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NRL REPORT R-3410

BROAD-BAND ANTENNA CONSIDERATIONS FOR ONE TYPE OF GUPPY SUBMARINE (SS350)

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BROAD-BAND ANTENNA CONSIDERATIONS FOR ONE TYPE OF GUPPY SUBMARINE (SS350)

A. W. Walters

March 24, 1949

Approved by:

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ABSTRACT

Using model techniques, an investigation has been conducted on the broad-band aspects of HF antennas for submarines of the SS350 Guppy type. This investigation has been restricted to the use of modified sleeve antennas in which the antenna is partially integrated into the ship's superstructure. Primarily the problem has resolved itself into one of selecting the correct type of whip antenna to work with the conning tower as a sleeve.

The experimental data presented indicate the general range of whip dimensions required to obtain optimum broad-band characteristics and include impedance-matching networks for matching the antenna to a 50-ohm transmission line. For one antenna design, the standing wave ratio was better than 0.3 for the frequency range of 5.4 to 14.3 Mc. Patterns in a vertical plane are shown for the transformed antenna.

PROBLEM STATUS

This is a final report on one phase of this problem. Additional work is being conducted on related phases.

AUTHORIZATION

NRL Problem R09-01R

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BROAD-BAND ANTENNA CONSIDERATIONS FOR ONE TYPE OF GUPPY SUBMARINE (SS350)

INTRODUCTION

Sleeve-antenna techniques have been applied to the Guppy-type submarine (SS350) for the purpose of obtaining broad-band antenna designs in the high-frequency band. The superstructure of the submarine at periscope location (hereafter termed "conning tower") is well adapted for use as part of a sleeve antenna. This type of design has many advantages over conventional antennas since a very effective broad-band antenna can be obtained with practically no increase in top-side weight and the antenna patterns are, in general, better in both the vertical and horizontal planes. A sleeve antenna has inherently good pattern characteristics in the vertical plane and should have a better pattern in the horizontal plane because the structure which normally distorts the pattern is an integral part of the antenna.

References (1) and (2)* have indicated that reasonably good broad-band modified sleeve antennas could be constructed using a relatively large, short, sleeve section in conjunction with a small diameter, long, top radiating section. That is, ratios of sleeve diameter to radiator diameter of the order of 16 or higher when used in conjunction with ratios of radiator length to sleeve length from 2 to 1.1, give reasonable broad-band possibilities. The results of References (1) and (2) apply only to cylindrical shapes and therefore are not directly applicable to the submarine problem.

The conning-tower structure of this submarine gave reasonably good possibilities as a sleeve section of a sleeve antenna with an insulated metal cylinder on top of this structure acting as the upper radiating section. This arrangement in general is true for all Guppy submarines in that the top radiating section consists of a whip antenna which is in reality a part of a sleeve antenna, the ultimate design of the whip being governed by optimum modified sleeve antenna characteristics.

In addition to the whip antenna, numerous other structures are present at the conning tower. These include radar antennas and periscopes which are adjustable in height. It is probable that some of these structures will affect the patterns and the impedance characteristic of the modified sleeve antenna, but it is unlikely that serious effects will result unless some resonance condition is present. This particular problem will be investigated, but in the present investigation the existance of these structures has been neglected.

THE OPTIMUM WHIP

With the general problem thus defined, it is now necessary to determine the optimum whip to simulate the top radiating section of the modified sleeve antenna. The maximum

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* References will be found at the end of the report on page 13.

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length of a self-supporting whip available for Navy use is the 35-foot whip having a maximum diameter of 3-1/4 inches at the base. This was considered as the largest practical length and diameter to be examined. If the resulting modified sleeve antenna is assumed to have a 1/4-wave resonance frequency approximately equal to that of a simple monopole, then, for a total physical height of the sleeve plus radiator of 60 feet, the corresponding frequency is 4.0 Mc. In general, it would be expected that, due to the extreme broadness of the sleeve structure below the bridge level, the effective physical height of this modified sleeve antenna would be somewhat less than that of a simple vertical; and the lowest frequency for broad-band operation would be somewhat higher than the calculated 1/4-wave frequency. The expected frequency range of operation for this type of antenna would be about 2.5 to 1 with a standing wave ratio of better than 0.3. The minimum length of the top radiating section, judging by the results obtained in Reference (1), would be the condition when the radiator and sleeve were approximately equal in length, and the minimum frequency for such a sleeve antenna would be about 6.0 Mc. Thus, the possibility exists for broad-band antennas between approximately 4 and 10 Mc and between 6 and 15 Mc.

MEASUREMENT DETAILS

Methods of impedance measurement used for these modified sleeve antennas are described in detail in Reference (1). The physical arrangement for making measurements and the details of construction of the model antennas are shown in Figures 1 and 2. Briefly, the model antenna was placed on the ground screen as shown in Figure 1. At each measuring frequency, the position of the current minimum and the ratio of the current maximum to current minimum were recorded. These quantities, together with the position of the current minimum when the line is shorted at the antenna terminals, and with the impedance of the measuring line, determine the antenna impedance.

The impedance-measuring system used for obtaining these experimental data is essentially that in common usage with the probe-slotted line technique. It differs only in that the ground plane has been mounted on the side of a building with the center at a second-floor level. This arrangement provided sufficient clearance from surrounding objects and permits the use of an unusually short section of dielectric feed cable between the antenna and the end of the slotted line. Moreover, this method of feed provides numerous advantages over a system employing a long dielectric or air feed line.

Detailed methods of pattern measurement are given in Reference (2). Figure 3 is a sketch of the measuring system showing the receiving and transmitting antenna. At a given frequency the transmitting antenna was placed in the system, and radio frequency power was supplied by a model LAF signal generator. Field strength at the receiving antenna was maintained constant at all angles in a vertical plane by adjusting the power input to the transmitting antenna. The angle in the vertical plane was varied in five-degree steps. Thus, the attenuator readings of the signal generator indicated the values of relative field strength at the receiver terminals. These values of field strength have been normalized to some extent and plotted. Limitations of this pattern measuring system are similar to those described in Reference (2). The errors in the measurements are, in general, less than ± 2 db. This excludes angles in the order of 90 ± 5 degrees, where in some cases the true depth of the nulls are probably much greater than measurements indicate.

It was possible to utilize the same impedance- and pattern-measuring systems as described in References (1) and (2) by using scale-model modified sleeve antennas. Since the systems described in References (1) and (2) operate most satisfactorily in the frequency range 90 to 390 Mc, and since the generally expected range of operation of the

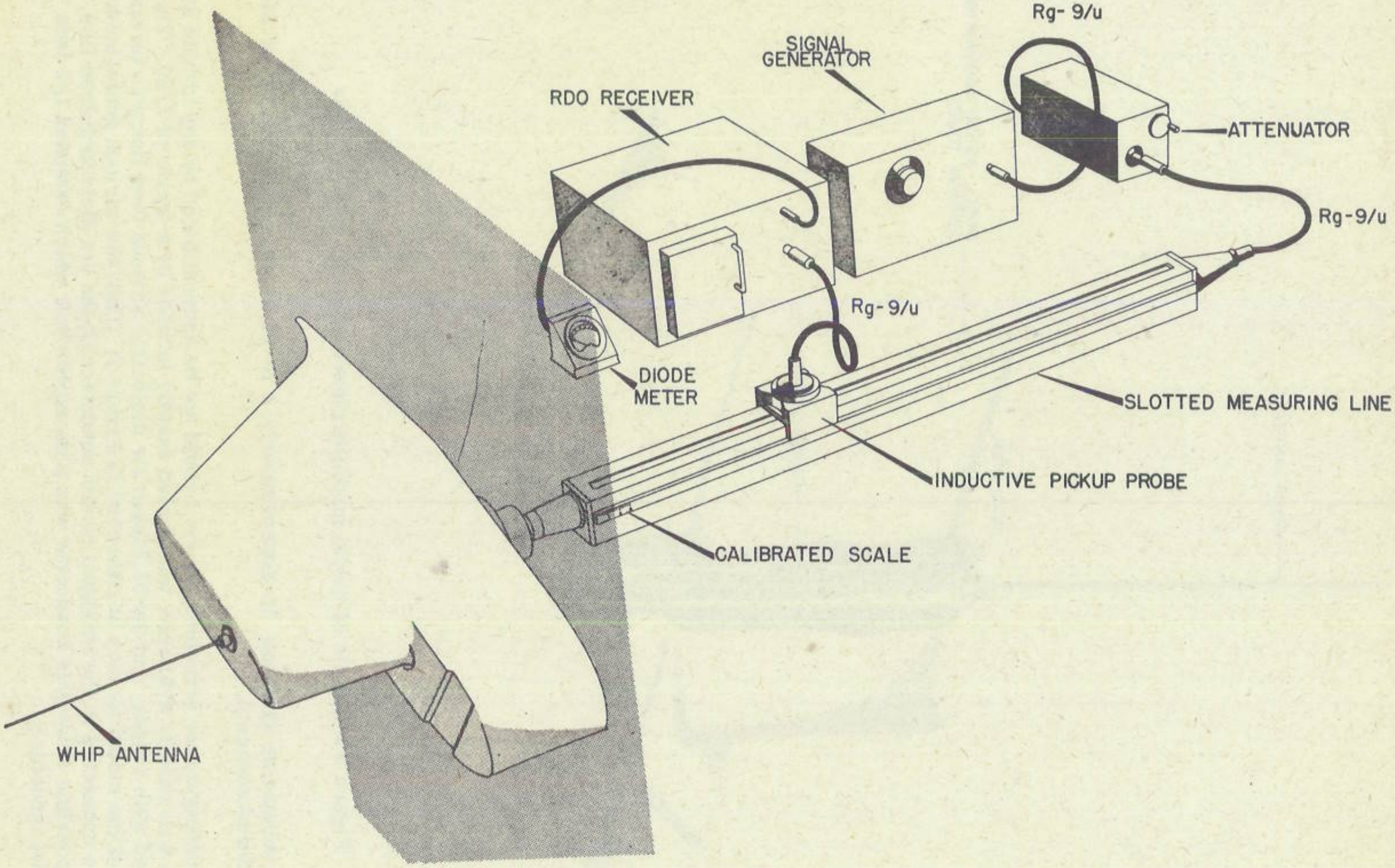

Figure 1 - Arrangement for making impedance measurements

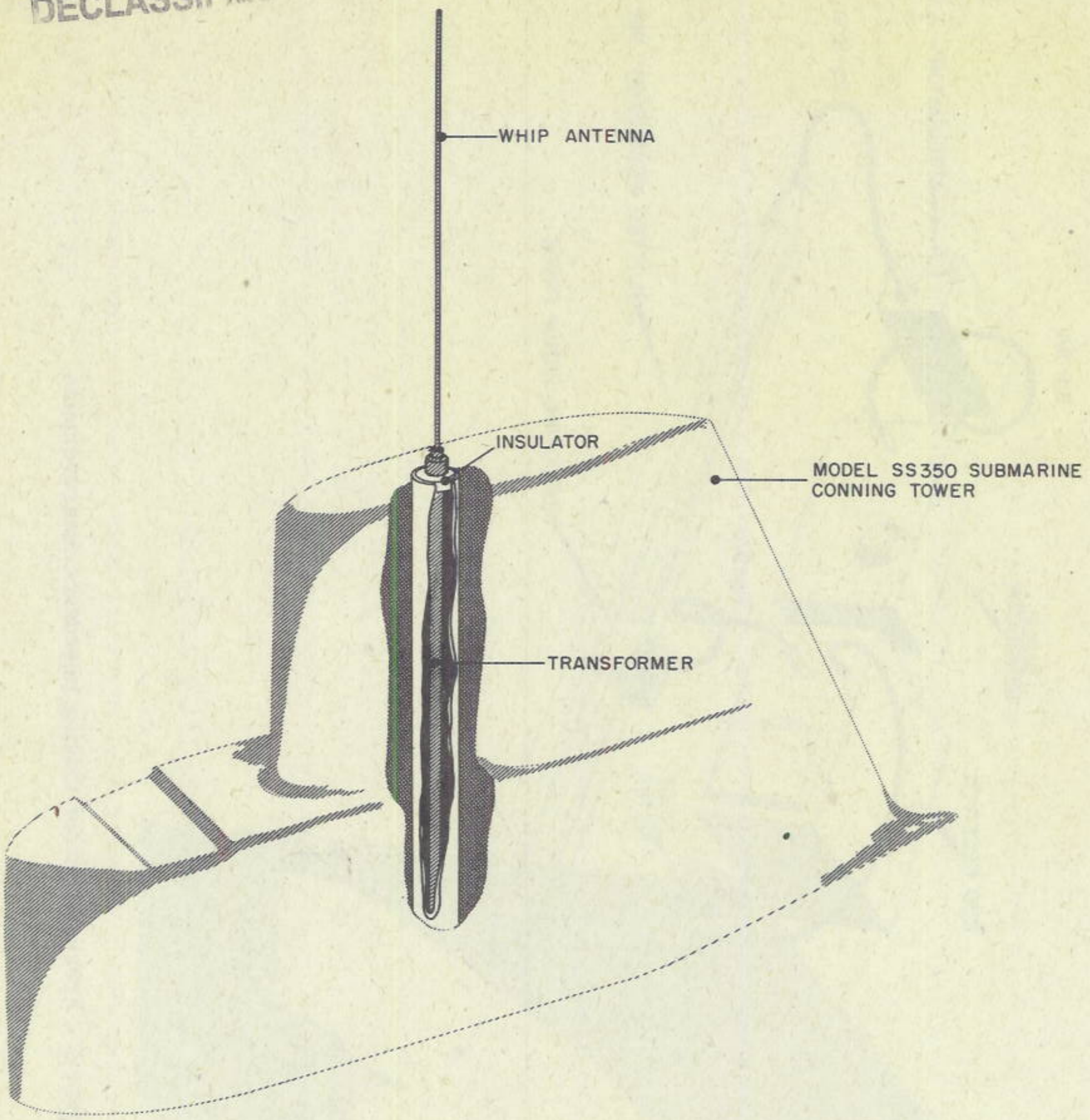

Figure 2 - Details of model modified sleeve antenna, cutaway view

full-scale submarine antennas is approximately 4 to 15 Mc a scaling factor of 24 was considered adequate.

The conning-tower structure, since it could not be approximated by any simple structure which was readily available, was scaled exactly in wood by a factor of 1/24. This was sprayed with copper, and the 51.5-ohm air dielectric antenna feed line was terminated at the top of the model as may be observed in Figure 2. Then the various scale-model whips were connected to the extended center conductor of the air dielectric feed line. This was possible since this conductor was a threaded shaft which extended 1/2 inch above model structure.

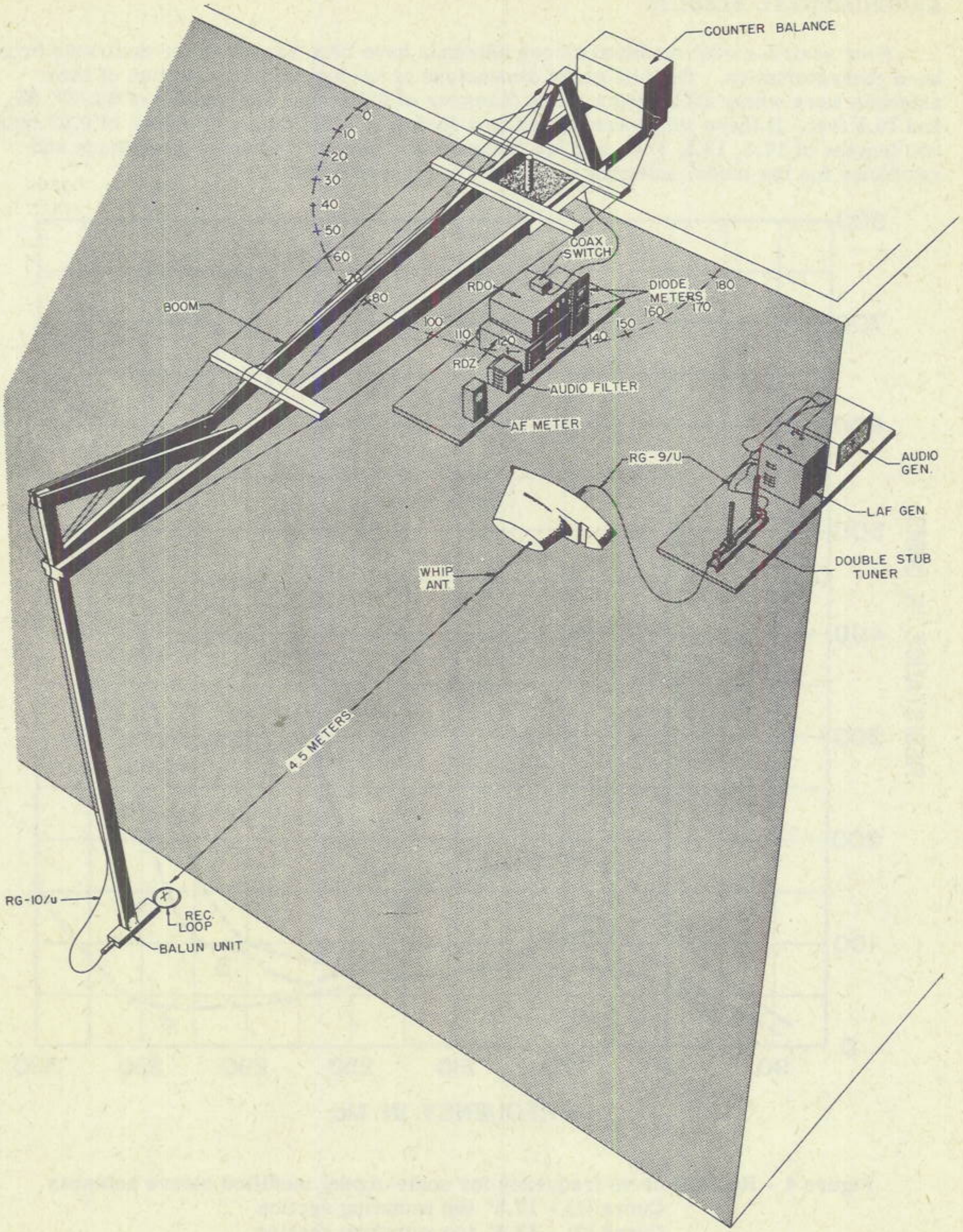

Figure 3 - Arrangement for making pattern measurements

EXPERIMENTAL RESULTS

Four scaled-model modified sleeve antennas have been examined for desirable broadband characteristics. The full-scale dimensions of the top radiating section of these antennas were whips all having a mean diameter of 2.2 inches and lengths of 35, 27, 24, and 19.5 feet. If these whips are scaled by a factor of 1/24, then a diameter of 0.09 inch and lengths of 17.5, 13.5, 12.0, and 9,8 inches would result. Values of resistance and reactance for the model antennas are shown in Figures 4 and 5.

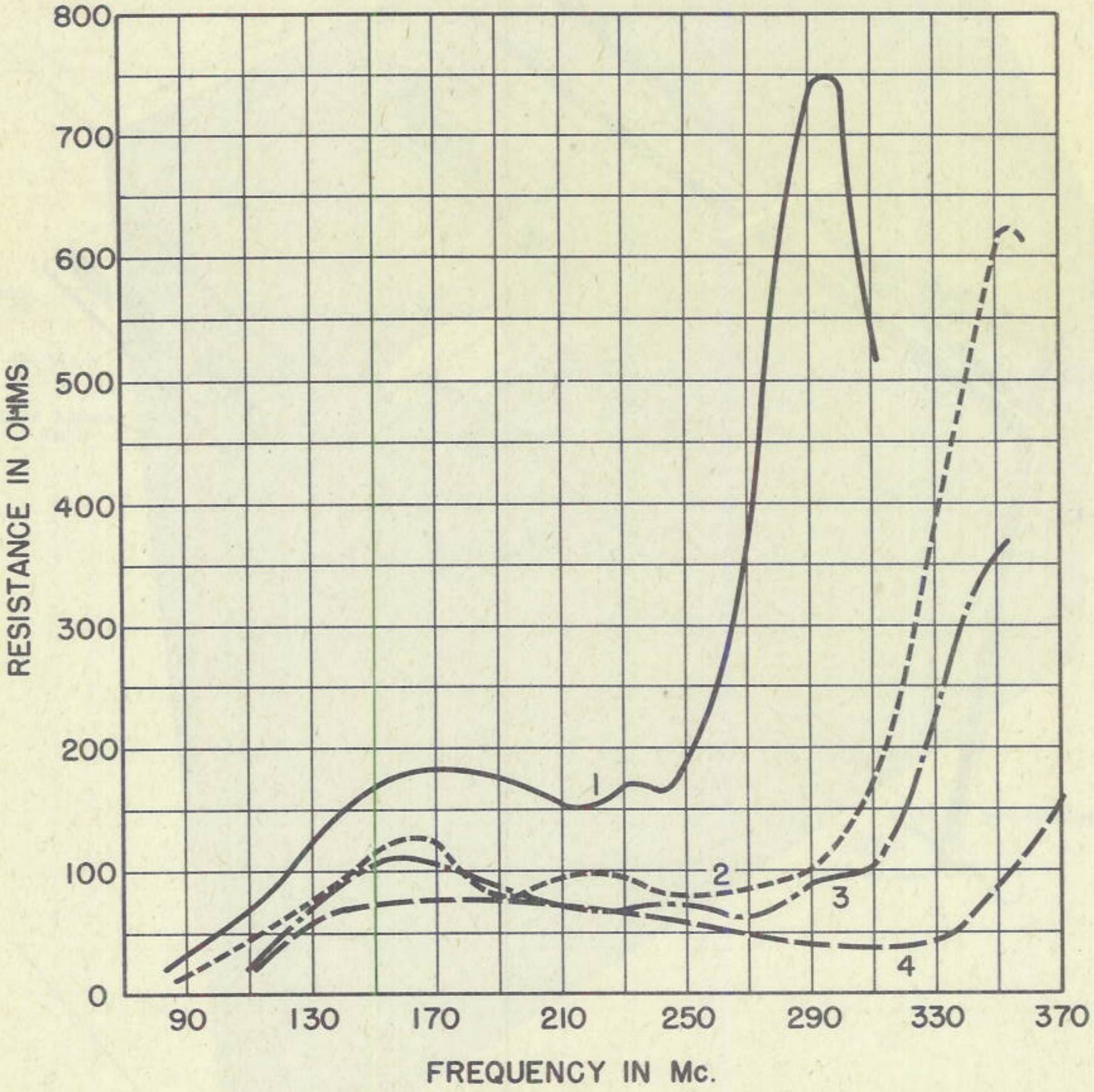

Figure 4 - Resistance vs frequency for scale-model modified sleeve antennas
Curve (1) - 17.5″ top radiating section
Curve (2) - 13.3″ top radiating section
Curve (3) - 12.0″ top radiating section
Curve (4) - 9.8″ top radiating section

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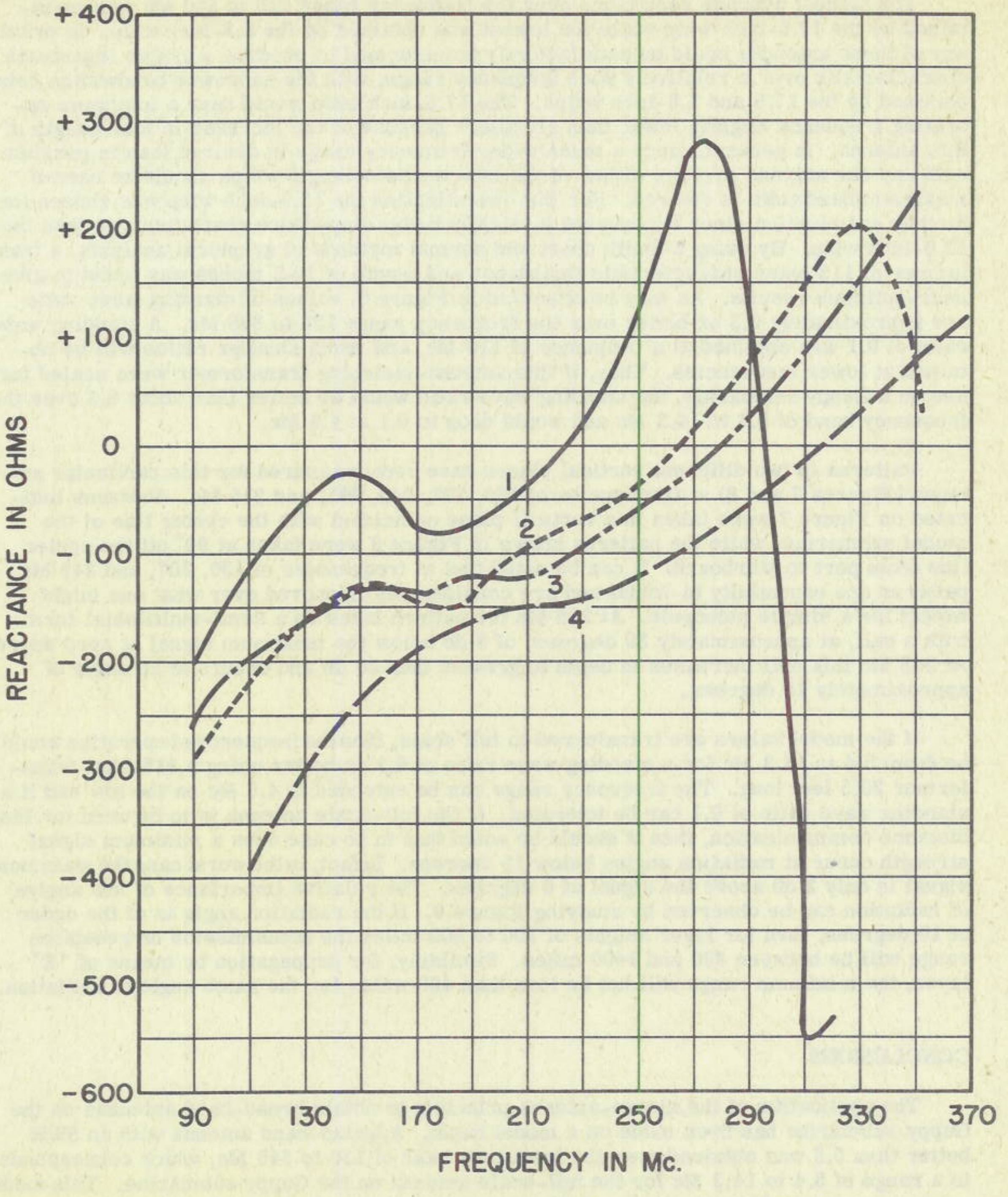

Figure 5 - Reactance vs frequency for scale-model modified sleeve antennas

Curve (1) - 17.5″ top radiating section
Curve (2) - 13.3″ top radiating section
Curve (3) - 12.0″ top radiating section
Curve (4) - 9.8″ top radiating section

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The highest average resistance over the frequency range 110 to 310 Mc was maintained by the 17.5-inch whip while the lowest was obtained by the 9.8-inch whip. In practice any of these antennas could be satisfactorily transformed to produce a usable impedance characteristic over a relatively wide frequency range, with the narrower bandwidths being obtained by the 17.5 and 9.8-inch whips. The 17.5-inch whip would have a minimum operating frequency slightly lower than all others because of the increase in total length of this antenna. In general, since a much wider frequency range is desired than is possible with any one antenna system, either of the intermediate-length whips should be used if maximum bandwidth is desired. For this investigation the 13.3-inch whip was chosen for further examination since it posseses a slightly better impedance characteristic than the 12.0-inch whip. By using a Smith chart and normal methods of graphical analysis, a transformer of 115 ohms characteristic impedance and length of 10.3 inches was found to give near-optimum results. As may be observed in Figure 6, values of standing wave ratio are approximately 0.3 or better over the frequency range 130 to 345 Mc. A standing wave ratio of 0.1 was obtained at a frequency of 110 Mc, and much smaller ratios will be obtained at lower frequencies. Thus, if this antenna-matching transformer were scaled for use on a Guppy submarine, the standing wave ratio would be better than about 0.3 over the frequency band of 5.4 to 14.3 Mc and would drop to 0.1 at 4.5 Mc.

Patterns in two different vertical planes have been measured for this particular antenna (Figures 7 and 8) at frequencies of 130, 207, 243, 295, and 345 Mc. Patterns indicated on Figure 7 were taken in a vertical plane coincident with the center line of the model submarine, while the patterns shown in Figure 8 were taken at 90° off the center line from port to starboard. It can be noted that at frequencies of 130, 207, and 243 Mc patterns are essentially bi-lobial and are considerably improved over what one might expect for a simple monopole. At 295 Mc the pattern takes on a semi-multilobial form with a null, at approximately 30 degrees, of 9 db below the maximum signal at zero degrees. At 345 Mc this null increases in depth to greater than 20 db and occurs at an angle of approximately 15 degrees.

If the model values are transferred to full scale, then the frequency of operation would be from 5.4 to 14.3 Mc for a standing wave ratio of 0.3 or better using a 115-ohm transformer 20.5 feet long. The frequency range can be extended to 4.5 Mc on the low end if a standing wave ratio of 0.1 can be tolerated. If the full-scale antenna is to be used for long-distance communication, then it should be noted that in no case does a minimum signal strength occur at radiation angles below 10 degrees. In fact, in the worst case the maximum signal is only 2 db above the signal at 0 degrees. The relative importance of low angles of radiation can be observed by studying Figure 9. If the radiation angle is of the order of 10 degrees, then for layer heights of 100 to 200 miles the transmission or reception range will be between 800 and 1400 miles. Similarly, for propagation by means of "E" layer, the minimum range will not be less than 400 miles for the same angle of radiation.

CONCLUSIONS

The application of the sleeve-antenna principle to obtain broad-band antennas on the Guppy submarine has been made on a model basis. A broad-band antenna with an SWR better than 0.3 was obtained over the frequency band of 130 to 345 Mc, which corresponds to a range of 5.4 to 14.3 Mc for the full-scale antenna on the Guppy submarine. This model antenna was a single-whip antenna 0.09 inch in diameter and 13.3 inches long mounted on top of the conning tower. The full-scale whip antenna would be 2.2 inches in diameter and 27 feet long. The use of this broad-band antenna with a HF Common Antenna Working unit now under development will provide adequate and efficient antenna facilities for transmission and reception over the frequency band of 5.4 to 14.3 Mc. A study is now in

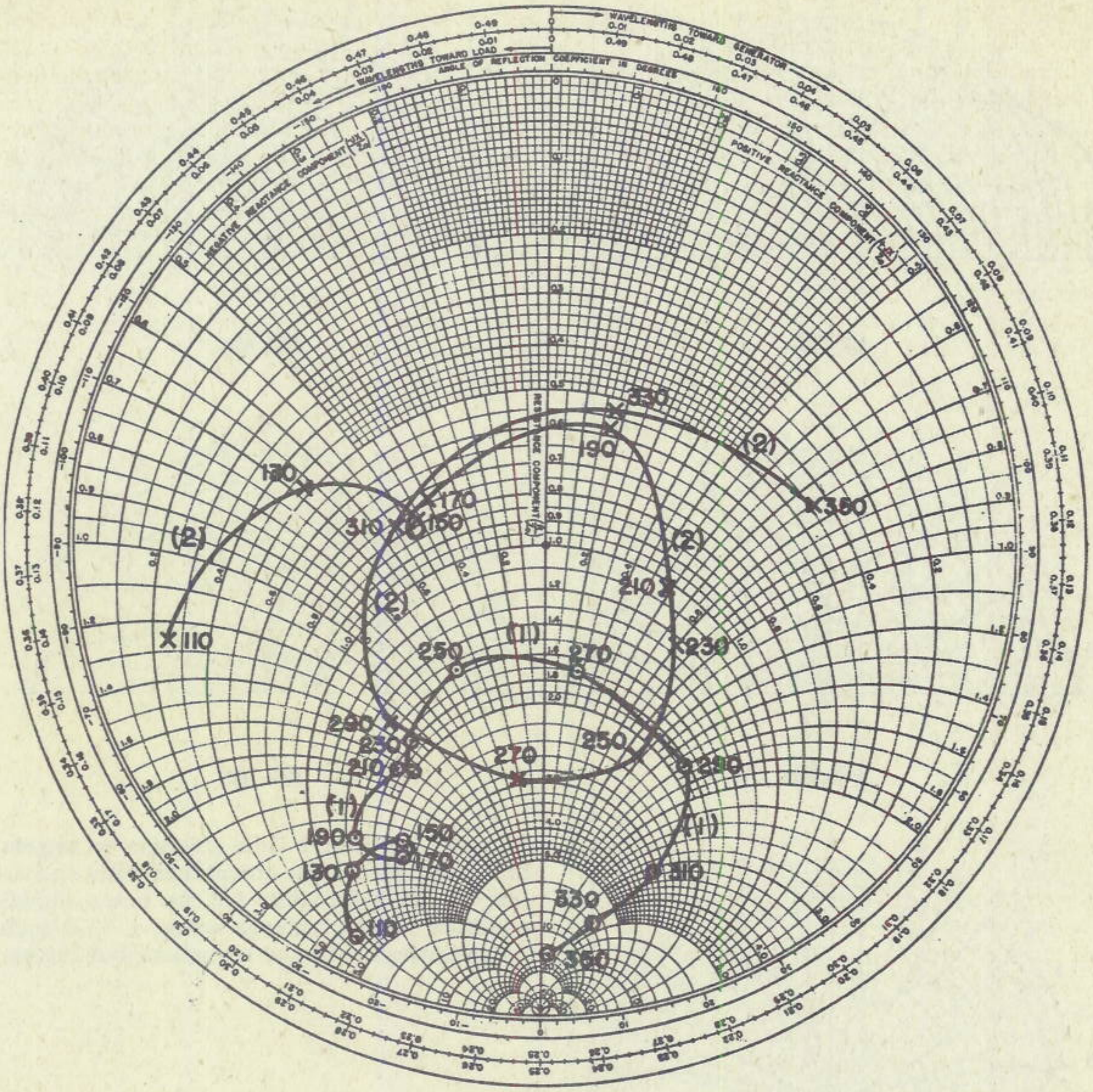

Figure 6 - Impedance characteristic for scale-model modified sleeve antennas with 13.3-inch top radiating section
Curve (1) - Impedance characteristic
Curve (2) - Transformed impedance characteristic

progress to determine if it is possible to use this same antenna simultaneously for reception on frequencies below 5.4 Mc.

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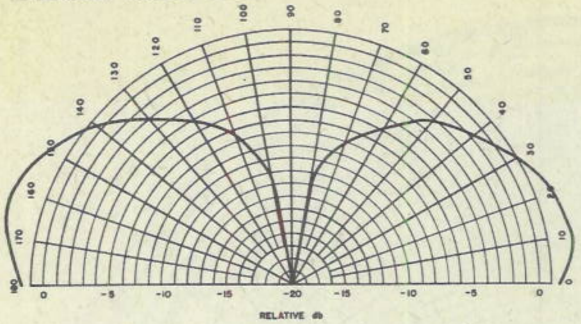
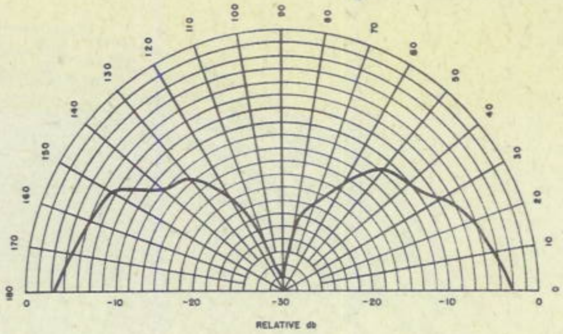
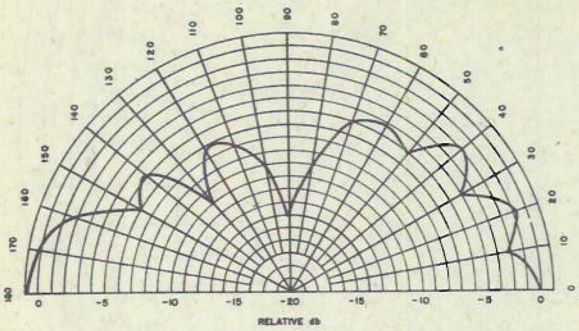


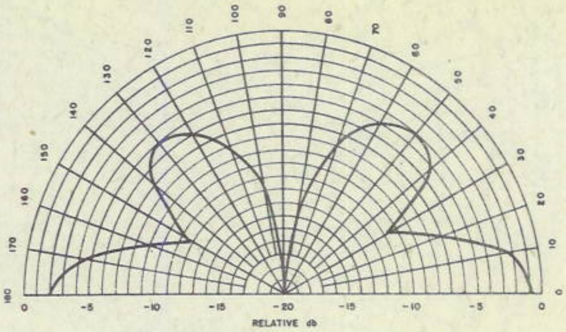
130 Mc



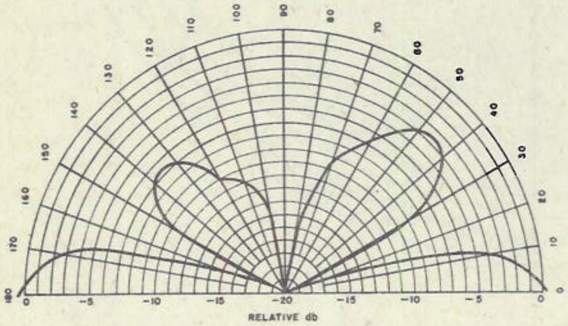
207 Mc



243 Mc

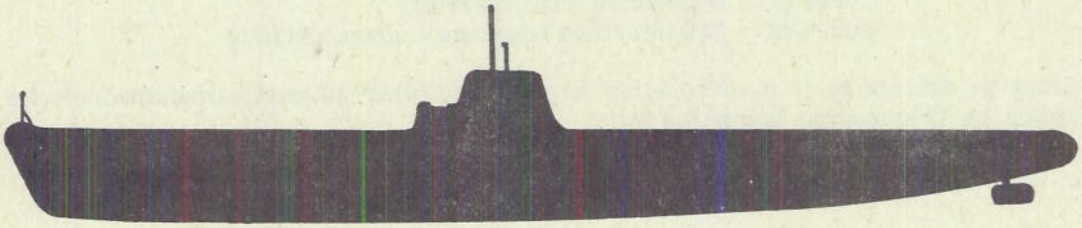


295 Mc



345 Mc

Figure 7 - Relative field strength vs angles in a vertical plane coincident with center line of the submarine for the scale-model modified sleeve antenna using a 13.3-inch top radiating section at a frequency of 130 Mc



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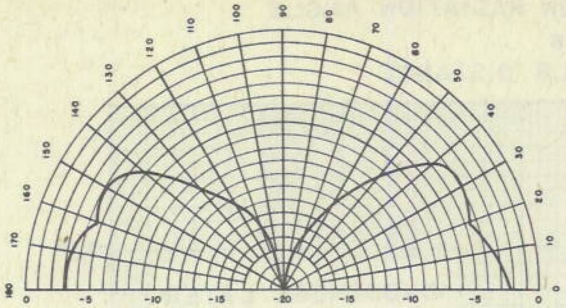
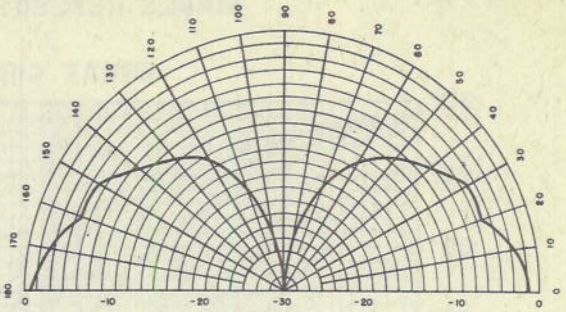
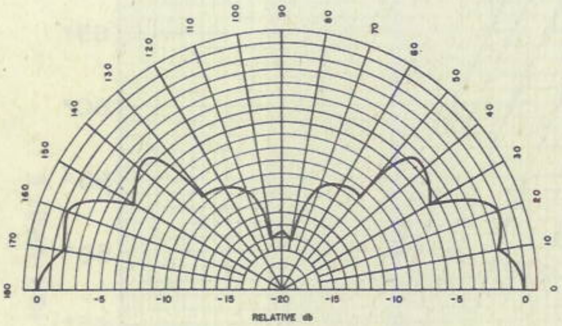


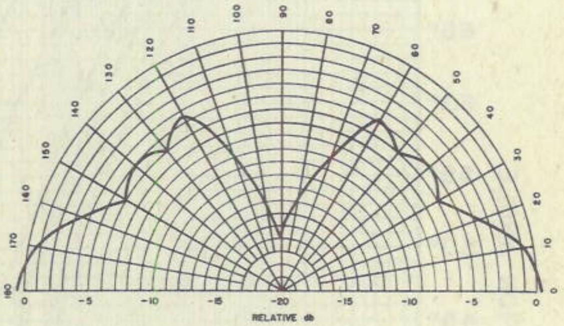
130 Mc



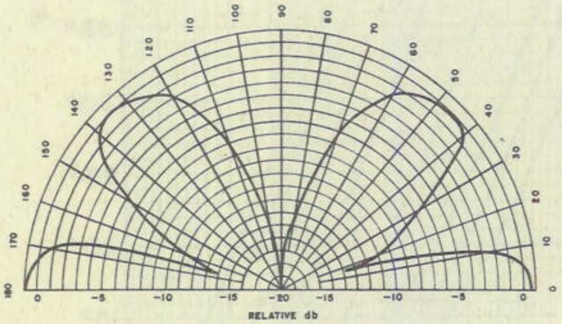
207 Mc



243 Mc



295 Mc



345 Mc

Figure 8 - Relative field strength vs angles in a vertical plane perpendicular to the center line of the submarine and in the plane of the top radiating section of the antenna for the scale-model modified sleeve antenna using a 13.3-inch top radiating section at a frequency of 130 Mc

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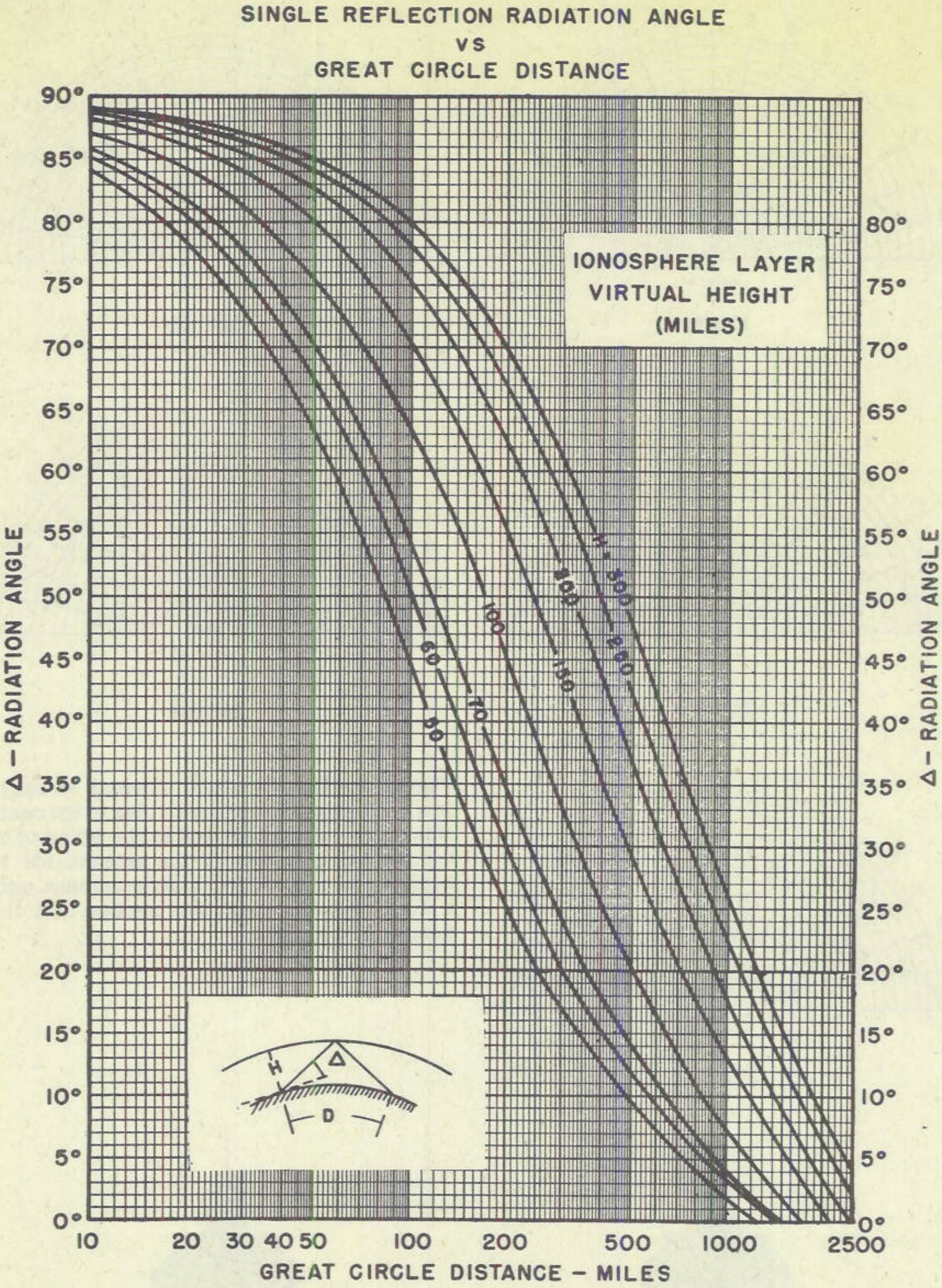

Figure 9 - Single reflection radiation angle vs great-circle distance

REFERENCES

1. Walters, A. W. and Huffman, L. C., "Experimentally Determined Characteristics of Cylindrical Sleeve Antennas," NRL Report R-3354, September 13, 1948 (Restricted)
2. Walters, A. W. and Huffman, L. C., "Vertical Pattern Measurements of Cylindrical Sleeve Antennas," NRL Report R-3411, February 7, 1949 (Restricted)
3. 9463 TSU, Signal Corps., Radio Propagation Unit, Holabird Signal Depot, Baltimore, Md., Technical Report No. 2, July 1947