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# MLS Antenna Locations For The de Havilland DASH 7 Aircraft

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# MLS ANTENNA LOCATIONS FOR THE de HAVILLAND DASH 7 AIRCRAFT

by

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## SUMMARY

The first commuter airline to utilize the new Microwave Landing System (MLS) will be Ransom Airlines operating between the Washington and Philadelphia areas. The airline will use de Havilland DASH 7 aircraft. Several proposed aircraft antenna locations were investigated to determine their potential for satisfying the MLS antenna coverage requirements. The results of this investigation are presented and antenna locations are recommended for the de Havilland DASH 7 aircraft.

## INTRODUCTION

The first commuter airline to be used in the Federal Aviation Administration's MLS flight test program, STEP (Service, Test and Evaluation Program) is scheduled to start operating with the MLS in the late summer of 1981. To insure that the required antenna pattern coverage is provided by the airborne antennas, scale model measurements or calculations must be done to determine the antenna performance. The antenna location has a very significant affect on the pattern coverage, therefore, the location must be optimized when it's necessary to satisfy a certain set of pattern coverage requirements. Typical airborne antenna coverage requirements (References 1, 2) for large commercial aircraft range from 25 to 30 degrees above the horizon to 30 to 40 degrees below the horizon with complete 360 degree coverage in azimuth. It is assumed that the commuter aircraft requirements are similar.

The objective of this work was to investigate the antenna locations available for MLS applications and, based on antenna performance, recommend the antenna locations that would better satisfy the MLS antenna coverage requirements. A scale model of the front section of the de Havilland DASH 7 was constructed for evaluating those antenna locations on the forward nose and top fuselage. Calculations were performed for other locations under consideration.

## ANTENNA LOCATIONS

Several proposed antenna locations on the de Havilland DASH 7 were investigated and these are shown in Figure 1. Locations 3 and 4 were selected, prior to any antenna measurements or calculations, because of their proximity to the MLS electronics and available mounting fixtures. These locations; however, do not provide the optimum antenna pattern coverage. The antenna at location 3 (station 97.75) is mounted on a 20.3 cm (8 in.) square ground plane which is attached to the fiberglass nose section. Top forward fuselage locations are desirable because adequate elevation plane coverage can be obtained and normally better azimuth coverage is provided than for a bottom fuselage location that is influenced by the landing gear. Two top forward fuselage locations were investigated. Location 1 is at station 231.7 and location 2 at station 189.5. Location 1 was chosen for evaluation because of an existing mounting fixture. This location appears to be too far back on the fuselage to provide the required down coverage in the forward sector.

To provide coverage in the rear sector for MLS approaches and missed-approaches an antenna must be located on the bottom rear fuselage. The bottom fuselage locations investigated were at stations 354.0 (location 4) and 714.50 (location 5).

## ANTENNA RADIATION PATTERNS

Radiation patterns were measured for some of the proposed antenna locations and calculated for the others. A one-seventh scale model of the front portion of the de Havilland DASH 7 aircraft was constructed for evaluating the forward antenna locations. The test model is shown in Figure 2. Radiation patterns were measured for the two top forward fuselage locations and the nose location. The antennas measured were one-quarter wavelength monopoles and one-quarter wavelength monopoles with reflectors. The monopoles with reflectors were used to simulate the actual flight antennas. The measurements were conducted at 35 GHz since a one-seventh scale model was used. The nose section of the test model (i.e., between stations 74 and 147.0) was constructed from thin fiberglass material to simulate the test aircraft. Measurements were also conducted with the nose avionics compartment, between body stations 97.75 and 147.0, covered with a conducting metal foil. The foil simulates the production aircraft which will have an aluminum acreen on the outer surface of this compartment to prevent structural damage from lightning strikes and to shield the avionics from the indirect effects of a lightning strike.

Radiation patterns measured for a centerline mounted monopole at location 1 are presented in Figure 3. Results for a dielectric nose compartment only are given since the nose compartment has a very small effect on the antenna performance at this location.

The conducting nose should provide essentially the same results. As indicated by the elevation pattern shown in Figure 3(a), this location is not suitable because the required down coverage in the forward region is not provided. A more forward location on the down sloping part of the fuselage is required to improve the down coverage; therefore, location 2 was chosen for evaluation. Measurements were performed for several different test conditions at location 2. For the final flight configuration a back-up system will be used requiring an additional antenna located at the same station location and separated by at least 20.3 cm (8 in.). Measurements were conducted simulating this condition with two antennas to determine the influence of a second antenna on the radiation patterns of the primary antenna. The primary antenna was fed and the secondary antenna was terminated in a 50 ohm matched load during the measurements. Both monopoles and monopoles with reflectors were used. The results are given in Figure 4 for two monopoles spaced 3.0 cm (1.2 in.) apart at location 2 with a fiberglass nose compartment. The fiberglass nose compartment was covered with a conducting metal foil and the measurements were repeated. These results are shown in Figure 5. By comparing the elevation patterns in Figures 4(a) and 5(a) one can see the effect of the conducting nose compartment. The radiation shown in Figure 4(a) in the region from theta equals 120 to 140 degrees has been reduced considerably by the conducting nose compartment as shown in Figure 5(a). The pattern fluctuations above the nose in the forward direction increased slightly due to reflections off the conducting nose. The effects of the secondary antenna appear to be limited primarily to small pattern fluctuations visible in the azimuth patterns of Figures 4(c) and 5(c) in the phi = 180 to 300 degrees region.

A reflector was added behind the monopoles to direct the radiation forward and simulate the actual flight antennas. The patterns measured for a single monopole with reflector at location 2 are shown in Figure 6 for the fiberglass nose. Figure 7 shows the results obtained for the same test conditions except now the nose compartment is conducting. Essentially the same effects are observed on the forward portions of the elevation patterns as those observed for the monopole case. The down coverage is reduced in the theta equals 120 to 140 degree range and the pattern fluctuations above the nose increase for the conducting nose compartment condition. When the secondary antenna is installed the azimuth pattern fluctuations in the phi range of approximately 180 to 300 degrees increase slightly as shown in Figure 8(c).

The antennas measured at location 3 were mounted on a 3.0 cm (1.2 in) square ground plane simulating the 20.3 cm (3 in.) ground plane used on the actual aircraft. The ground plane was bonded directly to the fiberglass nose section as shown in Figure 2(b). The antennas evaluated at this location were mounted on the centerline of the scale model. The radiation patterns measured for a monopole at location 3 for a fiberglass nose are presented in Figure 9. Large fluctuations are present in all the patterns caused by the small ground plane size and scattering off the metal bulkhead at station 147.0 and the nose landing gear. A reflector was added behind the monopole and the results obtained for that antenna are given in Figure 10. The forward portion of the pattern improved considerably; however, there is still to much radiation on the bottom of the aircraft. Only the elevation and azimuth patterns are presented for this series of measurements. The roll plane patterns are not presented; however, the azimuth patterns can be used to obtain an indication of the roll plane levels. The ground plane size was increased in the forward direction in an effort to improve the patterns and these results are presented in Figures 11-13. Figure 11 shows the results obtained for an increase in the ground plane size in front of the antenna of 2.2 cm (0.875 in.) providing a total ground plane length in the forward direction of 3.75 cm (1.475 in.) while maintaining the same ground plane size 1.5 cm (0.60 in.) in the rear direction. This improved the forward coverage somewhat and lowered the radiation below the aircraft. The ground plane was increased again in the forward direction by 2.2 cm (0.875 in.) and the results obtained for this case are shown in Figure 12. Further improvement can be seen in the elevation pattern, Figure 12(a). Figure 13(a) shows more improvement in the elevation pattern when the ground plane is increased to a total length of 8.2 cm (3.2 in.) in the forward direction. Most of the pattern fluctuations in the forward direction and the radiation below the aircraft were caused by strong illumination of the ground plane edges and possibly surface wave effects. The patterns can be improved to provide very good forward region courage by using a larger ground plane; however, the ground plane size required may be to large to be used at this location.

The radiation patterns of antennas at locations 4 and 5 were calculated since it was not possible to perform measurements for those locations with the scale model available. These calculations were done at NASA Langley Research Center using computer programs developed at the Ohio State University. The calculations were performed by Timothy J. Kneer, a Graduate Research Assistant from the Old Dominion University, working at NASA LaRC on NASA Research Grant NSG 1655. Calculations of the elevation and roll plane patterns were done for monopole antennas; however, the results should indicate the type of coverage that can be obtained in the rear direction of the elevation plane at the different locations. The results obtained for locations 4 and 5 are presented in Figures 14 and 15 respectively. Location 4 doesn't provide enough up coverage in the tail region plus blockage and scattering off the landing gear can degrade the coverage. The up coverage is improved at location 5 and the landing gear effects are reduced; however, additional improvement can be achieved by moving farther back on the aircraft. Station locations as far back as 793.4 could be used; however, a bulkhead at this station would make locations beyond that point less desirable because the installation becomes more difficult and the cable loss increases.

## CONCLUDING REMARKS

Several proposed MLS antenna locations on the de Havilland DASH 7 aircraft were investigated. The antenna pattern measurements and calculations show that at least two MLS antennas are required to provide the necessary coverage. The top forward fuselage locations provide adequate coverage for the front sector, and the bottom rear fuselage location gives good coverage in the rear sector. The coverage provided by the two antennas together should satisfy the MLS requirements.

The MLS antenna locations recommended, based on the results of this study, for the de Havilland DASH 7 are location 2 (station 189.5) for providing the front sector coverage and a location on the bottom rear fuselage as near station 793.4 as possible to provide good rear sector coverage.

## REFERENCES

1. Gilreath, Melvin C., and White, William F.: "Flight Test Evaluation of Microwave Landing System Airborne Antennas," IEEE AP-S International Symposium Digest, May 1978.

2. Thompson, A. D., Stapleton, B. P., Walen, D. B., Reider, P.F., and Moss, D. G.: "MLS-Airplane System Modeling" Boeing Commercial Airplane Company, NASA Contractor Report 165700, NAS1-14880, April 1981.

| Location | Station |
|---|---|
| 1 | 231.70 |
| 2 | 189.50 |
| 3 | 97.75 |
| 4 | 354.00 |
| 5 | 714.50 |

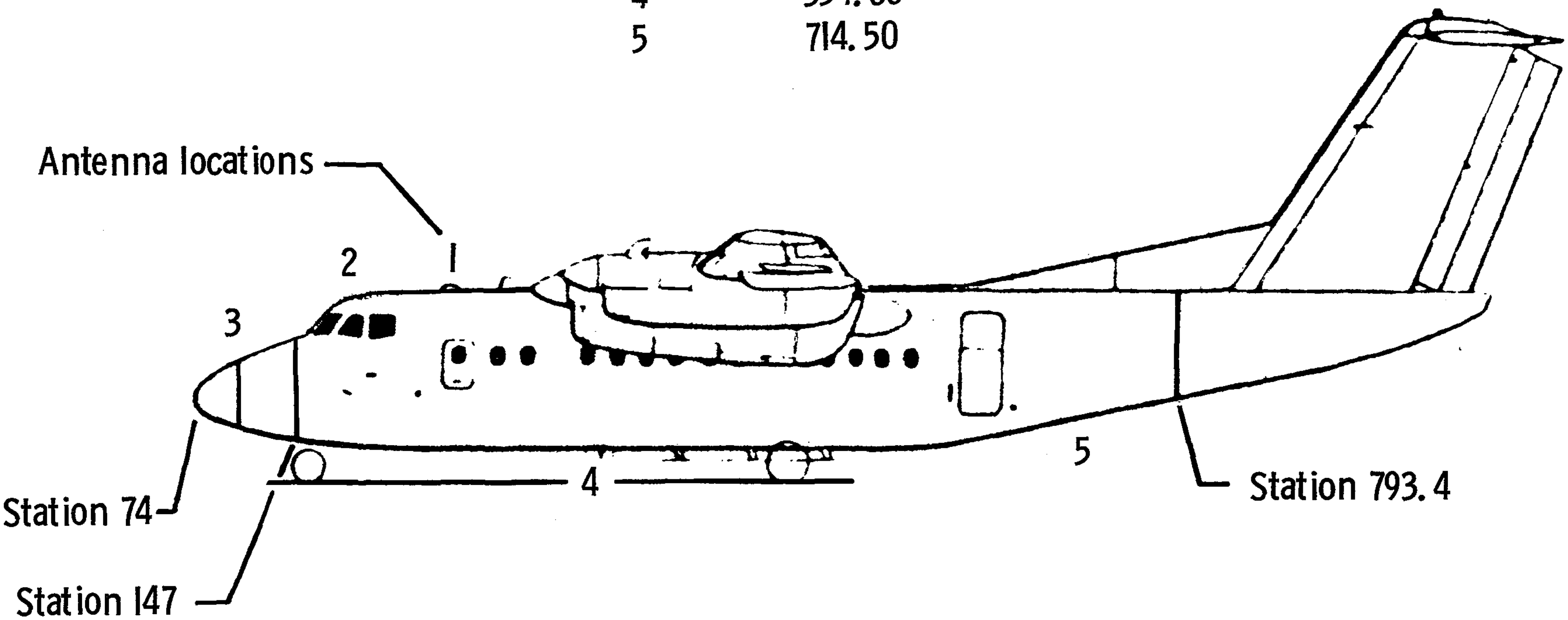



Figure 1. Antenna locations on deHavilland DASH 7.

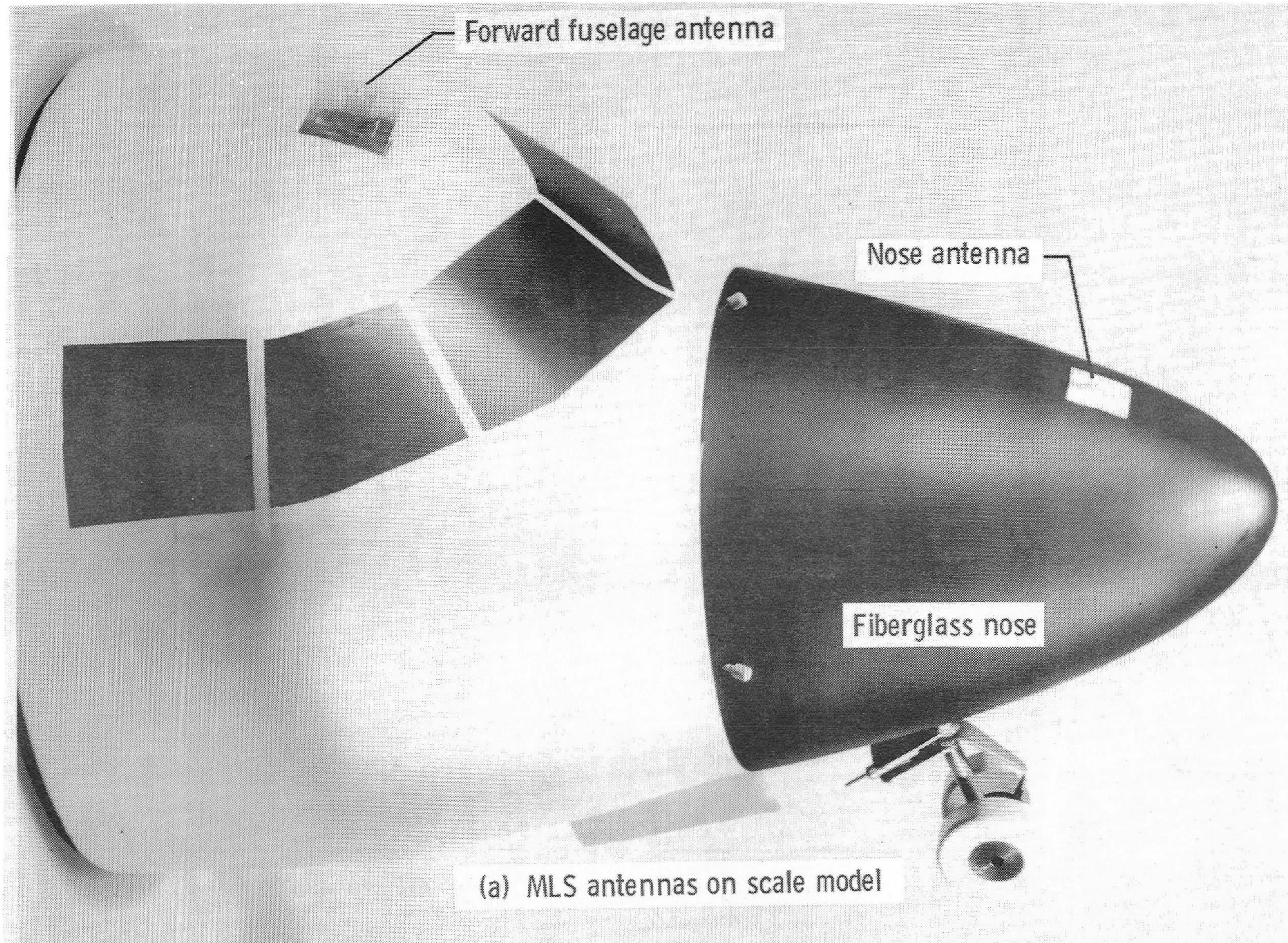
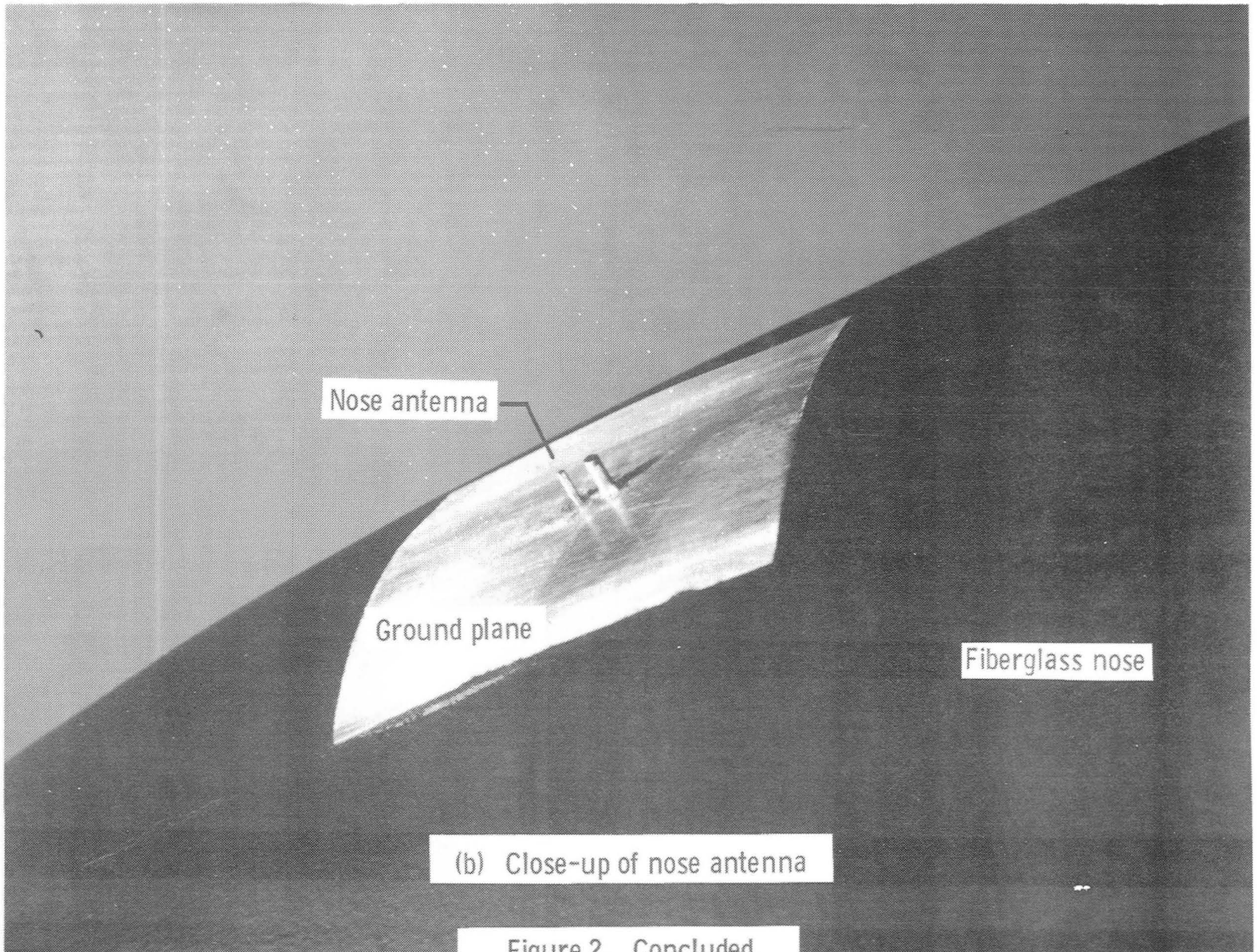



Figure 2. One-seventh scale model of forward section of deHavilland DASH 7 aircraft.



(b) Close-up of nose antenna

Figure 2. Concluded.

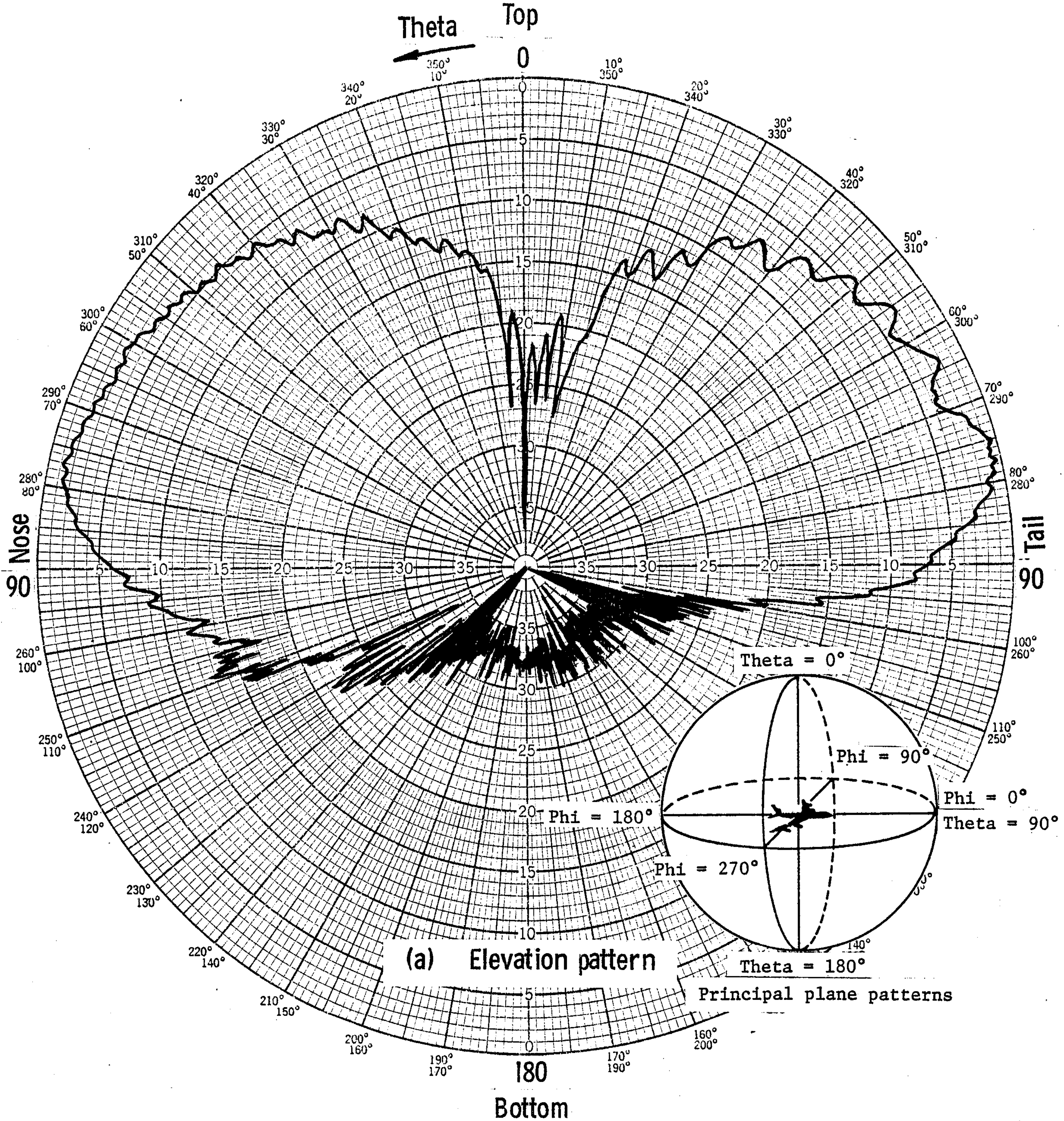
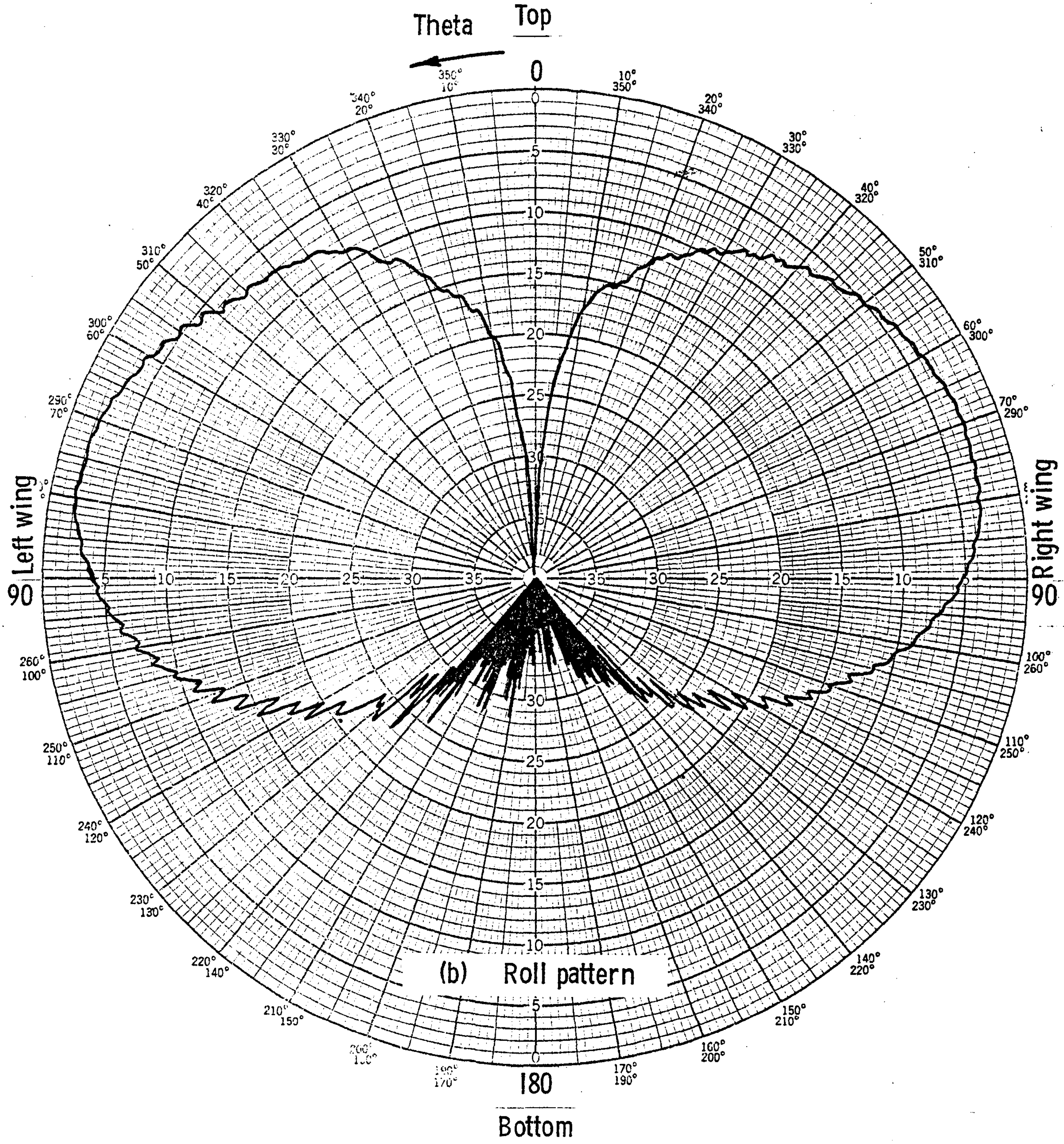



Figure 3. Measured principal plane patterns of a monopole at location no. 1.

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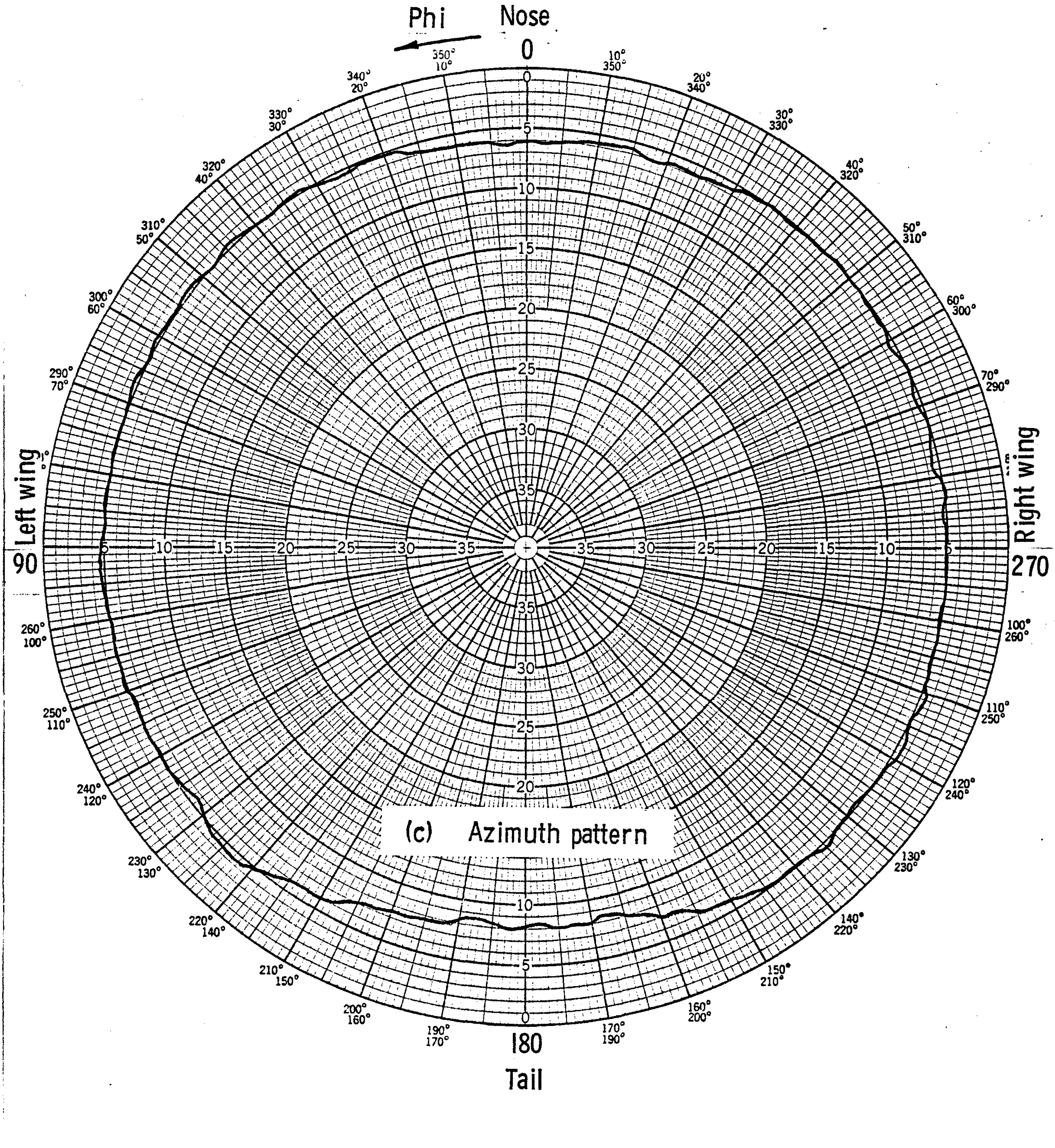


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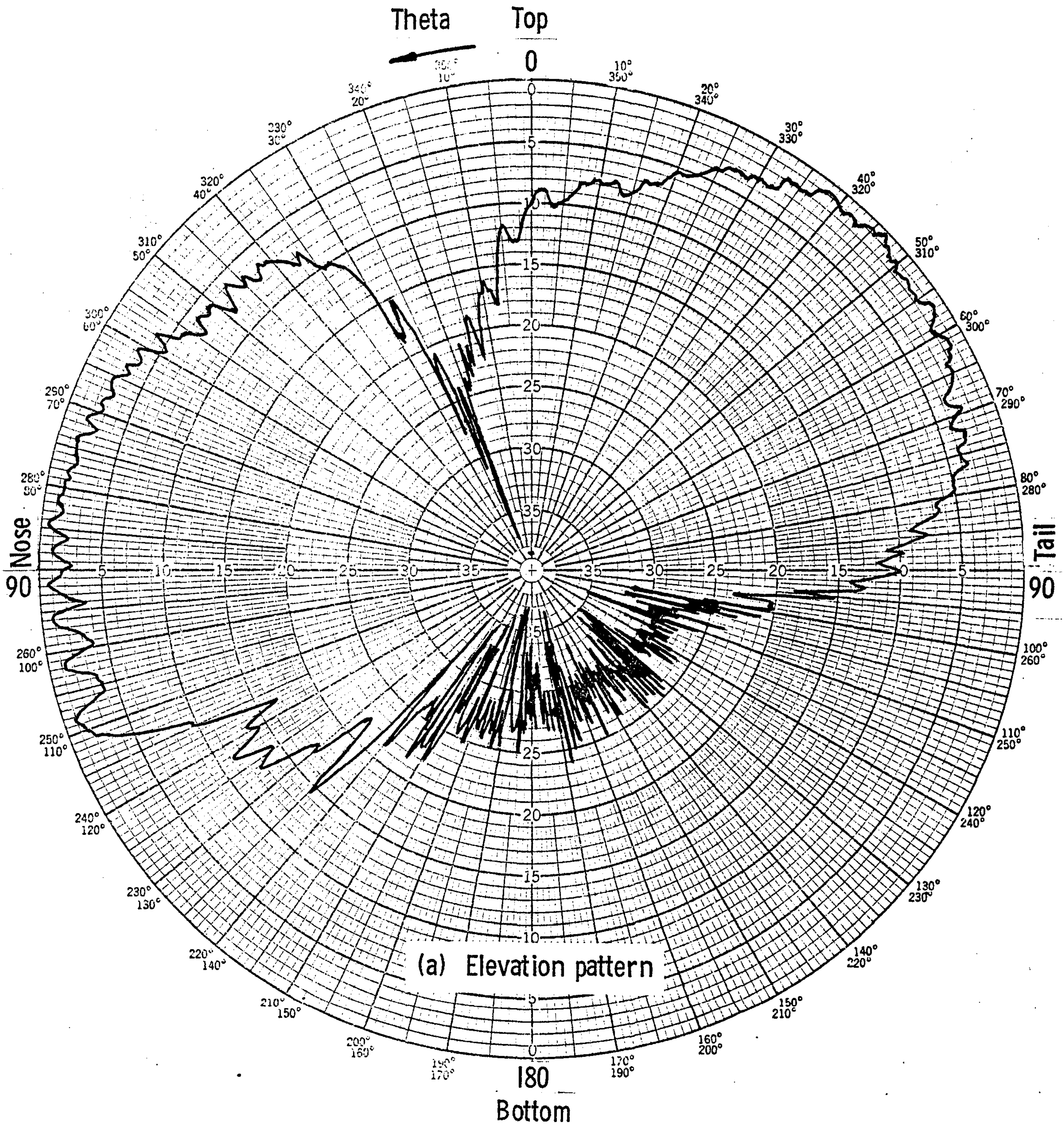



Figure 4. Measured principal plane patterns of two monopoles spaced 3 cm (1.2 in) apart at location no. 2 with a fiberglass nose.

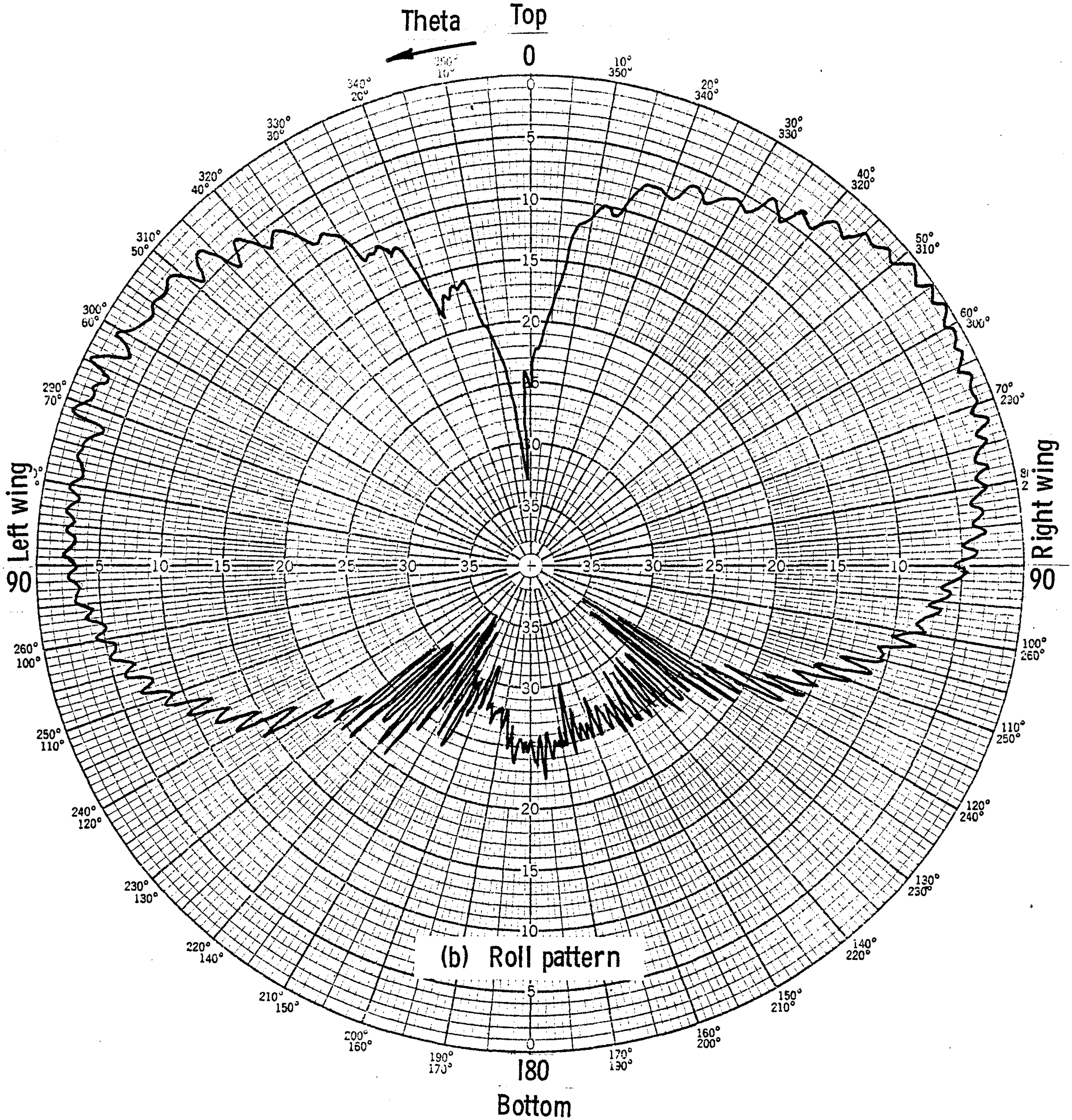
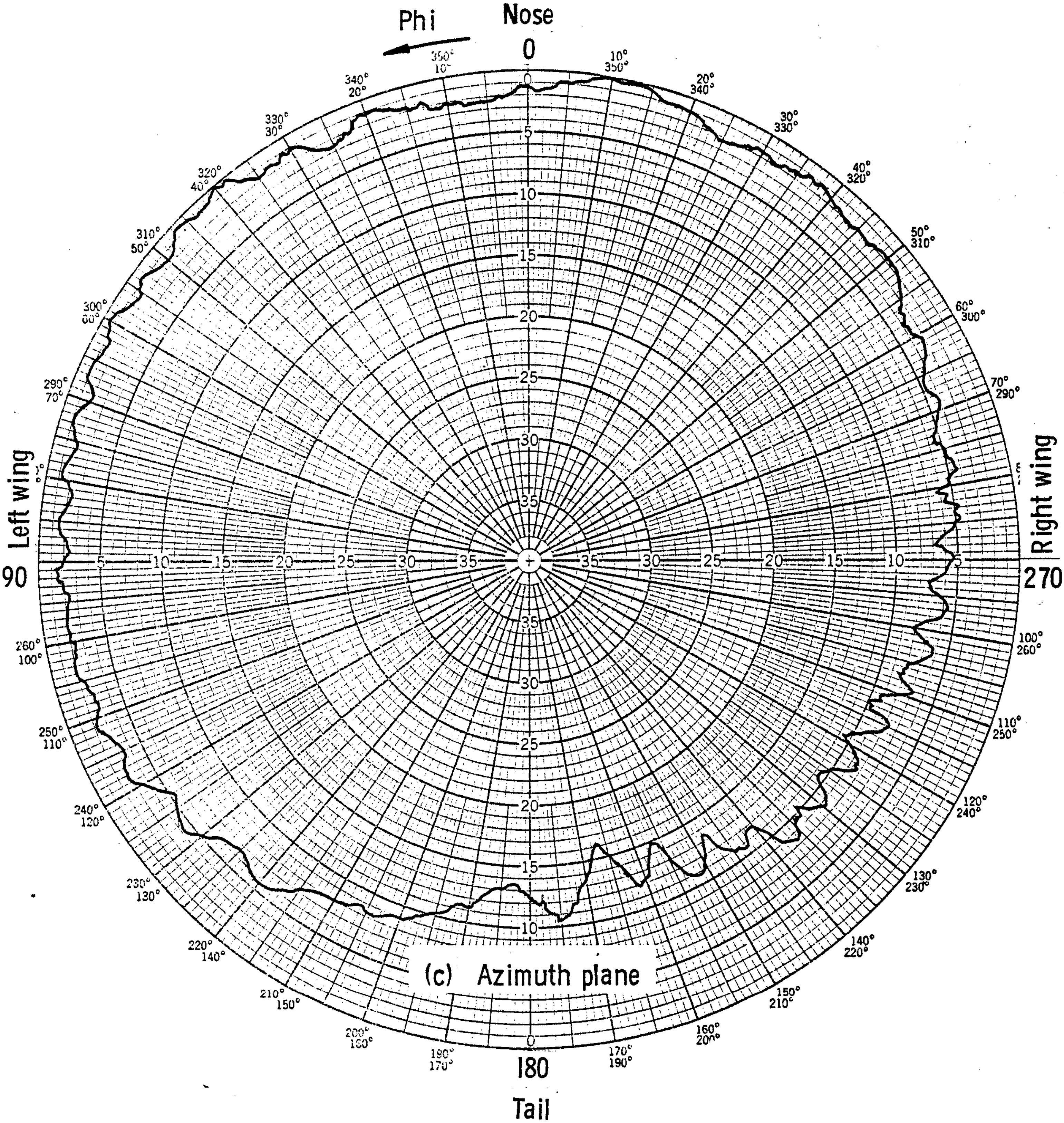



Figure 4. Continued.

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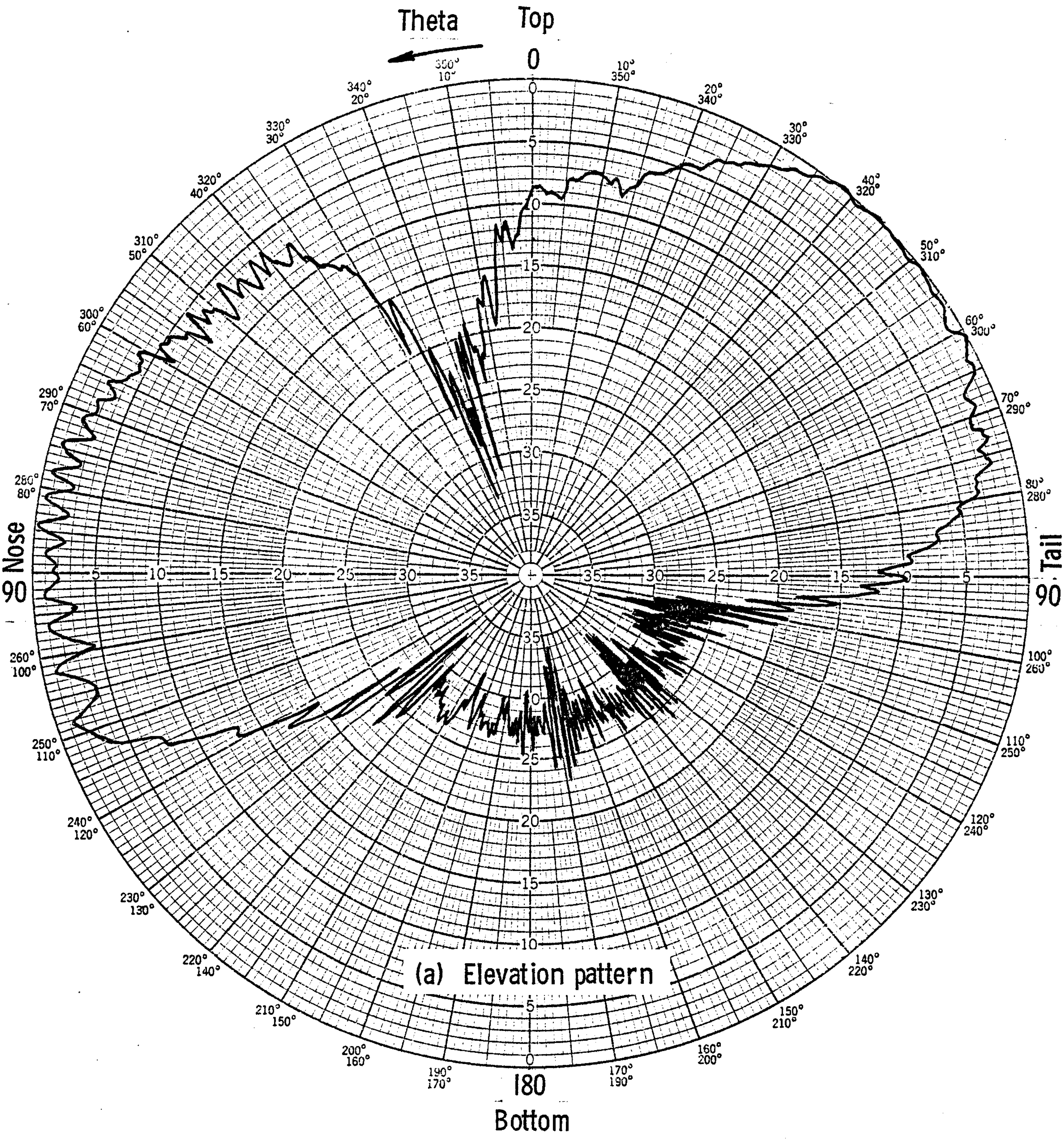
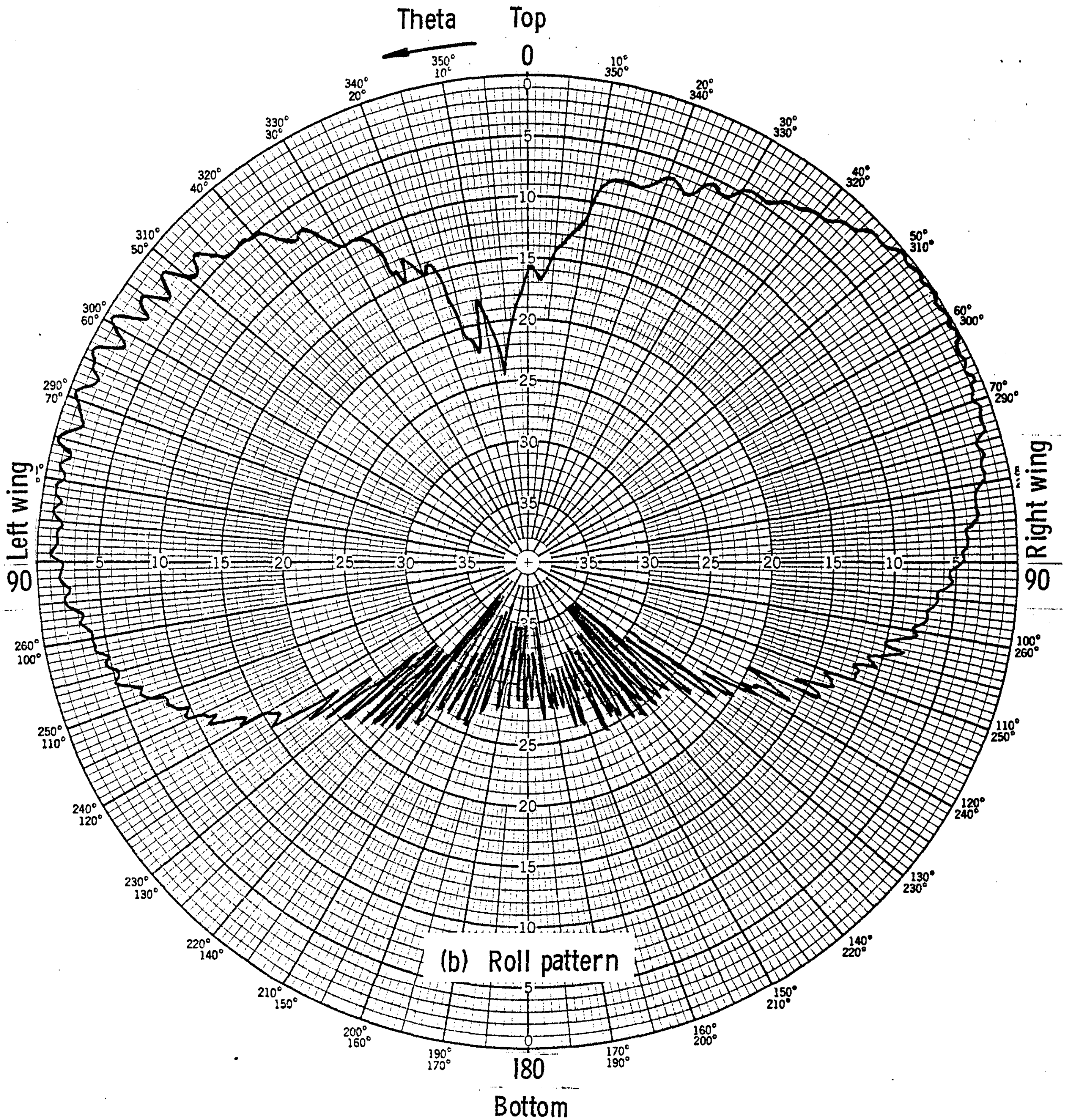



Figure 5. Measured principal plane patterns of two monopoles spaced 3 cm (1.2 in) apart at location no. 2 with a conducting nose.

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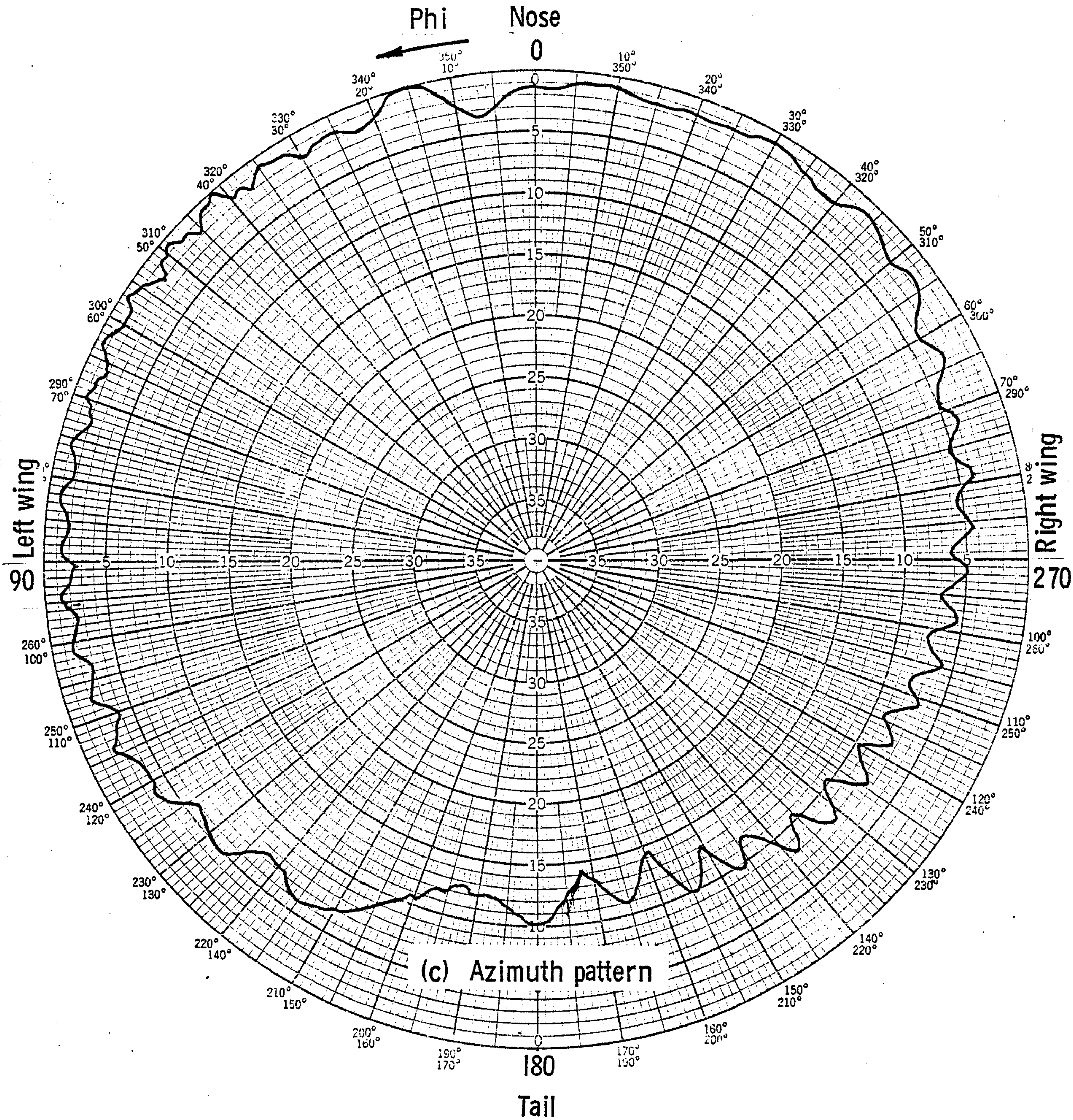


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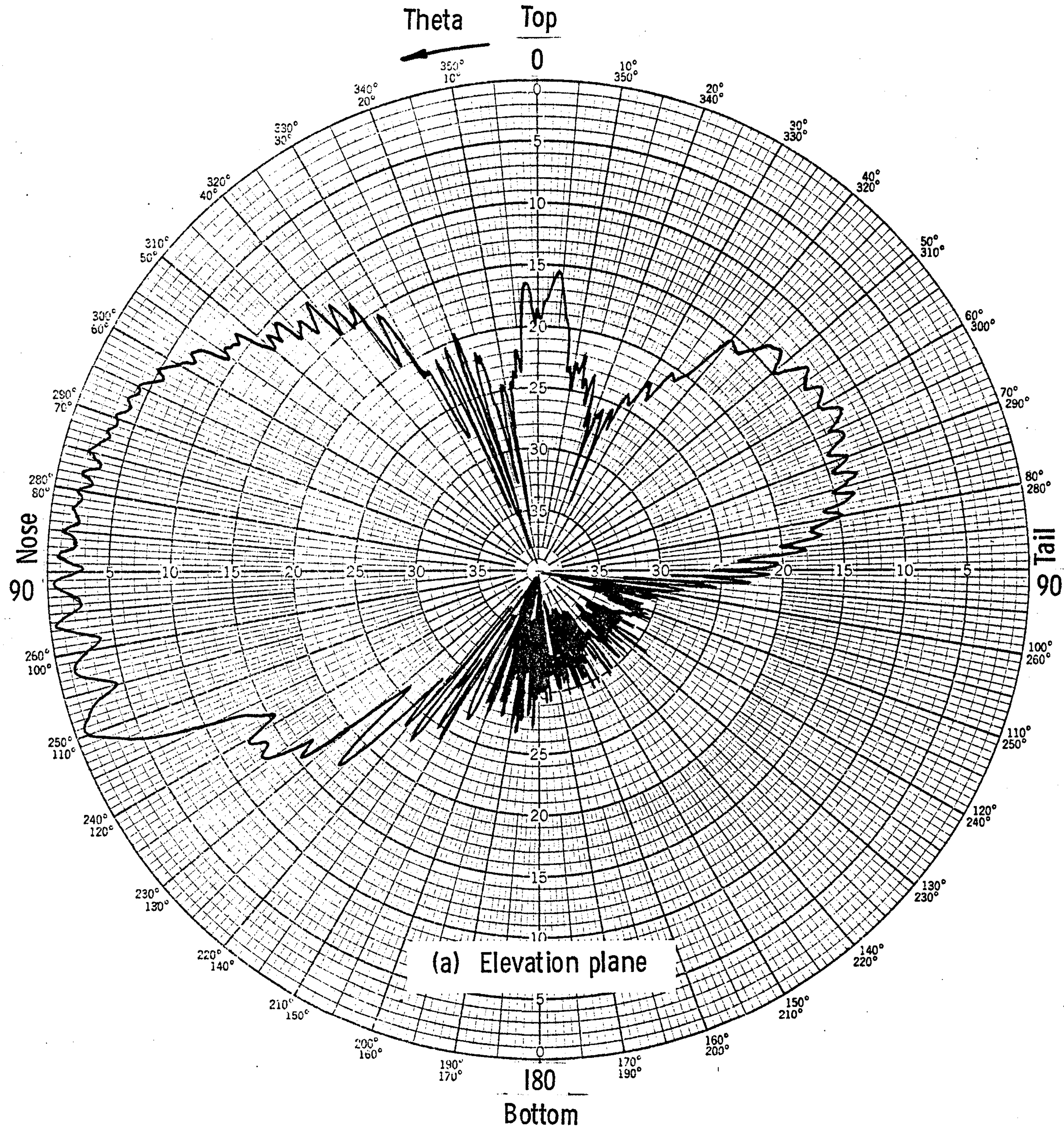
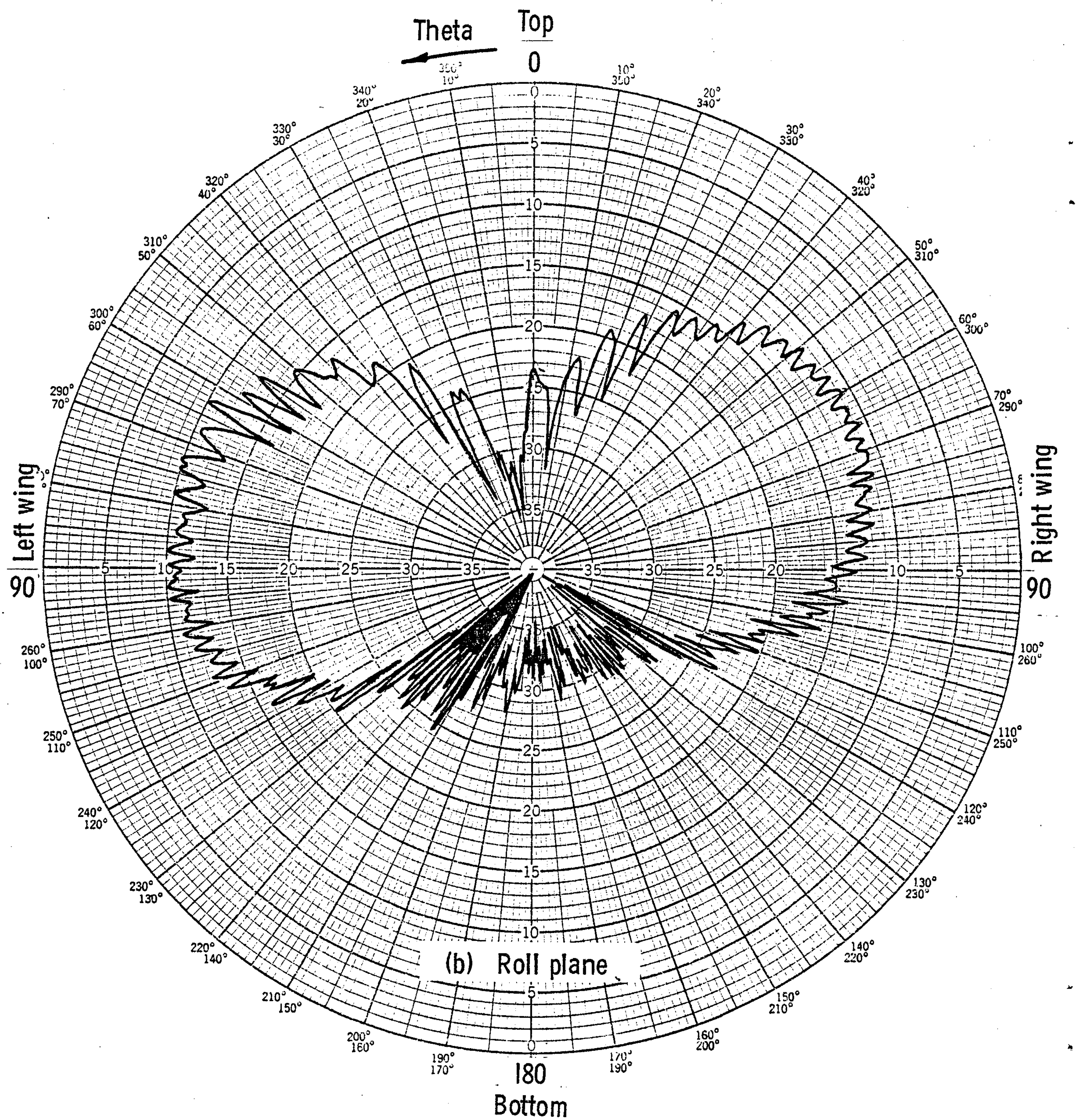



Figure 6. Measured principal plane patterns for a single monopole with reflector spaced 1.5 cm (0.6 in) off centerline with a fiberglass nose.

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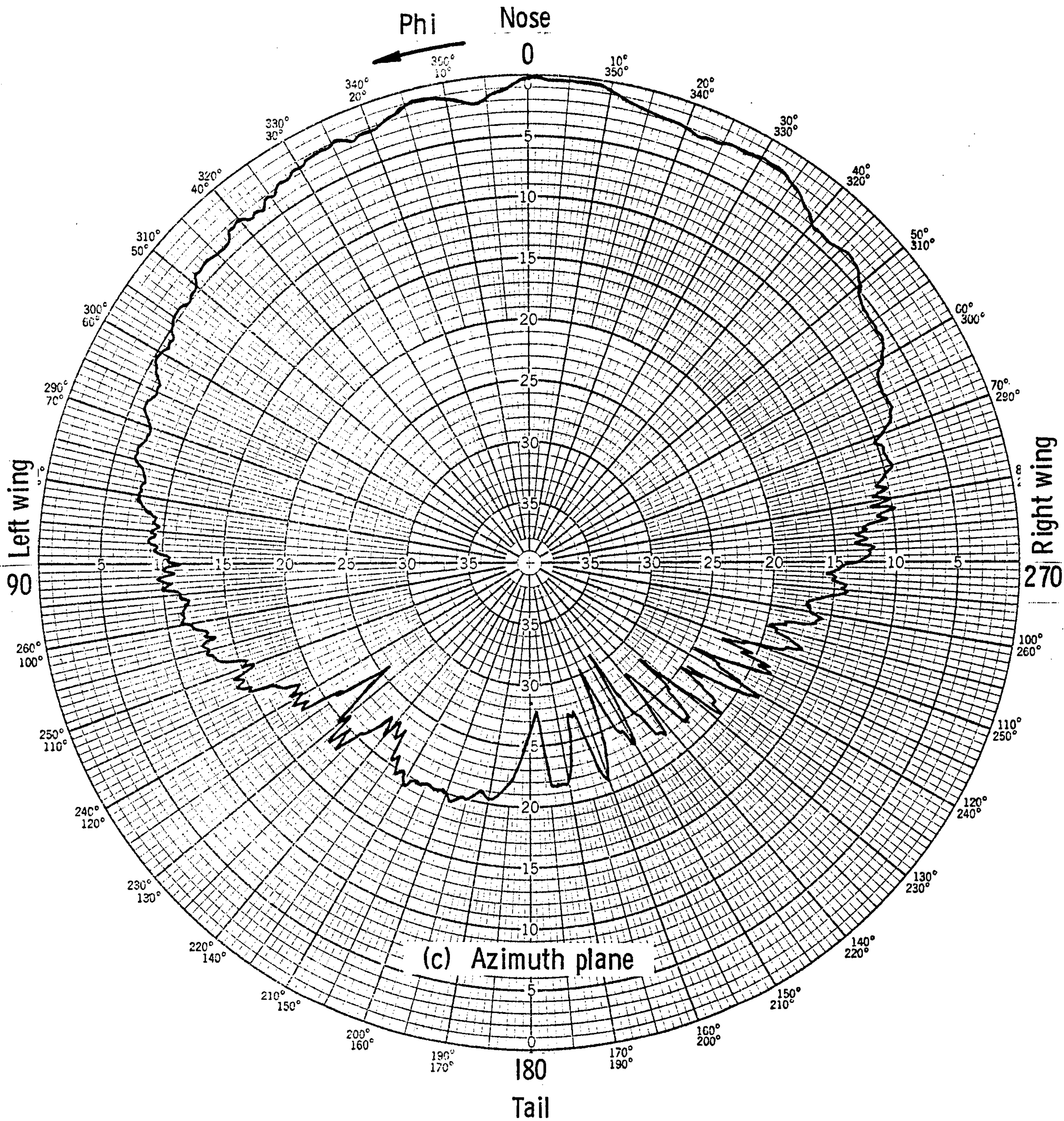


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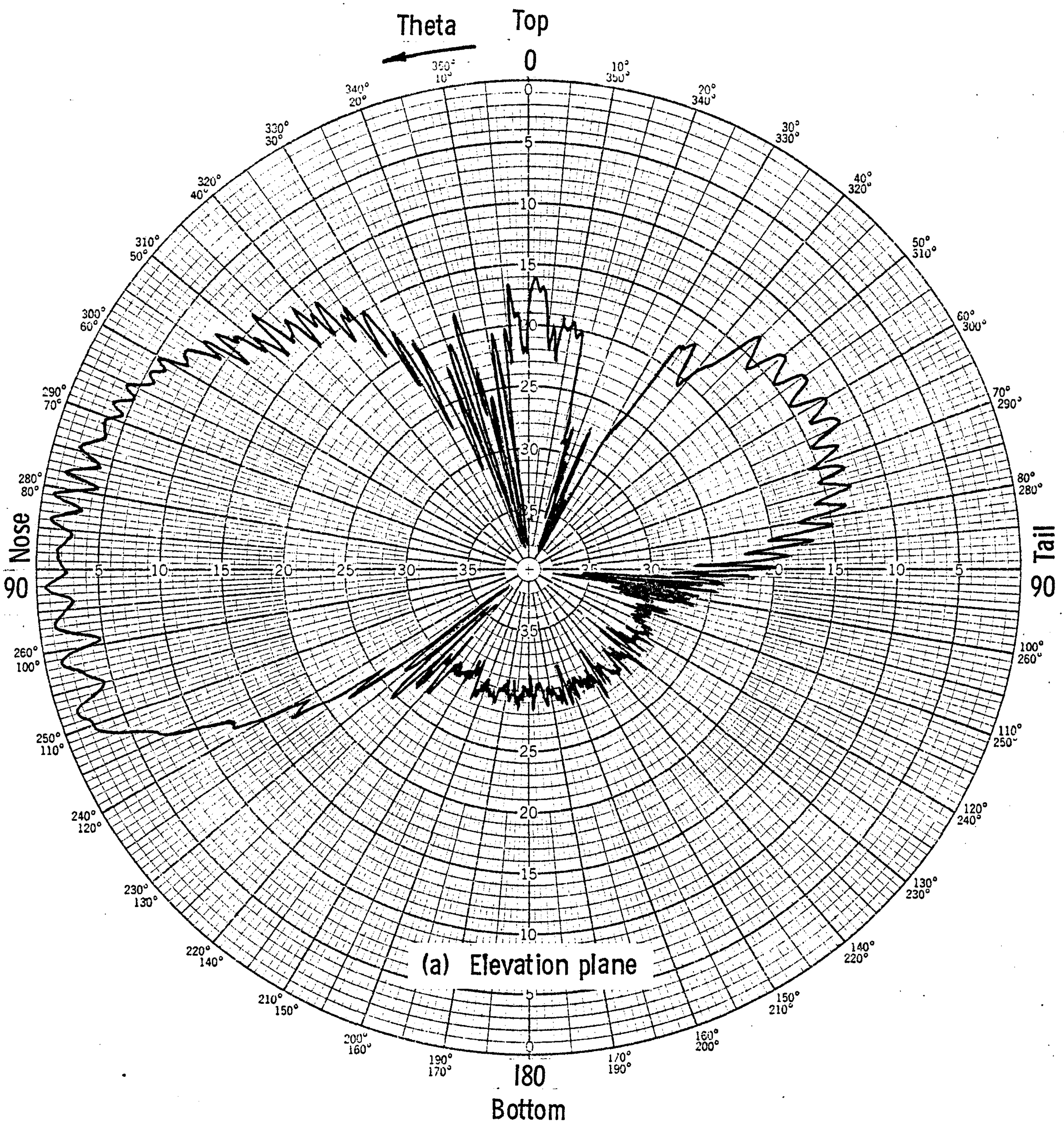



Figure 7. Measured principal plane patterns of a single monopole with reflector spaced 1.5 cm (0.6 in) off centerline with a conducting nose.

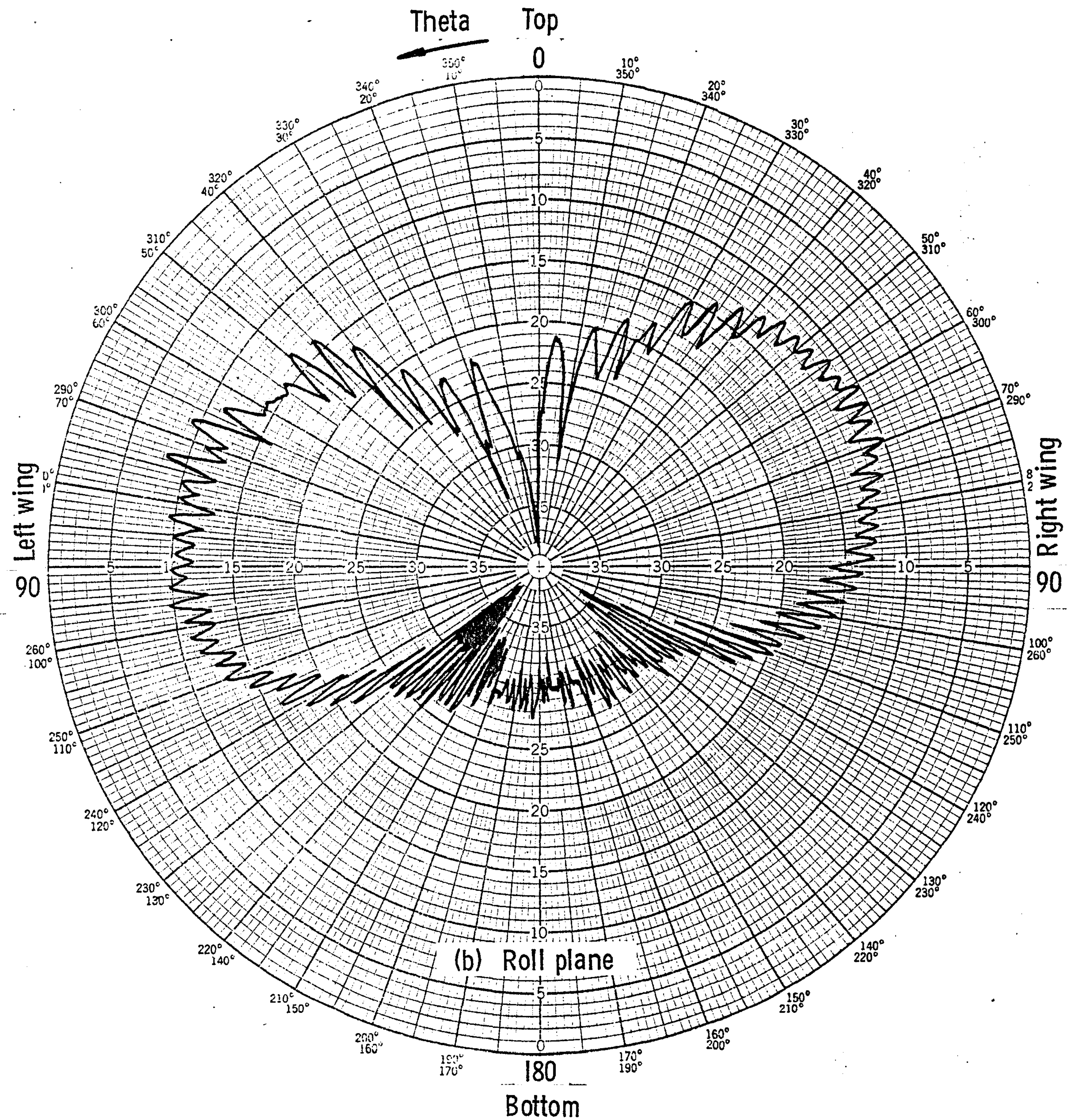
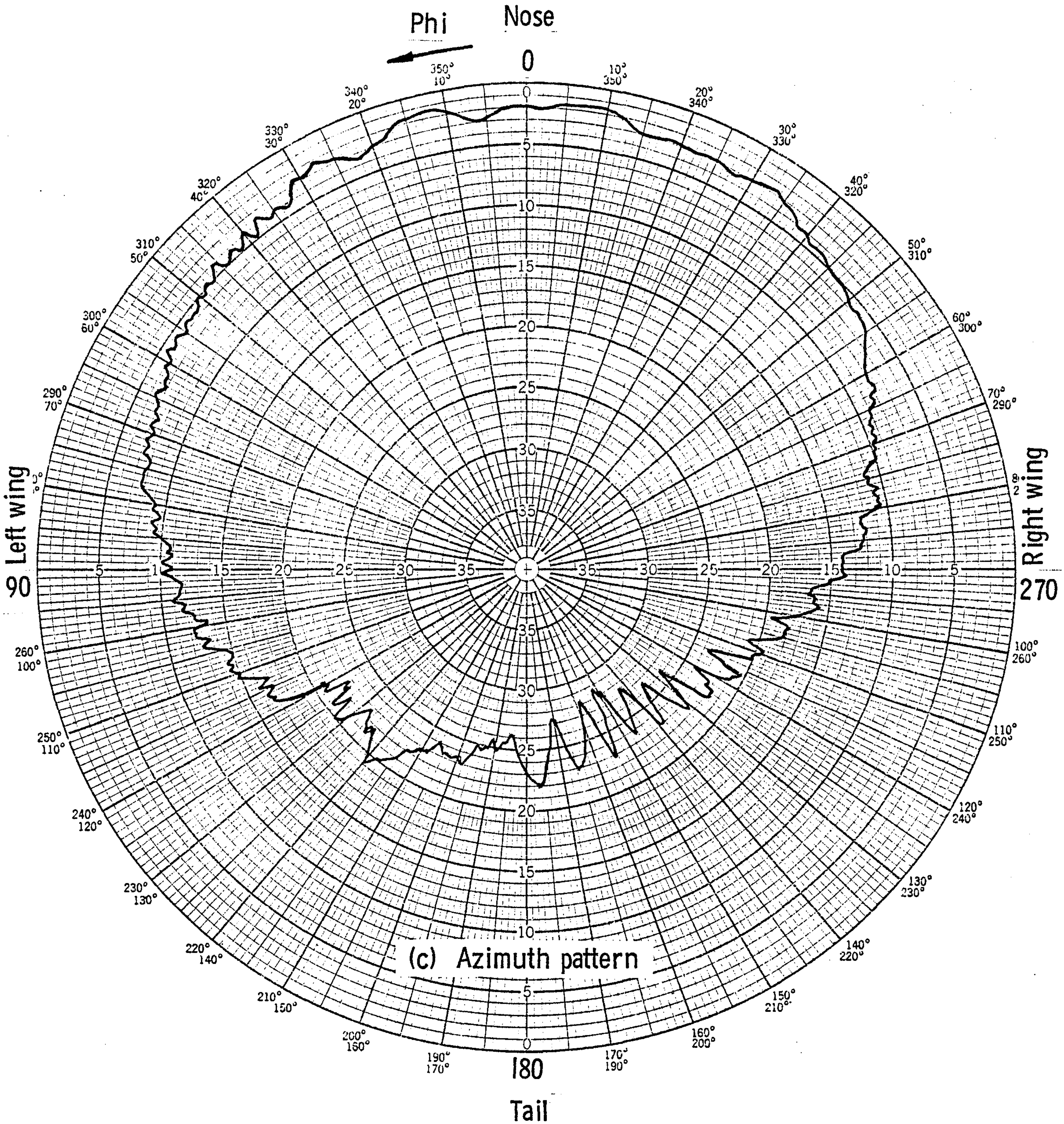



Figure 7. Continued.

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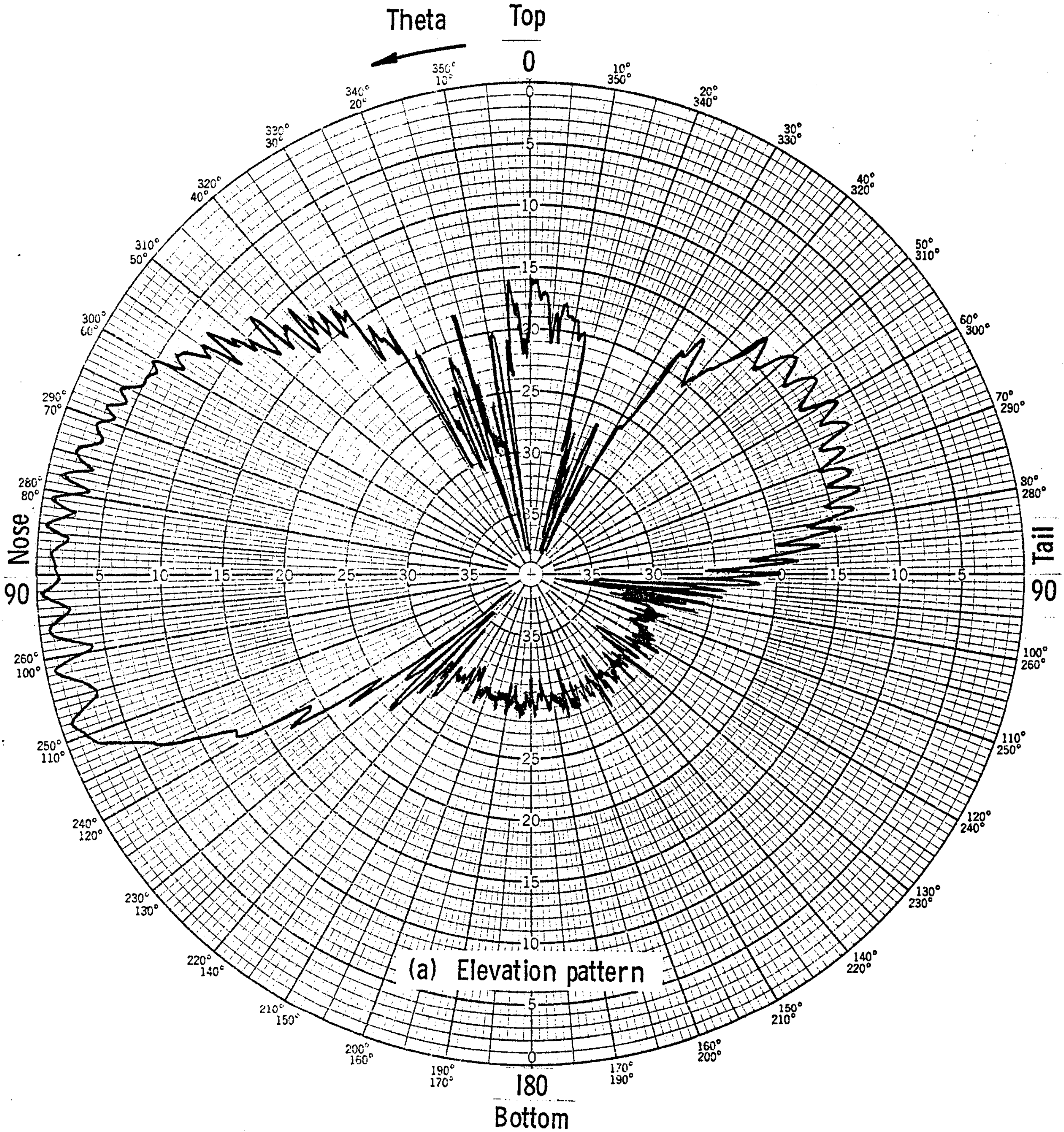
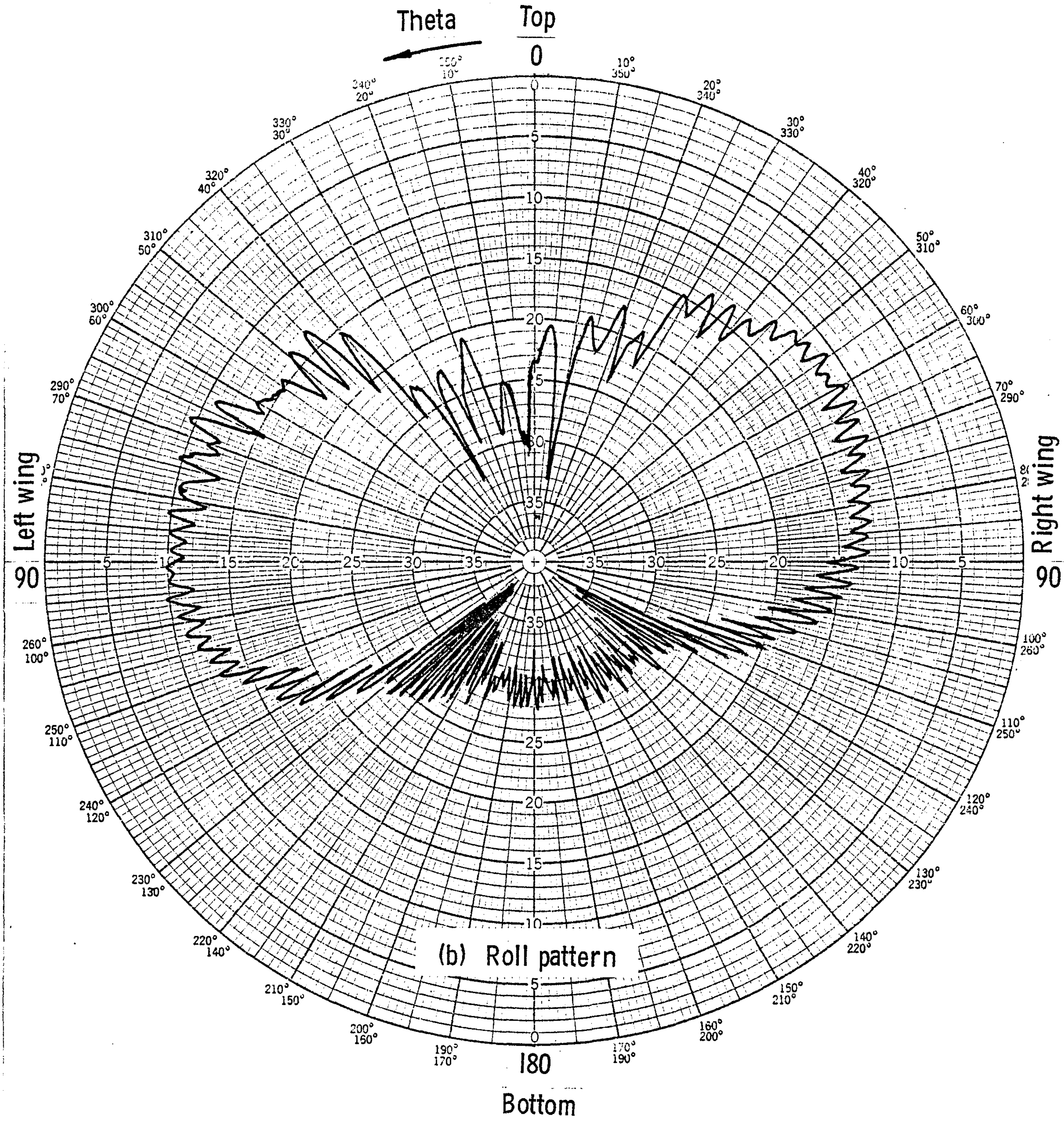



Figure 8. Measured principal plane patterns of two monopoles with reflectors spaced 3 cm (1.2 in) apart at location no. 2 with a conducting nose.

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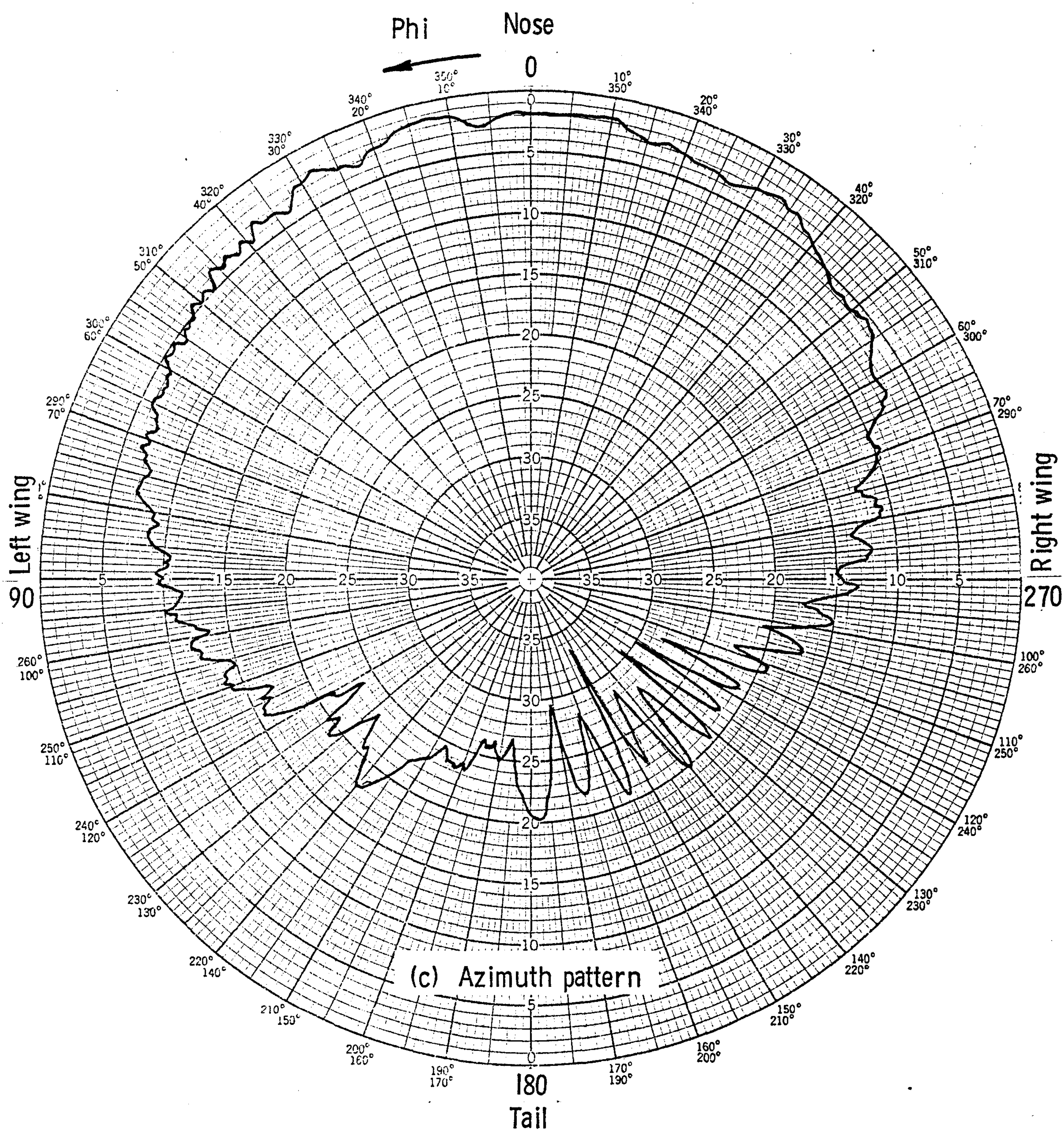


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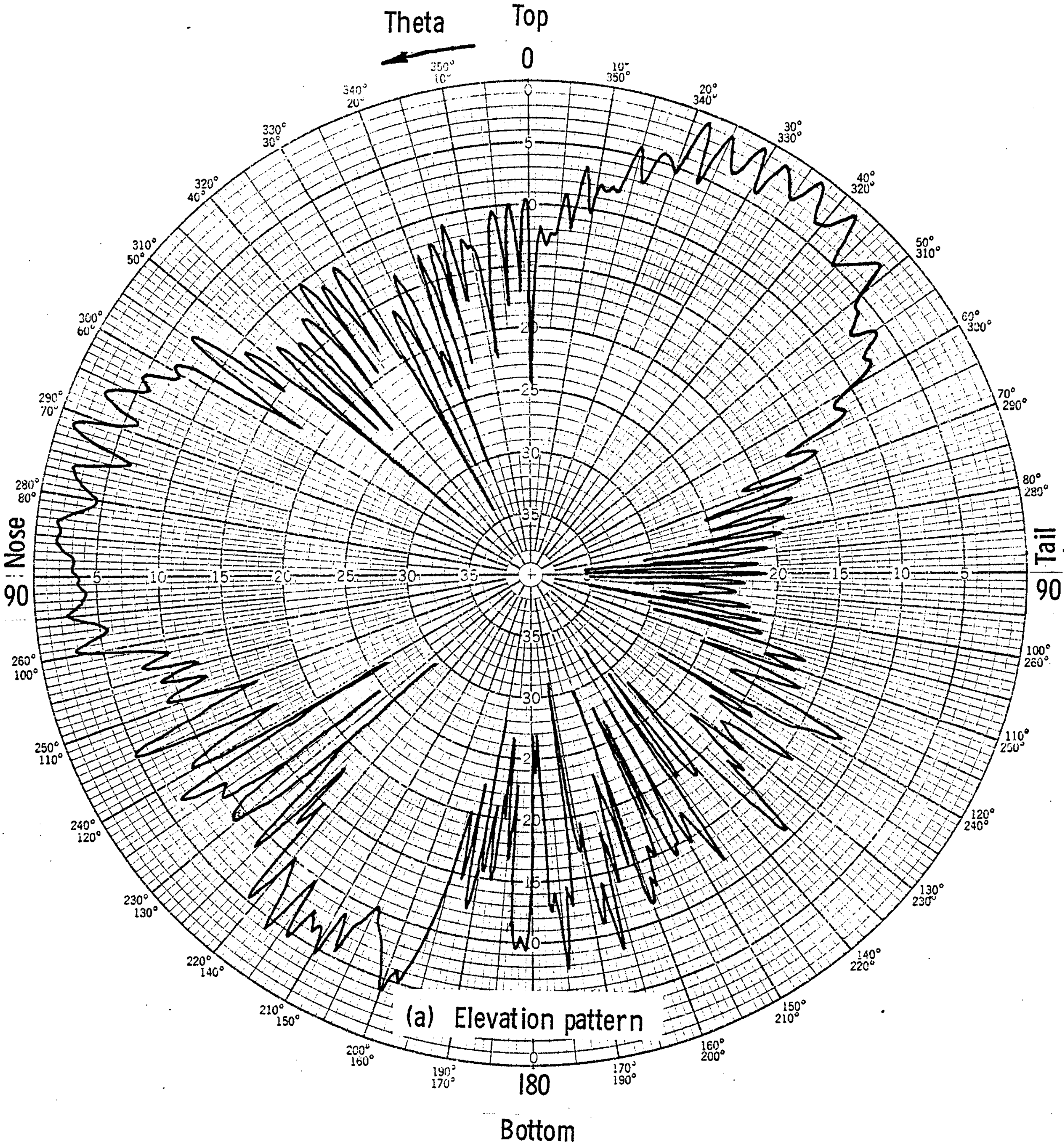
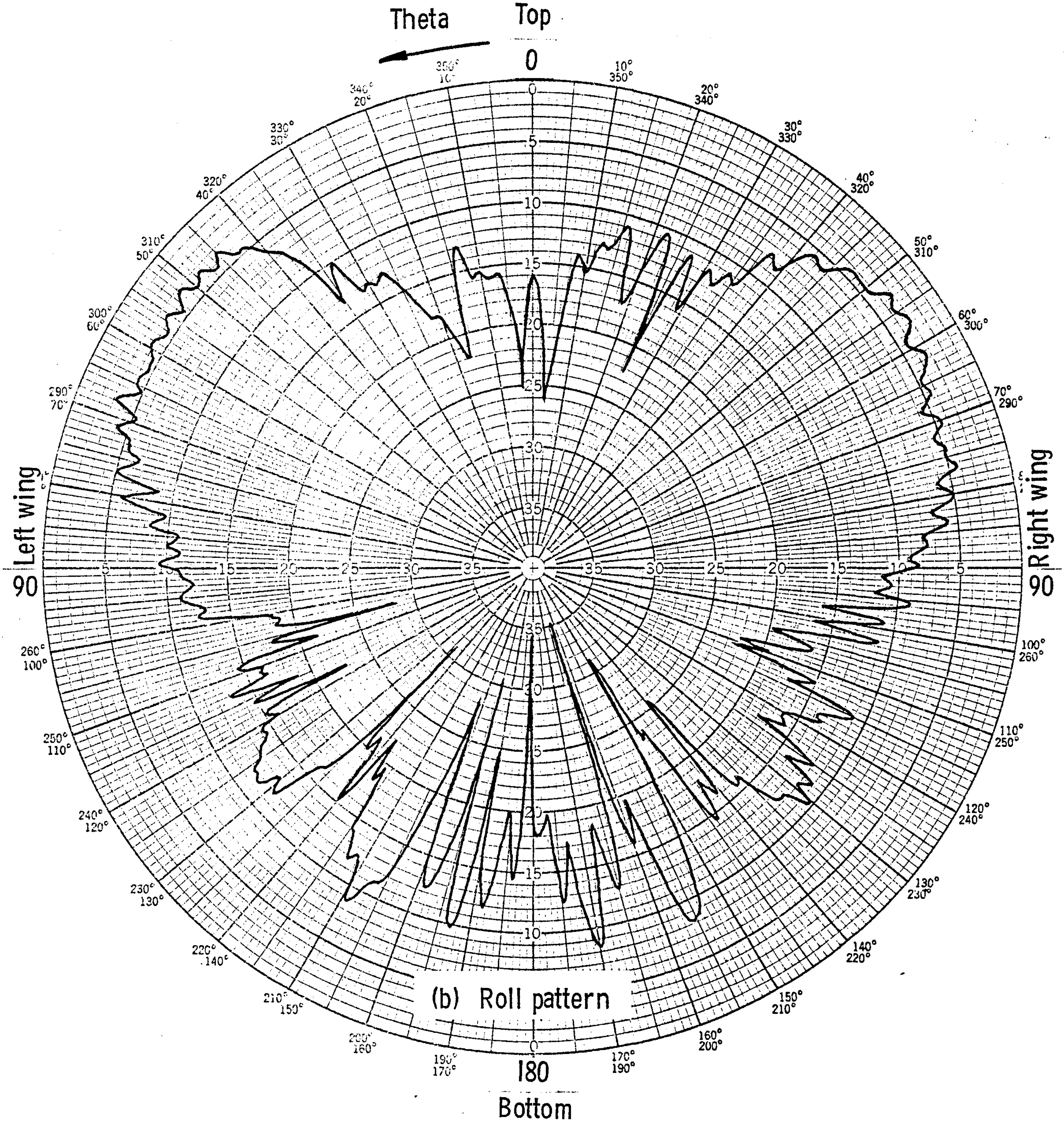



Figure 9. Measured principal plane patterns of a monopole at location no. 3 with a fiberglass nose.

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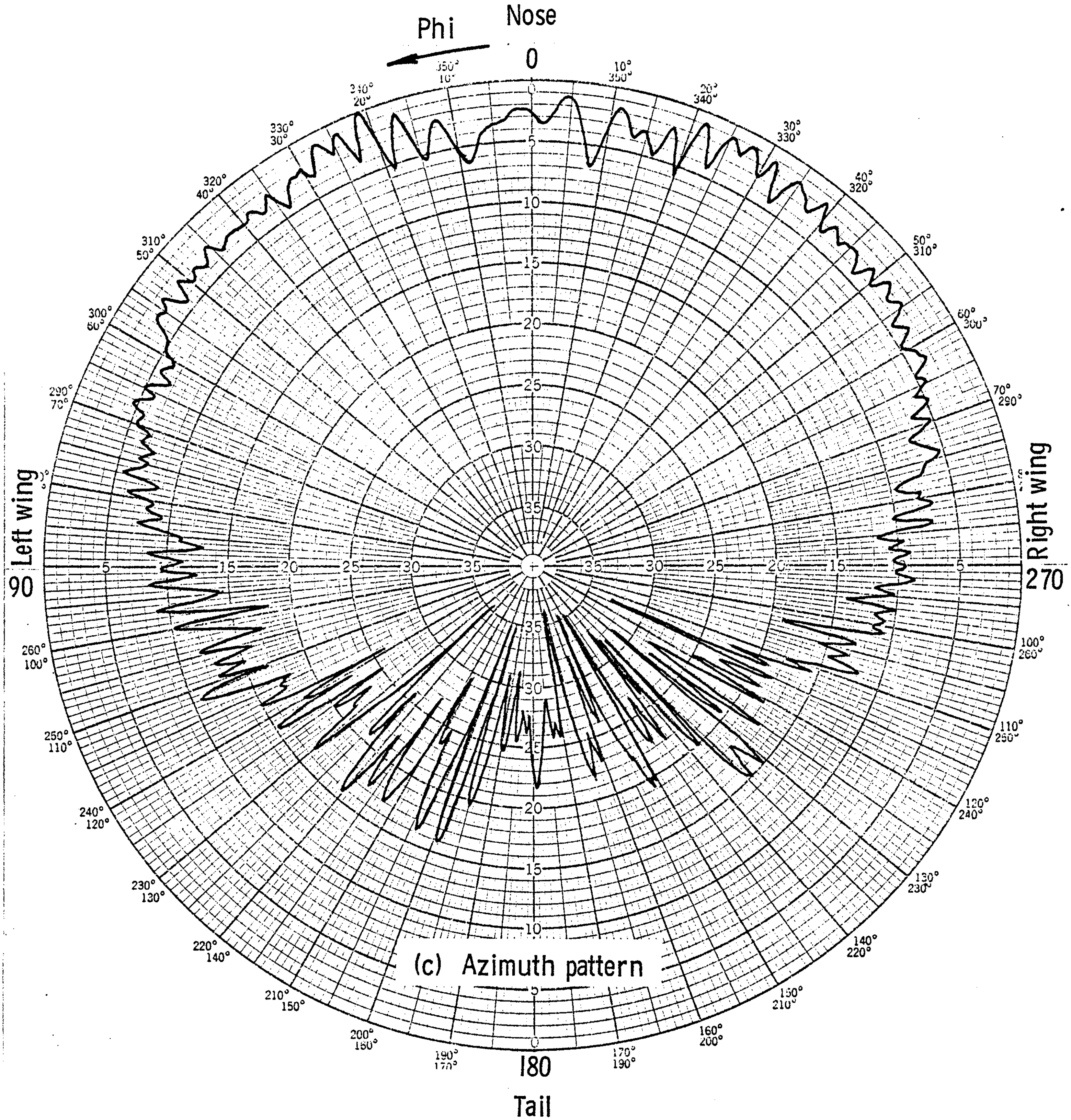


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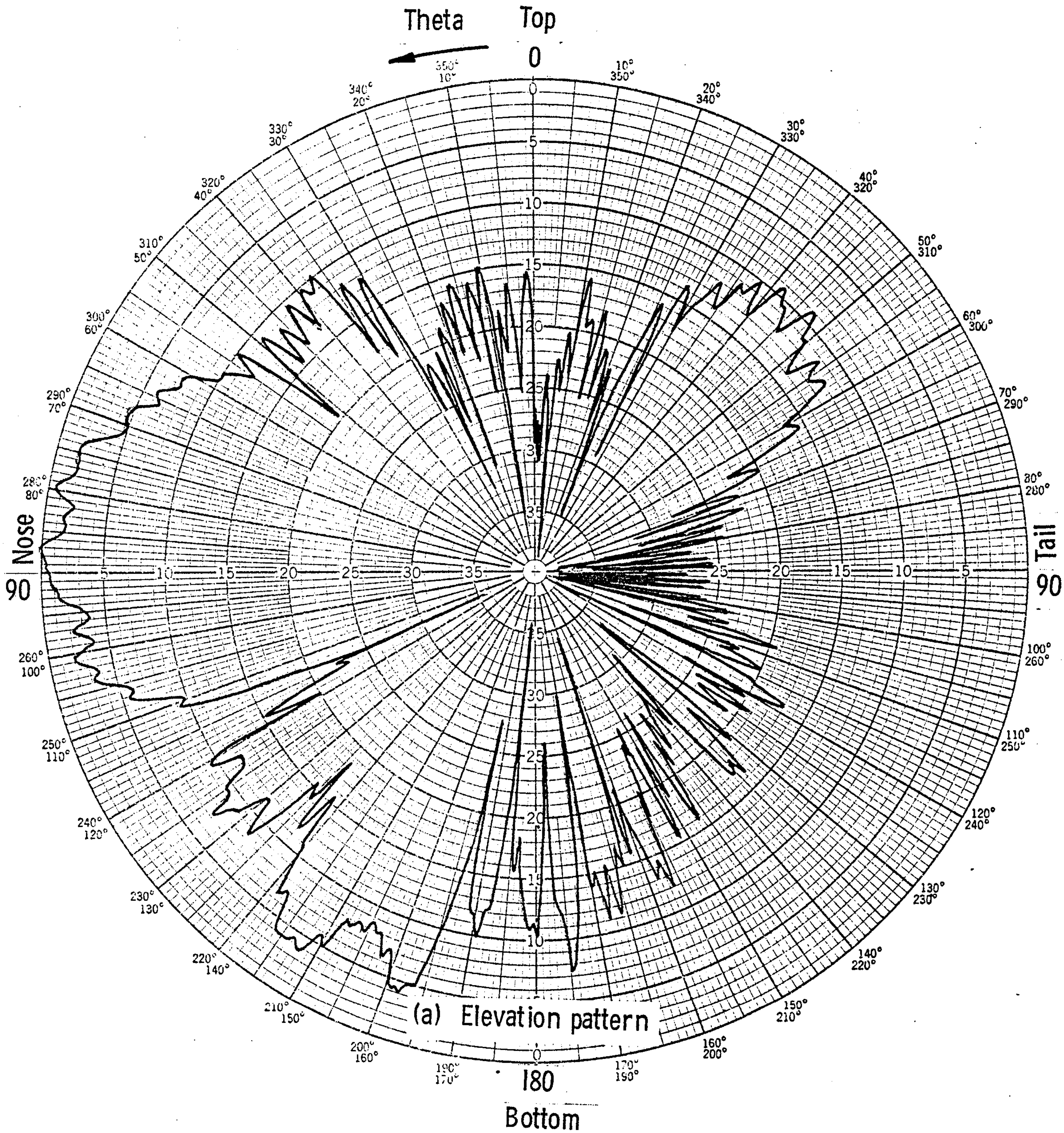
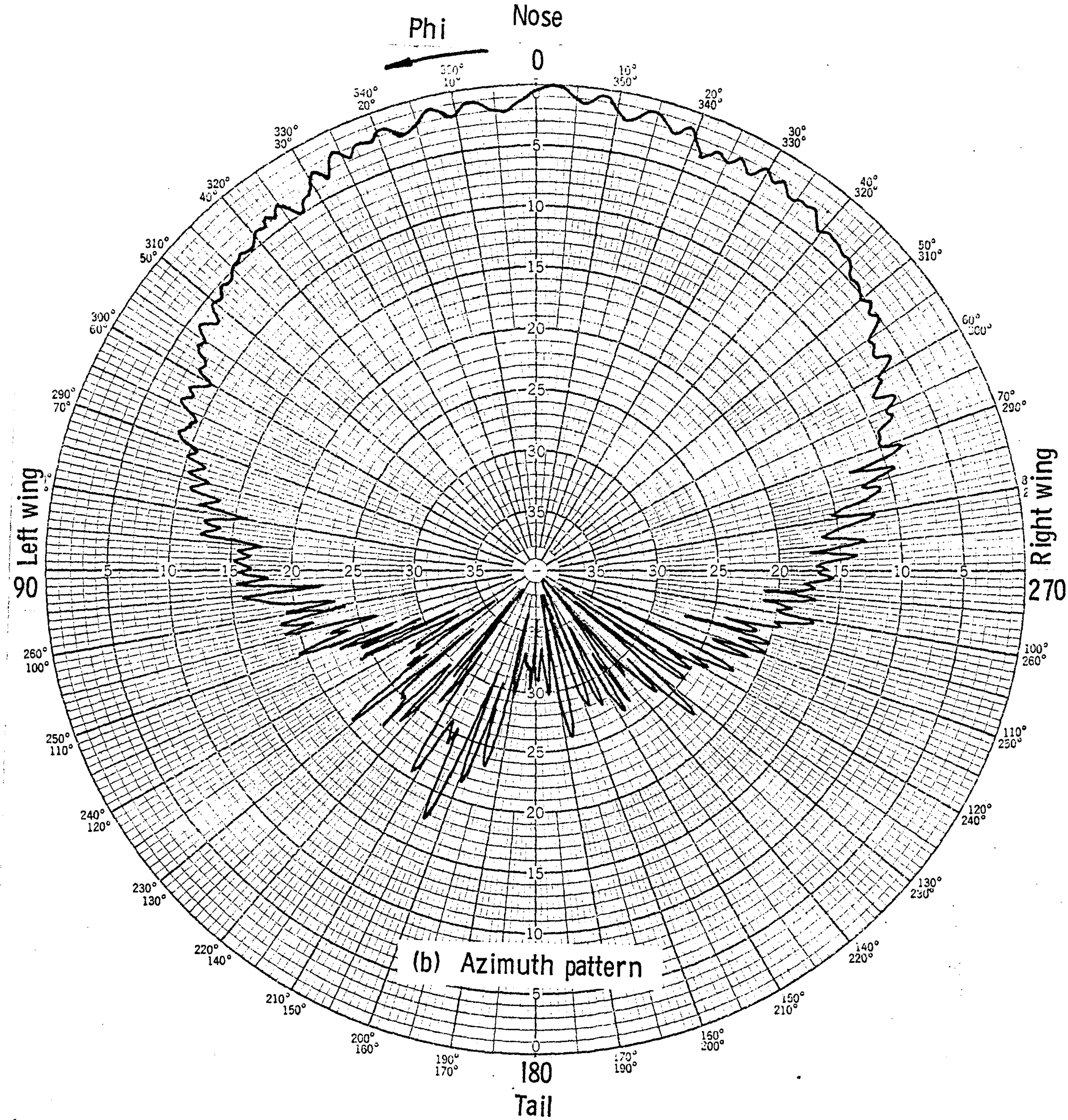



Figure 10. Measured principal plane patterns of a monopole with reflector at location no. 3 with a fiberglass nose.

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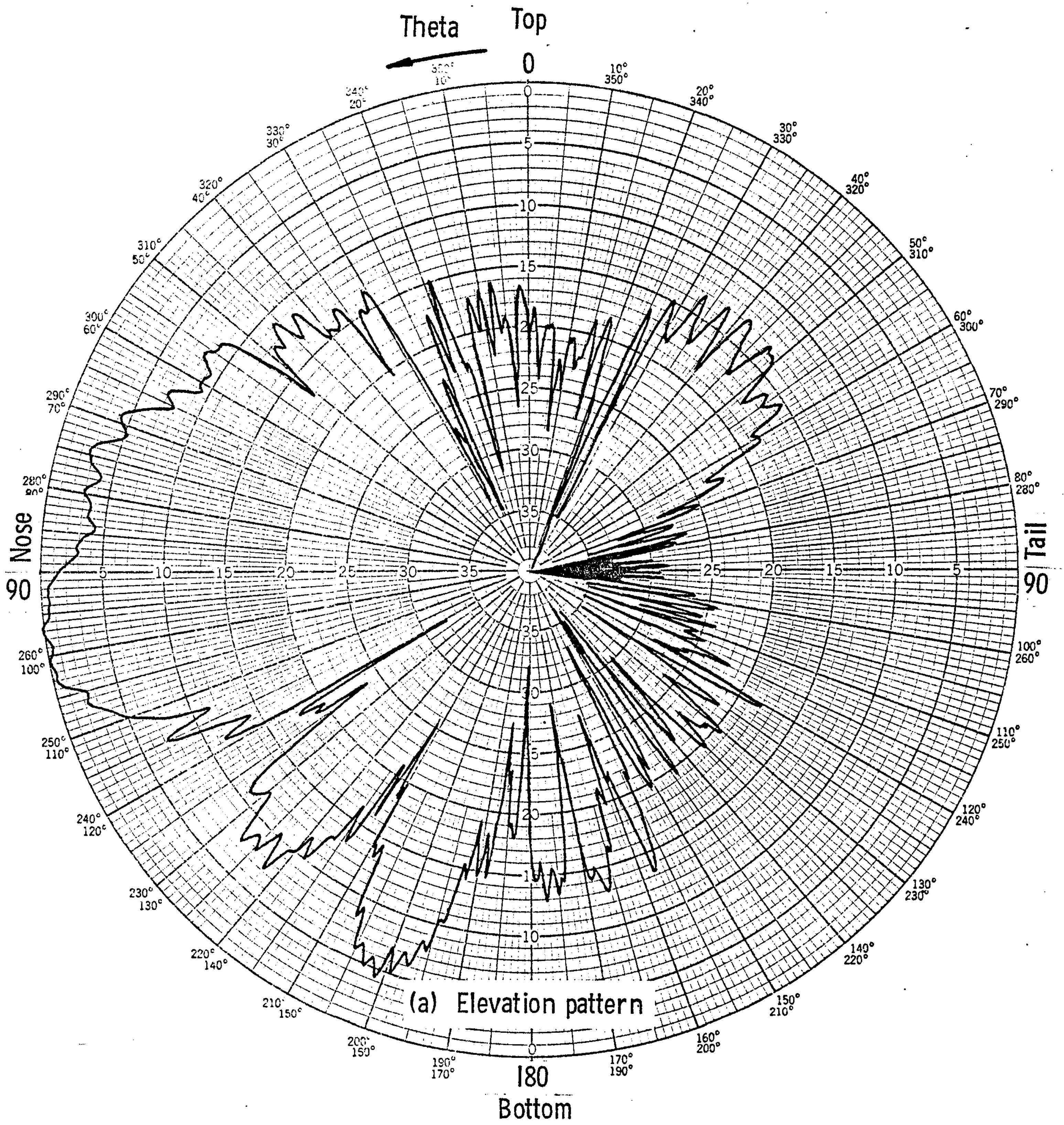
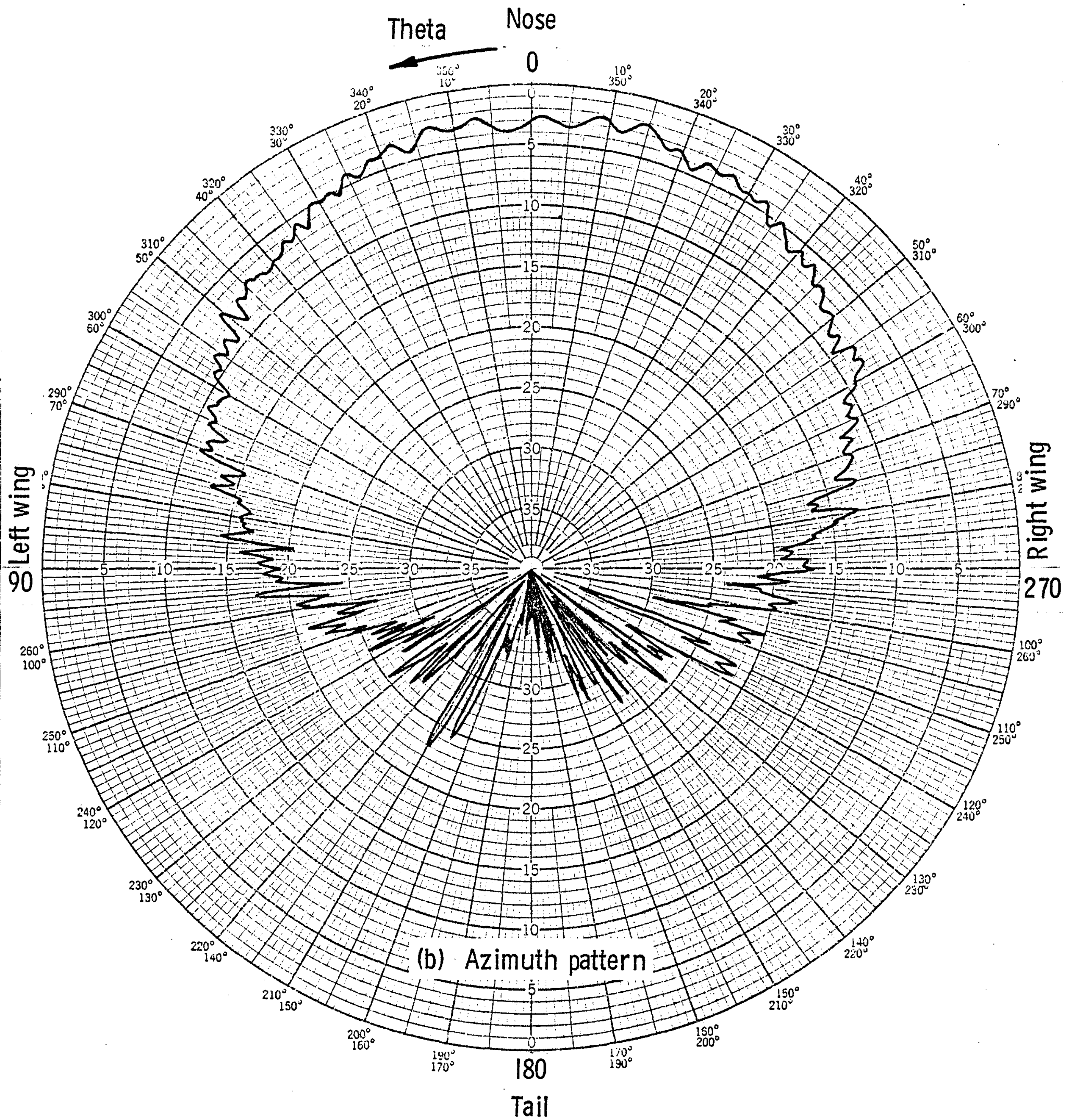



Figure 11. Measured principal plane patterns of a monopole with reflector at location no. 3 with a fiberglass nose.

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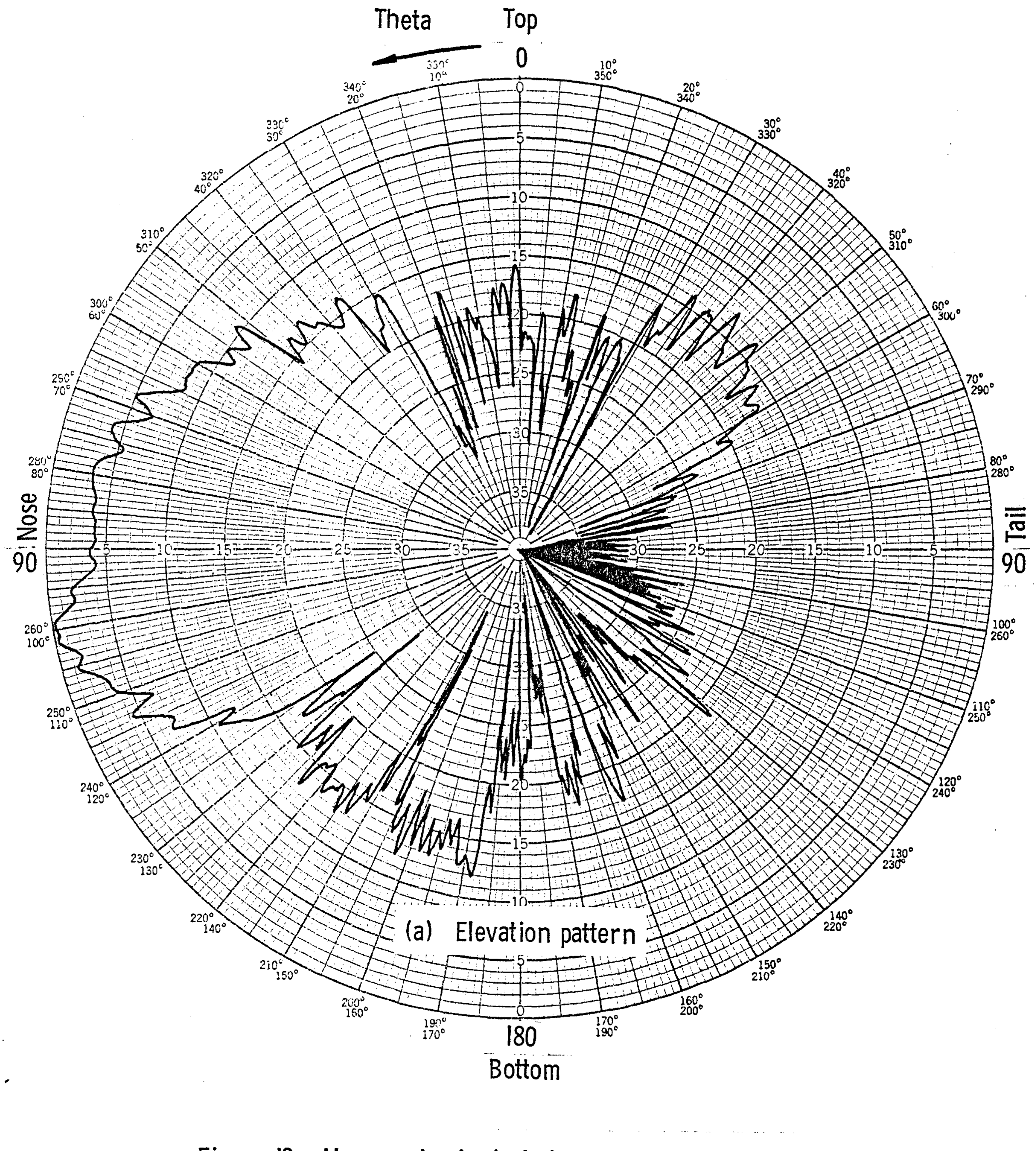
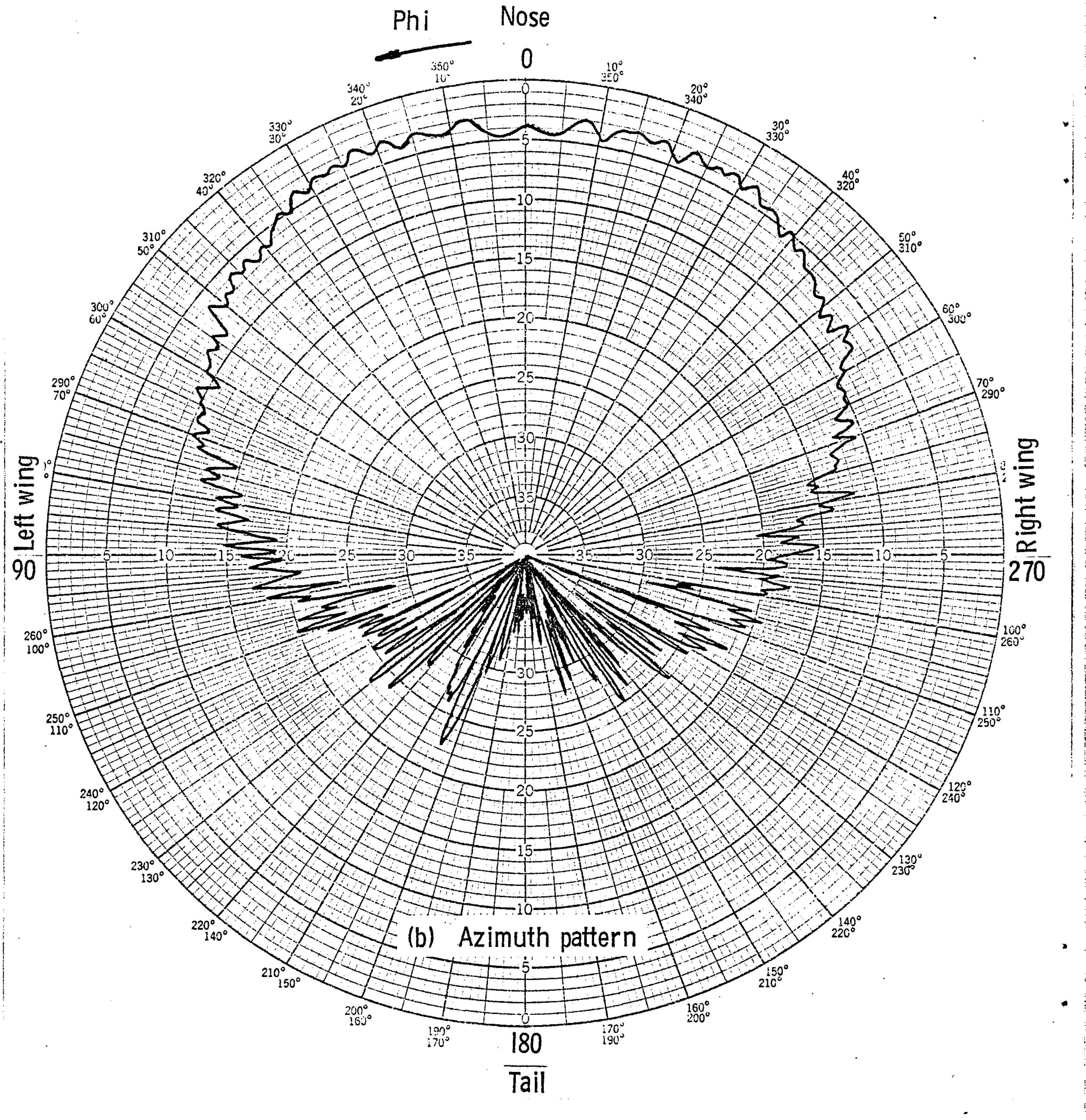



Figure 12. Measured principal plane patterns of a monopole with reflector at location no. 3 with a fiberglass nose.

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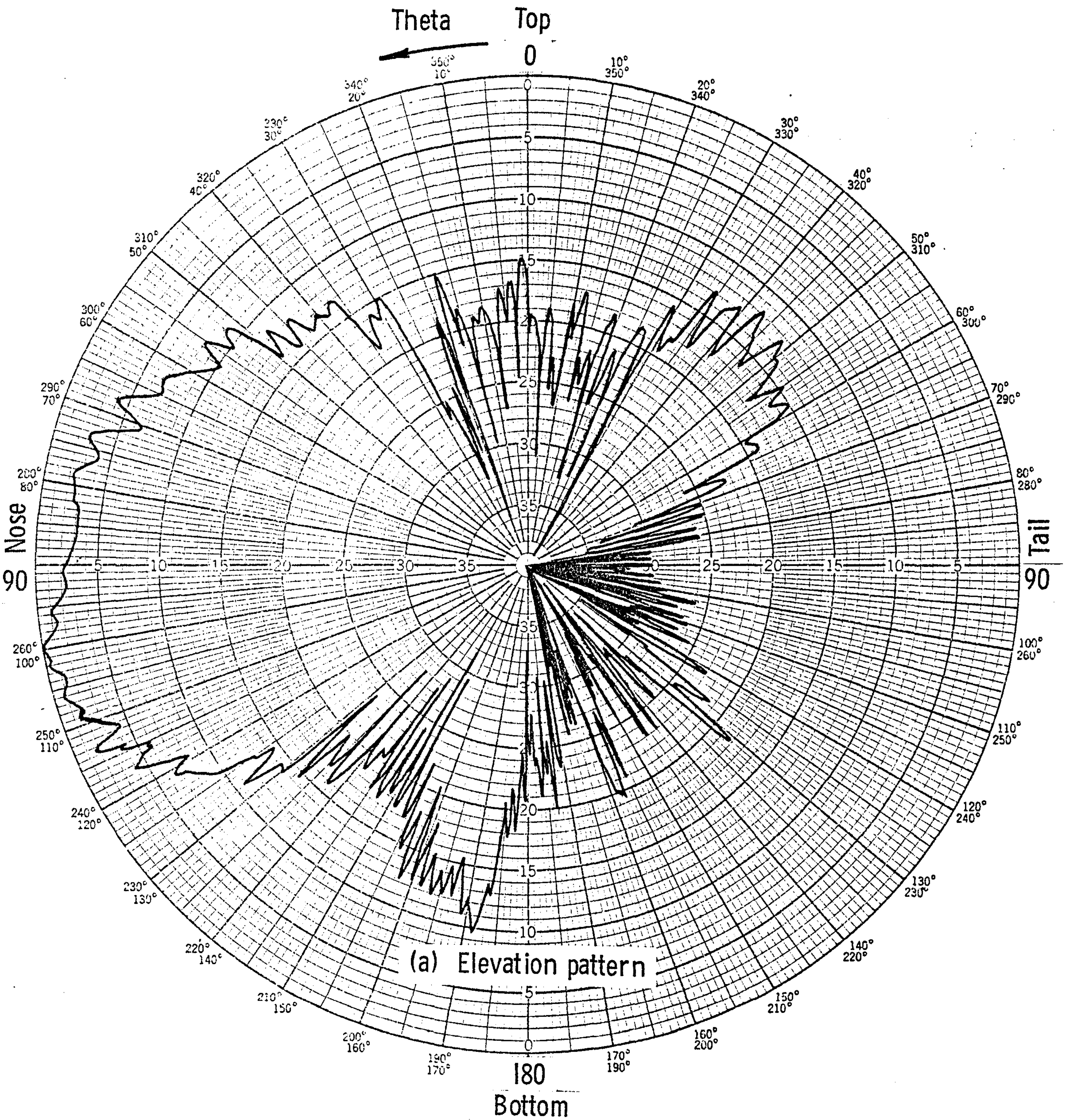
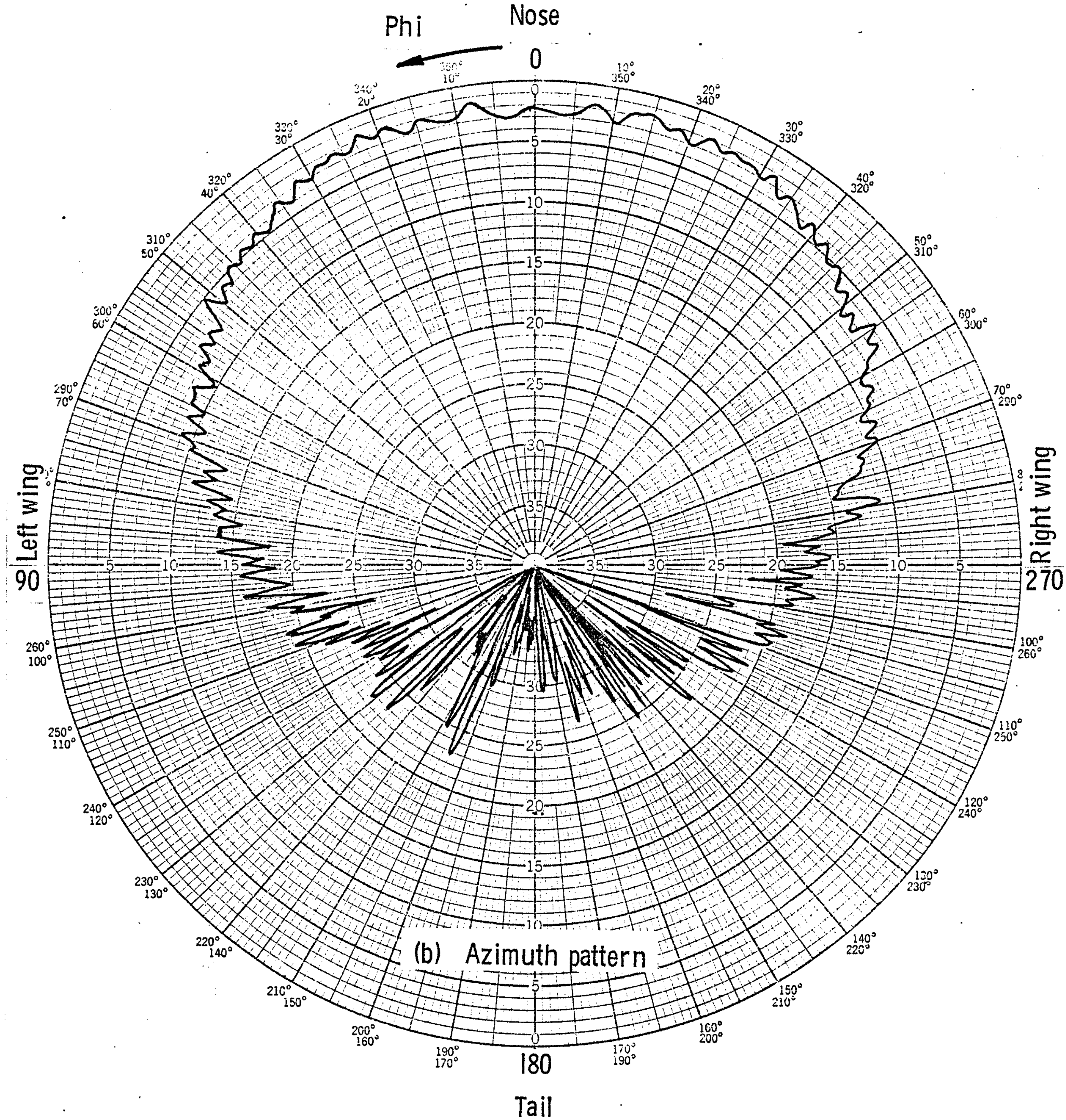



Figure 13. Measured principal plane patterns of a monopole with reflector at location no. 3 with a fiberglass nose.

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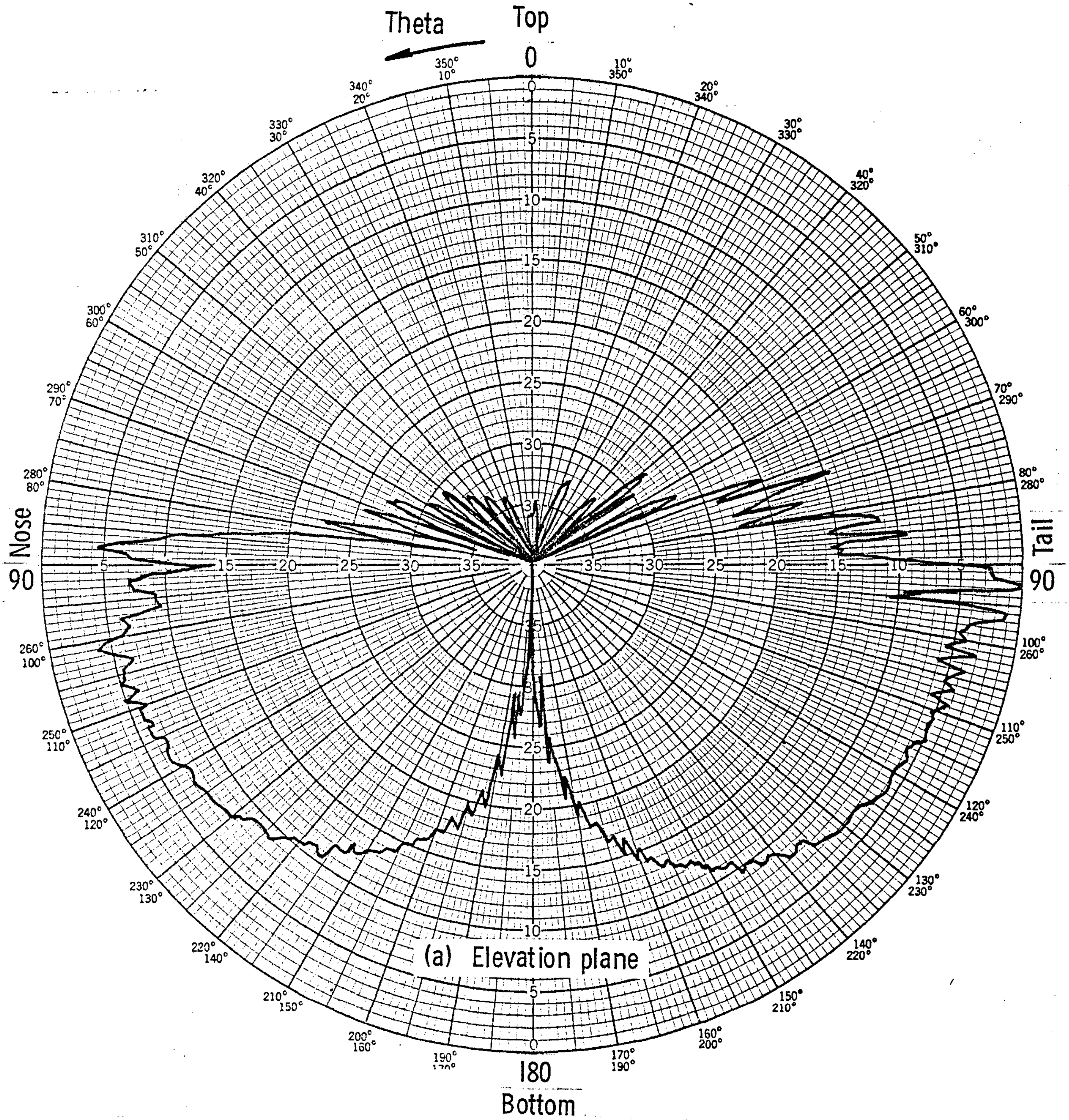
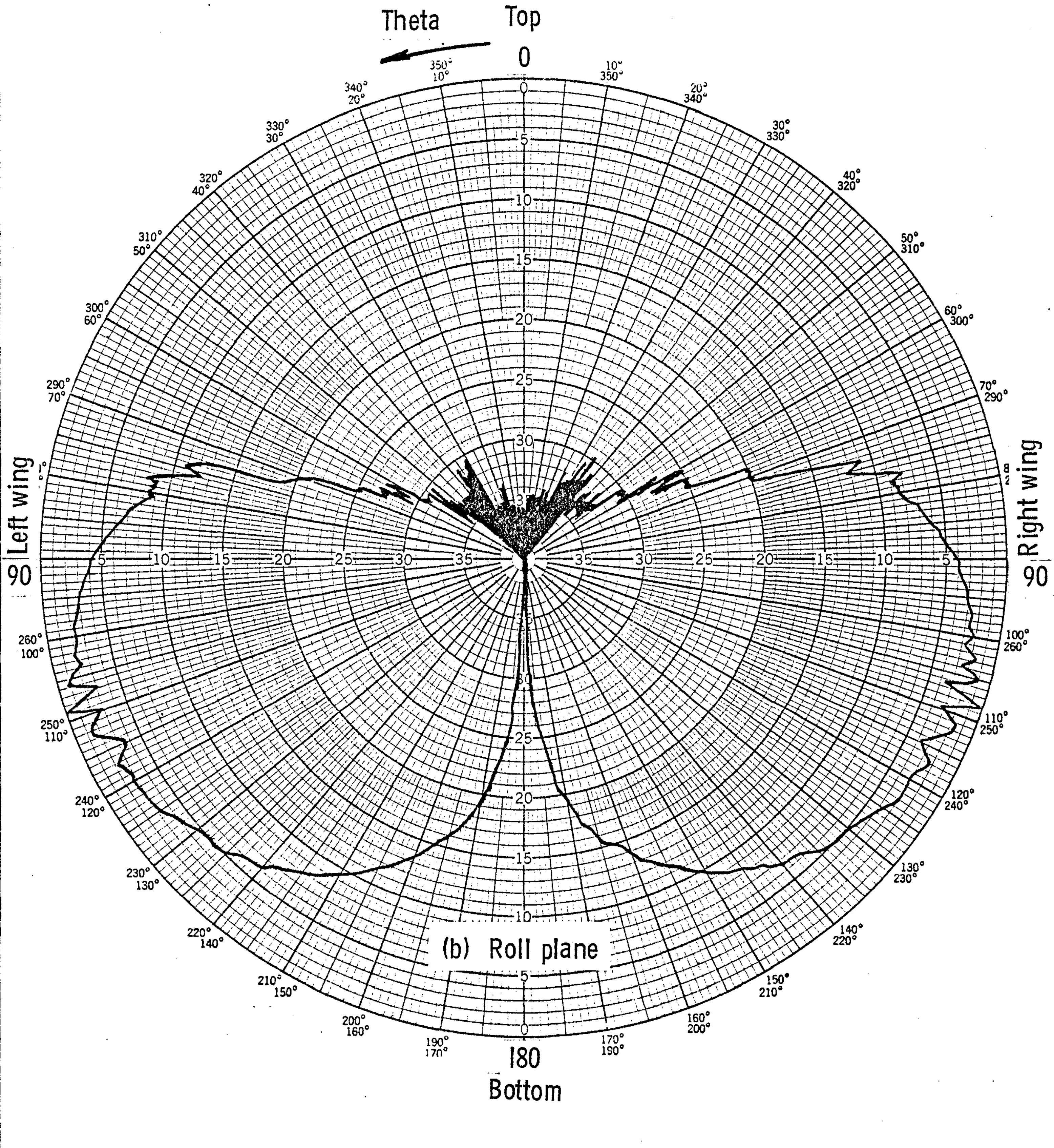



Figure 14. Calculated principal plane patterns of a monopole at location no. 4.

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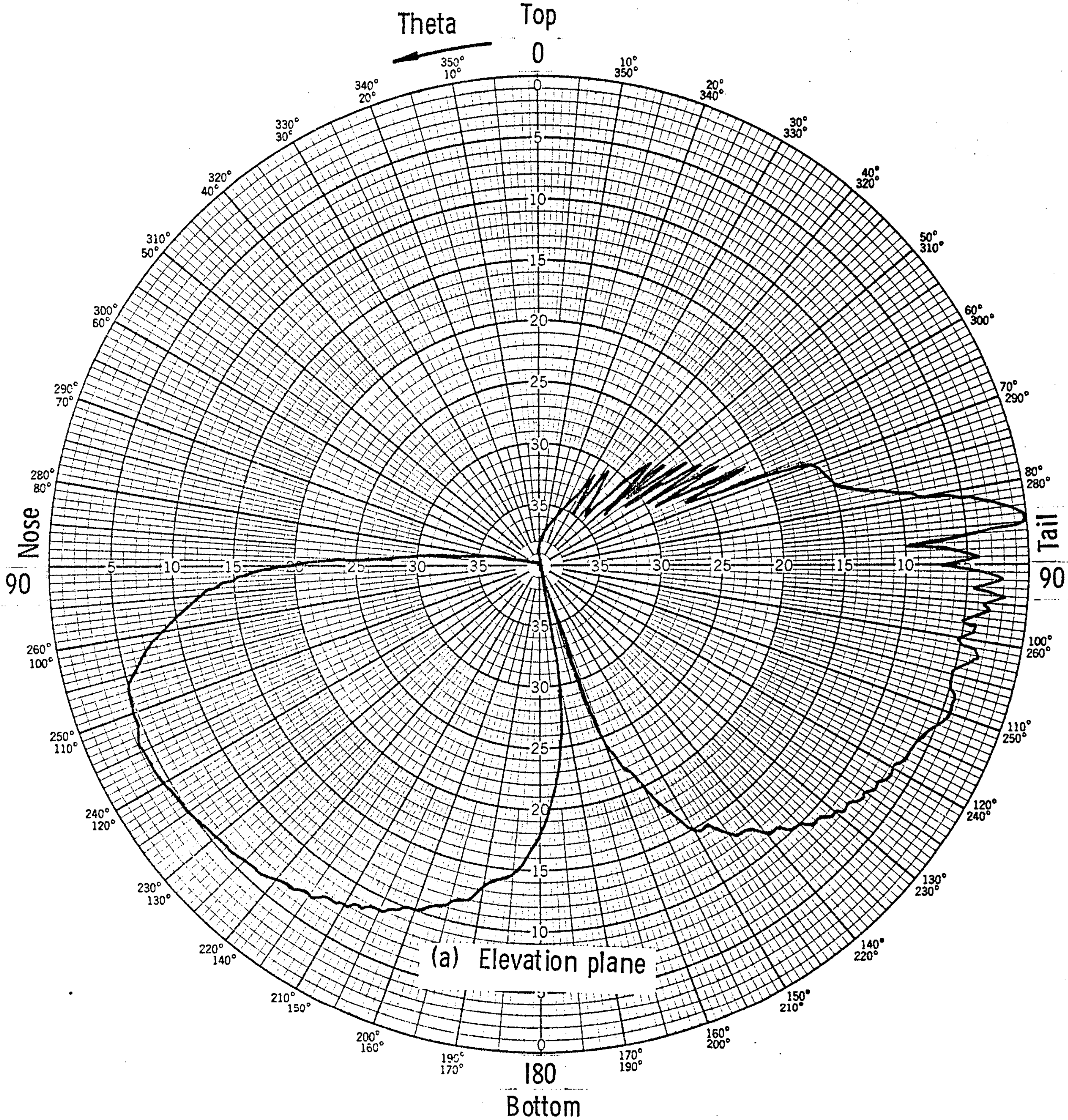


Figure 15. Calculated principal plane patterns of a monopole at location no. 5.

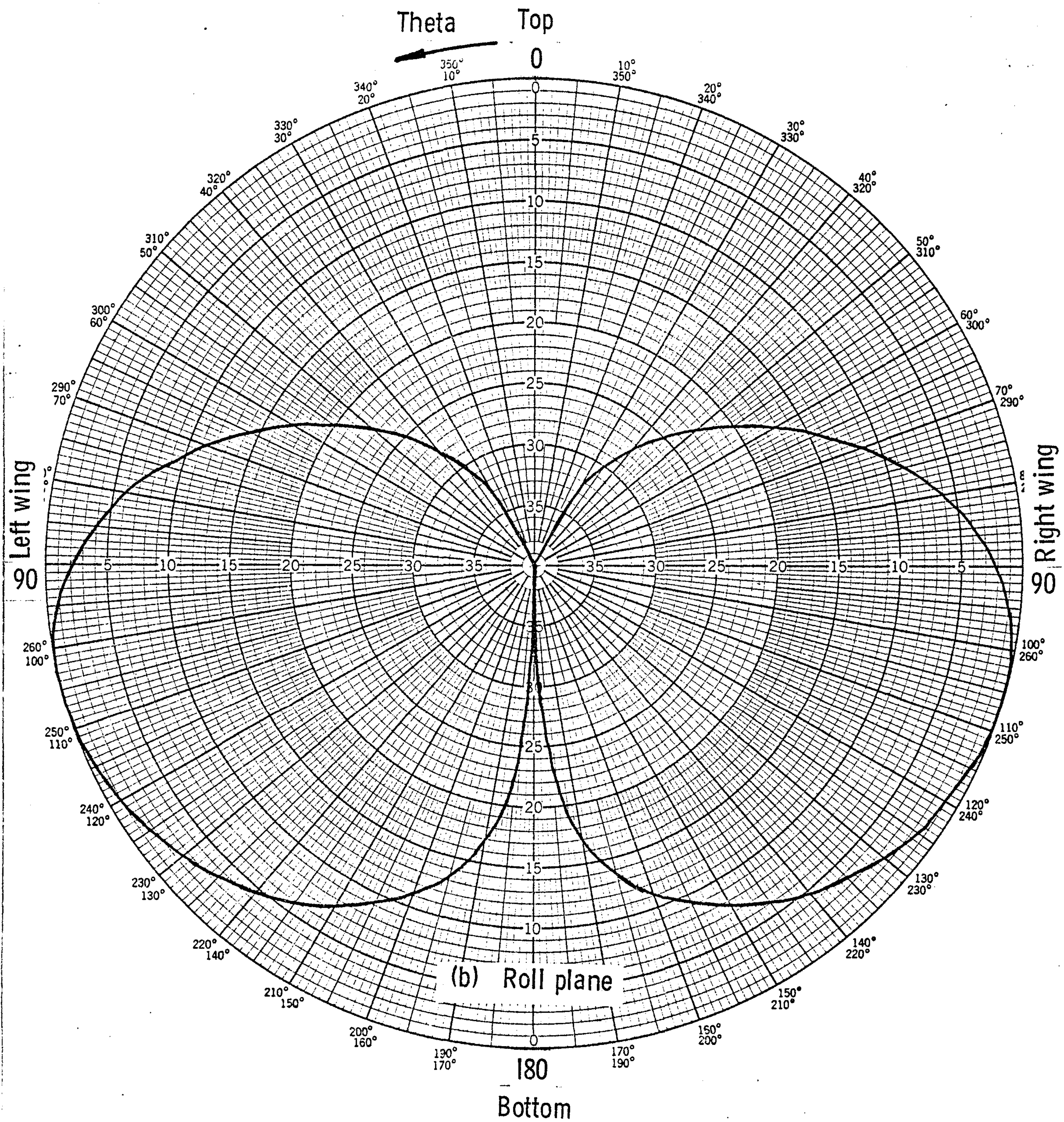


Figure 15. Concluded.