so critical or objectionable as the minimum coupling and resonant effects. In reference letter(j) some success is reported with the laying of corrector wires as indicated in the following:

> "8. It may be stated that there is a necessity at shore direction finder locations to maintain greater electrical symmetry through the proper directional arrangement of cables causing deviation relative to the geological conditions which also contribute to the deviation. Where unsymmetrically arrayed the resultant deviation is of a complex nature but when the station is symmetrically laid out, due regard being given to proper placing of underground conductors relative to shore lines, etc., the problem from a practicable point of view seems to be a comparatively simple one, as has been demonstrated at Fourth Cliff(x). Here the solution has been worked backward from effect noted to contributing causes. There is still, however, much research work to be accomplished in order to clear up some of the problems involving the coupling of cables to the D.F. loop, especially now that higher frequencies are to be used ashore.
>
> "12. In conclusion, where there is a lack of consistency between the curves of successive calibrated frequencies for a particular site, it will be impossible to interpolate between them accurately. Where certain stations show normal deviation curves, their resultant performance has been due either to the accidental or purposeful correct placing of the radial electrical conductors entering the direction finder house. Their lengths, electrical constants and positional bearing relative to geological electrical influences being the deciding factor. In a few cases where resonant vertical metallic structures coupled to the direction finder are involved these can be electrically loaded, bonded to each other or to a wet ground so as to change or alter their natural periods, moving them out of the band desired for direction finding.
>
> "13. From the excellent curves obtained at Deer Island it would seem that the previous much discussed and recommended radial copper wire ground system around the D.F. house would be of assistance after all. As this station now has an extensive radial network an entirely different problem is presented compared to a station layout with only a one wire control system. "

[redacted]

15. The polar composite chart, Plate 1, gives a simple and summarized picture of deviation and balance disturbances which can be coordinated with the structures, coast lines, etc., of the station "layout." Use of the polar composite chart, in conjunction with Tables 1 and 2, has been most effective in increasing the ease and accuracy of these analyses.

CONCLUSIONS

16. Coast line as well as terrain, sub-strata, and structures peculiar to radio direction finder stations have been reported in the literature as having marked deviation effects on the direction finder calibrations made at these stations.

17. Analyses made in this report indicate the presence of coast line and structure deviation influences at practically every radio direction finder station in the First Naval District.

18. Many instances of pronounced reradiations (approaches to resonance) from the metallic structures of several stations are indicated by the great irregularities of their deviation and balance curves.

19. Resonance effects and their resultant deviation and balancer irregularities are generally unstable with time and changes of electrical constants of the structure, e.g., drift, load and switching changes. This may result in abrupt and large calibration changes unknown to the direction finder operator.

20. The polar coordinate method of plotting composite deviation curves together with the station "layout" improves the ease and accuracy of analyzing deviation influences.

21. The polar composite chart, Plate 1, gives a striking summarization of the deviation and balancer variations and simultaneously permits their maximum coordination with the components of the "Station Layout" most responsible for their cause. Increasing the scale of the chart increases the accuracy of the analyses as well as assisting in its clarification.

22. In using the polar composite chart, an important psychological advantage may be realized from the pictorial summarization of the complete direction finder calibration behavior and the "Station Layout"; namely, an increased desire to assist in the correction of the more serious irregularities, due to the continuous visual evidence of and the greater ease in spotting the cause of such irregularities.

23. Harmonic analyses of deviation curves do not contribute much significant additional correlation between the deviation effects and the components of the station "layout." The added complexity, in determining and plotting the harmonic components makes this method unwieldy to apply. Paragraph 6(c)(3), however, shows that harmonic analyses may be very useful for analyzing ship direction finder calibration data, particularly those from aircraft carriers.

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RECOMMENDATIONS

24. It is recommended:

(a) That the polar composite chart (see Plate 1) be utilized and adopted for analyzing irregularities in radio direction finder station calibrations.

(b) That in view of the greater ease and accuracy permitted by the polar composite method of determining the factors most responsible for deviation and balance irregularities, a serious investigation be made at one of the stations having very pronounced irregular deviation and balance curves in an effort to determine definite and satisfactory means for reducing the seriousness of the more unstable deviation influences. Radio direction finder station North Truro is recommended for such an investigation.

(c) That stations exhibiting the more serious deviations be investigated with the object of determining and possibly minimizing the principal sources responsible. The following tests are recommended for this purpose:

(1) Excite the most suspicious structure by directly connecting a signal generator (or driver) over a portion of its length, while simultaneously measuring the response vs frequency of the structure with a receiver (preferably untuned) acting as a voltmeter.

(2) Moving a portable transmitter and non-directional antenna around the direction finder (at a radius of several wave lengths) while simultaneously taking true and observed bearings for different frequencies.

(3) Moving a portable direction finder around the direction finder site while simultaneously taking bearings on fixed stations of different frequencies.

These tests will assist in determining the source and magnitude of the disturbance causing critical or marked changes in response (or calibration data vs frequency and azimuth) and will further permit evaluation of any corrective measures applied.

(d) That more accurate information about the radio direction finder station layout (i.e., dimensions and orientations of structures, coast line, etc.) be taken at the time direction finder calibrations are made.

(e) That radio direction finder station polar composite charts (Plate 1) be plotted to as large a scale as possible.

[redacted]

(f) That a Laboratory project be set up for investigating resonance, reradiation, and coupling effects on deviation and balance abnormalities. It is believed that precise and revealing tests can be conducted in this direction by the utilization of structures and of locally generated homogeneous, heterogeneous, direct and reflected radio frequency induction fields under the complete control of the operator.

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[redacted]

Table 1

Directional Coupling Characteristics of Reradiating Structures
(Frequency of Signal,f, held constant)

θ = Loop Position	K = Magnitude of Loop Coupling to Structure	Data Behavior for $\pm \Delta\theta$*				Summary of Structure's Principal Coupling Identifying Characteristics with $\pm \Delta\theta$
		Deviation		Balancer		
		Magnitude (Approx.)	Polarity	Magnitude (Approx.)	Polarity	
$\theta = (\theta_o \pm 90^o)$	Maximum (Positive)	Constant	$\pm$ Constant	Constant	$\pm$ Constant	Maximum Coupling ** A. Deviation and Balance: Constant in magnitude and polarity. ** Loop plane and structure axis parallel.
$\theta = (\theta_o \pm 180^o)$	Zero (K_o)	Variable (Generally goes through a minimum)	$\pm$ to $\mp$	Variable (Generally goes through a minimum)	$\pm$ to $\mp$	
$\theta = (\theta_o \mp 90^o)$	Maximum (negative)	Constant	$\mp$ Constant	Constant	$\mp$ Constant	Minimum Coupling*** A. Deviation and balance: variable in magnitude and reversal of polarity at zero coupling, K_o. *** Loop plane and structure axis at right angles.

θ_o = loop position for minimum coupling to reradiating structure.

* $\Delta\theta$ is a small variation in loop position about any fixed position θ .

[redacted]

Table 2

Frequency Characteristics of Reradiating Structures
(Loop position θ, held constant)

f = Signal Frequency with respect to Resonant Frequency of Structure	Data Behavior for ± Δf*				Summary of Structure's Principal Resonant Frequency Identifying Characteristics with ± Δf
	Deviation		Balancer		
	Magnitude (Approx.)	Polarity	Magnitude (Approx.)	Polarity	
Below resonance $(f < f_r)$	Constant	± Constant	Constant	± Constant	Non-Resonant: A. Deviation and Balance: Constant in magnitude and polarity.
At resonance $(f = f_r)$	Constant (generally goes through a maximum)	± Constant	Variable (generally goes through a minimum)	± to ∓	Resonant: A. Deviation: Constant in magnitude and polarity. B. Balance: Variable in magnitude and reversal in polarity at resonant frequency, f_r.
Above resonance $(f > f_r)$	Constant	± Constant	Constant	∓ Constant	

* Δf is the variation in signal frequency between adjacent calibration curves.

[redacted]

APPENDIX I

Calibration Analysis of
Surfside, Nantucket, Massachusetts, Direction Finder Station

(Refer to Plate 3)

A. STRUCTURAL EFFECTS

1. 95 - 110° Sector.

(a) The 1480 kilocycle deviation curve changes sharply from 30° below to 15° above the average of the group. The maximum deviation occurs at approximately 90° azimuth. The 1480 kilocycle balance curve has a very sharp peak, a maximum rate of change, and a slope reversal in this sector. Table 2 indicates a resonating structure near this frequency.

(b) The 1250 and 1010 kilocycle deviation curves are affected in a manner similar to the 1480 kilocycle deviation curves, but to a lesser extent. These balance curves have smaller peaks and less rapid changes in slope.

(c) The 750 kilocycle balance curve exhibits a very sharp slope change, and a maximum deviation dip near 112° azimuth.

(d) Probable Cause. Structure D (electric power cable buried two feet) passes close to the direction finder and has an active length of about 330 feet along the 90° azimuth. This roughly corresponds to half wave resonance at 1500 kilocycles. Table 1 indicates a minimum coupling to this structure which also may be acting partly as a Beverage Antenna, that is, having a maximum response in one direction, indicating also that it tends to reradiate more in one direction than it does in its reciprocal direction. This effect may account for the near cardioid pattern it makes of the 1480 kilocycle deviation curve. Bibliography (i) carries a discussion of Beverage Antennas.

This structure, (D), appears to affect the other deviation curves in a more or less non-resonant manner, since it seems to cause smaller deviation maximum without causing much disturbance of the balance curve.

2. 240 - 250° Sector.

(a) The 1480 kilocycle deviation curve has a maximum deviation of +12° from the average of the group. Its balance curve has a polarity reversal and a maximum slope change in this region. From Table 1 minimum coupling to some structure is indicated.

(b) The 750 kilocycle deviation and balance curves are affected in a manner similar to (a).

(c) The 525 kilocycle curve is affected in a manner similar to (b), but to a lesser extent.

[redacted]

(d) Probable Cause. Structure G (transmitting antenna 200 feet long) has a direction of approximately 40° - 220° which is approximately correct for minimum coupling to the loop. When considered with approximately 100 feet of lead-in G may resonate near 1500 kilocycles with a quarter wave resonance of approximately 750 kilocycles. Structure (D) described under paragraph A1-(d) may also introduce an appreciable quadrature effective in this region.

3. <u>300 - 310° Sector</u>.

(a) Nearly all deviation and balance curves show large variations and slope reversals. The 1480 kilocycle balance curve has the steepest slope and the balance curves for the lesser frequencies fall off in proportion. From Table 1, minimum coupling to some structure is indicated.

(b) <u>Probable Cause</u>. Structure F (control cable buried to a three-foot depth) connects to the direction finder and power house. Structure F has an approximate direction of 307° at which it has minimum coupling to the loop taking bearings at this azimuth. It also appears that it may couple to structure D described in paragraph (1) (the latter resonating near 1500 kilocycles).

B. <u>COASTAL EFFECTS</u>

1. Deviation curves have an average deviation of approximately -5° in the 110° - 120° sector. This corresponds roughly to the azimuth of the coast line. It should be noted that the sign of the coastal deviations is in the proper direction. Note also that the effect of structure D may be superimposed on the coastal effect (see paragraph A1(d)).

2. The group deviation (an average of +4°) may be principally due to the maximum coupling effect of D, yet the coast line appears to have a small though marked indent in this sector. It should be noted that the sign and frequency effect of the deviation are correct for coastal deviation.

3. An apparent coastal effect at about 300° may exist since the average tangent to the coast line is approximately in this direction. It should be noted that the sign and frequency effect of the deviation are difficult to interpret and appear unsatisfactory. It is probable that the deviation effect of structure D may be superimposed in this region.

C. <u>COMMENT</u>

1. One should expect from Table 1, that structure G (transmitting antenna) exhibit a minimum coupling effect when the loop is positioned at approximately 40° and 220° azimuths. For the same reason, one should expect minimum and maximum coupling effects as well as resonant effects, (Table 2) to be discernible at the azimuths where their particular effects are most pronounced. The simultaneous presence of these several effects in addition to coastal effects doubtless prevents their clear resolution.

[redacted]

APPENDIX II

Calibration Analysis of Deer Island, Massachusetts, Direction Finder Station

(Refer to Plate 8)

A. STRUCTURAL EFFECTS

1. 35 - 60° Sector.

(a) Nearly all deviation curves show some irregularity in this area. The 1,000 kilocycle deviation curve has a maximum irregularity in this sector with lesser disturbances appearing throughout the 20 - 100° sector.

(b) Probable Causes. Structure D (transmitting antenna) approximately 200 feet long has an approximate direction along 125 - 305° and its coupling is maximum to the loop taking bearings at about 35°. Quarter wave resonance of this structure is close to 1,000 kilocycles. Structure E (Army and Navy underground cable system) which is only a few feet from the direction finder, has an approximate direction along 135 - 315° and has maximum coupling to the loop positioned at 45°. Structure C (telephone and telegraph line) approaches within 75 feet of the direction finder and has an approximate direction along 47 - 227°.

2. 65 - 75° Sector.

(a) Nearly all deviation and balance curves show small but pronounced irregulatiries (i.e., slope reversals) in this sector.

(b) Probable Cause. A rear portion of the Army-Navy underground cable system has an approximate azimuth of 70°. The reversal in slope of several of the balance curves in this sector indicates that coupling to this structure passes through a minimum, i.e., direction of structure and loop axis are parallel. Structures E and D probably produce appreciable coupling affects to the loop in this sector which may account for the large steady component of the deviation and balance curves.

B. COASTAL EFFECTS

1. Maximum coastal effect may be expected in the 120 - 140° sector where the coast line has this approximate azimuth. It is to be noted that the deviation curves have an average +3° deviation which is correct in sign for this particular coast line angle.

C. COMMENT

1. All balancer curves are very flat and contribute little information in explaining structural effects. This may be due to the use of a very large antenna in connection with the balancer. Most deviations of this site are less than 5°. The maximum deviation of the site is about 10°. The small deviations characteristic of this site are probably due to the large distances or small couplings between the direction finder and the surrounding structures.

[redacted]

APPENDIX III

Calibration Analysis of North Truro, Massachusetts, Direction Finder Station

(Refer to Plate 7)

A. STRUCTURAL EFFECTS

1. 40 - 90° Sector.

(a) All deviation curves show an average dip of about -12° with the 525 and 750 kilocycle deviation curves having pronounced dips between 55 and 60° azimuth.

(b) All balance curves have large slope changes with the lower frequency balance curves passing through zero setting. The 525 kilocycle curve has maximum slope change in addition to polarity reversal.

(c) Probable Causes. Structure G (radio beacon tower 100 feet high, 200 feet from direction finder) and structure H (control cable 700 feet long and connecting to direction finder house) have an approximate direction along 135 - 315° which is the maximum coupling position for the loop taking bearings at the 45 and 225° azimuths. The change of magnitude and sign of the balancer settings with frequency indicates an additional or superimposed minimum coupling effect with the further suggestion that resonance of one of these structures is indicated by the sudden and large changes in phase of their reradiated field between 525 and 750 kilocycles. Structure F (a corrector wire laid in 1937) has an approximate length of 300 feet at an azimuth of 65°. It connects to the direction finder house and it may act as a form of Beverage antenna to account for the superimposed minimum coupling effect mentioned.

2. 135 - 160° Sector.

(a) All deviation curves show a pronounced peak which averages about +15°. The lower frequency deviation curves and particularly the 1480 kilocycle deviation curve appear most affected.

(b) All balance curves show a great dip in this sector with the higher frequency balance curves going off scale, resulting in poor minima. The minima for the 1480 kilocycle curve appear so broad that apparently no satisfactory bearings could be taken in this sector.

(c) Probable Causes. Structure F (a corrector wire laid in 1937) has an approximate length of 300 feet, connects to the direction finder house, and has a direction along 65°, which is the maximum coupling position to the loop taking bearings at approximate 155 and 335° azimuths. The increasing and off scale values of balancer required in this sector add confirmation* and further indicate a resonance of this structure near the higher frequencies.

* Note that the 375 kilocycle deviation curve is as irregular as the other low frequency deviation curves although correction structure F was originally added to correct the 375 kilocycle frequency curve.

[redacted]

The 300 foot length of this conductor corresponds to half wave resonance at approximately 1500 kilocycles. Unless greater deviations existed prior to its installation, this structure may no longer be serving a corrector purpose, since its presence at this time appears to result in more than 20° deviation and off scale balancer settings. If no greater deviations existed before, then shortening or removing the wire may yield an improvement. Structure H (control cable 700 feet long) connecting to the direction finder and the power house has an approximate direction along 137 - 317° and may act as a partial Beverage antenna superimposing minimum coupling effects on a loop taking bearings in this sector.

3. 170 - 210° Sector.

(a) The 1250 kilocycle deviation curve is very erratic in this sector. Bearings are indefinite and deviations greater than -45° exist. The balance curve is at a peaked maximum and even at this setting, it is inadequate in sharpening the minimum. Tables 1 and 2 would indicate a minimum coupling as well as a resonant frequency characteristic of nearby structures.

(b) The other high frequency deviation curves are similarly affected, but to a lesser extent. Nearly all balance curves have very sharp peaks in this region.

(c) Probable Causes. Structures A and D (transmitting antenna, and a one mile long control line) have a direction of 0 - 180° which may act as a Beverage antenna with minimum coupling to the loop at the 180° azimuth. Since A is a 200 foot antenna which has a quarter wave resonance at about 1225 kilocycles, it may account for the tremendous change in deviation at this frequency and in this sector.

Structure E (lighthouse building) is along the 110 - 290° direction. This is a direction that a reradiated field from E can cause maximum deviation to a loop taking bearings at 20° or 200°; hence a 1225 kilocycle resonance of a structure within E can also possibly be the cause of the disturbance in calibration. Receiving antennas resonant in the broadcast band in this building may be responsible.

4. 245 - 280° Sector.

(a) All deviation curves, particularly the low frequency group, have pronounced negative dips that average about -20°. The 434, the 1250, and particularly the 1480 kilocycle balance curves have very sharp dips at approximately 265° azimuth, with the latter two exhibiting definite polarity reversals.

(b) Probable Causes. Structure F (corrector wire laid in 1937), see paragraph A2(c), and structures A and D, see paragraph A3(c). These structures act to give superimposed minimum and maximum coupling characteristics.

[redacted]

5. 310 - 320° Sector.

(a) The higher frequency deviation and balance curves show a marked irregularity in this sector.

(b) Probable Cause. Structure H (700 feet of buried control cable) connects to direction finder and has a direction in this sector. Confirmation is obtained because of the polarity reversal for three balancer curves, the reversal in deviation and balancer slopes of several of these curves, and because of the zero or minimum coupling of this line when the loop is taking bearings in this sector.

6. 320 - 350° Sector.

(a) Structure F appears responsible for the deviation and balancer disturbances; see paragraph A2. Maximum coupling and resonant frequency characteristics for this structure being strongly indicated.

B. COASTAL EFFECTS

1. Maximum coastal effects may be expected at approximately 135°, 170 - 180°, and 315° azimuths. The coastal effects appear "swamped" by the larger structural influences that give pronounced deviation influences in these regions.

C. COMMENT

1. Structure F terminates in the ocean and structure H terminates in a well (used as the sites principal ground). F and H constitute a closed loop having an appreciable part of the loop in a vertical plane. Its quadrantal effect may be superimposed on the other effects discussed.

[redacted]

[redacted]

APPENDIX IV

Calibration Analysis of Fourth Cliff, Massachusetts, Direction Finder Station

(Refer to Plate 6)

A. STRUCTURAL EFFECTS

1. 340 - 25° Sector.

(a) Nearly all deviation and balance curves show irregularities with an average of -3° deviation and -15 balance divisions for the group.

(b) Probable Causes. Structure B (transmitting antenna approximately 130 feet from direction finder) has an approximate direction along 25 - 205° and may be acting as a Beverage antenna, with minimum coupling effects, although B is probably not causing all reversals in slopes of the deviation and balancer curves. The constant components of the deviation and balancer curves observed may be due to corrector wires C and D which have the proper direction to cause such maximum coupling effects.

2. 110 - 125° Sector.

(a) Several higher frequency calibrations have their deviation and balance curves showing polarity and slope reversals indicating a resonant frequency characteristic and other irregularities in this sector. Some maximum coupling effect as well as resonant frequency effect is indicated by the behavior of the low frequency calibrations.

(b) Probable Cause. Structure B (transmitting antenna) has a direction along 25 - 205° which corresponds to a position of maximum coupling to the loop taking bearings in this sector. The change in sign of the balance curves between 195 and 245 kilocycles indicates a change in phase of the reradiation field from B probably due to an in-between frequency of resonance. The cause of the higher frequency resonant characteristic is not apparent.

B. COASTAL EFFECTS

1. Maximum coastal effects may be expected in the 340 - 10° sector and again in the 120 - 140° sector since the coast line has these approximate azimuths. Although the sign of the deviations is in agreement with deviations caused by coastal effects, it is difficult to separate the latter from the two local condition effects which cause appreciable deviations in these sectors.

C. COMMENT

1. It is to be noted that no outstanding deviation or irregularities occur for this station. The maximum deviation is approximately 5°. It is possible that the relatively clear site and the buried corrector wires are responsible for the small deviations characteristic of this station. The deviations and balancer disturbances attributed to the specific structure B may be in part due to the corrector wires C and D.

[redacted]

2. The original calibration data (see par.1) shows that the low frequency data were taken in June 1938, while the high frequency data were taken in November 1938. Because the two sets of data do not overlap their calibrations, only the low frequency data have been plotted in Plate 7 in order to avoid any seasonal effect from confusing the analysis.

[redacted]

APPENDIX V

Calibration Analysis of
Winter Harbor, Maine, Direction Finder Station

(Refer to Plate 5)

A. STRUCTURAL EFFECTS

1. 65 - 95° Sector.

(a) All deviation curves show pronounced irregularities in this sector which are particularly large near 65° for the higher and lower frequencies.

(b) The balance curves in this sector show no marked irregularities except that the two lowest frequency balancer settings are of reversed polarity with respect to the others. The deviation and balance curves approach a minimum near 95°.

(c) Probable Cause. Structure A (part of water pipe system) and an adjacent parallel power line connecting from the power house to the receiving building has a direction along 93 - 273° which is a position where it has minimum coupling to the loop when taking bearings at 93° azimuth. The reversal in polarity of the reradiation from this structure with frequency, as indicated by the balancer setting reversing in sign with frequency, may be due to part of the power line system becoming resonant between 245 and 195 kilocycles.

2. 110 - 130° Sector.

(a) The medium and higher frequency deviation curves show polarity reversals and large irregularities in this sector with some balance curve irregularity and polarity reversal being evident.

(b) Probable Causes. Structures F (control lines) and C (transmitting antenna) both have an approximate direction along 20 - 200° which is a position where they have maximum coupling to the loop when bearings are taken at about 115° azimuth. Part of structure A having a direction along 130 - 310° has a minimum coupling characteristic to the loop at 130° and may also be reradiating to account for some of the balancer curves going to zero, indicating zero coupling or parallel axes of loop and this part of structure A. A resonance effect possibly in structure C is indicated by the pronounced excursion and polarity reversals of the 790 kilocycle deviation and balancer curves.

3. 155 - 160° Sector.

(a) The deviation curves have an appreciable negative deviation irregularity near 157° with the 195 kilocycle balancer going off scale at 157°. The balancer curves for the other low frequency calibrations are also severely affected in this sector. A maximum coupling effect with an additional (or superimposed low frequency, resonant frequency) minimum coupling characteristic of some structure is indicated.

[redacted]

(b) Probable Causes. Structure B (control lines) has an approximate direction along 65 - 245° which is a position where it has maximum coupling to the loop when bearings are taken at approximately 155° azimuth. This structure also appears to account for the polarity reversal of the low frequency balancer curves. Part of structure A (buried water pipe) has about 500 feet or more of its active length along an approximate 157° azimuth. It appears as if A may have some minimum coupling deviation influence in this sector and may possibly account for the resonant characteristic as well as for the peaks in the 195 and 245 kilocycle balancer curve, due to its resonance (see A1(c)).

4. 200 - 225° Sector.

(a) Most deviation curves show an average +4° deviation irregularity in this region with the 195 kilocycle curve showing the maximum deviation.

(b) The 195 kilocycle balance curve has the greatest value with polarity reversal effects being evident in the other balance curves. A maximum coupling effect of a resonant structure is indicated.

(c) Probable Cause. Part of structure A has an approximate direction of 130 - 310° which is a position where it has maximum coupling to the loop when bearings are taken at 220° azimuth. Since certain portions of A appear resonant near 195 kilocycles (see paragraph A1(c)) this may account for the 195 kilocycle balance and deviation curves having larger values in this sector.

B. COASTAL EFFECT

1. A maximum coastal effect may be expected to appear at approximately 60°, 130°, 150°, and 325°. These effects are probably masked by the effect of the A and the C structures.

[redacted]

APPENDIX VI

Calibration Analysis of
Cape Elizabeth, Maine, Direction Finder Station

(Refer to Plates 1 and 2)

A. STRUCTURAL EFFECTS

1. General Disturbances.

(a) Most deviation curves go to zero near 75° and 200° and pass through a maximum near 125°. Many of the balancer curves pass through a minimum near 30°, 75°, and 200°, and have large values near 125°.

(b) Probable Causes. Structure E (buried telephone line, approximately 300 feet long) has a direction along 30 - 210° and approaches maximum coupling to the loop positioned at about 120° and minimum coupling at about 210°. The reradiations of structure F (telephone line connecting to direction finder house) appear to predominate and account for the deviation minima near 75° since F with a direction along 78° has minimum coupling to the loop at 78°.

2. Other Disturbances.

(a) The deviation irregularities at about 50° are probably due to structure C (telephone lines) and its adjacent power lines which have a direction along 48° where they have minimum coupling to the loop at this azimuth.

(b) A small irregularity in the 245 kilocycle deviation curve at 205° is probably due to structure E (telephone lines) which has a 210° direction where it has approximately minimum coupling to the loop at this azimuth.

3. Resonance Effects. (Refer to Table 2.)

(a) An approximate 500 kilocycle resonating structure is indicated due to variation and reversal of the balancer values near this frequency in the 35 - 90° sector.

(b) An approximate 1,000 kilocycle resonating structure is indicated due to variation and polarity reversal of the balancer values near this frequency in the 120 - 200° sector.

(c) Since the 525 kilocycle deviation and balancer curves show a maximum near 140° and minima at about 85° and 205°, structure F with a direction along 85° is the probable cause since it gives the necessary maximum and minimum couplings near these azimuths. Structure F is probably the cause of the resonance effect noted for the 1,000 kilocycle deviation and balancer curves, particularly since the latter exhibits the same general maximum and minimum points noted for the 525 kilocycle deviation and balancer curves. Structures C and E (with directions along 140°) may be acting as minimum coupling Beverage antennas, particularly at the higher frequencies, to account for the polarity reversals of the deviation and balancer curves in the 115 - 130° sector.

[redacted]

B. COASTAL EFFECTS

1. 30 - 40° Sector.

(a) Most deviation curves are smooth but have an average negative deviation which approaches -8°.

(b) The balance curves show no significant irregularity.

(c) Probable Causes. The coast line has an azimuth of approximately 30°. The coastal deviation effect should be minus in this area and agrees with the sign of the deviations obtained for the station in this sector. The small dip in the 375 kilocycle deviation and balance curve at approximately 40° azimuth may be due to structure C whose deviation influence has already been discussed under "STRUCTURAL EFFECTS," paragraph 2(a). The increase in deviation of the low frequency group for azimuths less than 40° indicates a maximum coupling deviation influence due to structure E (Coast Guard telephone lines buried 2 feet) which has a direction of approximately 140 - 320°.

2. 130 - 140° Sector.

(a) All deviation curves are smooth but have an average deviation for the group which approaches +10°.

(b) The balance curves show little irregularity in this area.

(c) Probable Cause. The coast line has a thumb-like projection at an azimuth of approximately 135°. The sign of the deviation to be expected from this azimuth of the coast line agrees with the sign of the deviation obtained. Note that structure E (see par. A1(b) tends to mask the coastal effect.

3. 190° Sector.

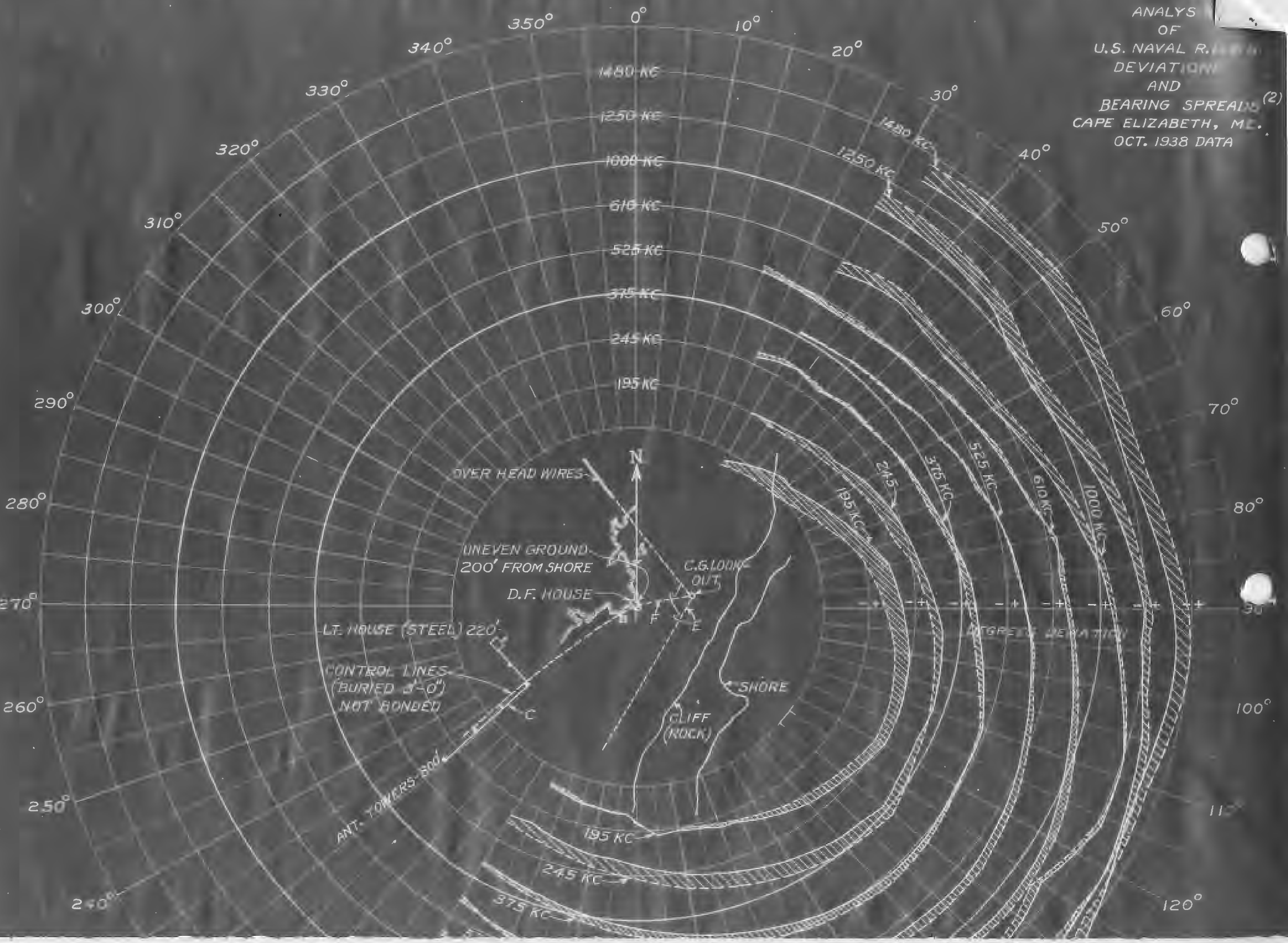
(a) Some coastal effect is indicated at 190° sector. All deviation curves are smooth but have an average deviation of approximately -5°.

(b) The balance curves show no irregularity.

(c) Probable Cause. The coast line has an approximate azimuth of 190°. Some effect of parallel structures E and C may be superimposed on the low frequency deviation curves causing them to have larger values of deviation.

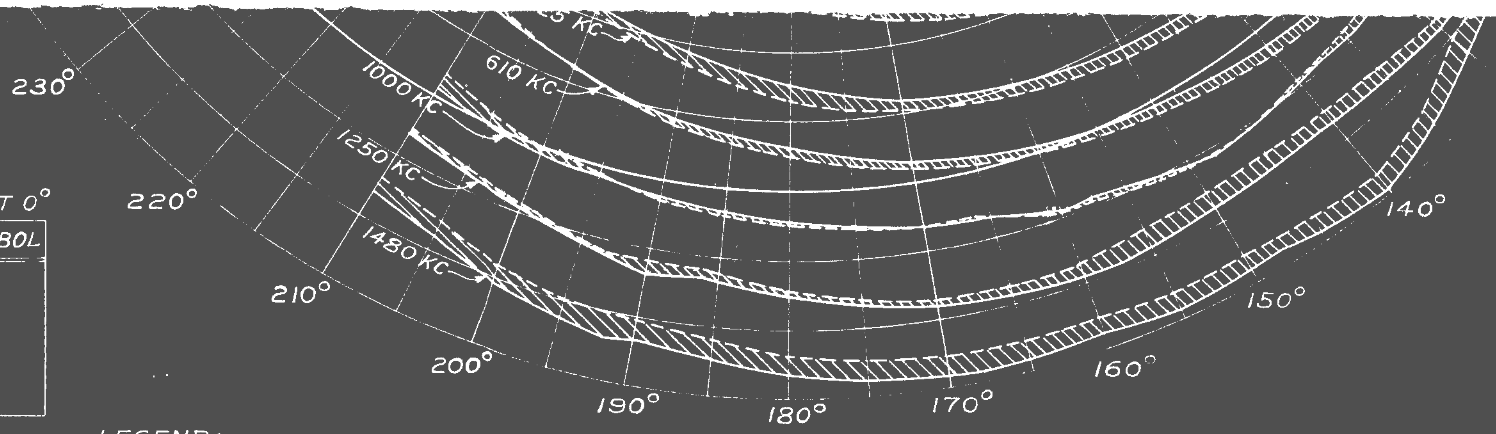
[redacted]

ANALYS
OF
U.S. NAVAL R.
DEVIATION
AND
BEARING SPREADS (2)
CAPE ELIZABETH, ME.
OCT. 1938 DATA



REFERENCE POINT 0°

FREQ.	SYMBOL



REFERENCE POINT 0.0°

FREQ.	SYMBOL

LEGEND:

TRUE BEARINGS OF STRUCTURES INDICATED

"C" - LT. HOUSE POWER LINES

"E" - C.G. TELEPHONE LINES, BURIED 2'-0"

"F" - " " " " " " " NOT BONDED

NOTES:

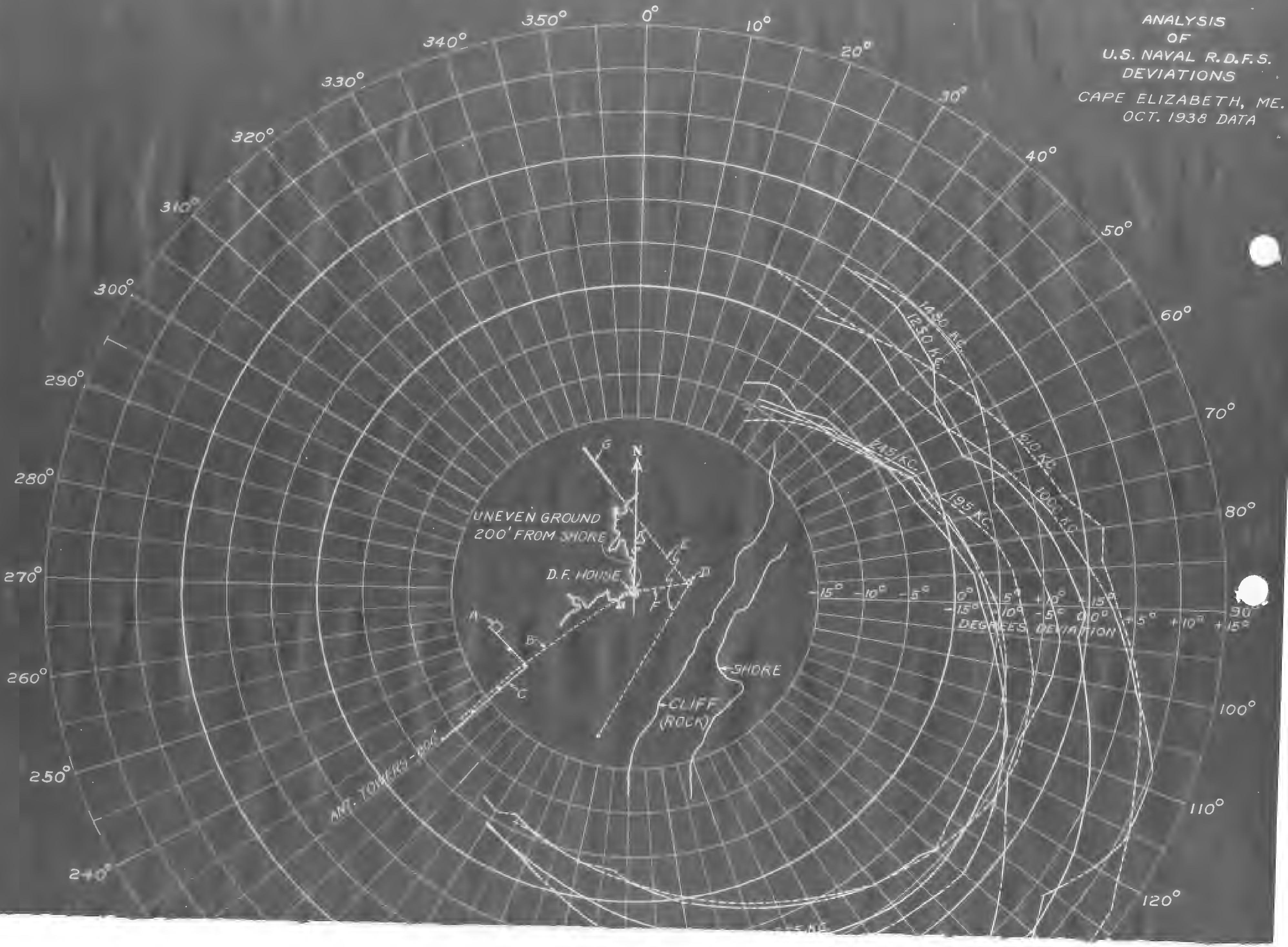
(1) THE SOLID LINES ARE THE NORMAL DEVIATIONS WHICH ARE CENTERED ON THEIR OWN ZERO DEVIATION REFERENCE CIRCLE.

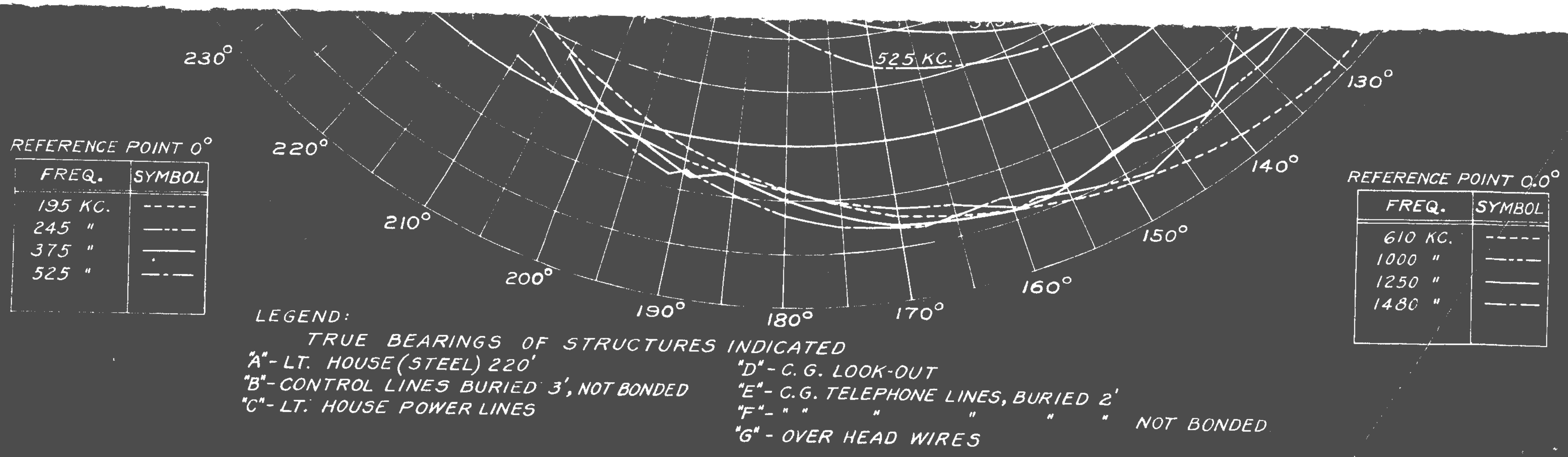
(2) THE DOTTED LINES ARE THE BEARING SPREADS OBTAINED BY MULTIPLYING THE CORRESPONDING BALANCE SETTING (WITH PROPER SIGN) BY 0.1 AND PLOTTING IT AS A NEW DEVIATION, USING THE ACTUAL DEVIATION CURVE AS A REFERENCE. THIS NEW DEVIATION WOULD CORRESPOND TO THE BEARING SPREAD IF NO BALANCER IS USED.

(3) THE SCALE FOR THE DEVIATION AND BEARING SPREAD CURVES IS: 1 DIVISION = 10 DEGREES DEVIATION.

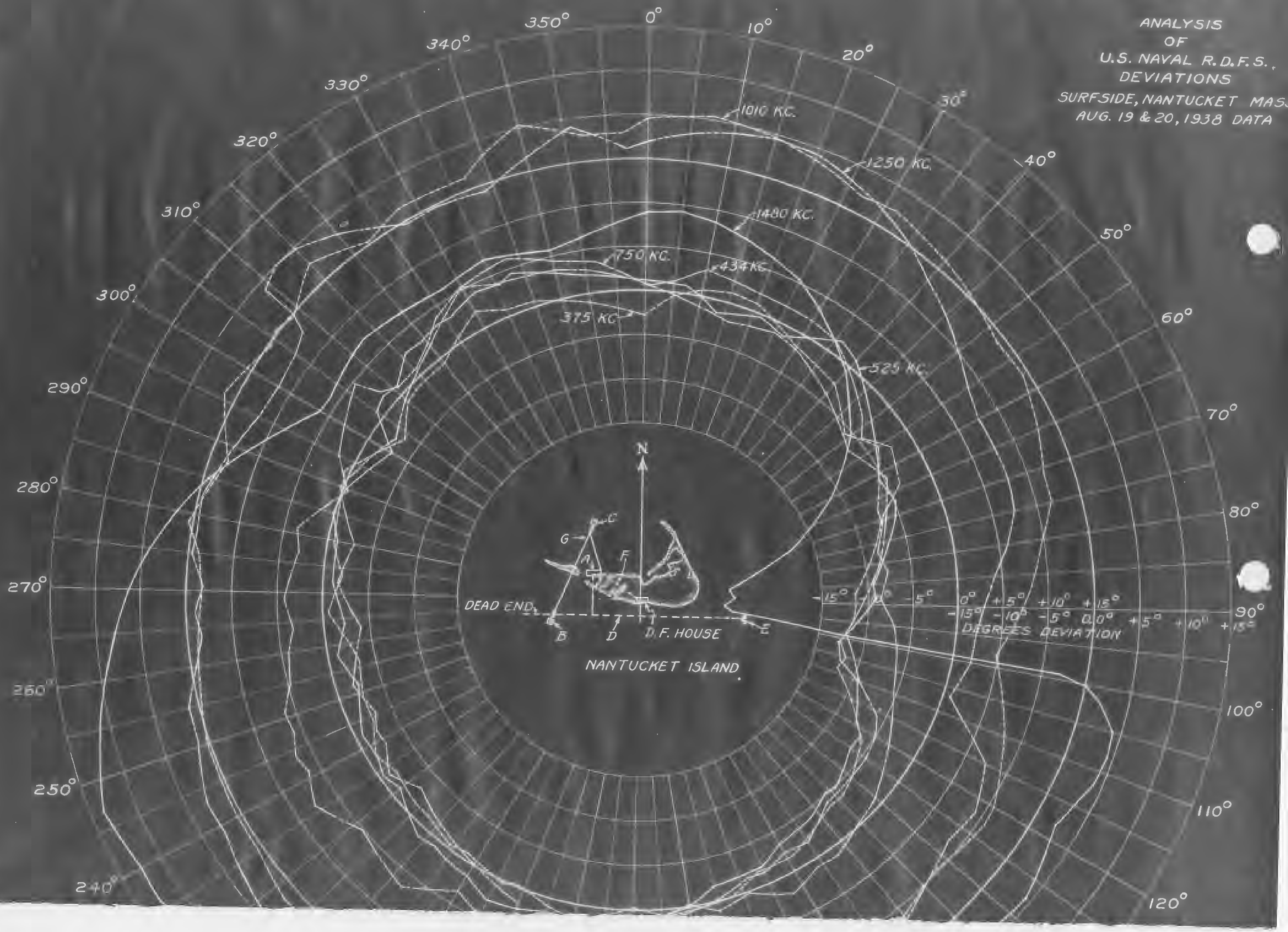
ANALYSIS OF U.S. NAVAL R.D.F.S. DEVIATIONS

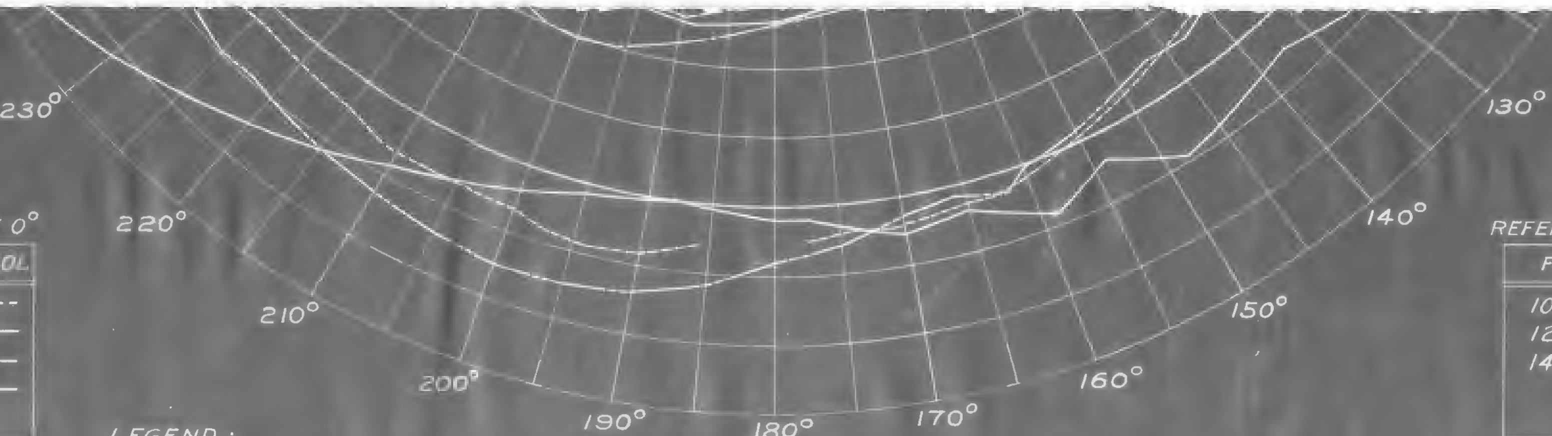
CAPE ELIZABETH, ME.
OCT. 1938 DATA




230°
220°
210°
200°
190°
180°
170°
160°
150°
140°
130°
525 KC.
REFERENCE POINT 0°
FREQ. SYMBOL
195 KC. - - - - -
245 " —·—·—
375 " ———
525 " —·—
REFERENCE POINT 0.0°
FREQ. SYMBOL
610 KC. - - - - -
1000 " —·—·—
1250 " ———
1480 " — — —
LEGEND:
TRUE BEARINGS OF STRUCTURES INDICATED
"A"- LT. HOUSE (STEEL) 220'
"B"- CONTROL LINES BURIED 3', NOT BONDED
"C"- LT. HOUSE POWER LINES
"D"- C.G. LOOK-OUT
"E"- C.G. TELEPHONE LINES, BURIED 2'
"F"- " " " " " " NOT BONDED
"G"- OVER HEAD WIRES

ANALYSIS
OF
U.S. NAVAL R.D.F.S.
DEVIATIONS
SURFSIDE, NANTUCKET MAS
AUG. 19 & 20, 1938 DATA





REFERENCE POINT 0°

FREQ.	SYMBOL
375 KC.	-----
434 "	—·—
525 "	——
750 "	—-—

REFERENCE POINT 0.0°

FREQ.	SYMBOL
1010 KC.	-----
1250 "	—·—
1480 "	——

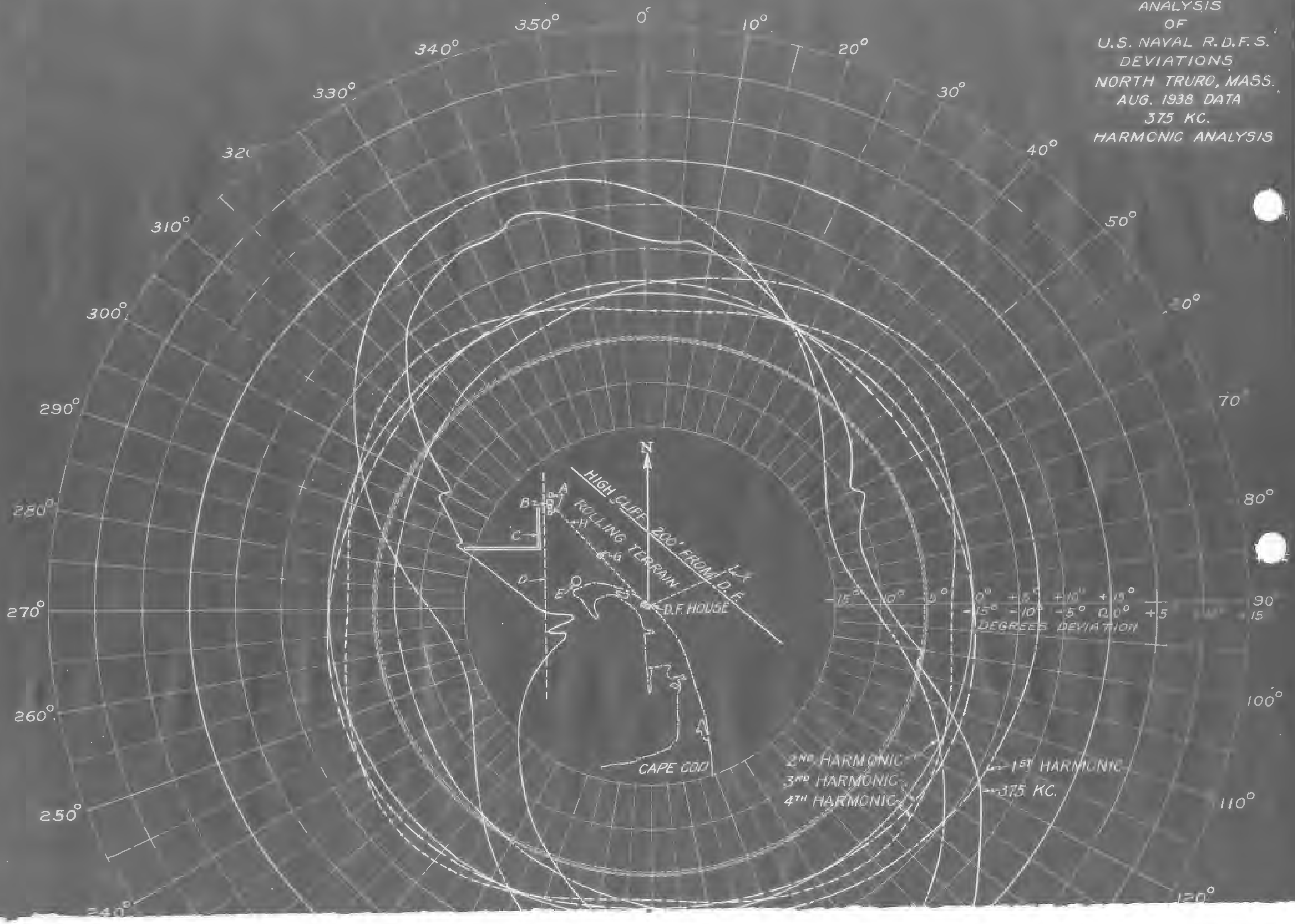
LEGEND :

TRUE BEARINGS OF STRUCTURES INDICATED

"A"- POWER HOUSE
"B"- S. TOWER (100' HIGH) 200' FROM D.F.
"C"- N. " " " " " "
"D"- ELECT. CABLE BURIED 2' IN STREET 200' TO OVER HEAD WIRES
"E"- TRANSFORMERS
"F"- CONTROL CABLE BURIED 3'
"G"- TRANSMITTING ANT. (200' LONG)

NOTE: D.F. 1000' FROM SHORE, LOW FLAT SURROUNDING AREAS

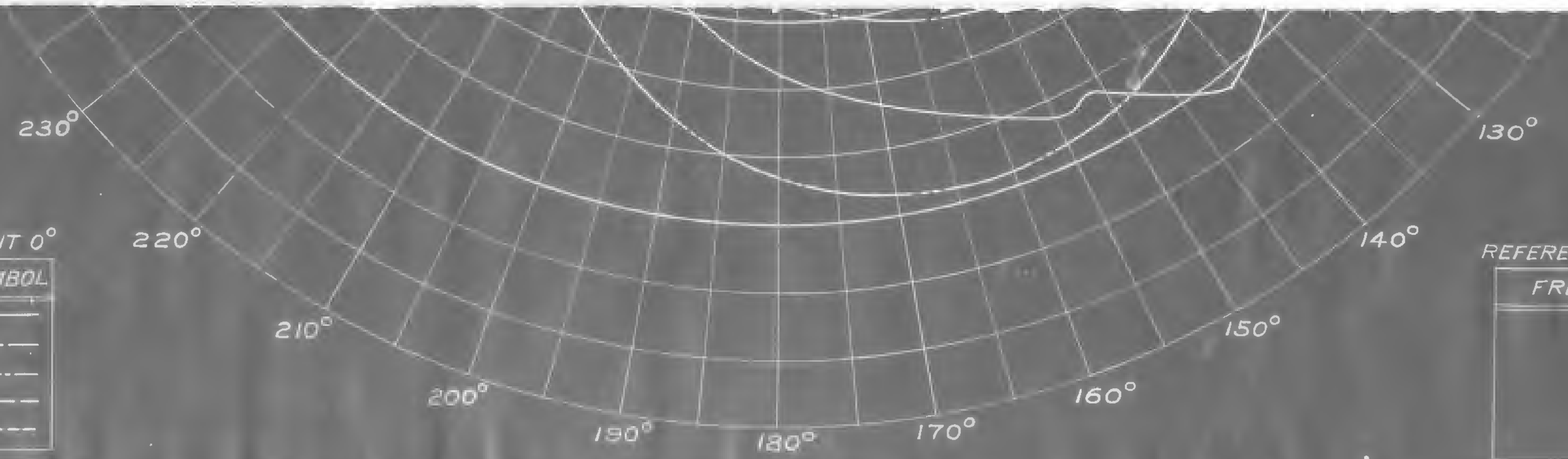
ANALYSIS
OF
U.S. NAVAL R.D.F.S.
DEVIATIONS
NORTH TRURO, MASS.
AUG. 1938 DATA
375 KC.
HARMONIC ANALYSIS



REFERENCE POINT 0°

FREQ.	SYMBOL
375 KC.	———
1ST HARMONIC	—·—
2ND "	—··—
3RD "	— — —
4TH "	- - - - -

MEAN OF 375 KC. ======



REFERENCE POINT 0.0°

FREQ.	SYMBOL

LEGEND:

TRUE BEARING OF STRUCTURES INDICATED

"A"=STEEL TOWERS 100' HIGH, 200' ANTENNA

"B"=POWER HOUSE

"C"=OUTSIDE ELEC. POWER

"D"=BURIED COAST GUARD CABLE, BURIED IN GROUND ONE MILE LONG TIED IN TO NAVY D.F. HOUSE VIA TELEPHONE

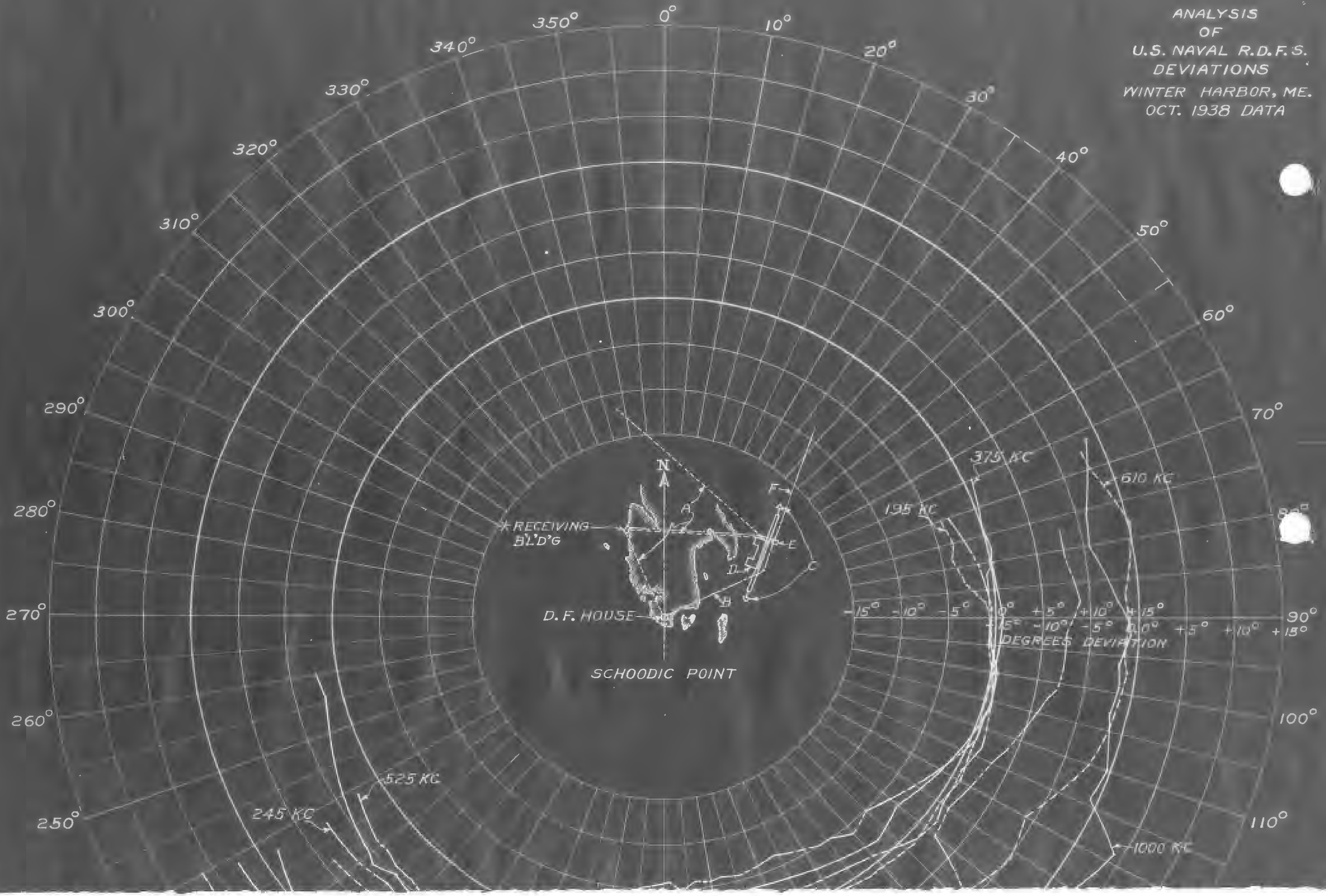
"E"= STEEL & BRICK LT. HOUSE 200' FROM D.F.

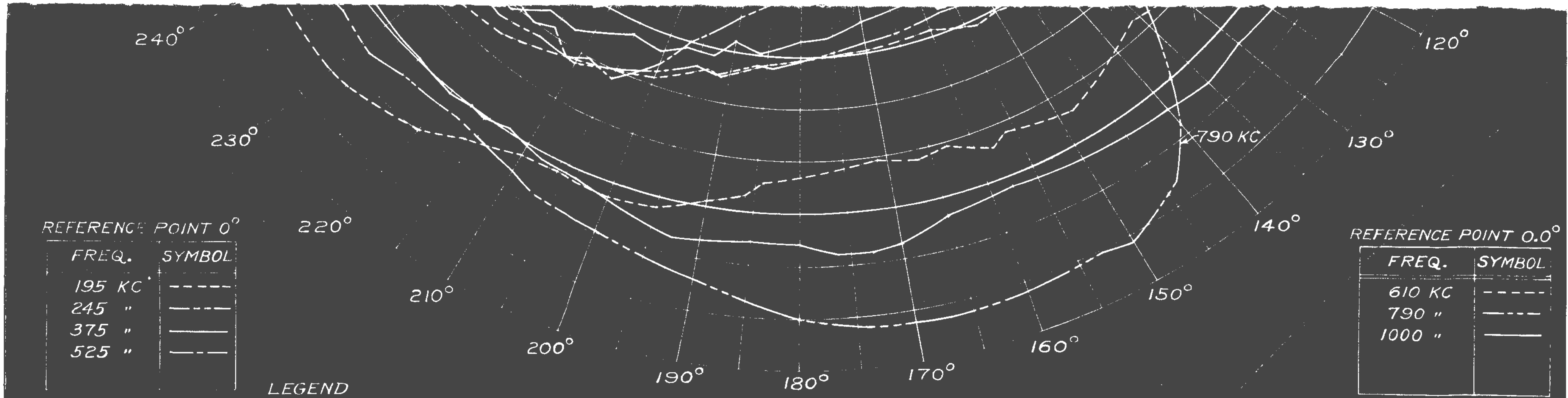
"F"= CORRECTOR WIRE LAID IN 1937

"G"= RADIO BEACON TOWER 100' HIGH, 200' FROM D.F.

"H"= CONTROL CABLE (700' LONG)

ANALYSIS
OF
U.S. NAVAL R.D.F.S.
DEVIATIONS
WINTER HARBOR, ME.
OCT. 1938 DATA





REFERENCE POINT 0°

FREQ.	SYMBOL
195 KC	- - - - -
245 "	—·—·—
375 "	———
525 "	— — —

REFERENCE POINT 0.0°

FREQ.	SYMBOL
610 KC	- - - - -
790 "	—·—·—
1000 "	———

LEGEND

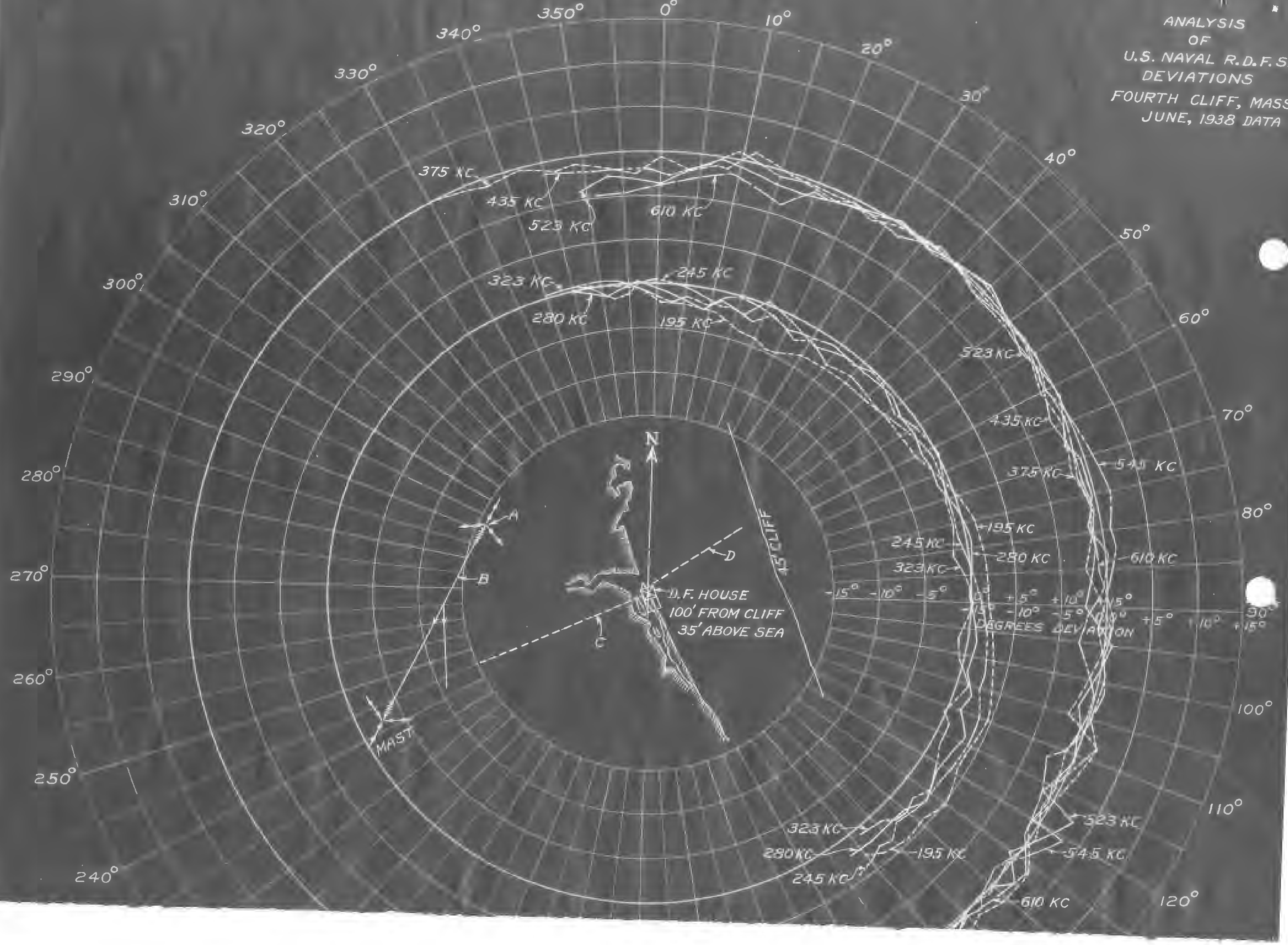
. TRUE BEARINGS OF STRUCTURES INDICATED

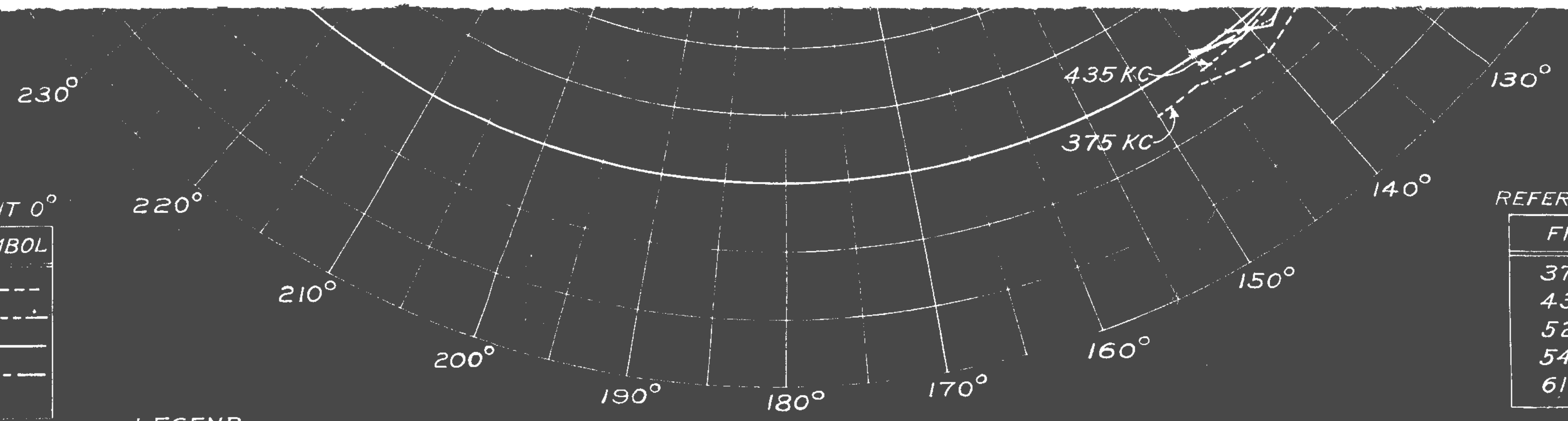
"A"- WATER PIPES BURIED 6'
"B"- CONTROL LINES BURIED 18"
"C"- STEEL TOWER 200' HIGH
"D"- BARRACKS
"E"- POWER HOUSE
"F"- POWER SERVICE BURIED 2'

NOTE:- D.F. HOUSE HALF MILE FROM SHORE, 120' ABOVE SEA LEVEL

✱ ORIENTATION ON ORIGINAL CHART APPEARS TO BE 329° BUT DATA GIVEN IS 339°

ANALYSIS
OF
U.S. NAVAL R.D.F.S.
DEVIATIONS
FOURTH CLIFF, MASS.
JUNE, 1938 DATA





REFERENCE POINT 0°

FREQ.	SYMBOL
195 KC	-----
245 "	—-·-·
280 "	——
323 "	—-—

REFERENCE POINT 0.0°

FREQ.	SYMBOL
375 KC	-----
435 "	—-·—
523 "	——
545 "	—--
610 "	— —

LEGEND

TRUE BEARINGS OF STRUCTURES INDICATED.

"A"-STEEL MAST 40' HIGH, 130' FROM D.F. HOUSE.

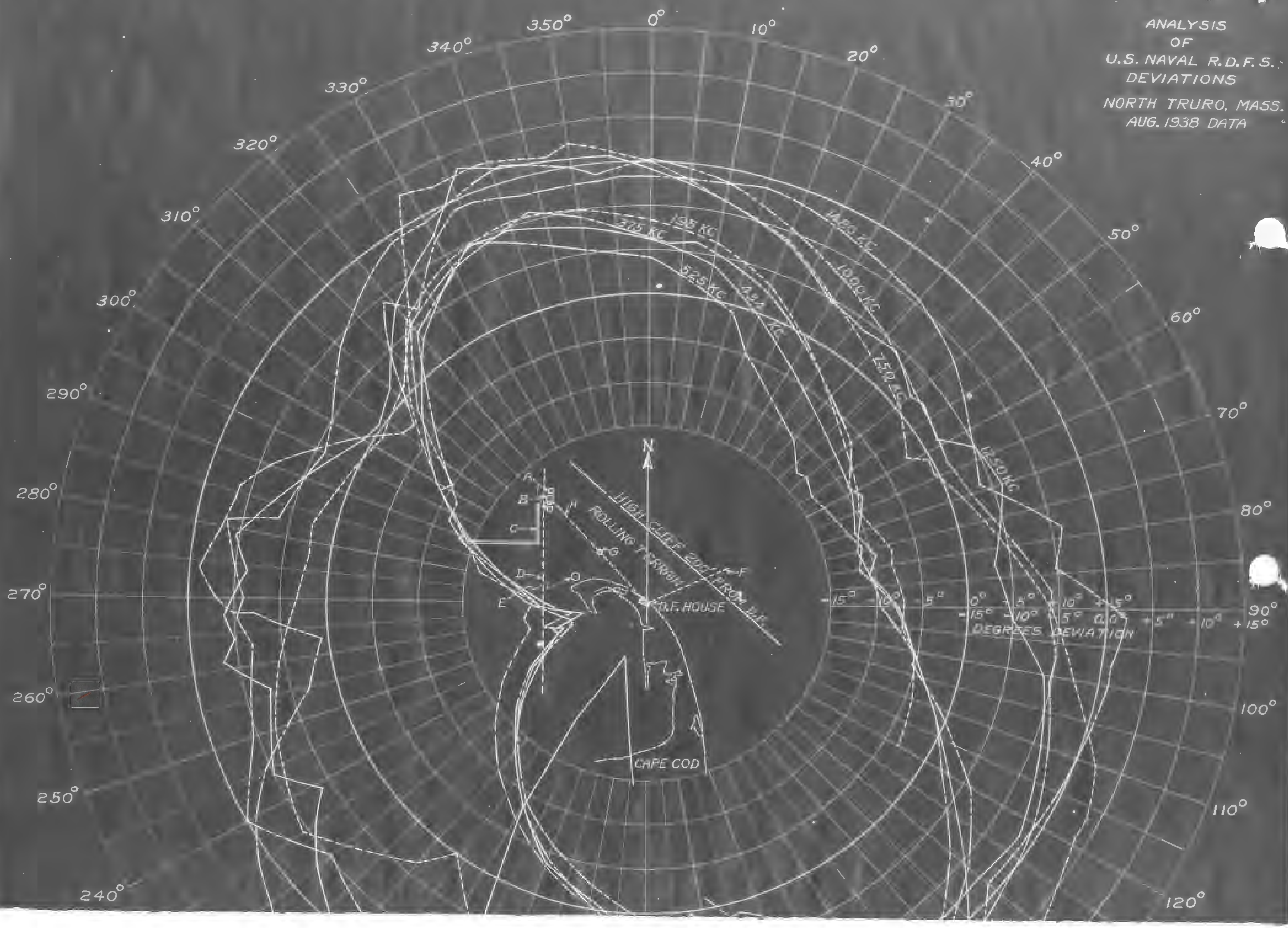
"B"-TRANSMITTING ANTENNA.

"C"-COMMUNICATION CABLES BURIED 12" IN GROUND, 158' LONG.

"D"-CORRECTOR WIRE (ORIENTATION ON ORIGINAL CHART APPEARS TO BE 44° BUT DATA GIVEN IS 56°)

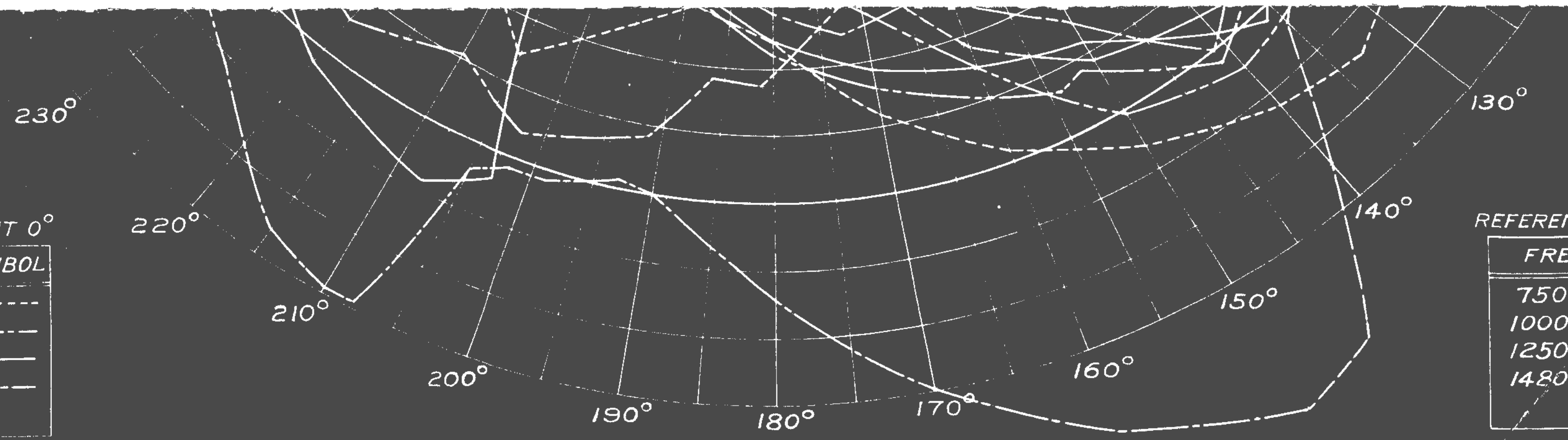
ANALYSIS
OF
U.S. NAVAL R.D.F.S.
DEVIATIONS

NORTH TRURO, MASS.
AUG. 1938 DATA



REFERENCE POINT 0°

FREQ.	SYMBOL
195 KC	------
375 "	—-·-—
434 "	———
525	—-·—



REFERENCE POINT 0.0°

FREQ.	SYMBOL
750 KC	------
1000 "	—---—
1250 "	———
1480 "	—-·—

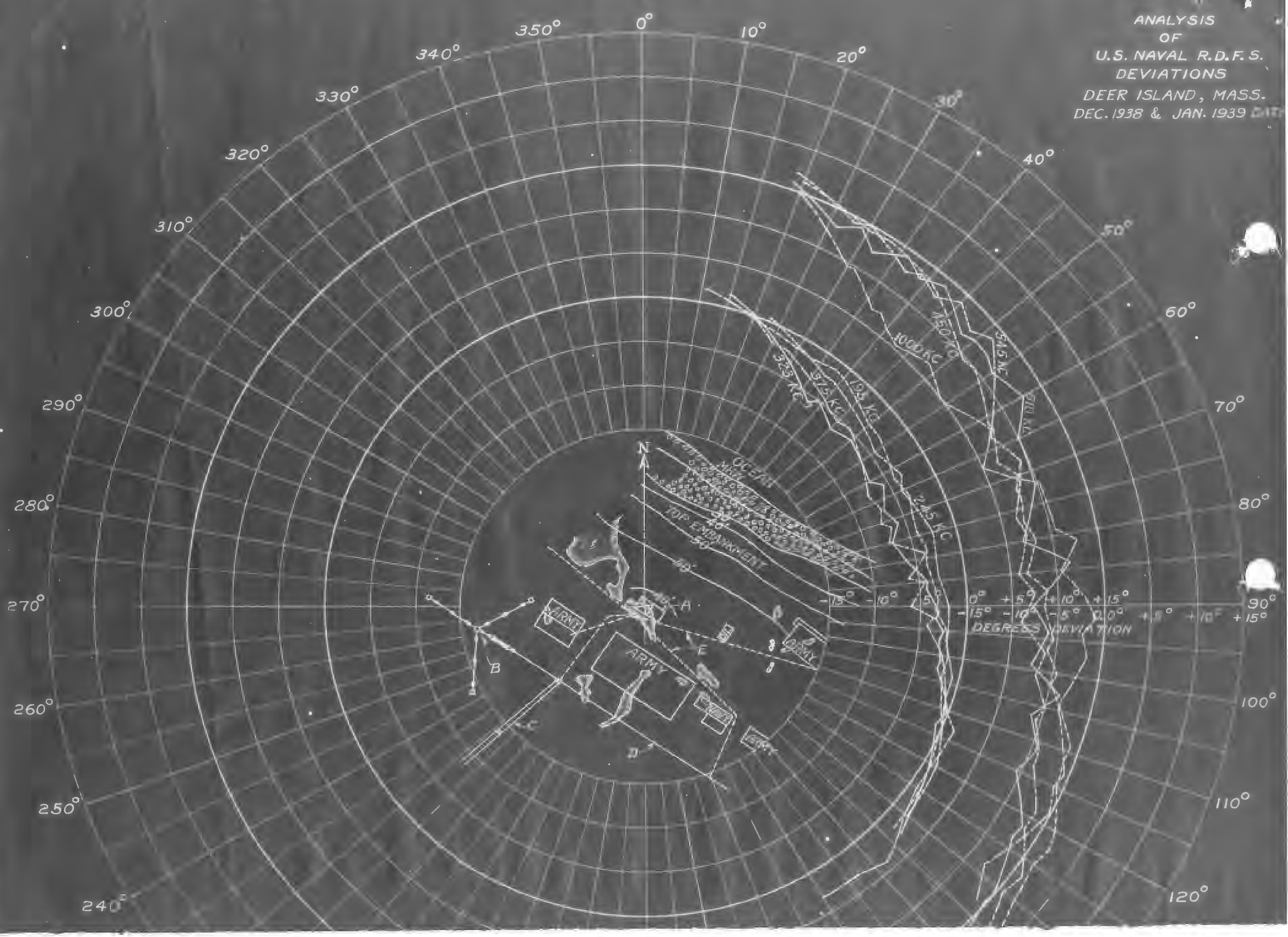
LEGEND:

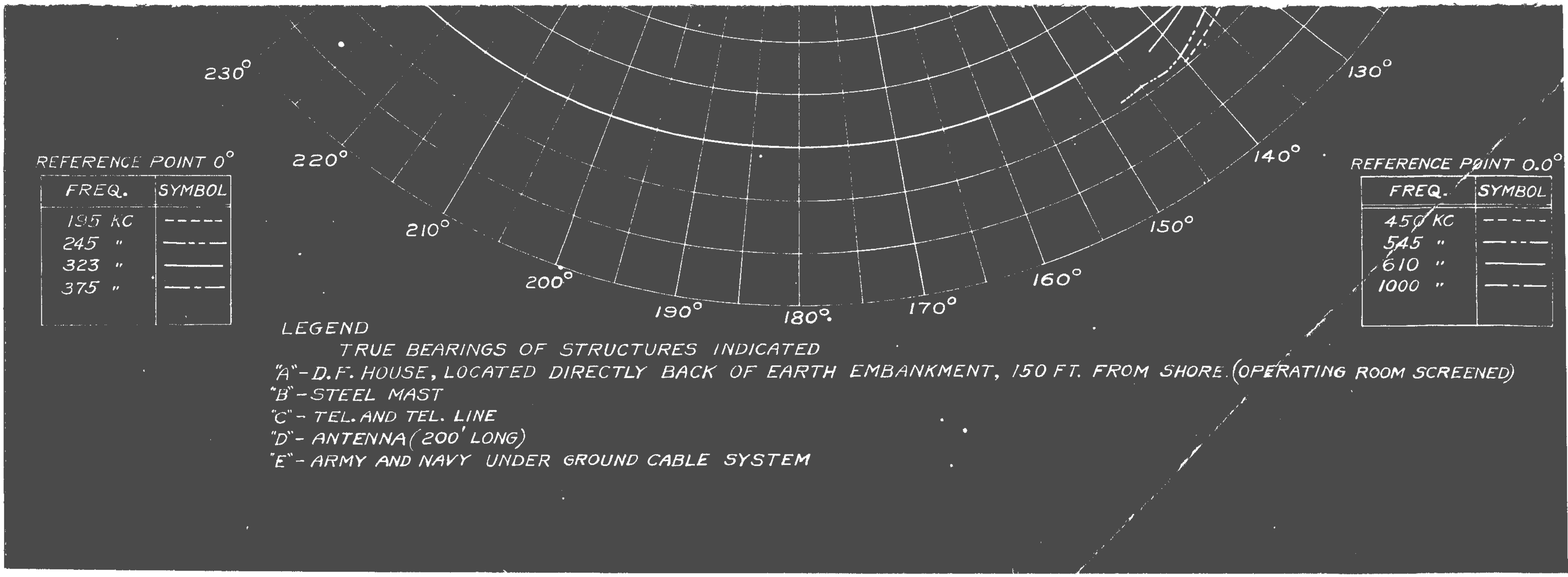
TRUE BEARING OF STRUCTURES INDICATED

"A" = STEEL TOWERS 100' HIGH, 200' ANTENNA
"B" = POWER HOUSE
"C" = OUTSIDE ELEC. POWER
"D" = BURIED COAST GUARD CABLE, BURIED IN GROUND ONE MILE LONG TIED IN TO NAVY D.F. HOUSE VIA TELEPHONE
"E" = STEEL & BRICK LT. HOUSE 200' FROM D.F.
"F" = CORRECTOR WIRE LAID IN 1937
"G" = RADIO BEACON TOWER 100' HIGH, 200' FROM D.F.
"H" = CONTROL CABLE (700' LONG)

ANALYSIS
OF
U.S. NAVAL R.D.F.S.
DEVIATIONS

DEER ISLAND, MASS.
DEC. 1938 & JAN. 1939





REFERENCE POINT 0°

FREQ.	SYMBOL
195 KC	- - - - -
245 "	—·—·—
323 "	———
375 "	—··—

REFERENCE POINT 0.0°

FREQ.	SYMBOL
450 KC	- - - - -
545 "	—·—·—
610 "	———
1000 "	—··—

LEGEND

TRUE BEARINGS OF STRUCTURES INDICATED

"A" - D.F. HOUSE, LOCATED DIRECTLY BACK OF EARTH EMBANKMENT, 150 FT. FROM SHORE. (OPERATING ROOM SCREENED)
"B" - STEEL MAST
"C" - TEL. AND TEL. LINE
"D" - ANTENNA (200' LONG)
"E" - ARMY AND NAVY UNDER GROUND CABLE SYSTEM