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A SHIPBOARD VHF ANTENNA FOR A SONOBUOY SYSTEM

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ABSTRACT

A VHF antenna for installation on the foremast of a destroyer escort has been designed for the frequency band 156 to 173 mc/s. The antenna consists of two co-phased dipole arrays; one array is mounted on the forward and after sides of the foremast, and the second array which is separated vertically by 36 inches is mounted on the port and starboard sides of the foremast. The azimuthal pattern variation within the Jezebel band, 162 to 173 mc/s, is less than 5 db. The VSWR over the extended frequency band is better than 1.7 to 1.

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A SHIPBOARD VHF ANTENNA FOR A SONOBUOY SYSTEM

- J. Y. Wong -

INTRODUCTION

As a further step towards fulfilling its role as an anti-submarine fleet, the Royal Canadian Navy is planning to install a Jezebel (sonobuoy-to-ship) system on all its destroyer escorts. The proposed system which operates in the frequency band 162 to 173 mc/s will use existing airborne Jezebel equipment. The terminal equipment which comprises basically the AN/ARR-22 receiver requires the use of two separate receiving antennas. As a supplementary requirement it is planned to operate a 156 to 162 mc/s FM transceiver on the same antenna. A block diagram of the combined communication system is shown in Fig. 1. Our problem was to design an antenna system to operate from 156 to 173 mc/s for a shipboard installation.

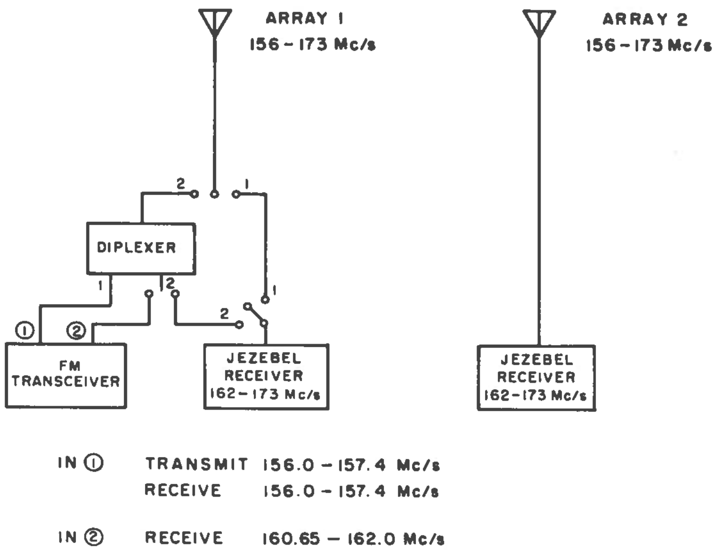

Fig. 1 Block diagram of combined communication system

In order to achieve maximum range between sonobuoy and ship the receiving antenna should be elevated as high as possible above the ship. At the frequencies under consideration Bullington [1] has shown that for a vertically polarized antenna over sea water the critical or minimum antenna height is of the order of 25 feet. This means that for an antenna elevated less than the minimum height, the received signal, and hence the range, is not affected appreciably by changes in height. On the other hand, for antenna heights greater than 25 feet, there is a substantial improvement in range and the received signal increases by a factor of 6 db each time the height is doubled.

These considerations dictate that the receiving antenna should be located at the highest point of the ship's superstructure, namely, the top of the foremast. However, other staff requirements have precluded the use of this optimum site and the antenna was therefore located just below the top of the foremast.

THEORETICAL CONSIDERATIONS

For simplicity of design and ease of construction, it was decided to use conventional dipole elements in the antenna array. Prior to any experimental measurements, a series of radiation pattern calculations were carried out in an effort to obtain some idea of the pattern distortion caused by the foremast and to arrive at an optimum antenna configuration — omnidirectional patterns were required. Using Carter's method [2, 3] for calculating the pattern of an antenna near a conducting cylinder, the following antenna configurations were considered:

i) single dipole

ii) two co-phased dipole array

iii) three co-phased dipole array

iv) three-dipole array in phase rotation

v) four co-phased dipole array.

As a result of the calculations, the two co-phased dipole array looked the most promising and was selected for further study. Fig. 2 shows the effect of dipole-to-cylinder spacing on the radiation pattern for this case. The patterns were calculated for 4 different spacings using a cylinder diameter of 14 inches at a frequency of 168 mc/s. It is seen that the pattern circularity becomes degraded as the dipole-to-cylinder spacing is increased.

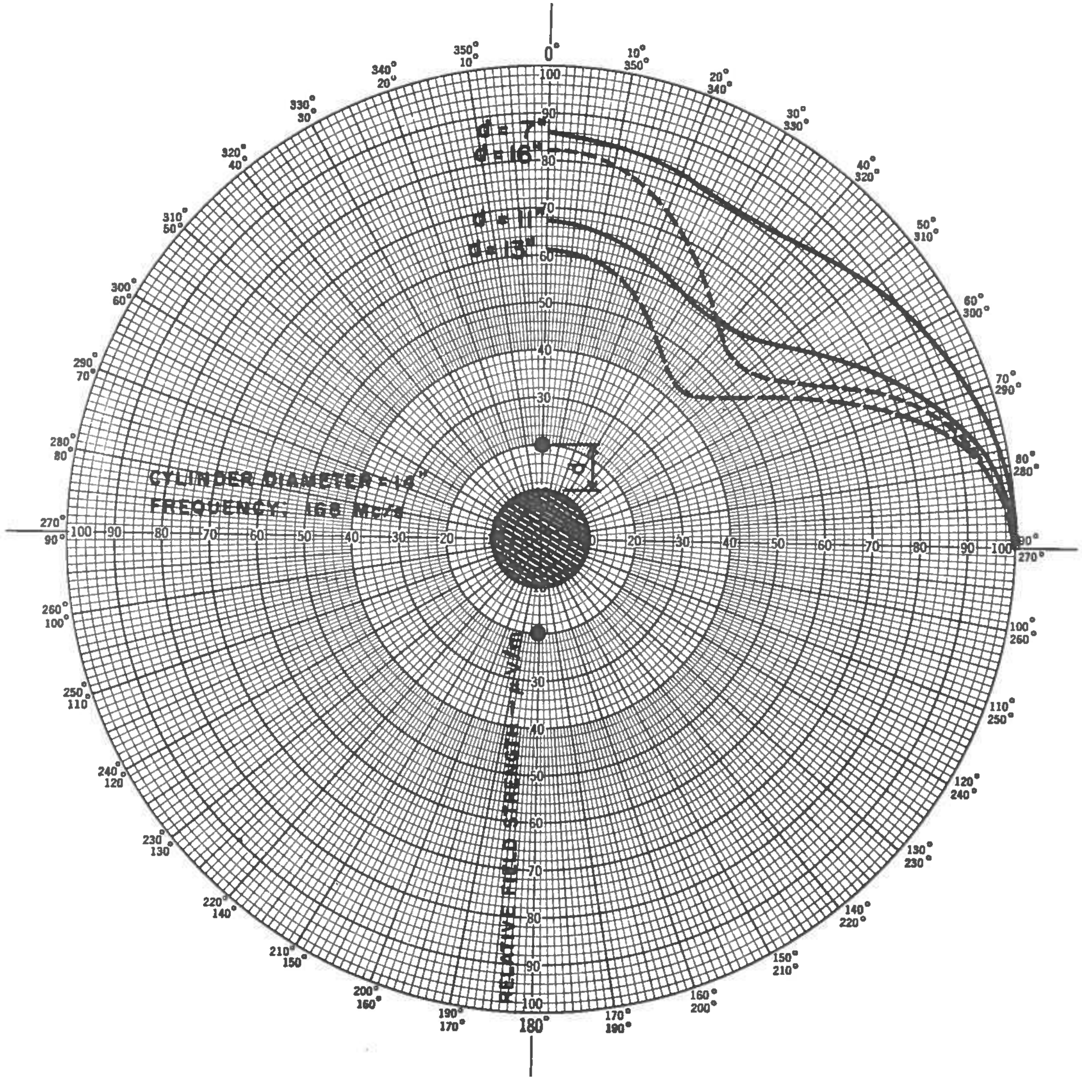

Fig. 2 Calculated radiation patterns of two co-phased dipoles around cylinder

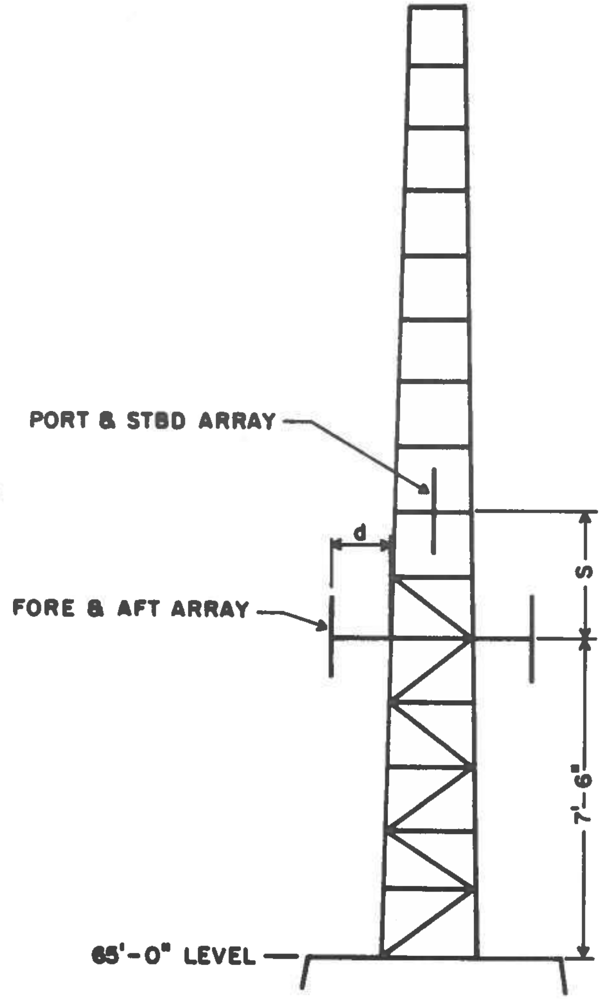

Fig. 3 Lattice mast showing antenna location

EXPERIMENTAL MEASUREMENTS

i) Radiation Patterns

A one-third scale mock-up of a 21-foot lattice mast was used for the pattern measurements. Although the measurements apply strictly to the converted DDE257 Restigouche class and the new DDH280 class, the mast dimensions are similar to those of the foremast of the DDE205 conversion class, and the results will apply for the latter case also. A sketch of the lattice mast showing the antenna location is given in Fig. 3. All dimensions are expressed in terms of the equivalent full-scale values. Plate I is a photograph of the scale mock-up. Both conventional λ/2 dipole and folded dipole elements were investigated. Insofar as the patterns are concerned there is little difference between the two types. The impedance characteristics, on the other hand, are different, as will be illustrated in the next section. Drawings of the two dipoles are shown in Fig. 4.

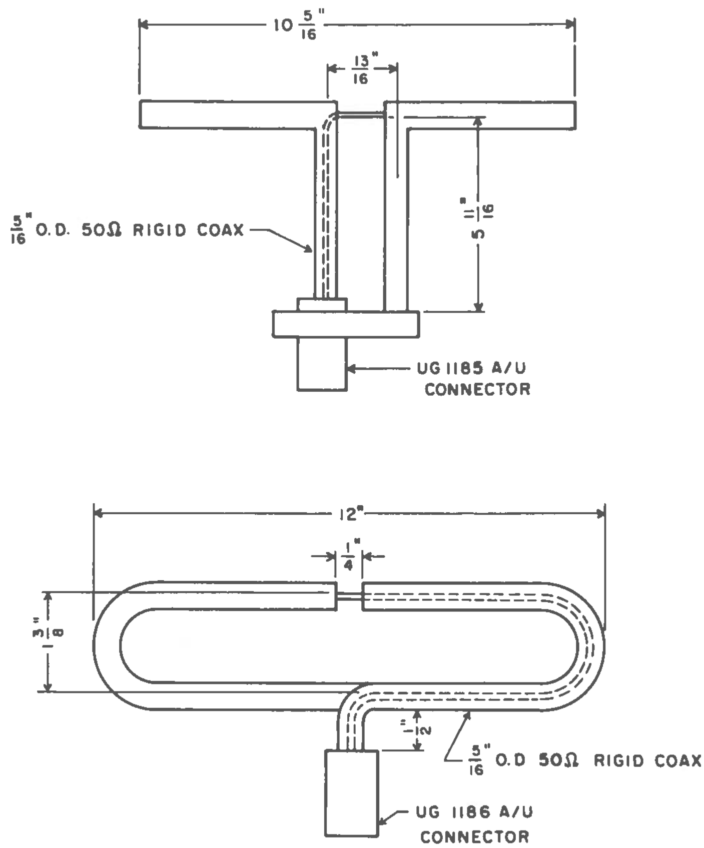

Fig. 4 Drawing of the dipoles used in the measurements: (above) λ/2 dipole (below) λ/2 folded dipole

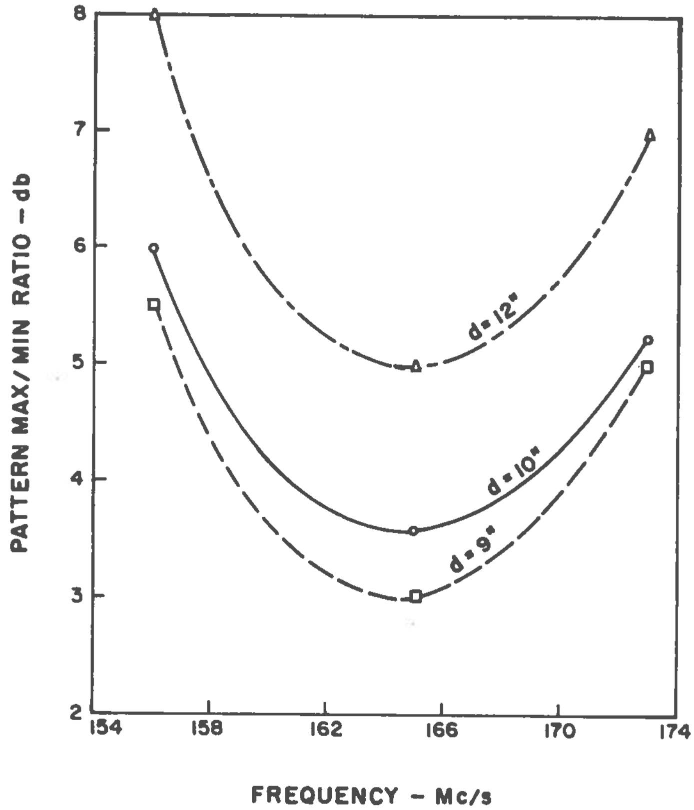

Fig. 5 Effect of dipole-to-mast spacing on measured pattern circularity

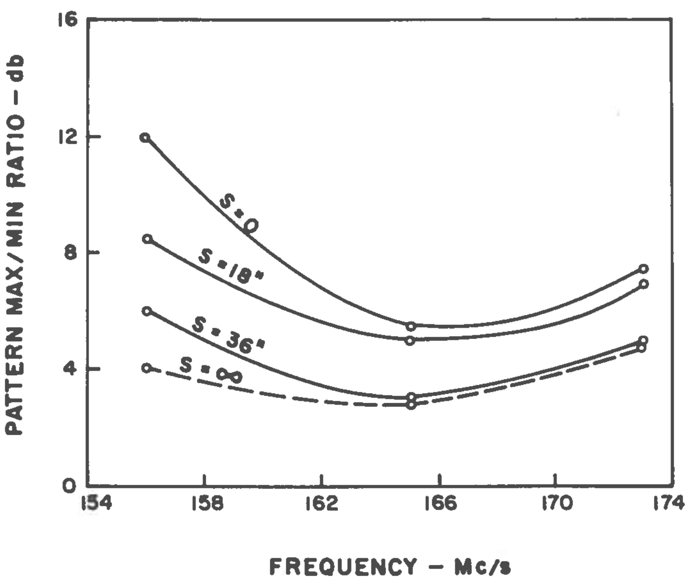

Fig. 6 Effect of vertical separation between the two arrays on pattern circularity

Measurements were carried out to determine the effect of dipole-to-mast spacing on the pattern circularity. For these measurements the second array was not mounted on the mast. In Fig. 5 the pattern maximum to pattern minimum is plotted for three different spacings: 9, 10, and 12 inches. The results corroborate the findings of our pattern calculations.

In the next set of measurements the effect of vertical separation between the two arrays on the pattern circularity was determined for three different separations. A dipole-to-mast spacing of 10 inches was used for all the measurements. The results are shown in Fig. 6. For the case where the two arrays are in the same plane, S = 0, the pattern variation is as great as 12 db at 156 mc/s. For the maximum separation investigated, S = 36 inches, the results approach the single array case.

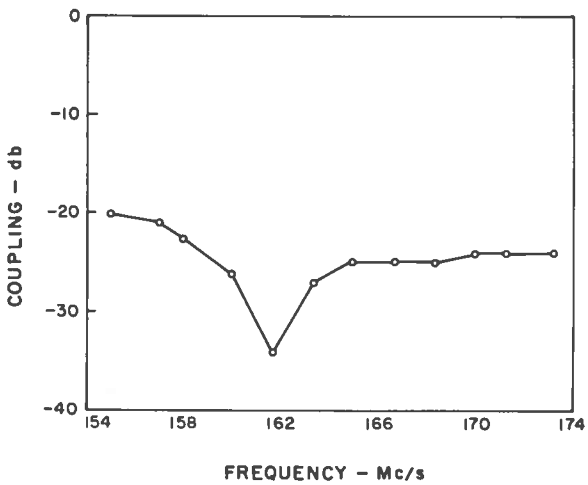

Fig. 7 Measured coupling between the two arrays

The results of Fig. 6 provide a qualitative measure of the mutual coupling between the two antenna arrays. The coupling was measured and the magnitude as a function of frequency for a separation of 36 inches is given in Fig. 7. On examination, the coupling is less than -20 db over the 156 to 173 mc/s band.

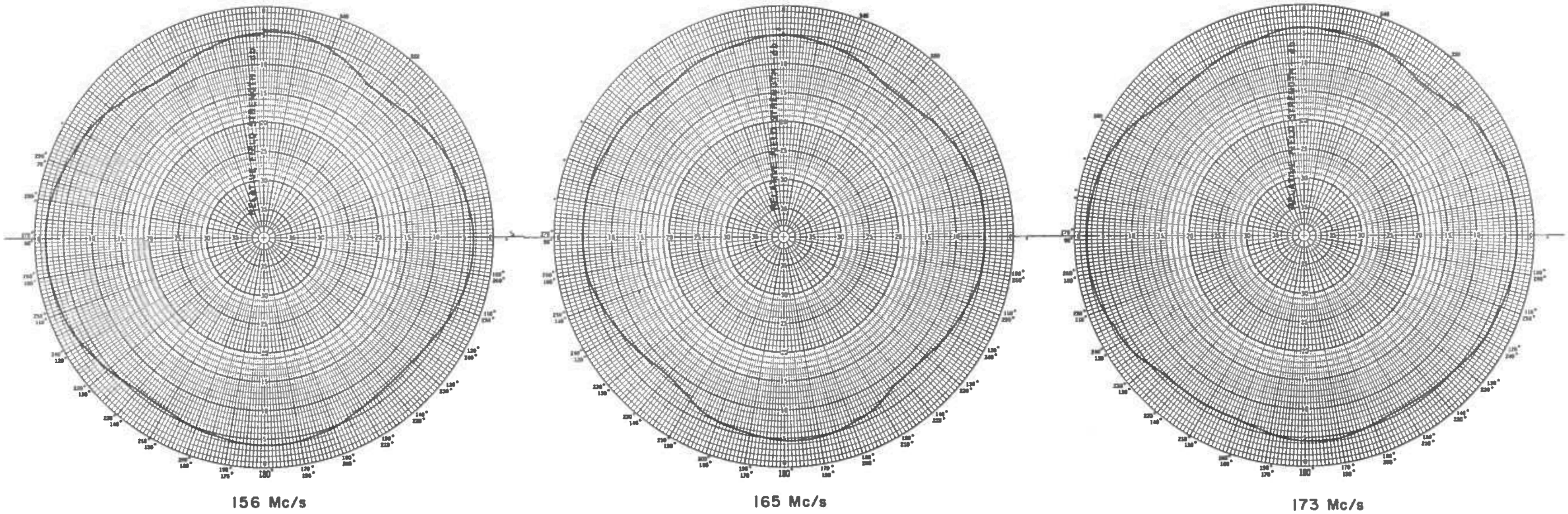

Fig. 8 Measured radiation patterns of final antenna configuration

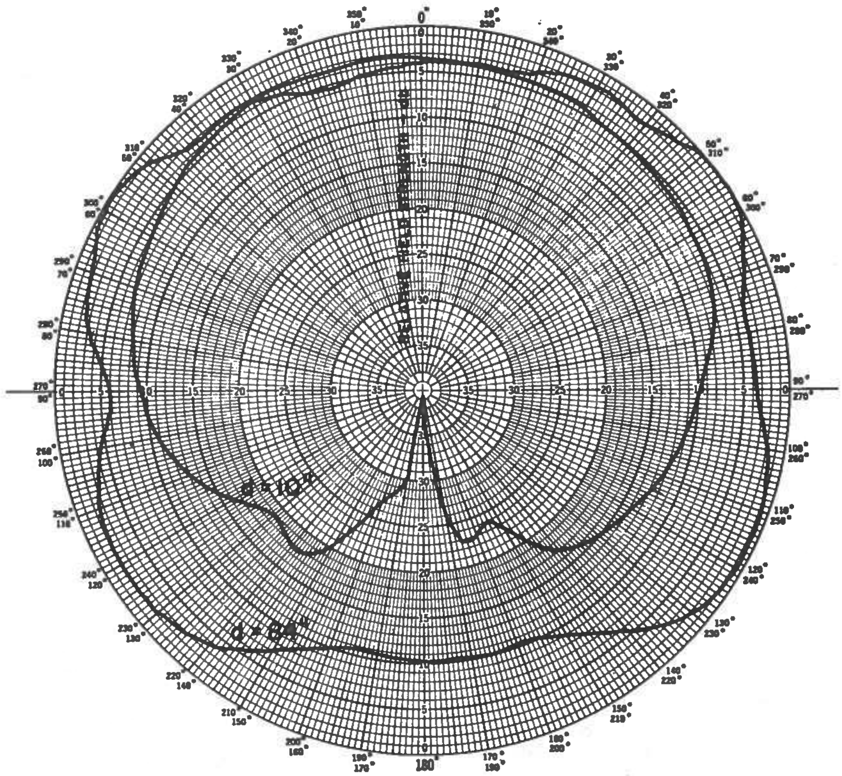

Fig. 9 Measured radiation patterns of single dipole for two different spacings

In Fig. 8, radiation patterns are shown for the final antenna configuration at frequencies of 156 mc/s, 165 mc/s, and 173 mc/s. The separation between arrays is 36 inches and the dipole-to-mast spacing is 10 inches. For comparison, the patterns of a single dipole for two different spacings, 10 inches and 84 inches, are shown in Fig. 9. For the larger spacing, the pattern variation is still about 10 db.

ii) Impedance

A Smith Chart plot of the input impedance using folded dipole elements is shown by the dashed curve in Fig. 10. The dipole-to-mast spacing is 10 inches. A transmission-line matching network shown in the insert was designed, and the calculated impedance characteristic is indicated by the solid curve. The VSWR is less than 1.7 to 1 over the frequency band 156 to 173 mc/s.

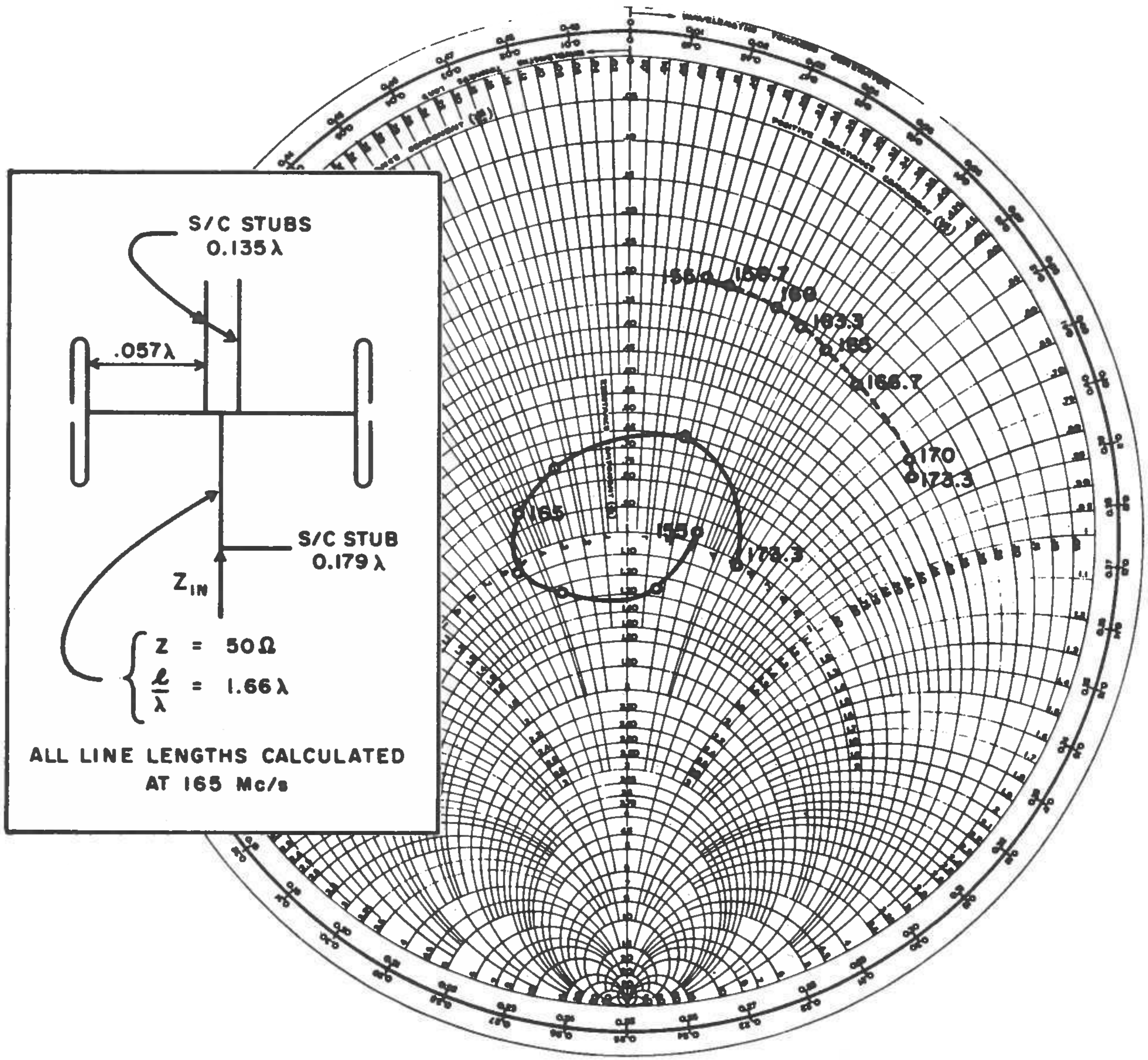

Fig. 10 Smith Chart impedance using folded dipole elements in array

A Smith Chart impedance plot using conventional dipoles is given in Fig. 11. Both raw impedance and the matched impedance are shown in the diagram. Again the VSWR is less than 1.7 to 1. However, for this case the matching network is much simpler than for the folded dipole case.

CONCLUSIONS

A VHF antenna for installation on the foremast of the destroyer escort class has been designed for the frequency band 156 to 173 mc/s. The antenna system consists of two co-phased dipole arrays. One array is mounted on the forward and after sides of the foremast and the second array which is displaced vertically by 36 inches is mounted on the port and starboard sides of the foremast. The azimuthal pattern variation within the Jezebel band of 162 to 173 mc/s is less than 5 db. Using either folded dipole or ordinary dipole elements the VSWR is better than 1.7 to 1 over the extended band 156 to 173 mc/s.

ACKNOWLEDGMENTS

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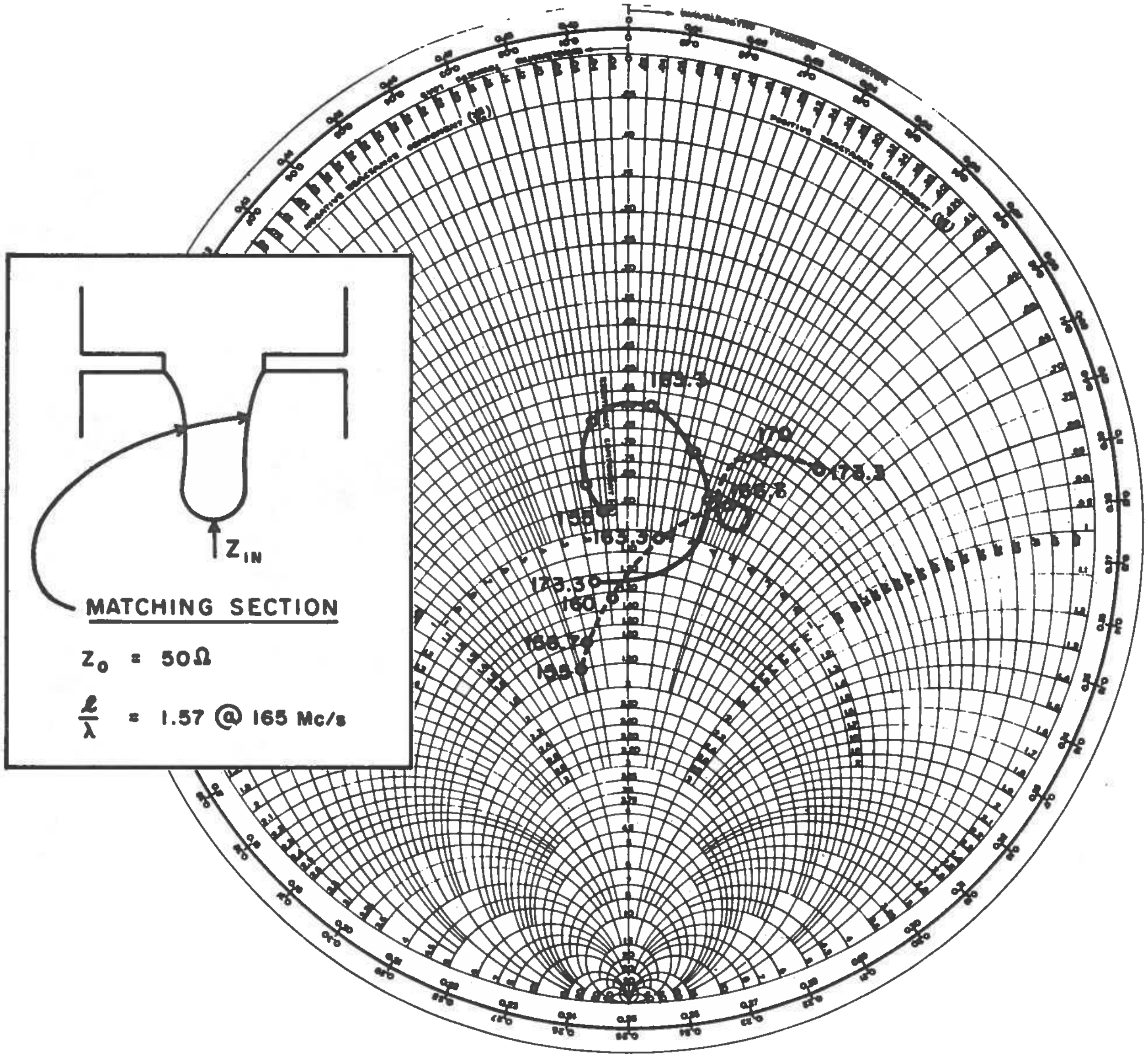

Fig. 11 Smith Chart impedance using conventional dipole elements in array

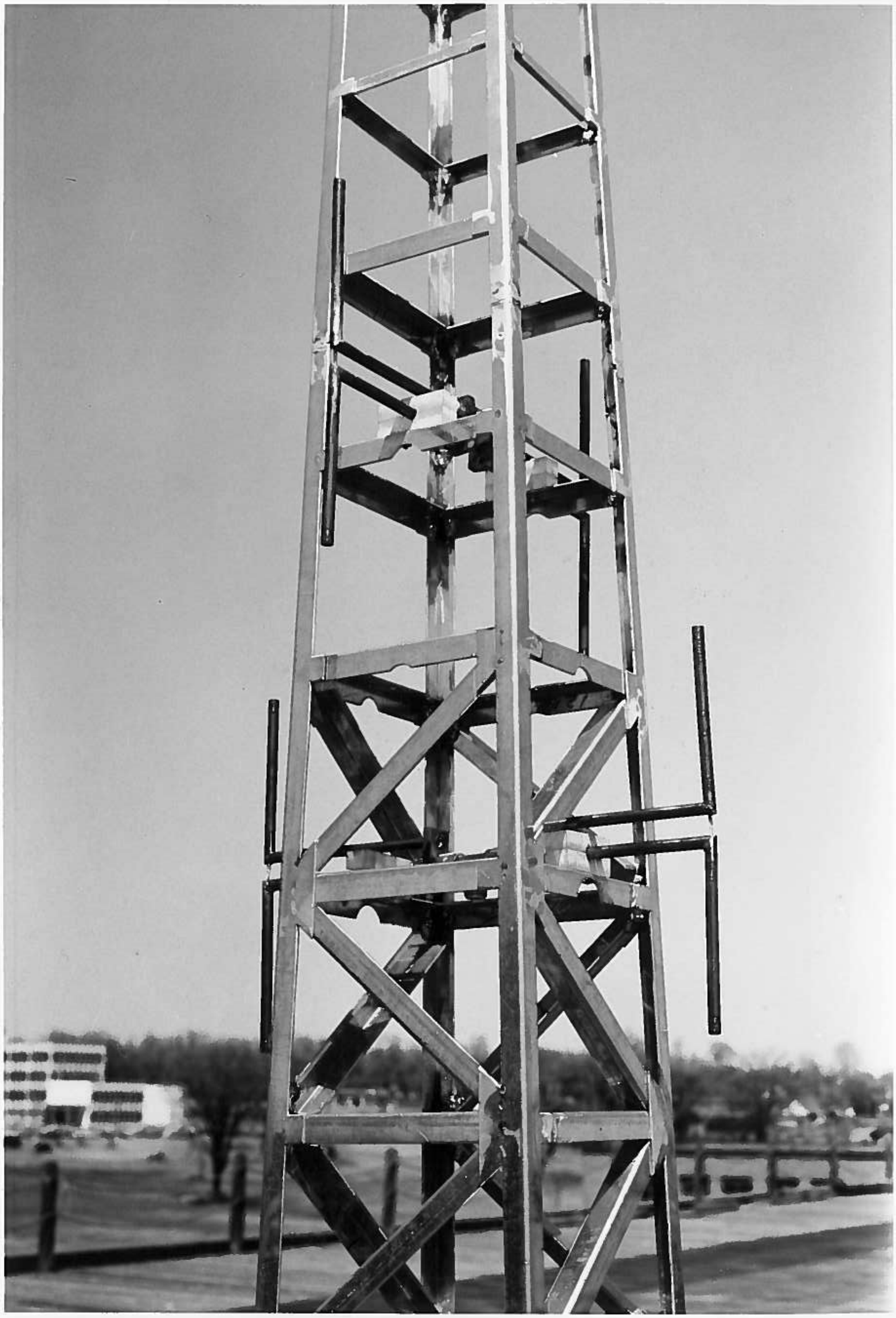

Plate I — Scale model of mast and dipole arrays