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Wong, J.Y.

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RADIO AND ELECTRICAL ENGINEERING DIVISION

EXPERIMENTAL INVESTIGATION OF THE IMPEDANCE CHARACTERISTICS OF THE MONOCONE ANTENNA

J. Y. WONG

OTTAWA

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ABSTRACT

The report describes an experimental investigation of the impedance characteristics of the monocone antenna. Curves are presented which show the effect of the physical parameters of the structure on the impedance bandwidth of the antenna. The radiation characteristics are also considered and patterns are given for a specific configuration. The intended application for this study is an antenna to provide omnidirectional coverage in the 2 to 30 MHz band although the results are valid for any operating frequency.

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EXPERIMENTAL INVESTIGATION OF THE IMPEDANCE CHARACTERISTICS OF THE MONOCONE ANTENNA

- J.Y. Wong -

INTRODUCTION

The monocone antenna first developed at the United States Naval Research Laboratory has been employed with moderate success as a broadband shunt-excited HF antenna (1, 2, 3). Although the antenna was developed primarily for shipboard operation, the monocone has potential application as a broadband, omni-directional, grounded vertical antenna because of its simple construction and desirable impedance characteristics. Lack of adequate design data for the monocone motivated an experimental investigation, and, in particular, measurements were carried out to determine the effect of the physical parameters on the impedance bandwidth of the antenna. The intended application for this study is an antenna to provide omnidirectional coverage in the 2 to 30 MHz band although the results are applicable for any operating frequency.

The basic antenna structure consists of four ungrounded conductors symmetrically arranged around a grounded mast to simulate a 60-degree cone. The four conductors are joined together near the apex of the cone by a feed ring which is fed by a 50-ohm coaxial cable located inside the mast. In the model used in the investigation, the mast consists of a brass tube 30 inches high and 1.5 inches in diameter. Each of the four conductors is 30 inches long. In addition to these critical dimensions, the following parameters are used to describe variations to the basic configurations:

H	height of antenna mast
N	number of exterior conductors
n	number of grounded mast wires
α	angle included between the mast and wires
h	distance from ground plane to point on mast where wires are connected

A sketch of the monocone is shown in Fig. 1 and a photograph of the model used in the investigation in shown in Plate I.

IMPEDANCE MEASUREMENTS

All measurements were carried out over the band of frequencies from 65 to 260 MHz. A Smith-chart impedance of the basic monocone is given in Fig. 2. The results have been plotted as a function of the antenna height H/λ. The first-order resonance occurs when the antenna height is about 0.23 λ and the input resistance has a value of approximately 500 Ω. For heights less than 0.23 λ the

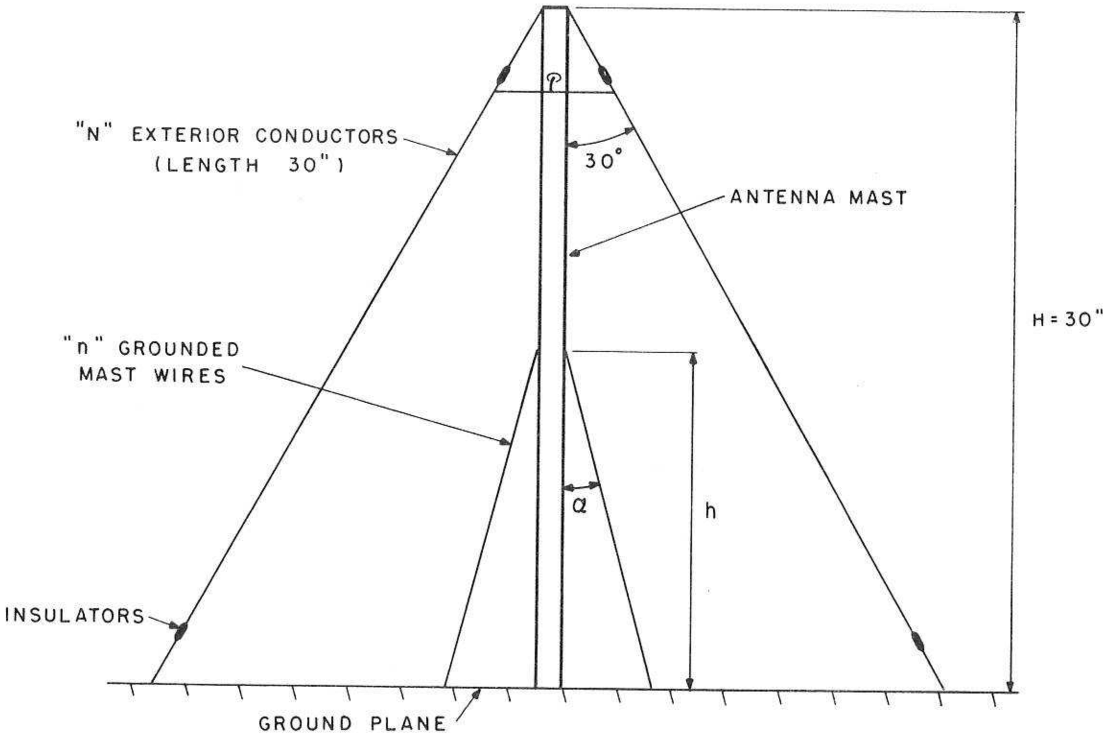

Fig. 1 Antenna showing physical parameters

input reactance is inductive. The second-order resonance occurs when the antenna height is 0.58 λ and the input resistance at this point is close to 30 Ω.

Measurements were carried out to determine the effect on the input impedance of increasing the cross section, in other words, modifying the characteristic impedance, of the mast. The increase was accomplished by connecting six ($n = 6$) grounded wires to the mast near the feed ring to simulate a cone. The results for $\alpha = 10°$ are shown in Fig. 3. Two significant changes in the impedance are noted. The first-order resonance has been shifted to a higher frequency and occurs when the antenna height is approximately 0.43 λ, and the value of the input resistance has been reduced to 200 Ω, compared to 500 Ω for the basic structure. A similar impedance plot was obtained for $\alpha = 20°$ and the results for this case are shown in Fig. 4.

Figure 5, which shows a plot of the VSWR as a function of the antenna height, gives a summary of the results. The improvement in the VSWR achieved by increasing the effective mast diameter is evident particularly for frequencies below the first-order resonance. However, in the region between the first- and second-order resonances, increasing the mast diameter tends to increase the VSWR.

The effect of connecting the grounded wires at about midpoint on the mast is shown in Fig. 6. This is for the case in which $h = 14$ inches and $\alpha = 10°$.

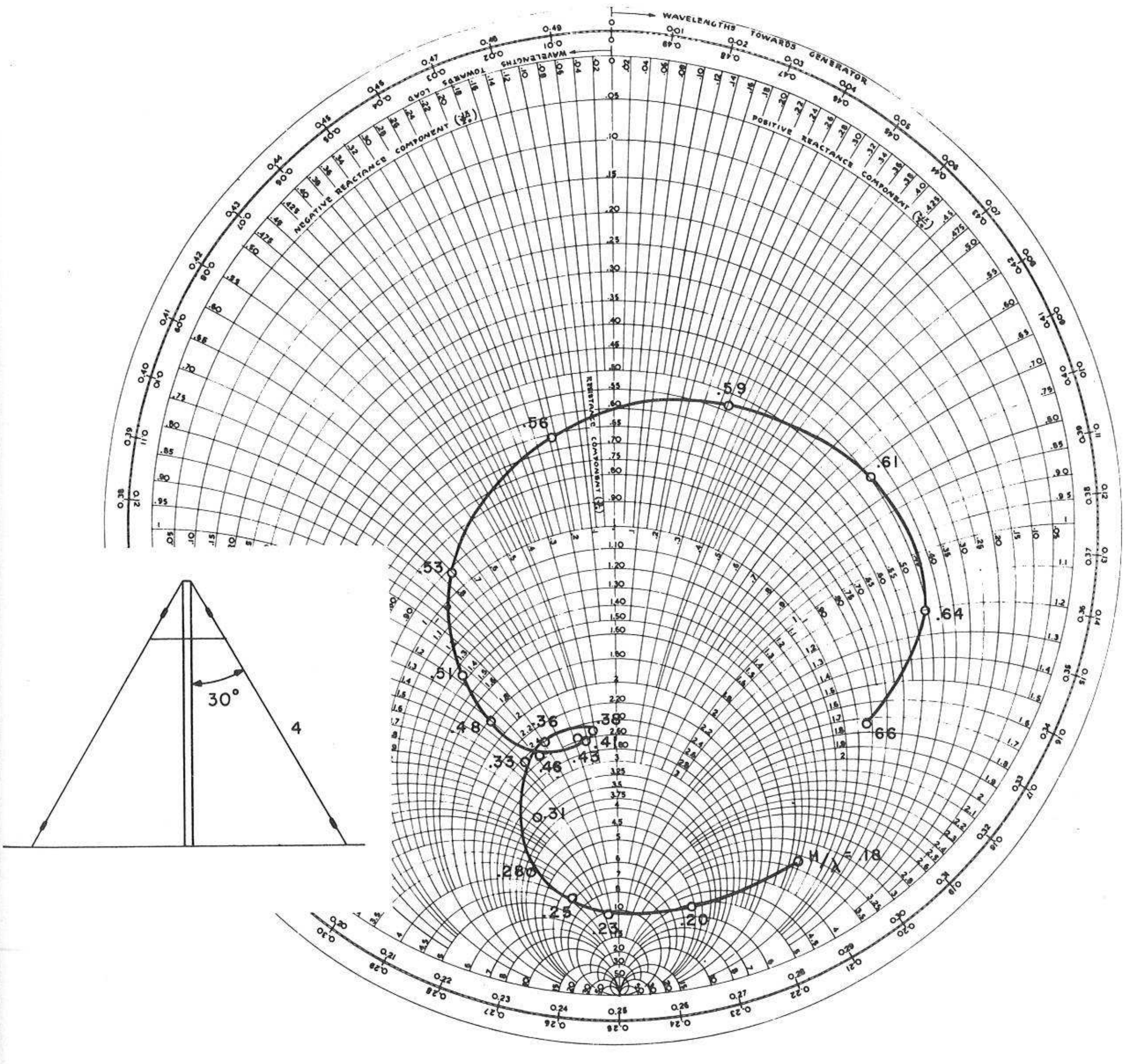

Fig. 2 Smith-chart impedance of basic monocone

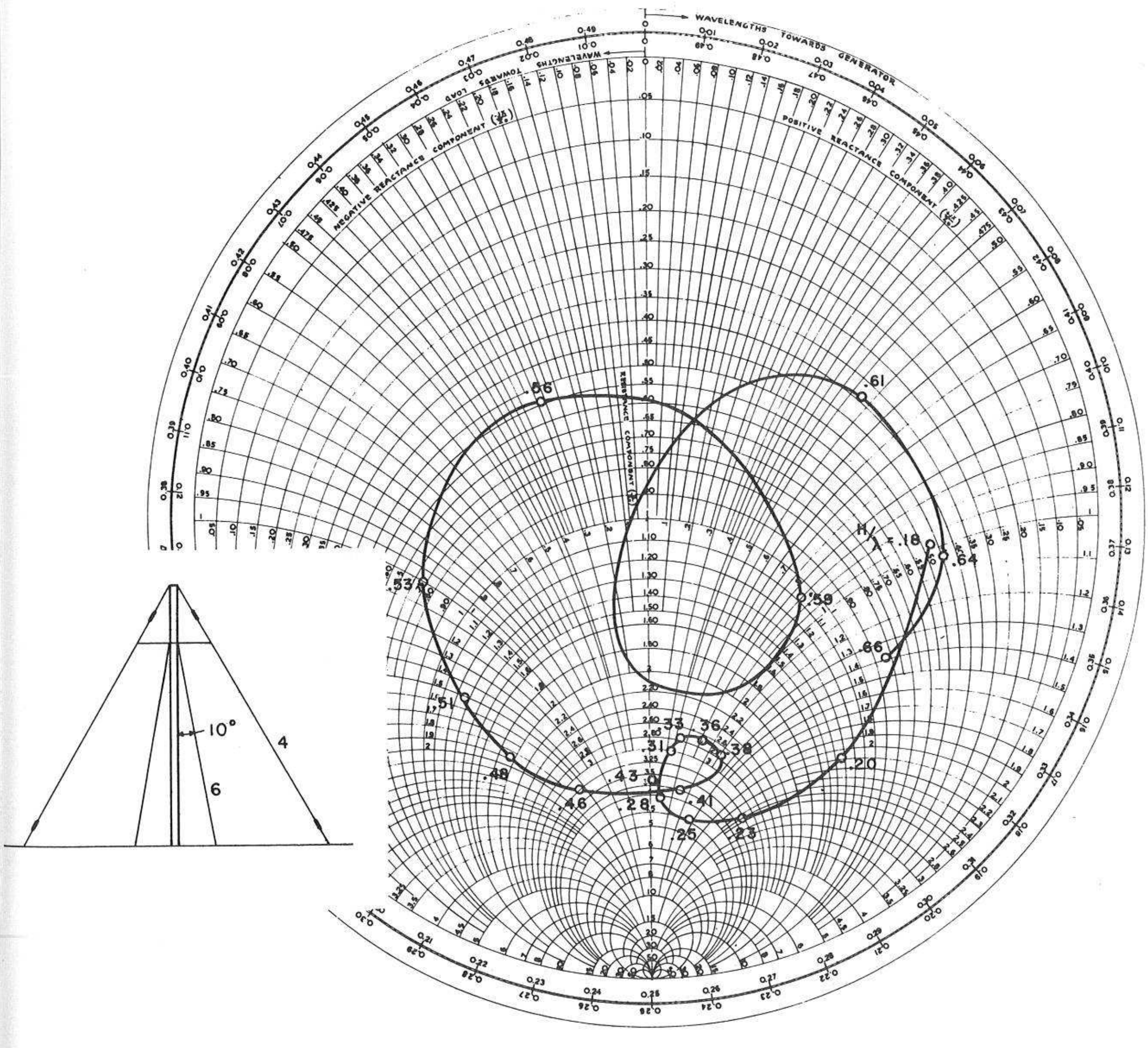

Fig. 3 Smith-chart impedance of basic mono-cone with six grounded mast wires, α = 10°

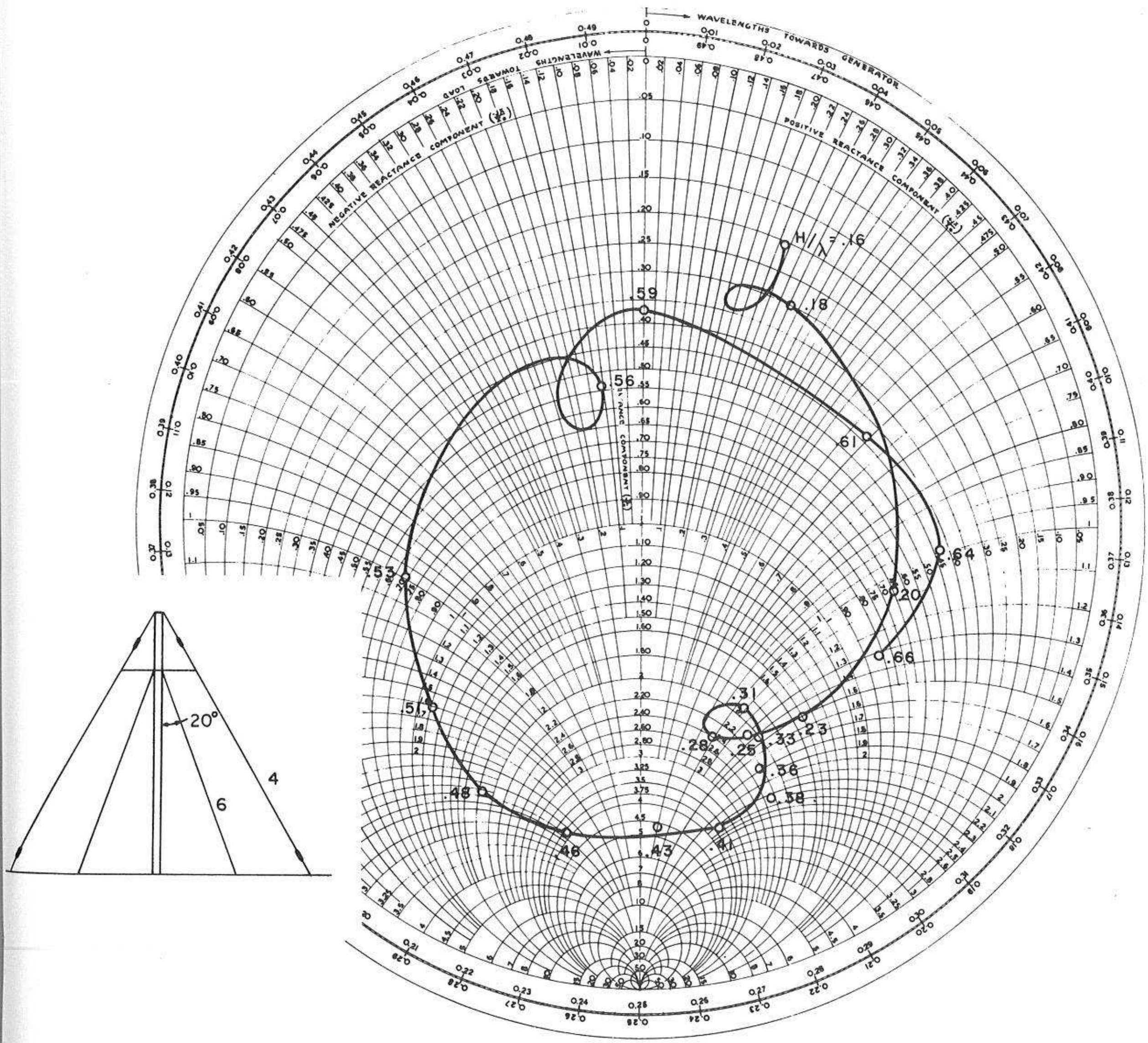

Fig. 4 Smith-chart impedance of basic mono-cone with six grounded mast wires, $\alpha = 20°$

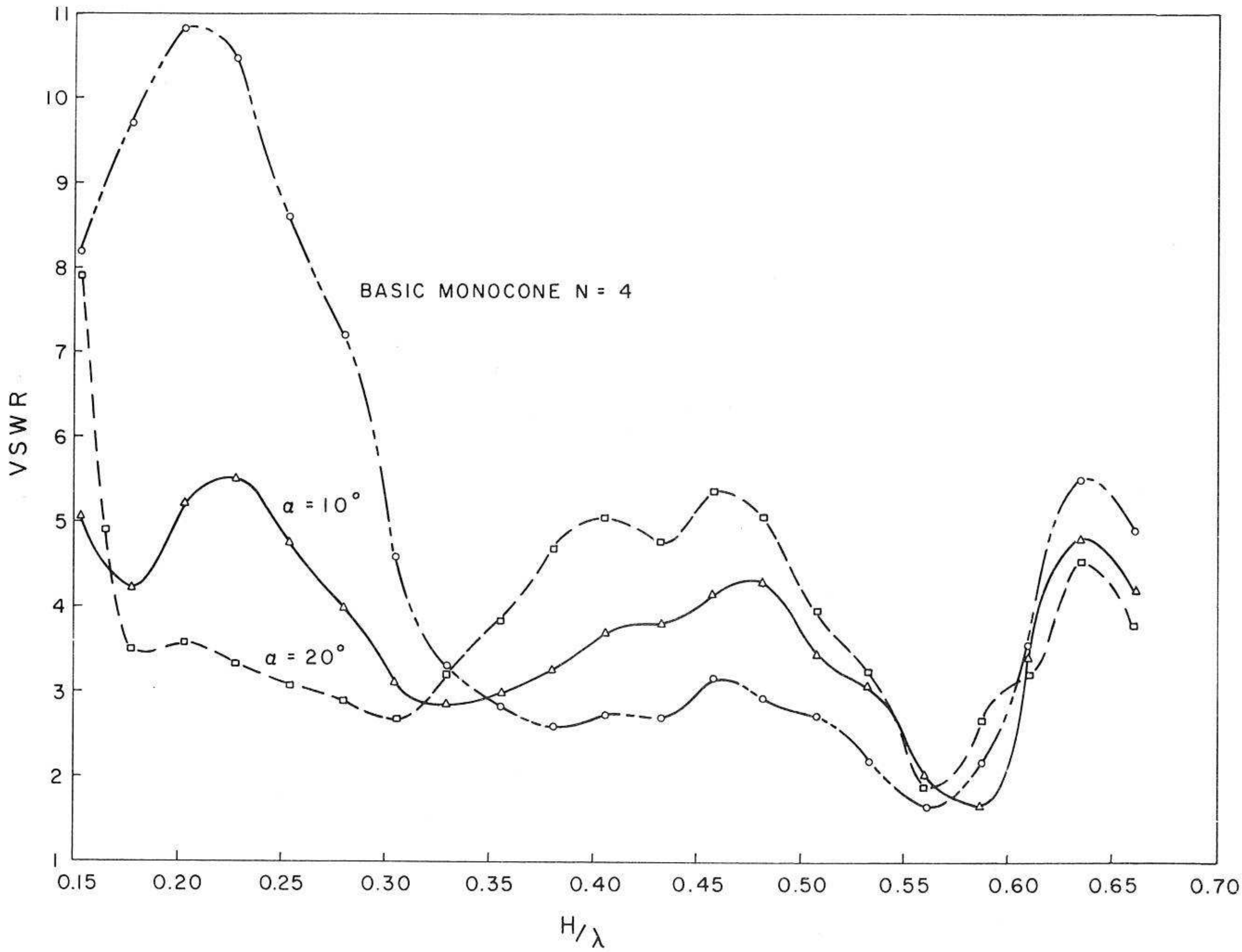

Fig. 5 Effect of angle α on VSWR ($N = 4$, $n = 6$)

Comparison of the results with Fig. 2 shows that the grounded wires have little effect on the impedance. The angle was increased so that the wires were grounded at a point just below the insulators of the exterior conductors. This case has been described in Reference 2 and it was reported that there was a general improvement in the impedance characteristics of the antenna. The results of our measurements are shown in Fig. 7 and no significant improvement in the impedance bandwidth is observed.

To determine the effect of the number of exterior conductors on the input impedance, measurements were carried out for N equal to 5, 6, and 8 conductors. For all three case, $n = 6$ and $\alpha = 10°$. The results are given in Figs. 8, 9, and 10 respectively. Figure 11 shows the VSWR plotted as a function of antenna height. For frequencies below the first-order resonance the VSWR becomes worse as the number of conductors is increased. However, between the first-

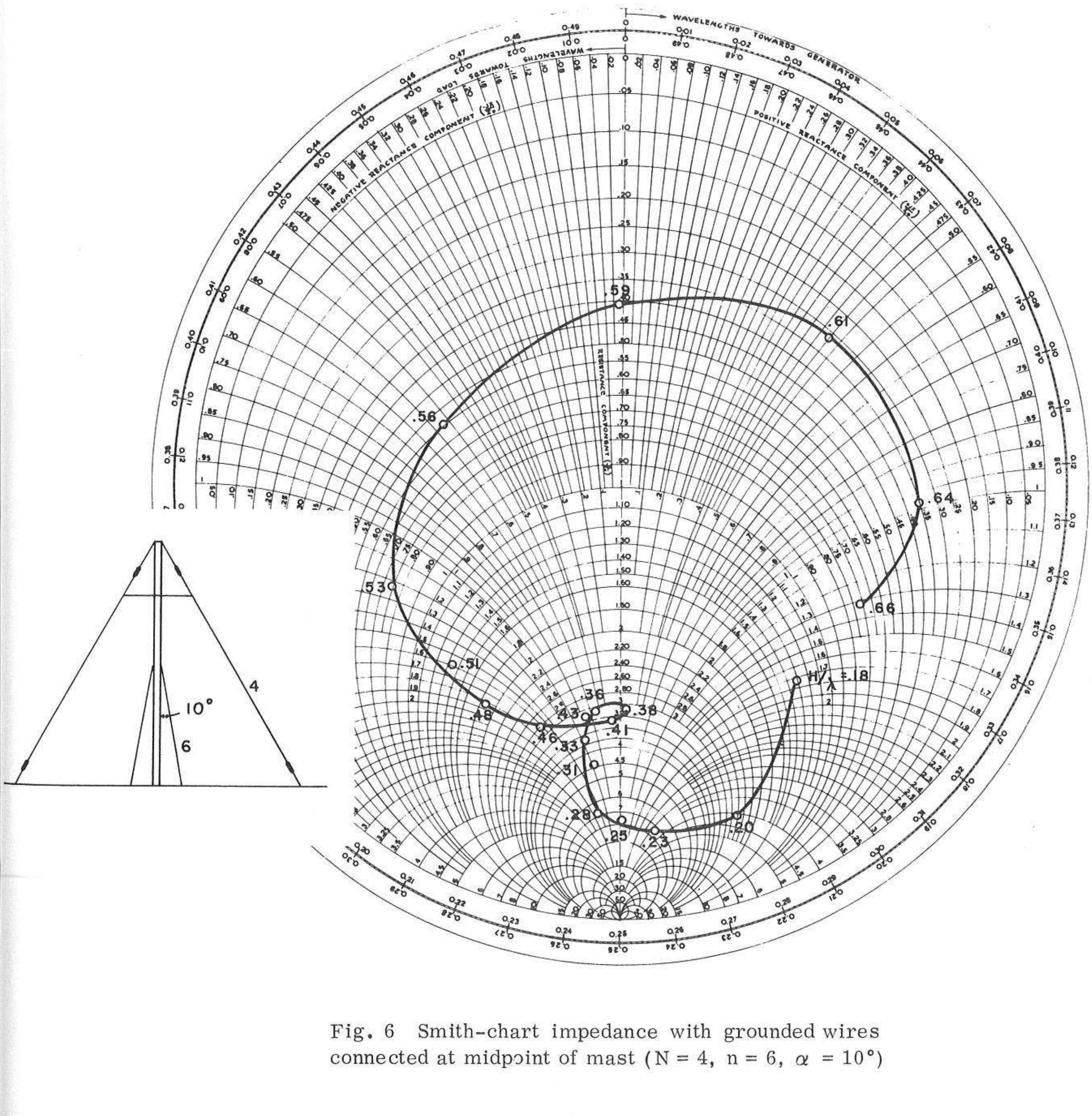

Fig. 6 Smith-chart impedance with grounded wires connected at midpoint of mast ($N = 4$, $n = 6$, $\alpha = 10°$)

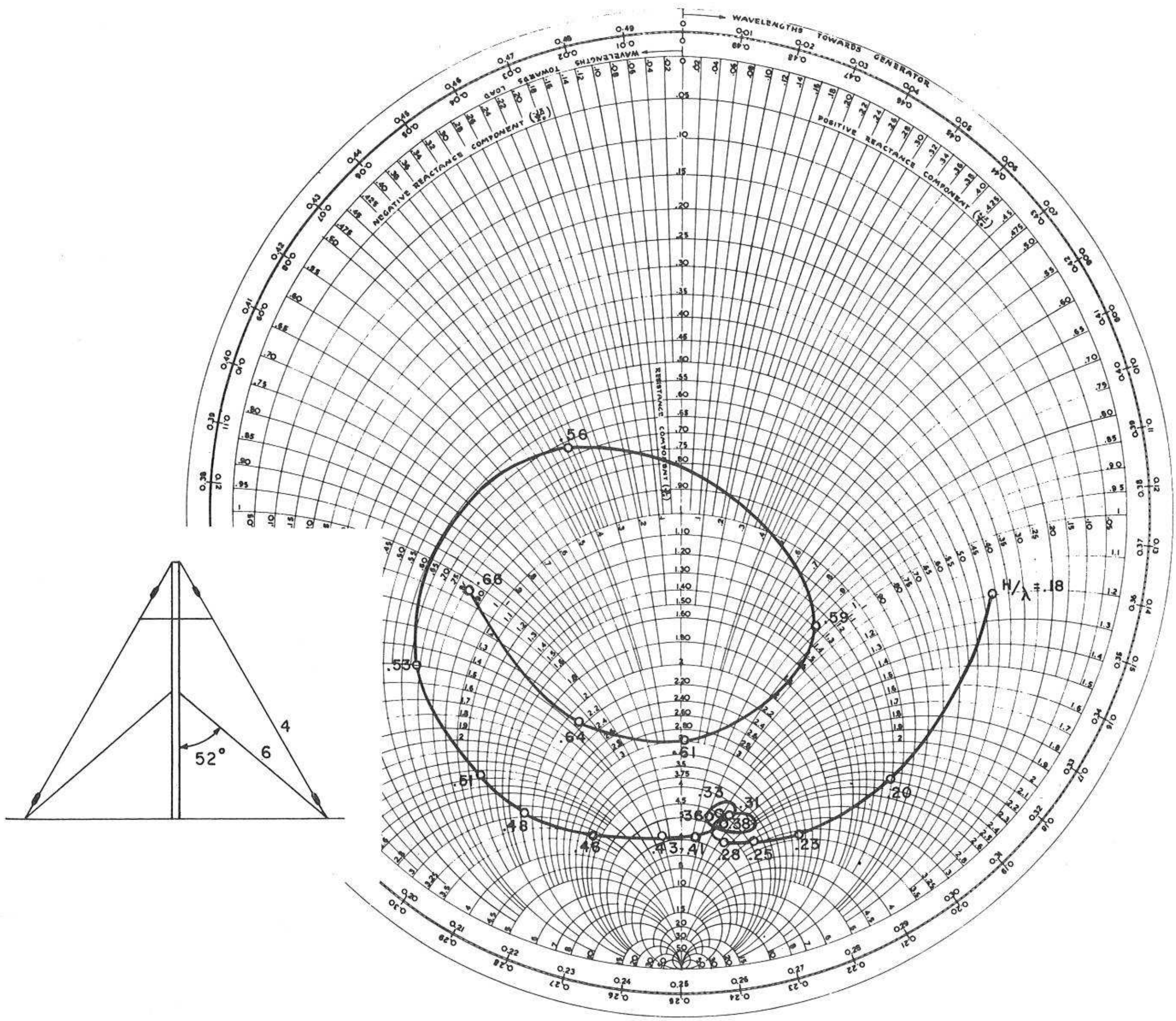

Fig. 7 Smith-chart impedance with grounded wires connected at midpoint of mast (N = 4, n = 6, α = 52°)

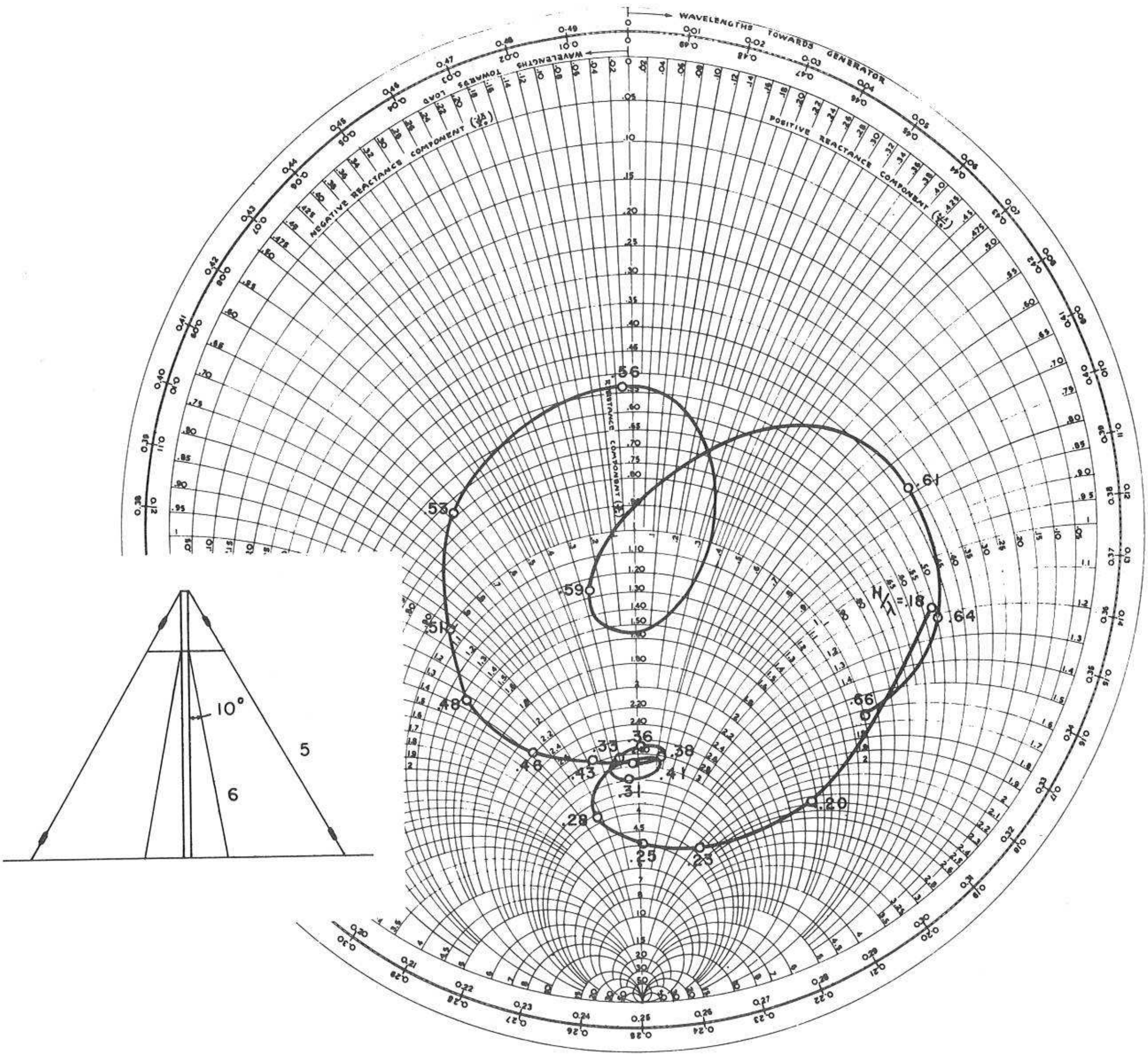

Fig. 8 Smith-chart impedance of monocone with five exterior conductors ($n = 6$, $\alpha = 10°$)

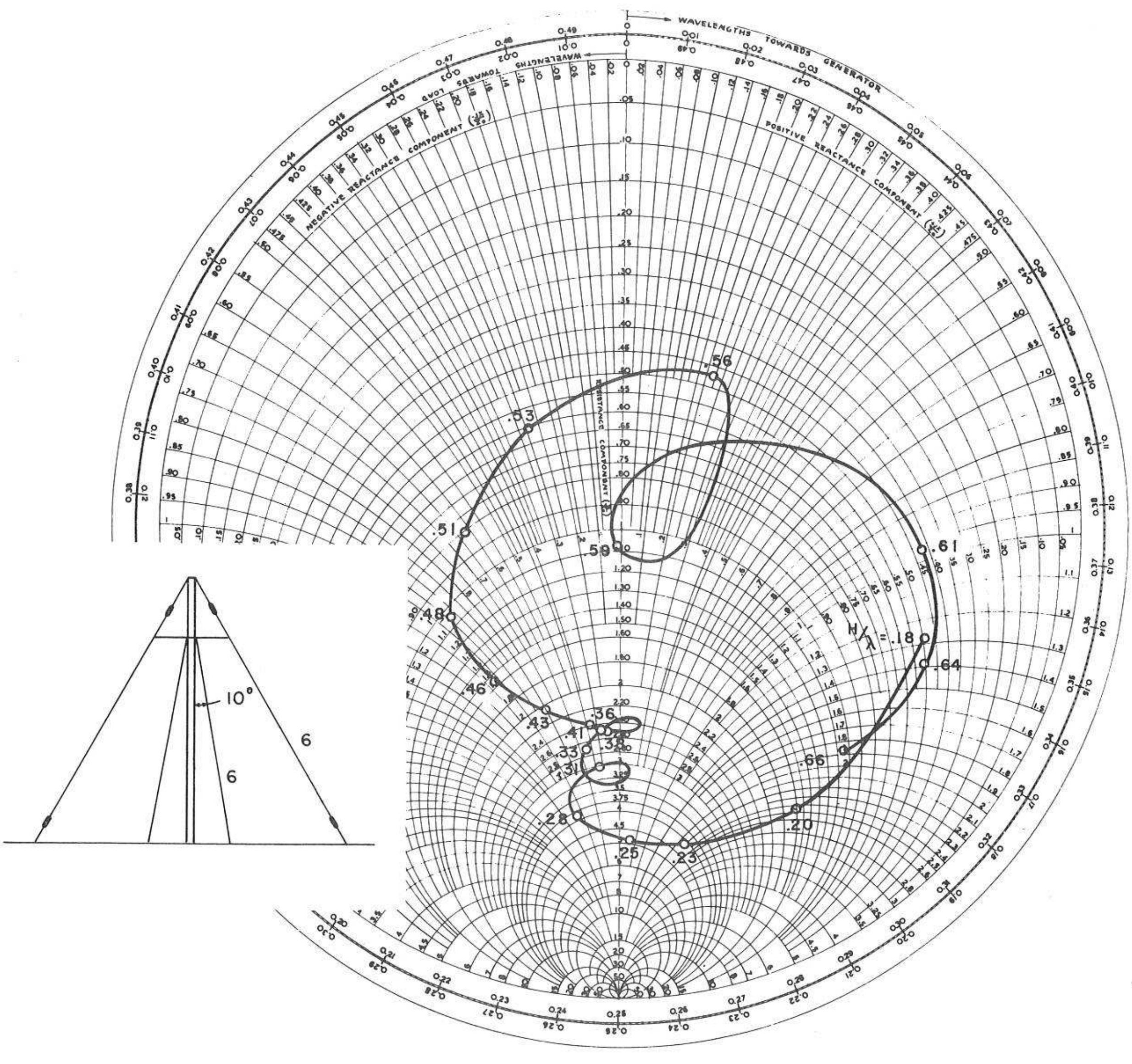

Fig. 9 Smith-chart impedance of monocone with six exterior conductors (n = 6, α = 10°)

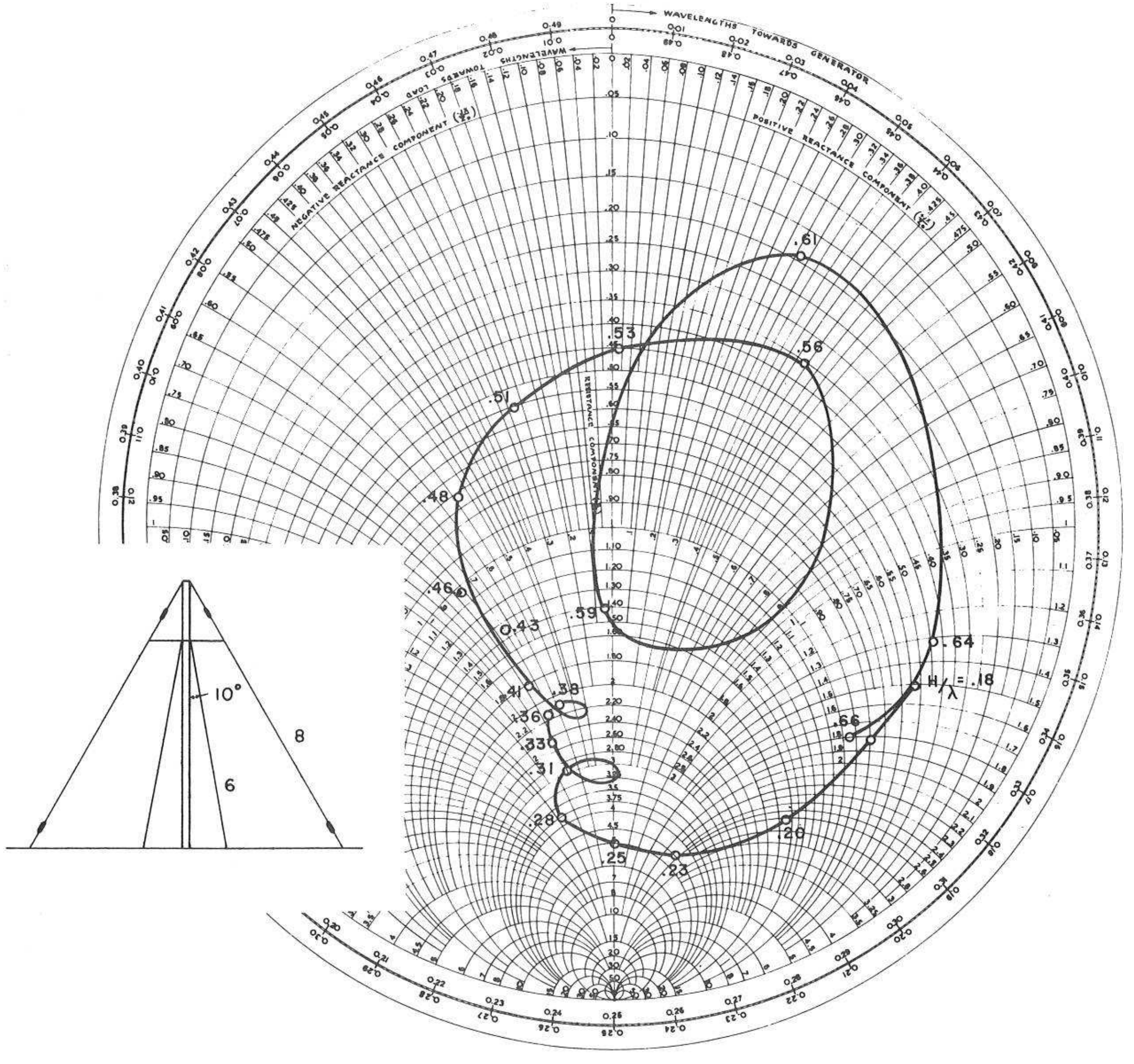

Fig. 10 Smith-chart impedance of monocone with eight exterior conductors ($n = 6$, $\alpha = 10°$)

and second-order resonance points, the opposite effect is observed — the VSWR is decreased as N is increased.

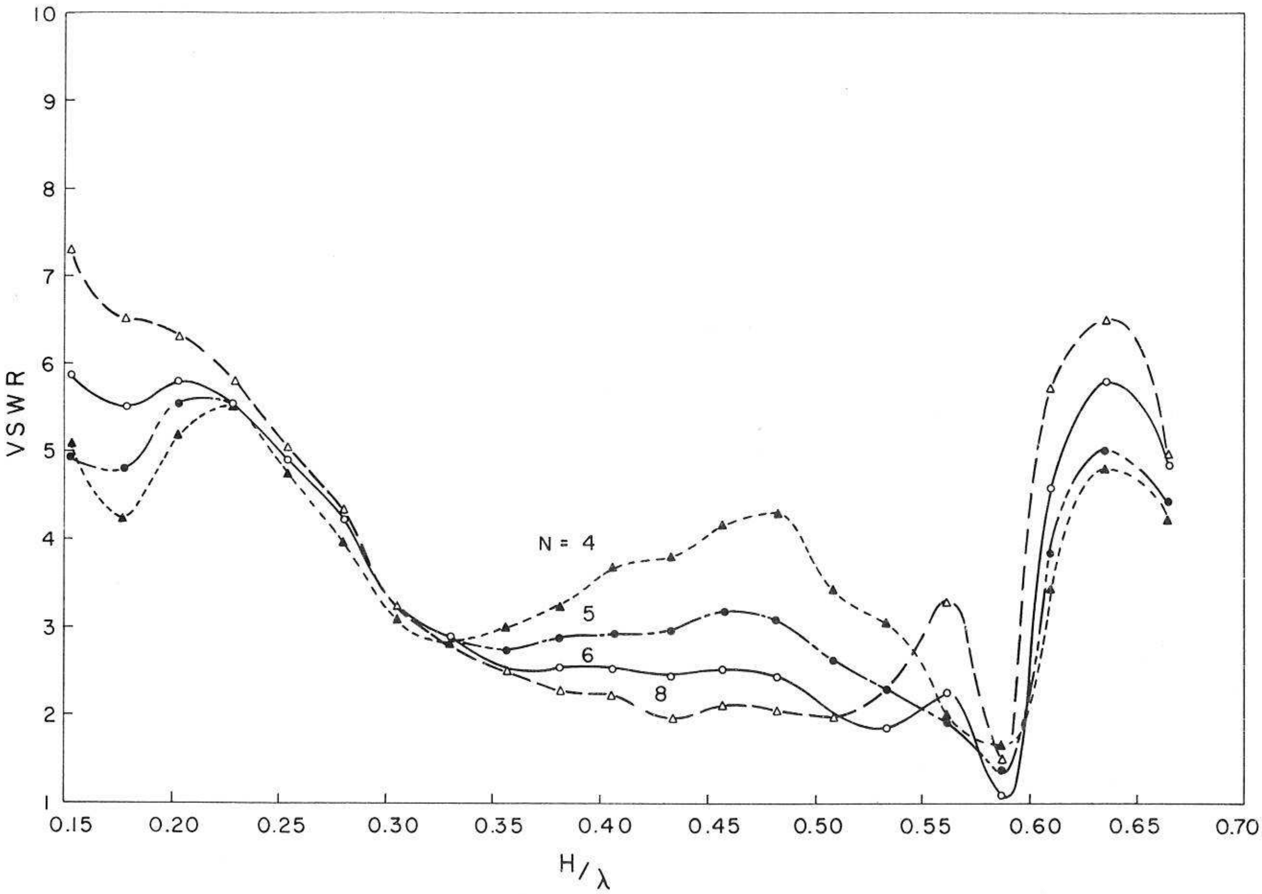

Fig. 11 Effect of number of exterior conductors on VSWR ($n = 6$, $\alpha = 10°$)

From Fig. 5 we have seen that increasing the effective cross section of the mast causes a decrease in the VSWR below the first-order resonance and increases the VSWR between the first- and second-order resonant frequencies. On the other hand, we have just observed from Fig. 11 that increasing the number of exterior conductors produces the opposite effect. If these two compensating effects are combined, it is expected that an improved impedance characteristic can be attained. A Smith-chart impedance for the case $N = 6$ and $\alpha = 20°$ is shown in Fig. 12 and the corresponding VSWR is plotted in Fig. 13. The improvement in the impedance bandwidth of the antenna is apparent. If a VSWR criterion of less than 3.5 to 1 is assumed, an operating bandwidth corresponding to $0.23 < H/\lambda < 0.58$ is readily achieved.

RADIATION PATTERNS

Radiation patterns were measured for the monocone configuration described in Fig. 12 over the frequency band from 100 to 200 MHz, which corresponds to an

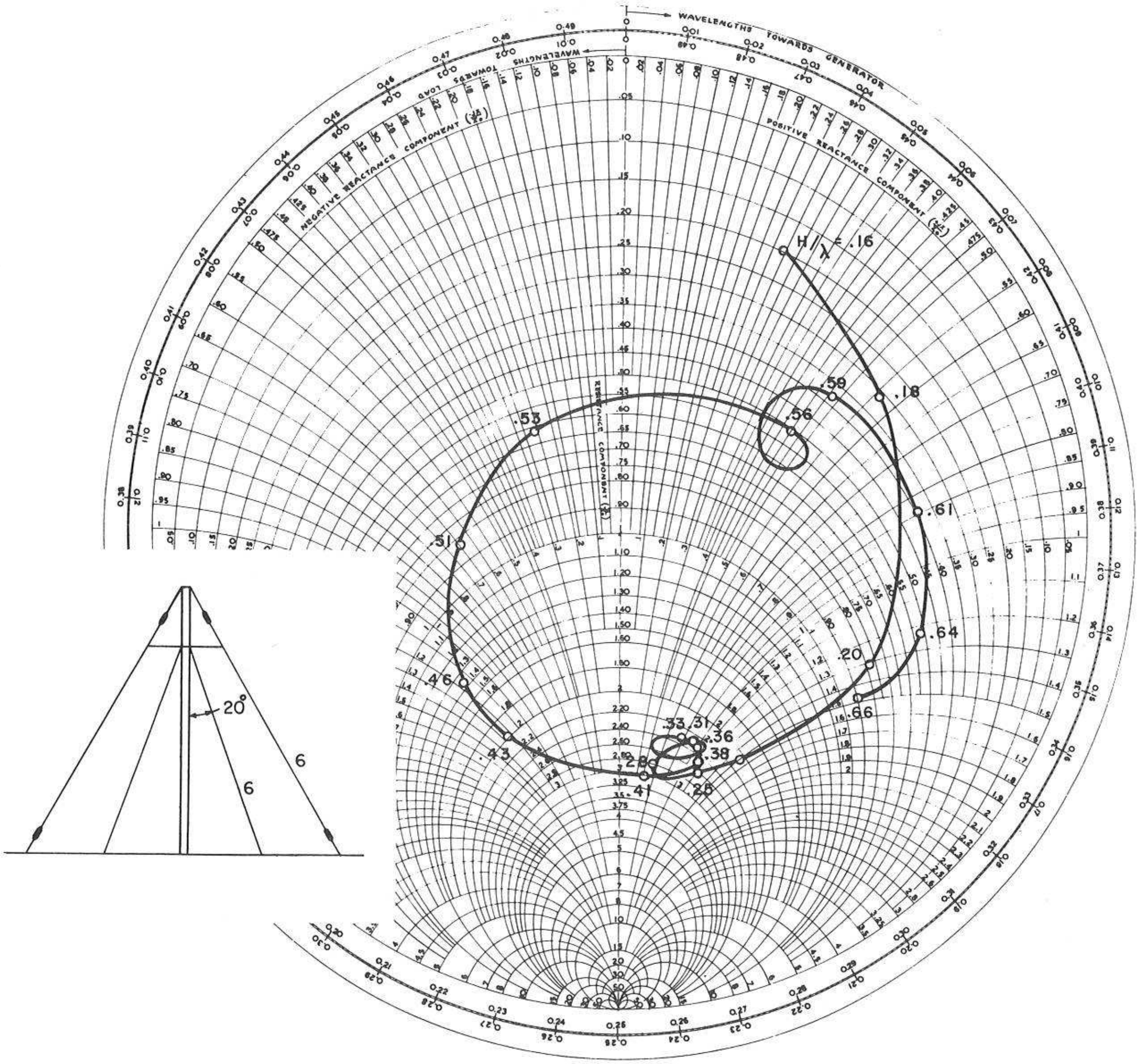

Fig. 12 Smith-chart impedance of monocone for $\alpha = 20°$ (N = 6, n = 6)

antenna height of 0.25 λ to 0.50 λ. Figure 14 shows the vertical plane patterns and it is seen that they are typically those of a conventional base-fed monopole.

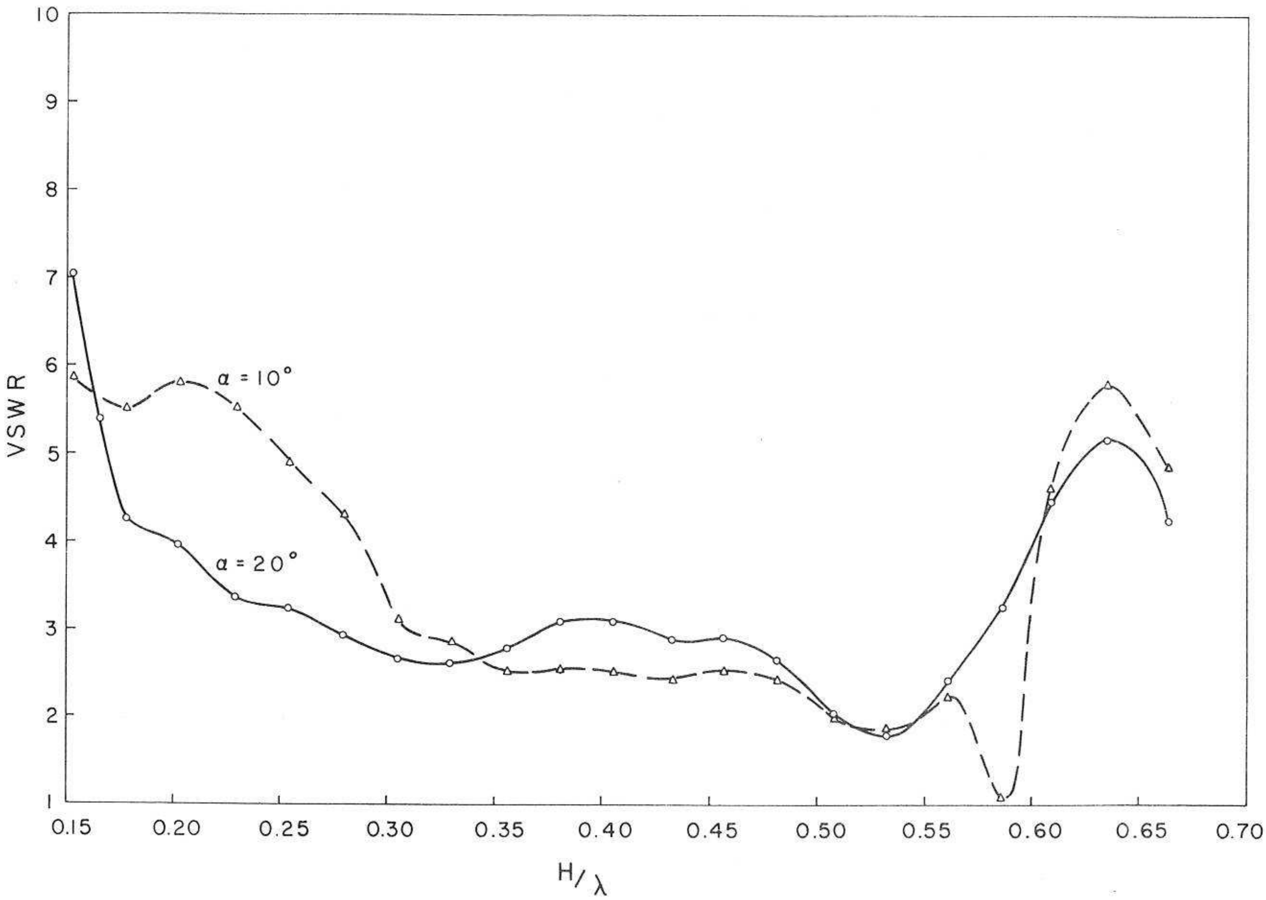

Fig. 13 Effect of angle α on VSWR (N = 6, n = 6)

CONCLUSION

The results presented in this report demonstrate the effect of some of the physical parameters on the impedance characteristics of the monocone. Sufficient data are provided to permit the design of an antenna for a specified bandwidth and VSWR limit.

ACKNOWLEDGMENT

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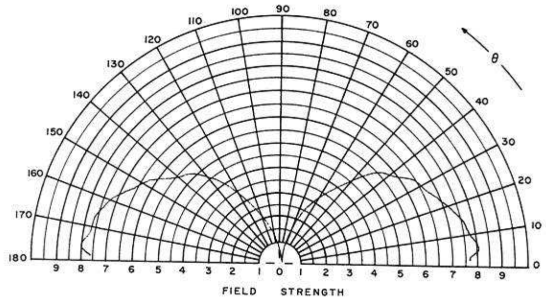
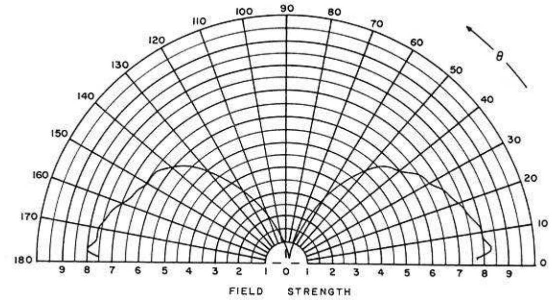
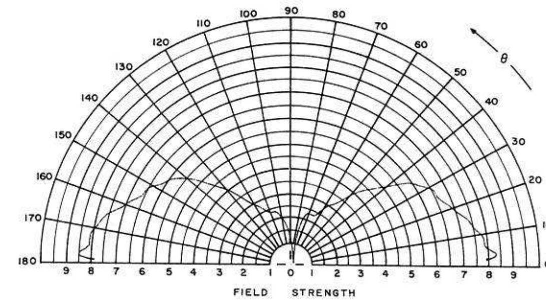


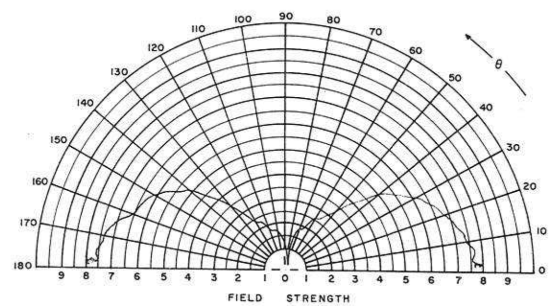
$H/\lambda = .25$



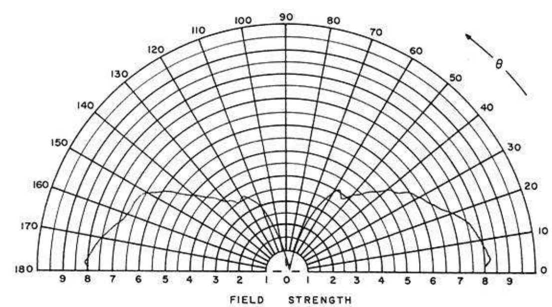
$H/\lambda = .31$



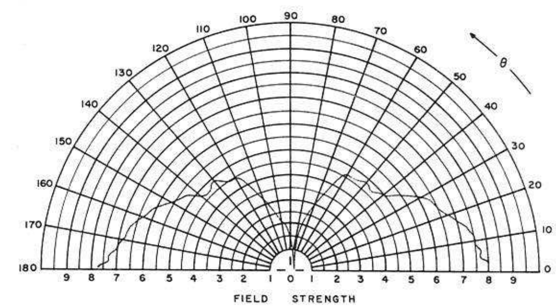
$H/\lambda = .36$



$H/\lambda = .41$



$H/\lambda = .46$



$H/\lambda = .51$

Fig. 14 Vertical radiation patterns of typical monocone antenna ($N = 6$, $n = 6$, $\alpha = 20°$)

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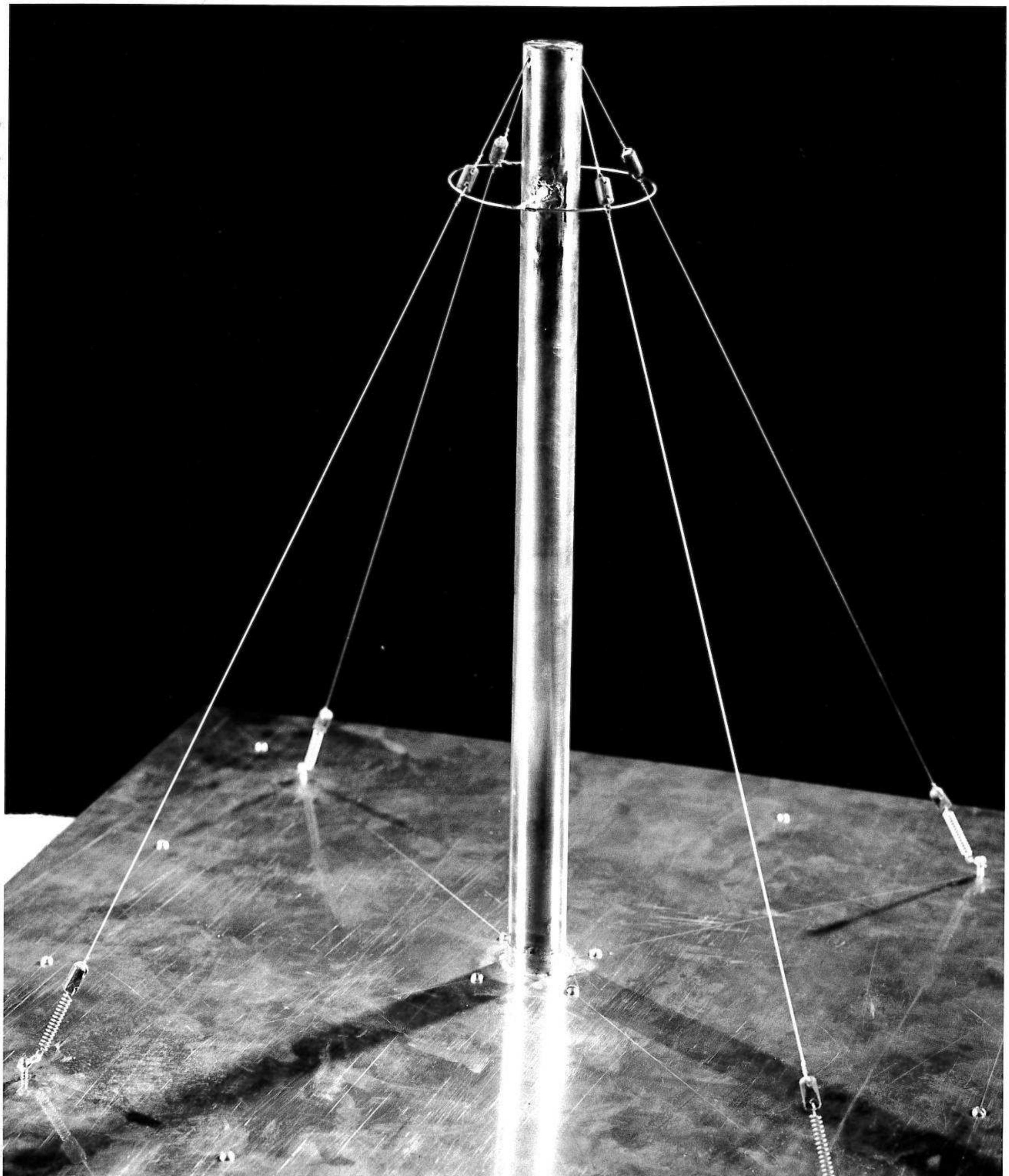

Plate I   Basic monocone antenna used in the investigation