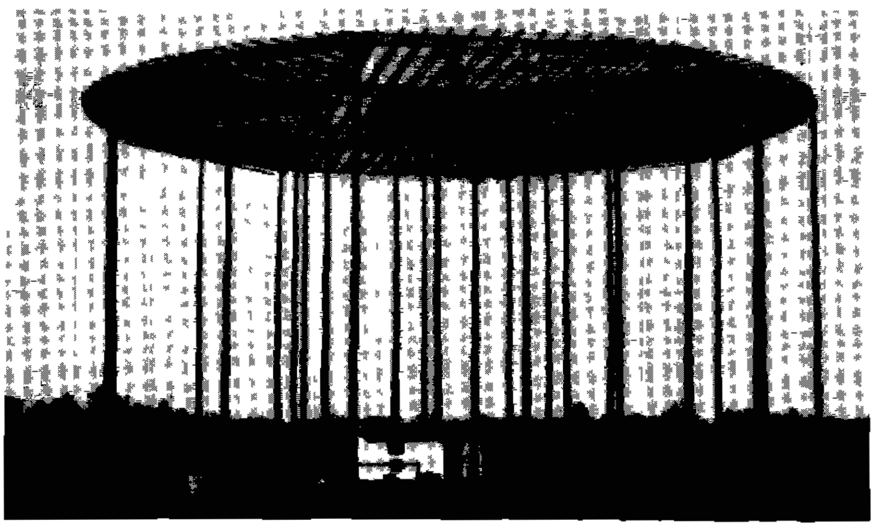
# BUREAU OF RESEARCH AND DEVELOPMENT



FINAL REPORT

# A STUDY OF VOR REFLECTION CHARACTERISTICS

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*Prepared by*

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# A STUDY OF VOR REFLECTION CHARACTERISTICS

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This report has been reviewed and is approved for distribution.

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# A STUDY OF VOR REFLECTION CHARACTERISTICS

## TECHNICAL DEVELOPMENT REPORT NO 417


## ABSTRACT

Frequently, a VOR station must be located at a site which is far from desirable The four-loop VOR installation at Charleston, S. C., was situated at the center of a 2,000-foot-diameter cleared space in a wooded area The station could not be commissioned because of excessive course scalloping, and the condition was not improved greatly even by mounting the antenna system on top of a 75-foot-high counterpoise 150 feet in diameter

Tests were conducted with a vertical screen made of horizontal wires to determine the effectiveness of a large counterpoise 75 feet high in reducing scalloping caused by reflecting objects beyond 1,000 feet from a VOR antenna.

It is recommended that no further consideration be given to using a counterpoise 150 feet in diameter and 75 feet high for reducing course scalloping caused by objects greater than 1,000 feet away from a four-loop VOR antenna.

## PURPOSE

The purpose of this task assignment was to determine the effectiveness of a 75-foot-high, 150-foot-diameter counterpoise in reducing course scalloping caused by trees beyond 1,000 feet from a conventional four-loop VOR antenna.

## SUMMARY

This report discusses the effect of reflecting objects near VOR stations. Airborne and ground measurements of course scalloping were made with standard VOR facilities using a counterpoise 35 feet in diameter and 10 feet high, and a 150-foot-diameter counterpoise 75 feet high. The study was confined to reflecting objects located 3,000 feet and less from a VOR.

## INTRODUCTION

In January 1957, the Charleston, S. C., VOR could not be commissioned because of excessive scalloping of the courses caused by trees beyond 1,000 feet of the station. The station was a standard VOR facility having a counterpoise 35 feet in diameter and 10 feet high. It was believed that a larger and higher counterpoise possibly would reduce the scalloping sufficiently to permit commissioning the station, therefore, a counterpoise 150 feet in diameter and 75 feet high was erected and flight tests were conducted Unfortunately, the course scalloping was found to be essentially unchanged.

It was proposed that tests be conducted, using horizontal wires as reflectors of electromagnetic waves, at a standard VOR and at the Charleston VOR to determine the reflection characteristics Wire-reflection tests were performed at the Technical Development Center (TDC) VOR where a 10-foot-high, 35-foot-diameter counterpoise was available and with the 75-foot-high, 150-foot-diameter counterpoise at Charleston Identical tests were conducted at both sites.

## DISCUSSION

The standard omnirange at TDC, with a counterpoise 35 feet in diameter and 10 feet high, is shown in Fig. 1. Figure 2 is a view of the Charleston VOR with its counterpoise 150 feet in diameter and 75 feet high. Figure 3 is an aerial view of the Charleston site.

Flight observations were made in a Douglas DC-3 aircraft employing standard VOR receiving equipment, which included a Collins Type 51R-3 navigation receiver and Esterline-Angus graphic recorders to record course deviation indicator (CDI) movements. Field strength measurements were made with a Collins 51R-1 receiver, converted for use as a linear field intensity meter

Figure 4 shows the course scalloping observed during a 20-mile radius orbital flight about the Charleston VOR for two counterpoise installations. There was no appreciable decrease in course scalloping with the large, high counterpoise compared to the scalloping with the standard counterpoise 10 feet high.

A vertical plane reflector was constructed of four 150-foot horizontal wires spaced 22 inches apart supported on wooden "A" frames with the top wire 40 feet above ground (see Fig. 5). The reflector was oriented 45° to the impinging wave front so that the energy traveling south from the TDC VOR was reflected to the east The aircraft was flown 20 miles east of the VOR along a north-south line through the 80° to 100° azimuthal sector Movements of the CDI were recorded for various separation distances between the reflector and the VOR antenna The results are shown in Fig 6 The scalloping caused by the reflector was easily discernible for even a 1,000-foot separation

The tests were repeated at the Charleston VOR (counterpoise 150 feet in diameter and 75 feet high) with the reflector positioned on the 337 5° radial The results are shown in Fig 7 Because the scalloping caused by the trees was so severe at this site, it was difficult to measure accurately even the largest amount of scalloping caused by the wire reflector

Figure 8 is a comparison of theoretical scalloping and similar measured data for various separation distances between a reflector and a VOR antenna. The theory assumed no counterpoise. The advantage of such a comparison was that it appeared to allow an accurate extrapolation of the measured data From approximately 1,500 feet to 3,000 feet and beyond, the theoretical and measured curves coincide, therefore, as far as scalloping is concerned, a VOR antenna 14 feet high is equivalent to a VOR antenna 79 feet high with a reflector at distances greater than approximately 1,500 feet

A flight was made along a radial line over the Charleston VOR station while field strength was measured and recorded in order to find out the effectiveness of the large-diameter counterpoise in suppressing the deep nulls that generally appear in the vertical plane radiation pattern of an antenna that is 79 feet above ground Figure 9 shows the results of this flight test. The theoretical positions for the nulls were 3.2°, 6.4°, 9.6°, and 12 8° The nulls in the measured radiation pattern were almost completely absent up through 14° verifying that the counterpoise was suppressing the nulls This was in agreement with the findings reported in a previous report.[1] Figure 10 is a plot in rectangular coordinates showing the lower part of the data in Fig 9 from 0° to 20°

[1]S. R. Anderson and T. S. Wonnell, "The Development and Testing of the Terminal VHF Omnirange," CAA Technical Development Report No. 225, January 1954, Fig. 37.

The field strength near the ground was measured along a radial at both VOR stations in order to show the shadow-casting effect of the large counterpoise at Charleston. Figure 11 displays these data for a receiving antenna approximately 50 feet to 850 feet from the VOR. The large counterpoise effectively shielded the VOR antenna from objects near the earth out to approximately 700 feet from the antenna.

## CONCLUSIONS

It is concluded that

1. A counterpoise 150 feet in diameter and 75 feet high was effective in reducing course scalloping caused by reflecting objects approximately 1,000 feet or less from a VOR angenna, but was not effective in reducing the scalloping caused by objects beyond 1,000 feet when compared to a VOR with a counterpoise 35 feet in diameter and 10 feet high

2. A counterpoise 150 feet in diameter was adequate in size for suppressing the nulls in the vertical plane radiation pattern for an antenna height of 79 feet (counterpoise height 75 feet)

## RECOMMENDATIONS

It is recommended that

No further consideration be given to using a counterpoise 150 feet in diameter and 75 feet high for reducing course scalloping caused by objects greater than 1,000 feet away from a conventional four-loop VOR antenna.

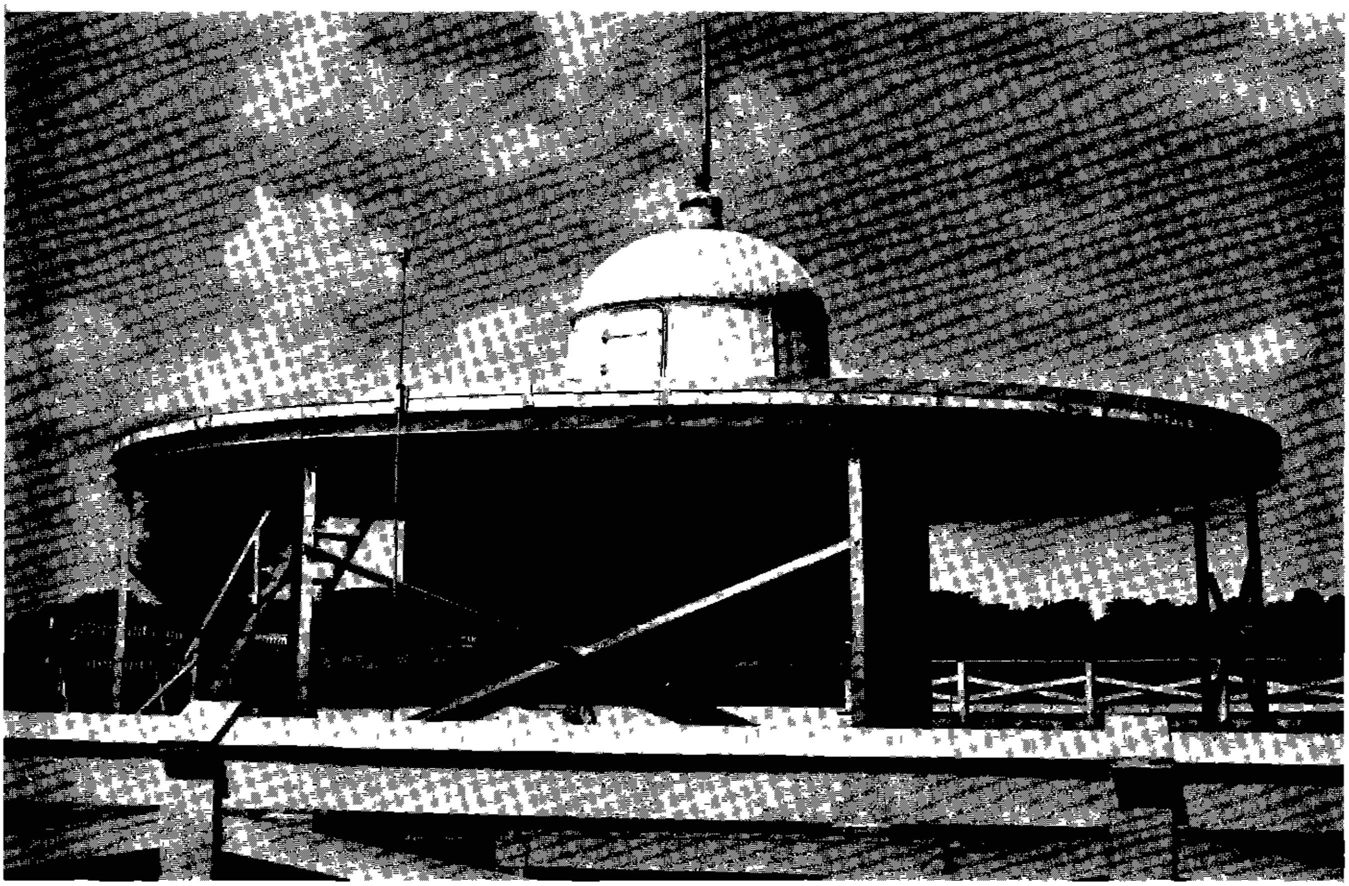


FIG 1 TDC VOR - COUNTERPOISE 35 FEET IN DIAMETER AND 10 FEET HIGH

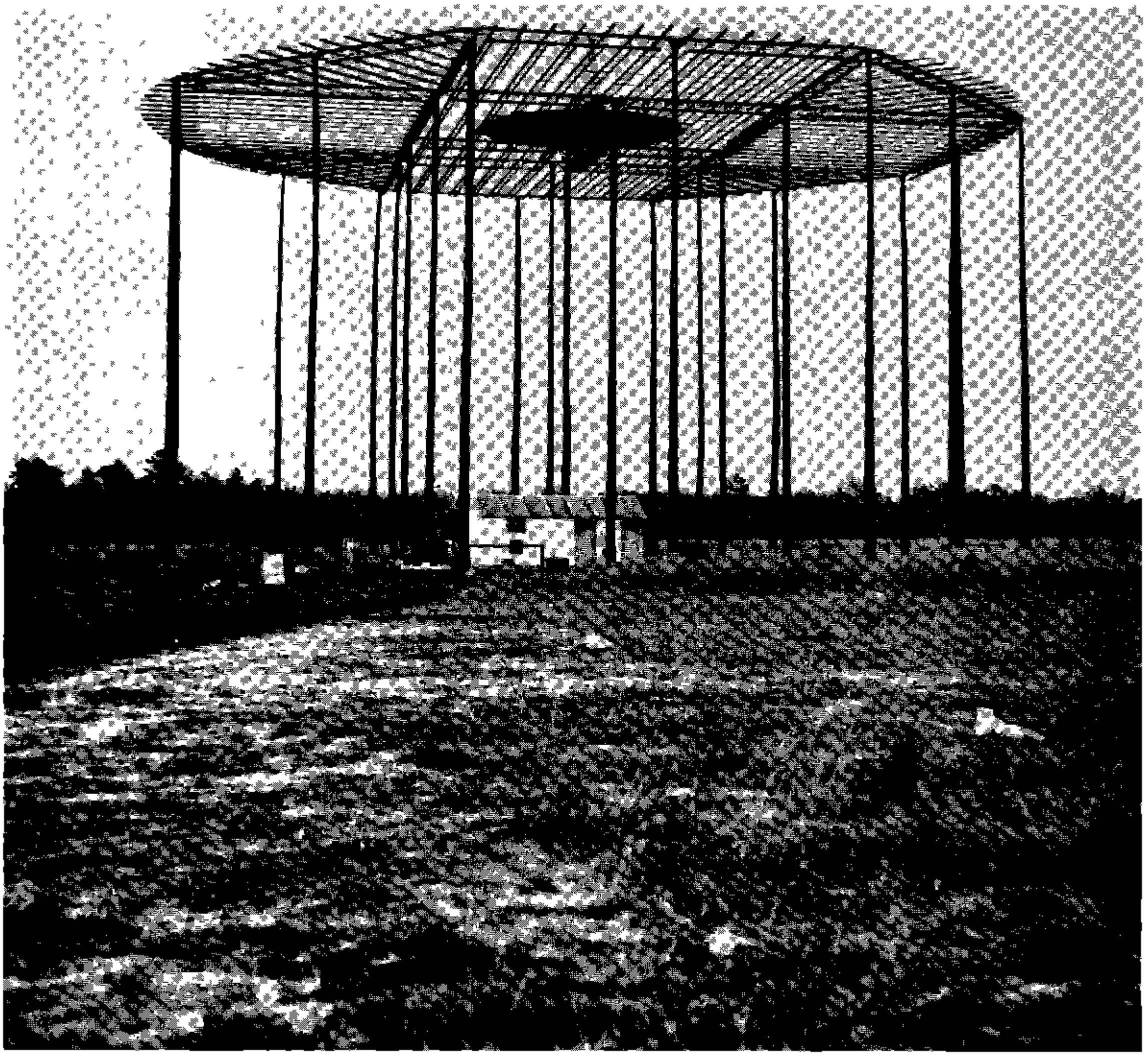


FIG. 2 GROUND VIEW OF CHARLESTON, S. C., VOR - COUNTERPOISE 150 FEET IN DIAMETER AND 75 FEET HIGH

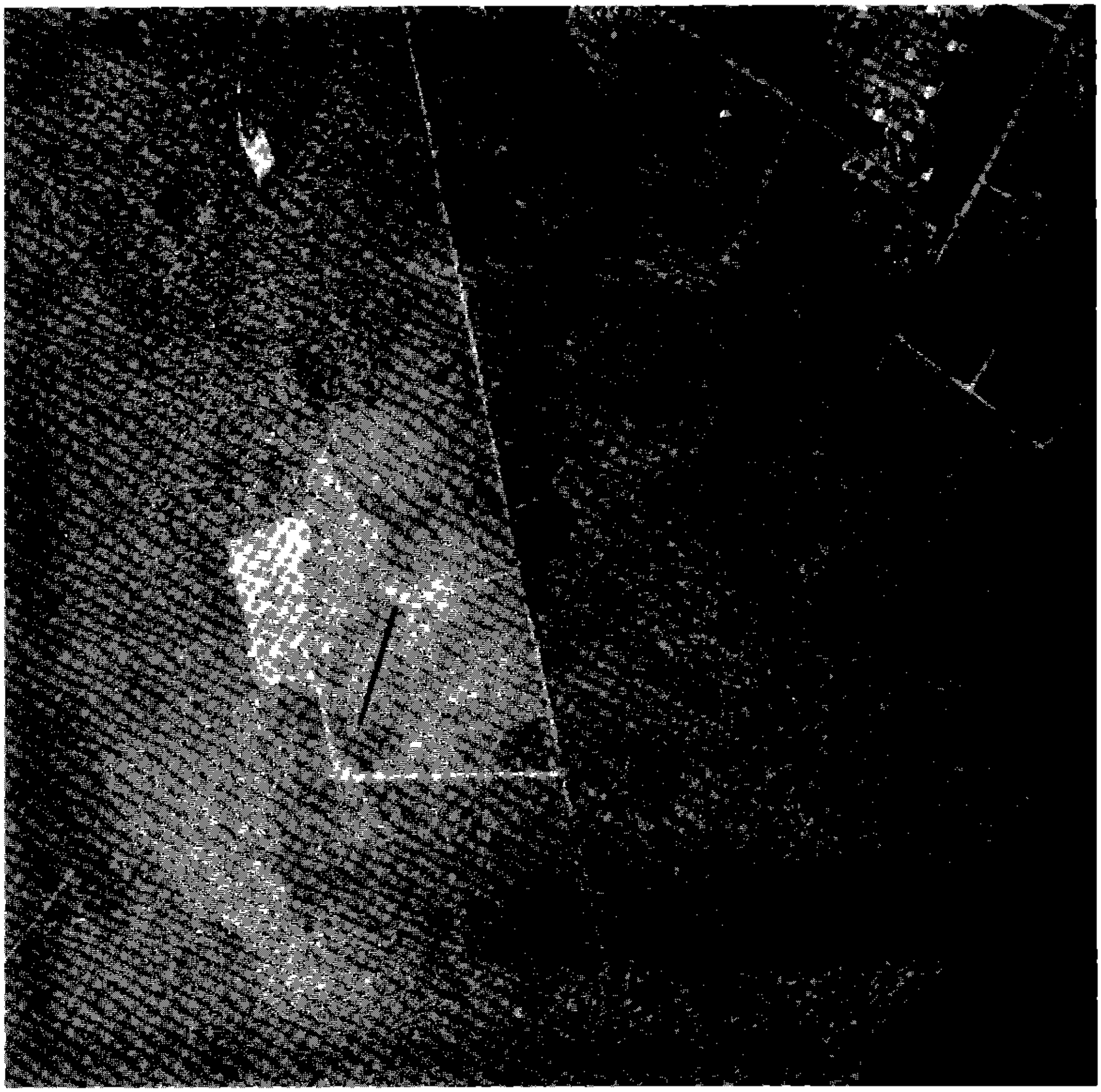
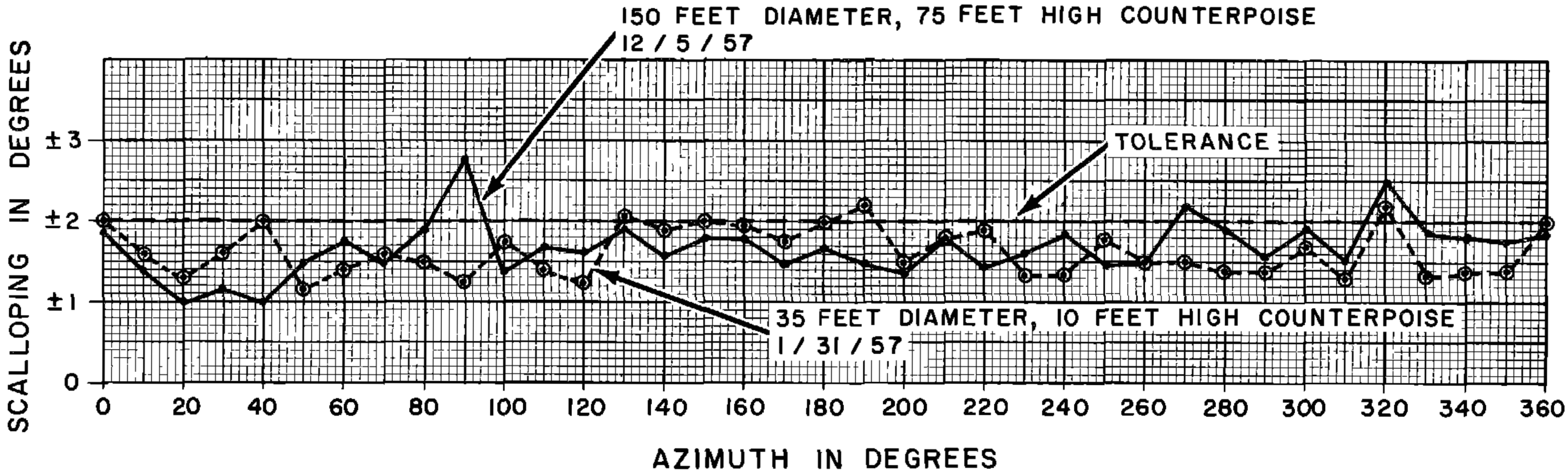


FIG. 3 AERIAL VIEW OF CHARLESTON, S. C., VOR SHOWING TREES SURROUNDING STATION




NOTE

DATA TAKEN DURING ORBITAL FLIGHTS AT A 20 MILE RADIUS

FIG. 4 COURSE SCALLOPING CHARLESTON, S. C., VOR TWO SIZES OF COUNTERPOISE

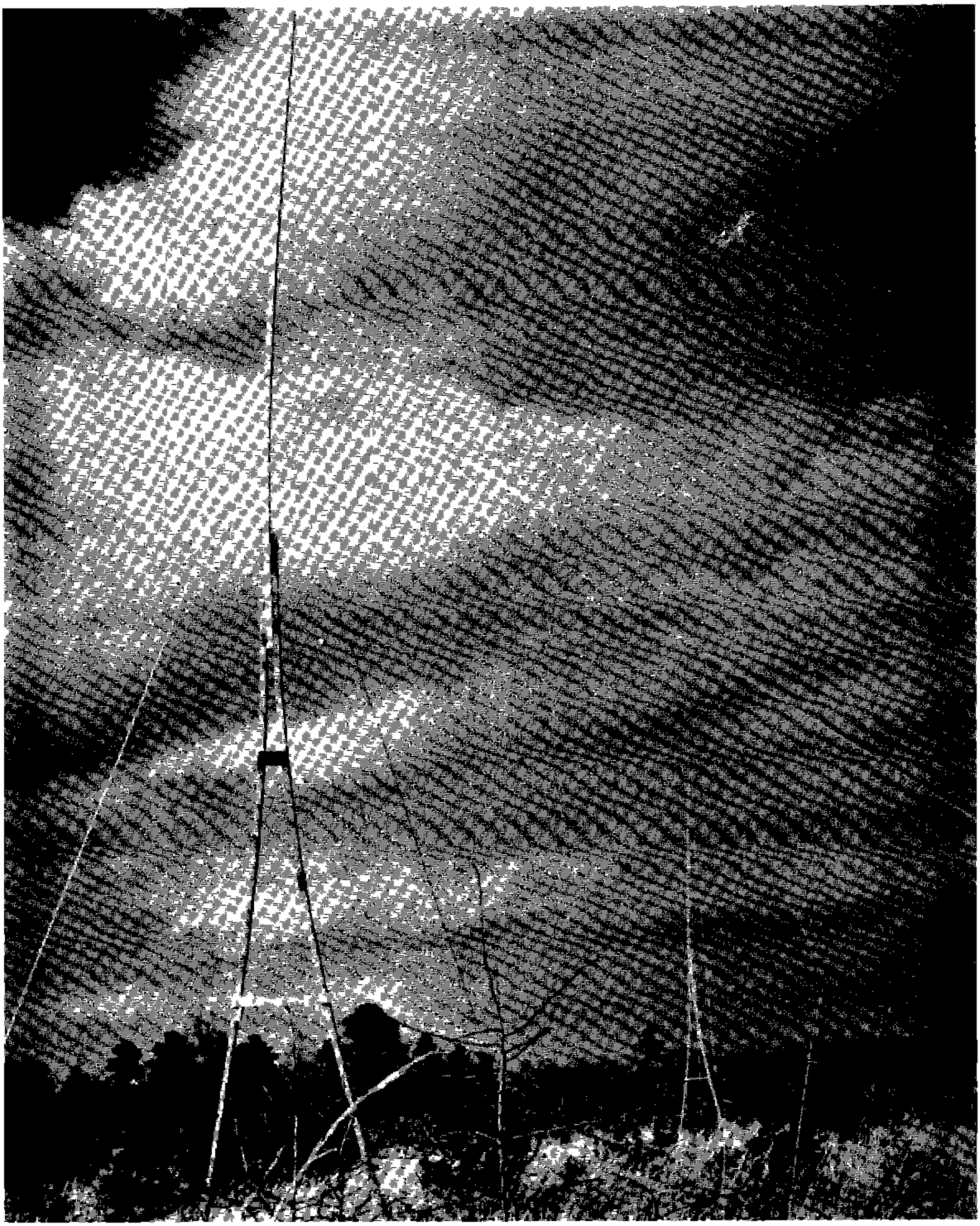


FIG. 5 WIRE REFLECTOR - CHARLESTON, S. C., VOR SITE

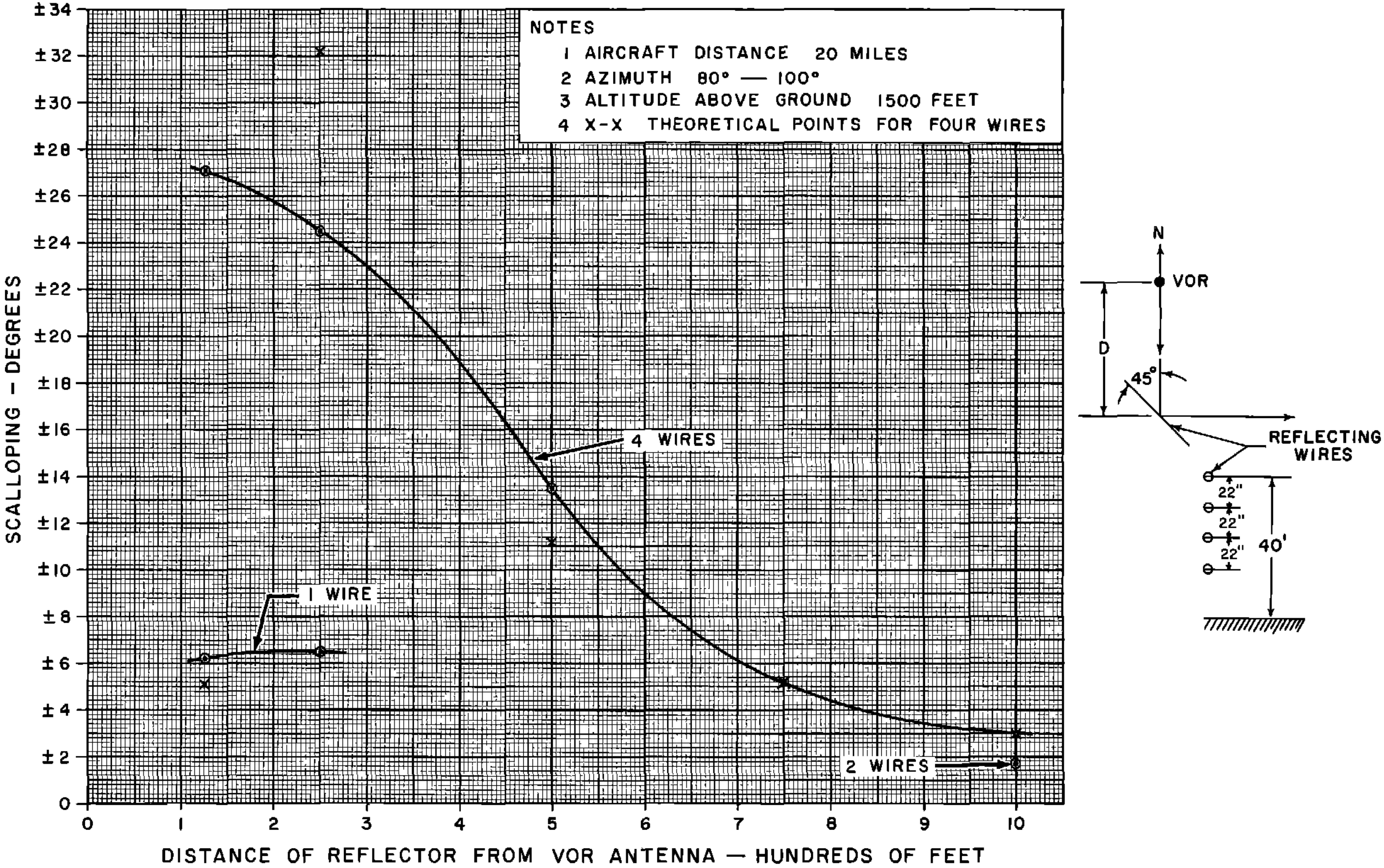



FIG. 6 COURSE SCALLOPING DUE TO HORIZONTAL WIRE REFLECTOR AT TDC VOR

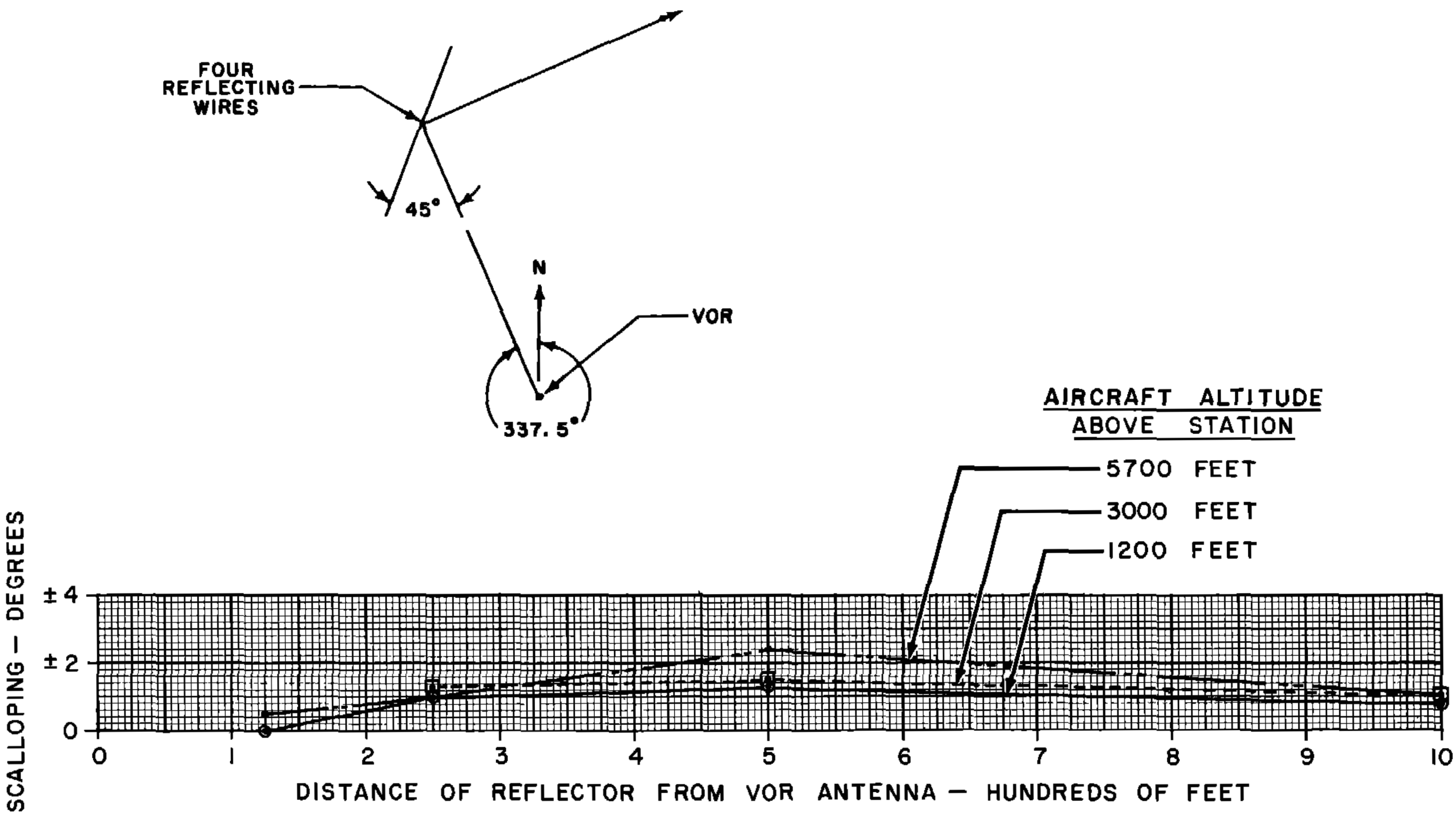



FIG. 7 COURSE SCALLOPING DUE TO HORIZONTAL WIRE REFLECTOR AT CHARLESTON, S. C., VOR

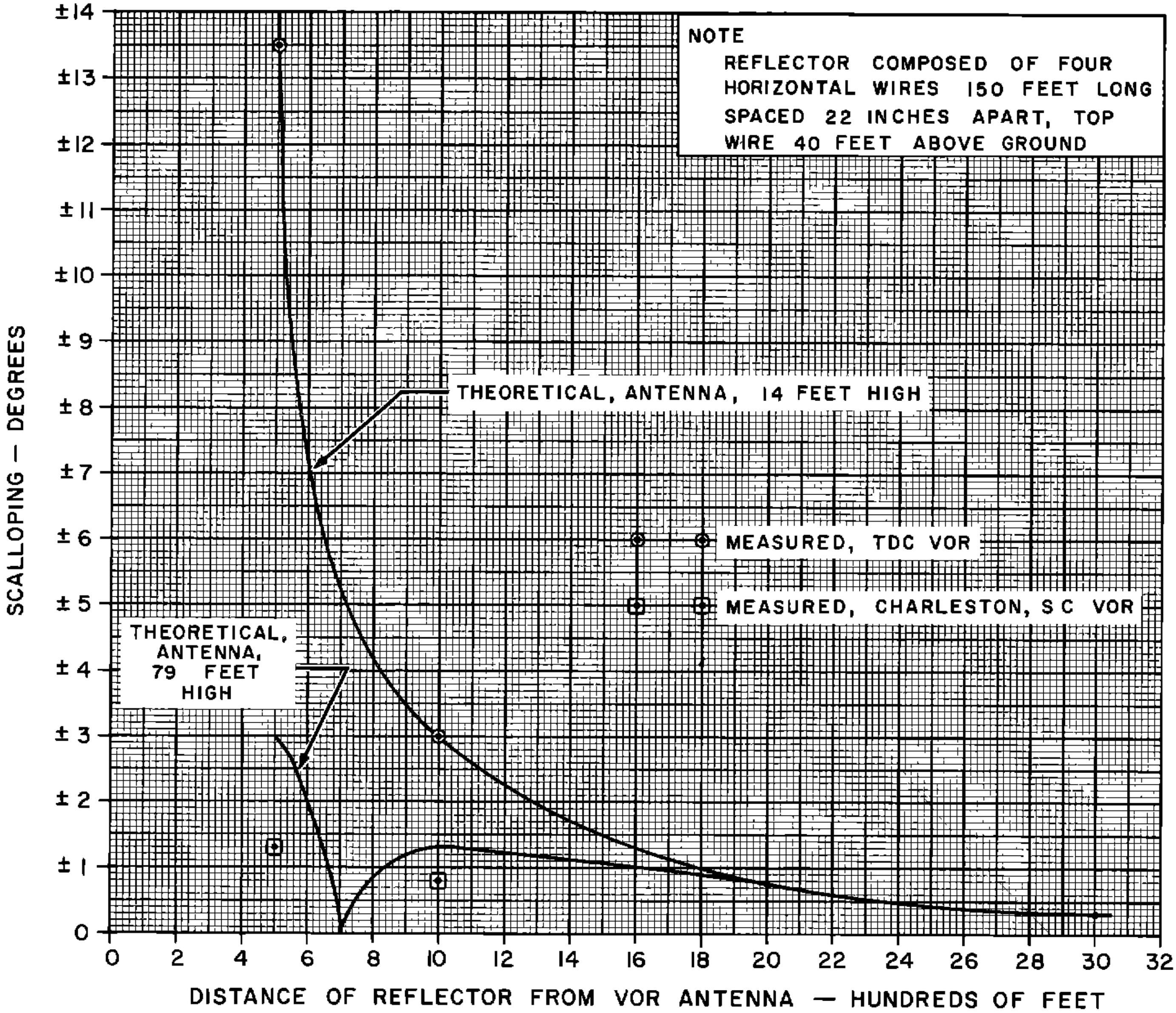
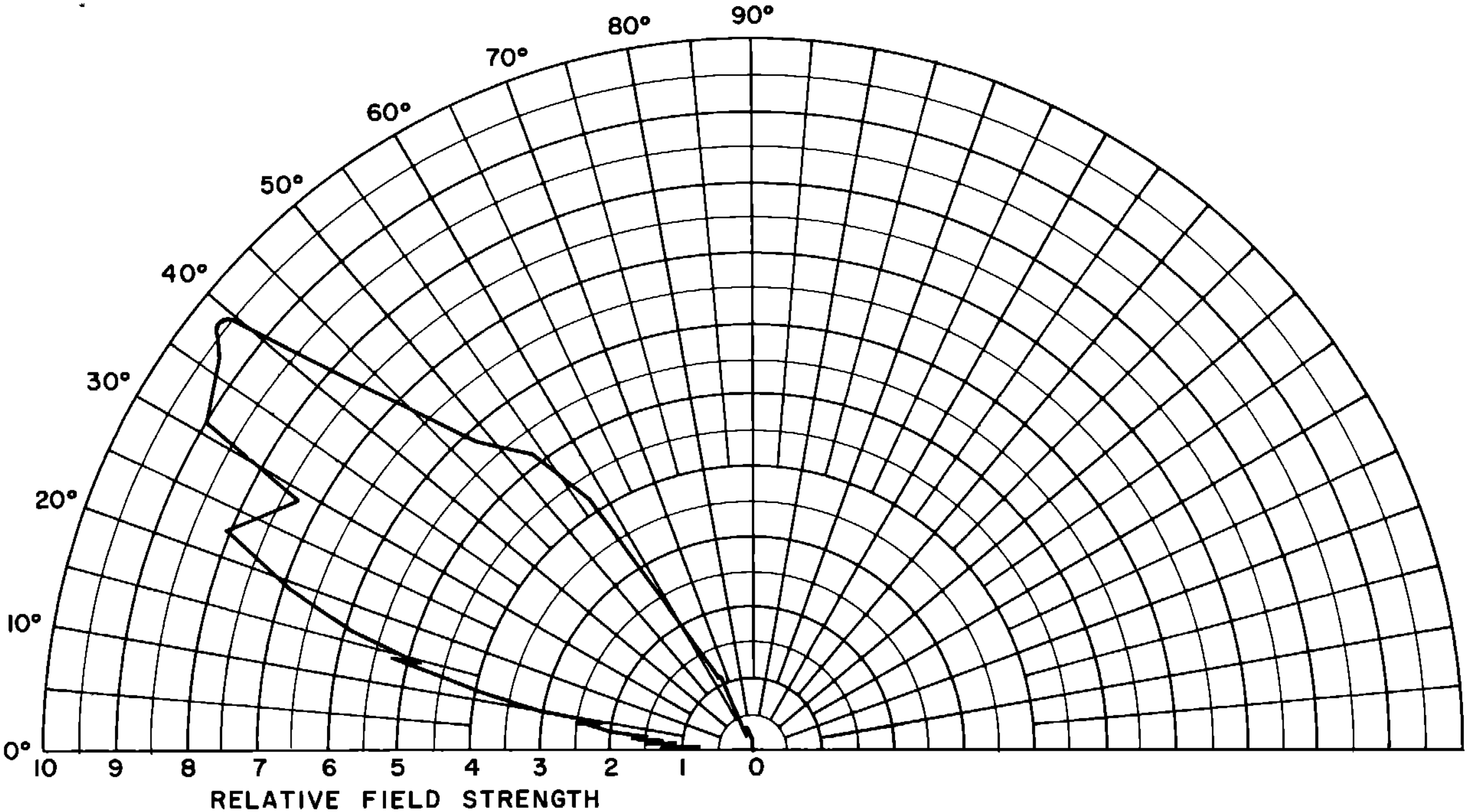
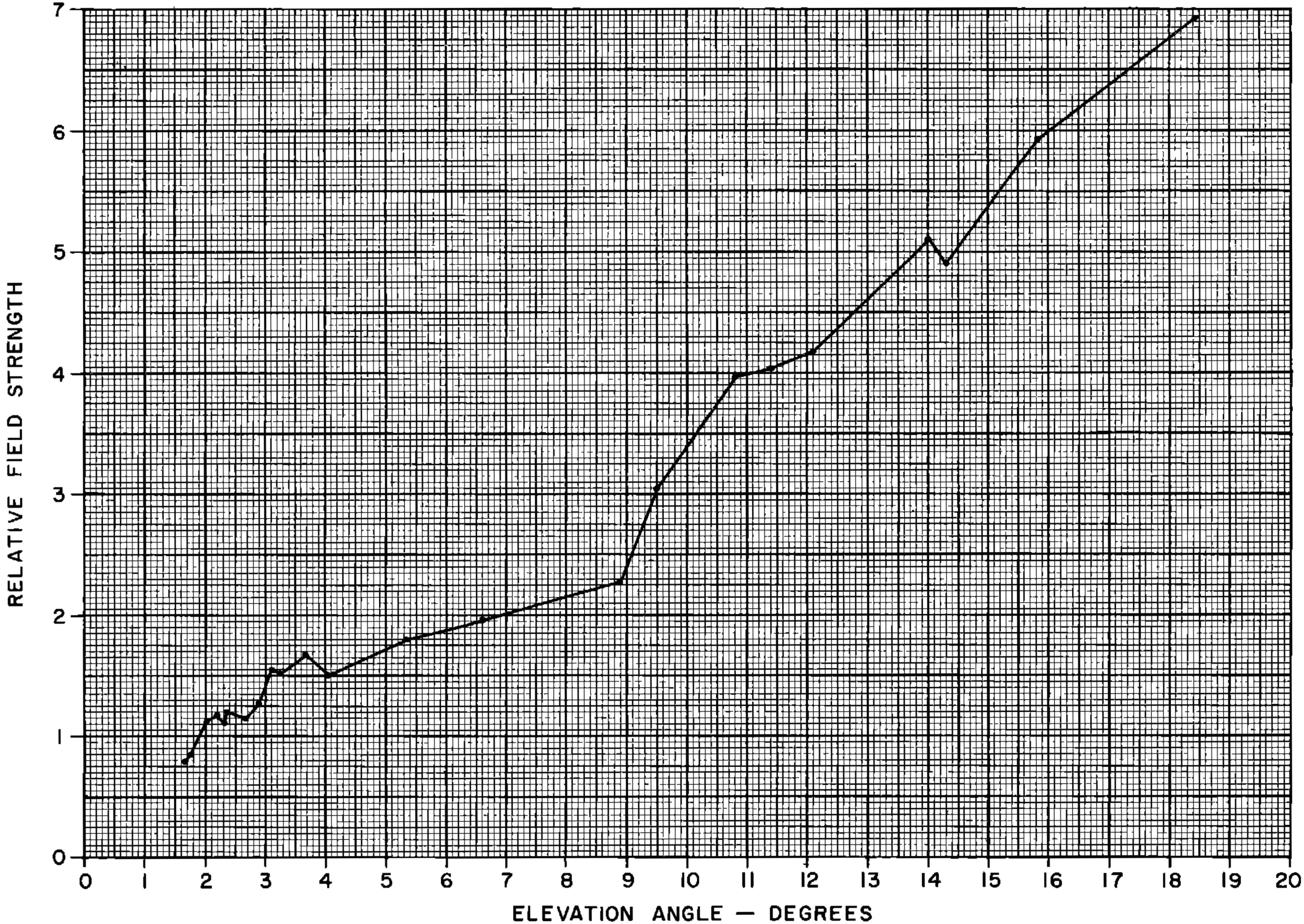



FIG. 8 COURSE SCALLOPING CAUSED BY HORIZONTAL WIRE REFLECTOR




NOTE
COUNTERPOISE 75 FEET HIGH
AND 150 FEET IN DIAMETER

FIG. 9 VERTICAL PLANE RADIATION PATTERN OF CHARLESTON, S. C., VOR




NOTE DATA TAKEN FROM FIGURE NO 9

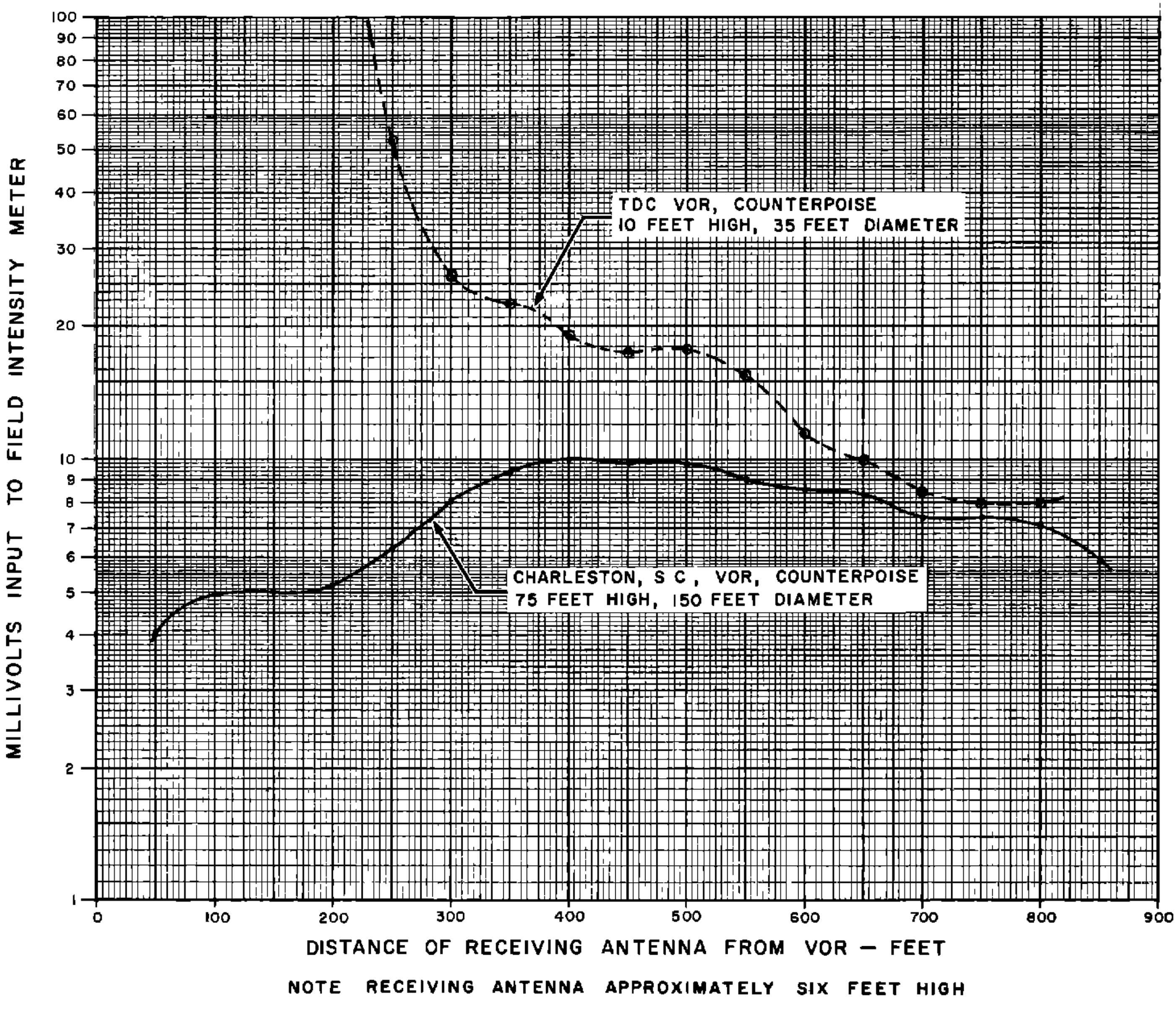



FIG. 11 GROUND FIELD STRENGTH ALONG RADIALS