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BACKFIRE YAGI ANTENNA MEASUREMENTS

L. R. DOD

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ABSTRACT

Radiation patterns and gain measurements on 1.0, 1.5, and 2.0λ backfire Yagi antennas are given. The backfire antenna was tested for two dipole feed locations, and variations in the diameters of the two planar reflectors forming the backfire cavity. The optimum dimensions of the three test antennas are tabulated. The frequency bandwidth of the backfire antenna is limited to several percent due to impedance matching. The backfire antenna should find application in broadside arrays where conventional endfire antennas are presently used.

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ILLUSTRATIONS (Continued)

BACKFIRE YAGI ANTENNA MEASUREMENTS

INTRODUCTION

An experimental test program has been conducted to supplement the available data on the backfire Yagi.[1-6] The backfire antenna has been considered for possible application in V.H.F. command and tracking arrays in the Space Tracking and Data Acquisition Network (STADAN). The backfire is being considered because it offers greater gain per unit length than the conventional endfire antennas in the existing arrays.

The backfire principle may be explained as follows. The backfire antenna may be considered as a leaky cavity resonator formed by two planar reflectors as shown in Figure 1. Energy is introduced into the cavity, in the transmitting case, by a dipole and is confined to the cavity by a surface wave guiding structure, e.g., Yagi, dielectric rod, disc-on-rod, etc. Radiation from the leaky cavity is normal to the smaller (secondary) reflector. Zucker[6] has compared the backfire antenna to a laser cavity with the smaller antenna reflector analagous to the partially silvered mirror of the laser. The larger (surface wave) reflector is analagous to the fully silvered mirror of the laser cavity. The separation of the two reflectors forming the cavity must be a multiple of a half-wavelength for backfire action. The velocity of the surfacc wave on the guiding structure is equal to the velocity of a conventional endfire antenna with twice the length of the backfire.[6]

In order to supplement existing data,[1-6] gain and radiation patterns were measured as functions of: (1) the diameters of the two reflectors forming the leaky cavity, (2) the feed dipole location in the cavity, and (3) the lengths of the Yagi directors forming the surface wave guiding structure. Backfire antennas with lengths of 1.0, 1.5, and 2.0 wavelength (λ) were tested. Measurements of a 0.5λ backfire have been reported previously.[4,8]

Test Models

The 1.0, 1.5, and 2.0λ backfire antennas are shown in Figures 2, 3, and 4. Two feed locations in the cavity were tested as shown in parts A and B of these figures.

The optimum dimensions of the three test antennas are given in Table 1.

Radiation Patterns

The linearly polarized E and H plane radiation patterns of the three test antennas are given in Figures 5-20. The radiation patterns of Figures 5-16 show the effects of variation in the diameter of the surface wave reflector and the feed dipole location in the cavity. Figures 17-20 show the effects of director length variation and secondary reflector diameter variation.

Gain Measurements

The gain curves of the three test antennas are shown in Figures 21-23. Figures 21 and 22 show the gain variation as a function of the feed dipole location and the diameter of the surface wave reflector. Figure 23 shows the gain variation as a function of the director lengths and the secondary reflector diameter for the 2.0λ antenna.

Test Site

The test site for the radiation patterns and gain measurements consisted of a pyramidal horn illuminating antenna separated 18 feet from the backfire test model with both antennas elevated 12 feet above ground. The backfire test antenna was compared with a 16.35 db standard horn for all gain measurements at the 1500 MHz test frequency. The accuracy of the gain measurements was limited to ±0.5 db by the tolerance of the recording equipment and the range site. All gain measurements were made with the backfire antenna impedance matched to less than 1.20 to 1.00 s.w.r.

CONCLUSIONS

The gains of the three backfire test models and a previously measured 0.5λ backfire[8] may be compared with a gain-optimized Yagi[9] as shown in Figure 24. The backfire gain is 3.8 db greater for the 0.5λ length, 3.0 db greater for the 1.0λ and 1.5λ lengths, and 3.3 db greater for the 2.0λ length. These gain improvements over the conventional endfire antenna are achieved by increasing the transverse dimension (surface wave reflector) of the backfire. In many applications, the larger transverse reflector is undesirable. The curves of gain versus diameter of the surface wave reflector given in Figures 21 and 22 show that the diameters of the reflectors may be reduced from the optimum values and still give gain increase over the conventional endfire antenna. There is a definite advantage in locating the feed dipole near the surface wave reflector as can be seen by comparing the gain curves of Figures 21 and 22 for the two feed locations tested. The gain differential using the two feed locations is greatest when the surface wave reflector diameter is reduced below the optimum value. There is also a mechanical advantage in locating the feed near the surface wave reflector since the strength of the antenna support tube can be reduced.

Figure 23 shows typical gain variation for director length and secondary reflector diameter for the 2.0λ backfire. The corresponding radiation patterns are shown in Figures 17-20. The secondary reflector diameter of 0.475-0.500λ gave optimum gain for all models tested. The director length of 0.388λ gave optimum gain for the 2.0λ antenna. This value is 0.060λ greater than the value predicted in reference 9 for an endfire with twice the length of the backfire. This difference may be due to the 0.127λ diameter of the support tube since the antennas of reference 9 were half-models without support tubes.

The frequency bandwidth of the antennas tested was limited to several percent due to impedance matching. The frequency bandwidth of the radiation patterns and gain was greater than 10%. The impedance bandwidth agrees with the data of reference 7 for a backfire disc-on-rod antenna.

The backfire antenna should be useful in broadside arrays that presently utilize conventional endfire antennas. The surface wave reflector can be made from wire mesh rather than a solid metal to reduce weight and wind loading. The gain curves of Figure 21 and the radiation patterns of Figures 5-16 should be useful for the array designer to supplement the data of reference 6.

ACKNOWLEDGEMENT

The author wishes to acknowledge the assistance of John Fuchs who performed all the measurements and assembled the test models.

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Table 1
Antenna Test Model Dimensions in Wavelengths

Antenna length	1.0	1.5	2.0
Number of directors	3	5	8
Spacing of directors	.2	.2	.2
Thickness of directors	.048	.048	.048
Total director length	.421	.406	.388
Secondary reflector diameter	.475	.475	.475
Secondary reflector thickness	.008	.008	.008
Surface wave reflector diameter	2.5	3.00	3.4
Surface wave reflector thickness	.008	.008	.008
Antenna support tube diameter	.127	.127	.127
Dipole sleeve diameter	.048	.048	.048
Dipole rod diameter	.0159	.0159	.0159
Dipole length	.5	.5	.5
Dipole spacing from surface wave reflector	.2	.3	.2
Dipole spacing from secondary reflector	.2	.2	.2

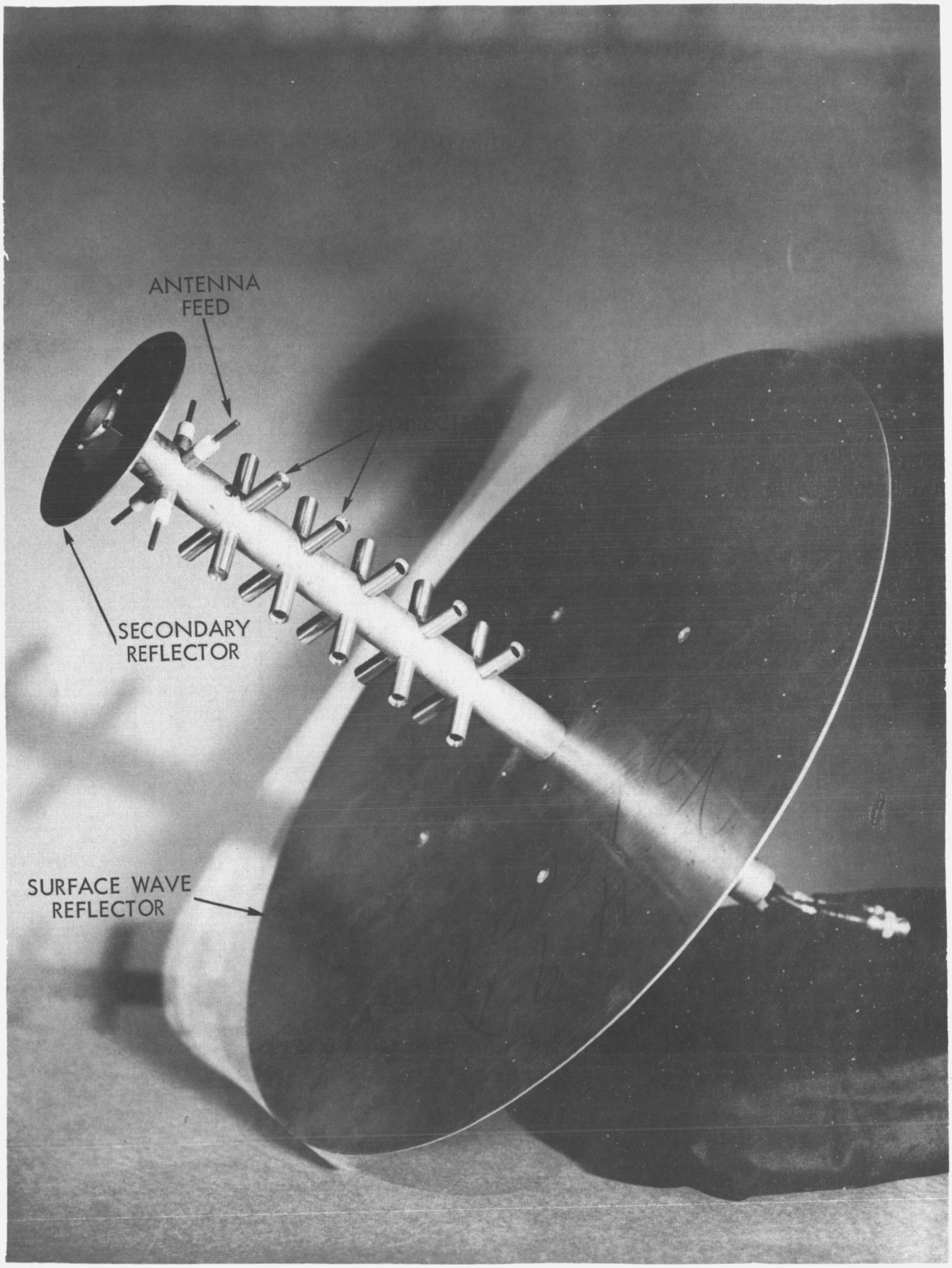
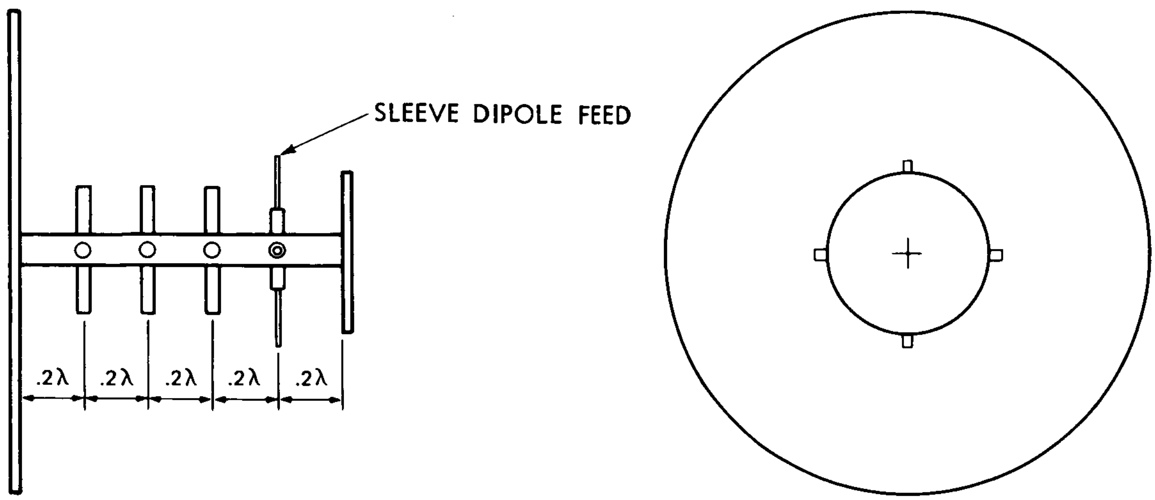


Figure 1. Photo of the Backfire Antenna

1.0λ MODEL

A



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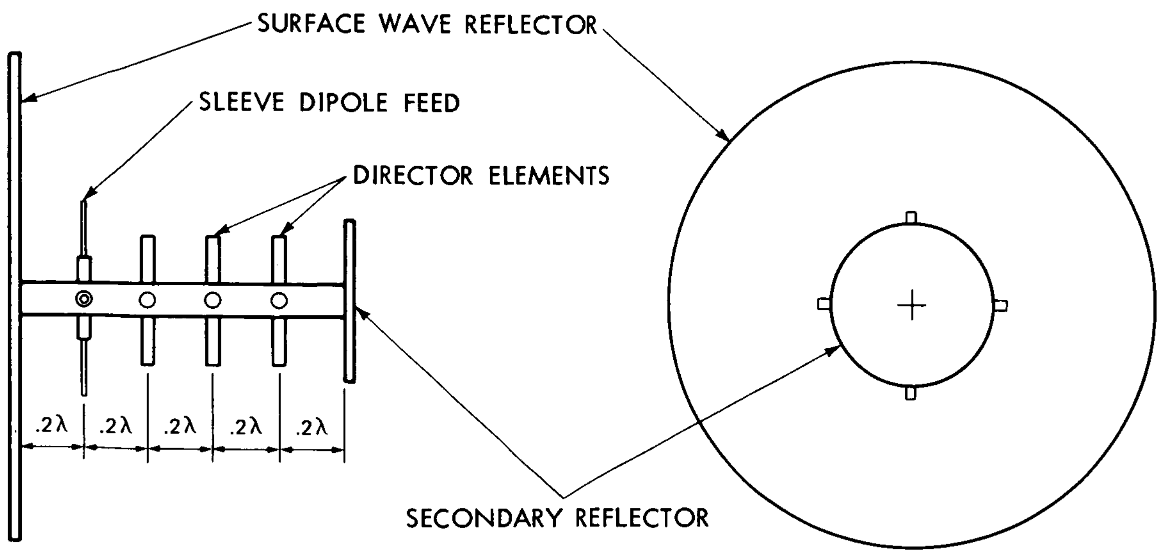


Figure 2. 1.0λ Backfire Antenna

1.5λ MODEL

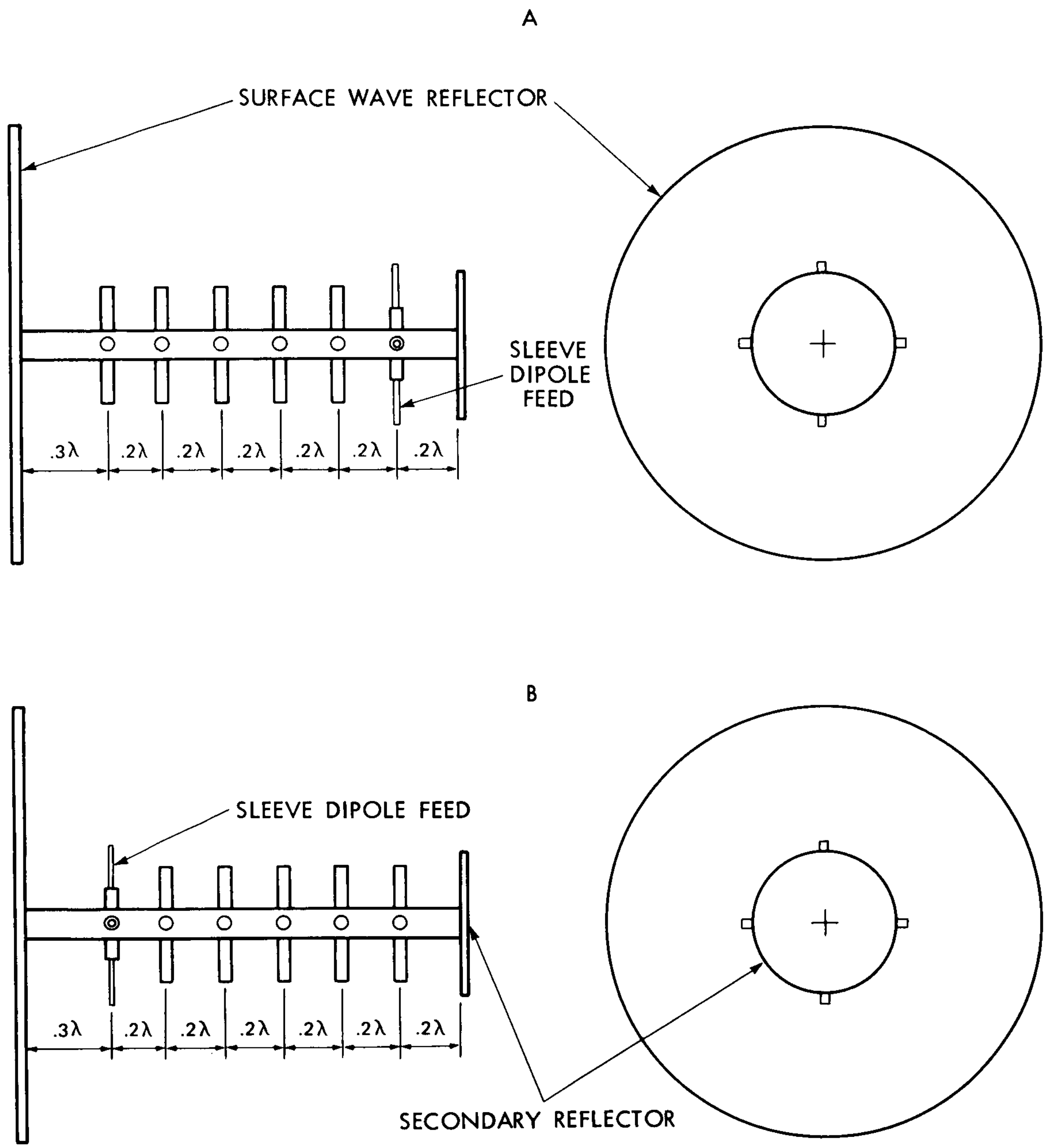


Figure 3. 1.5λ Backfire Antenna

2.0λ MODEL

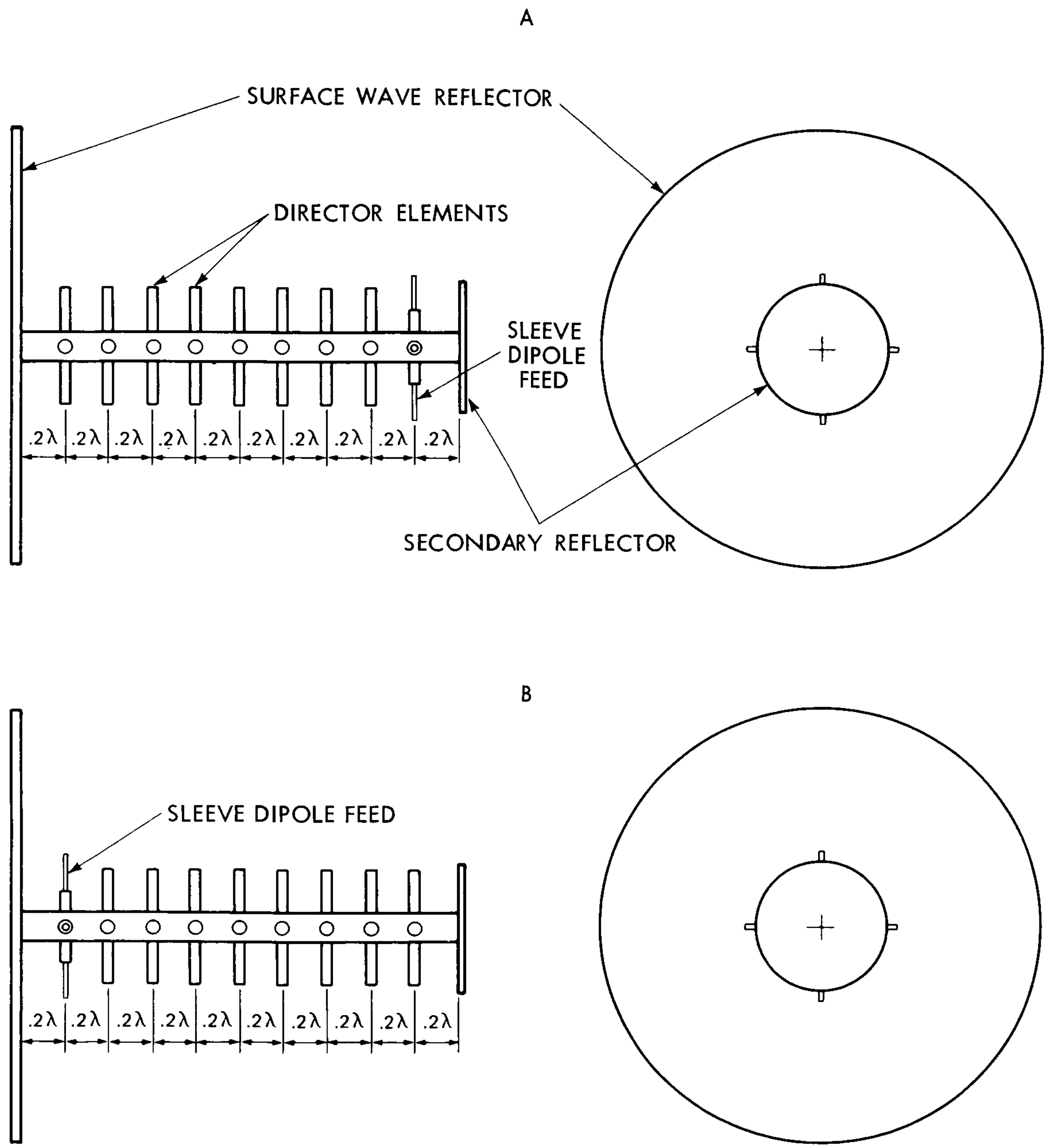
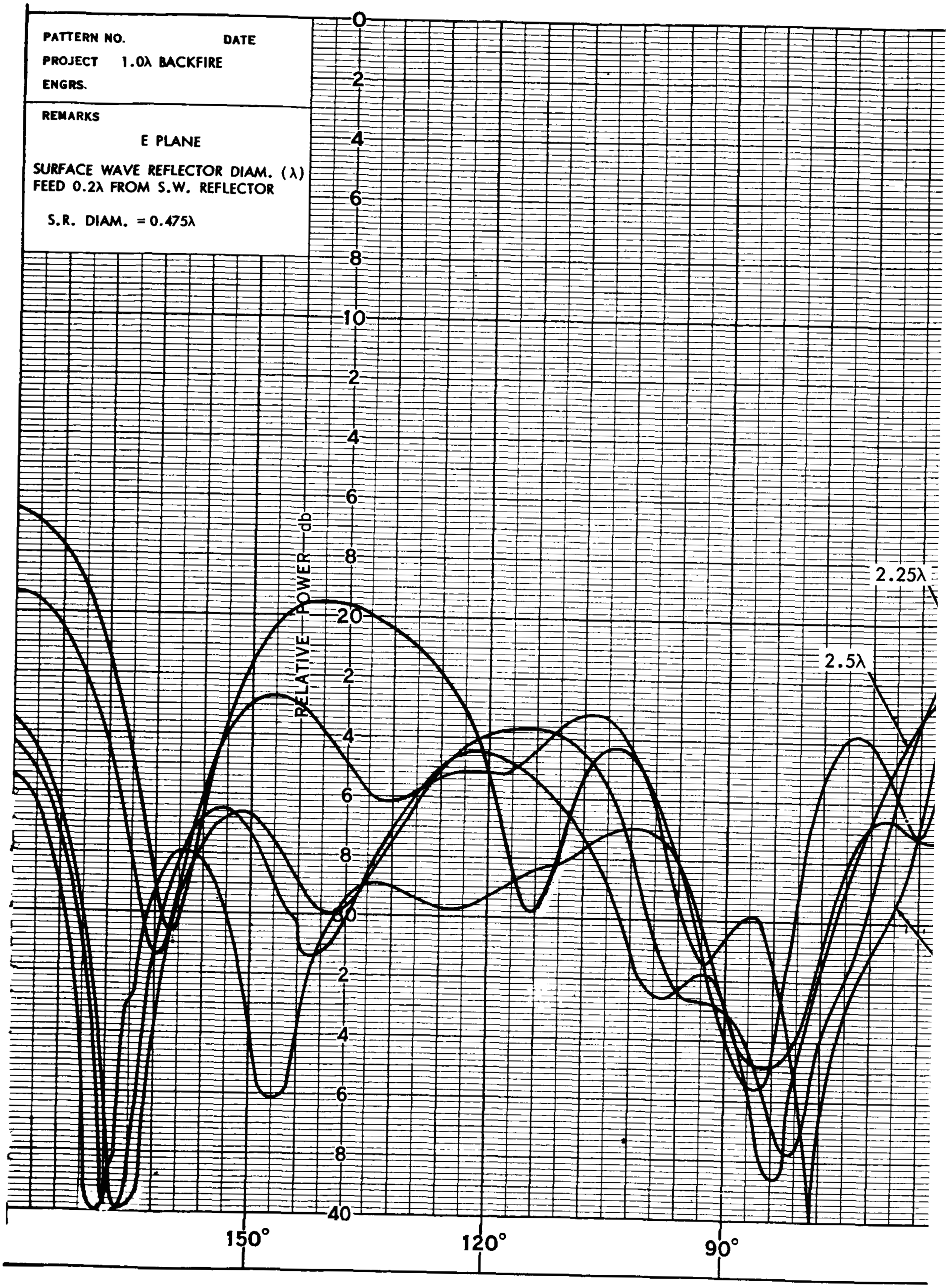


Figure 4. 2.0λ Backfire Antenna



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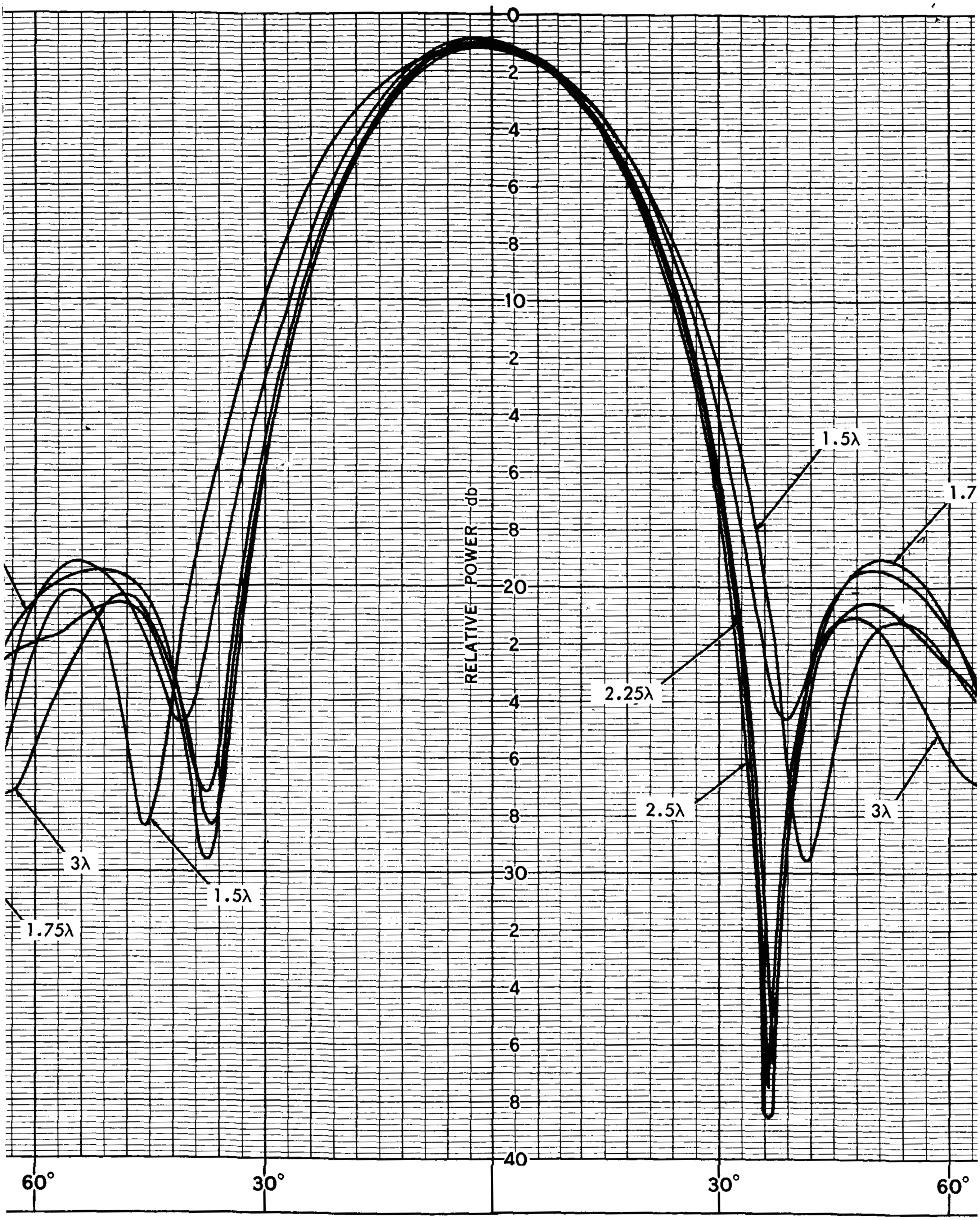
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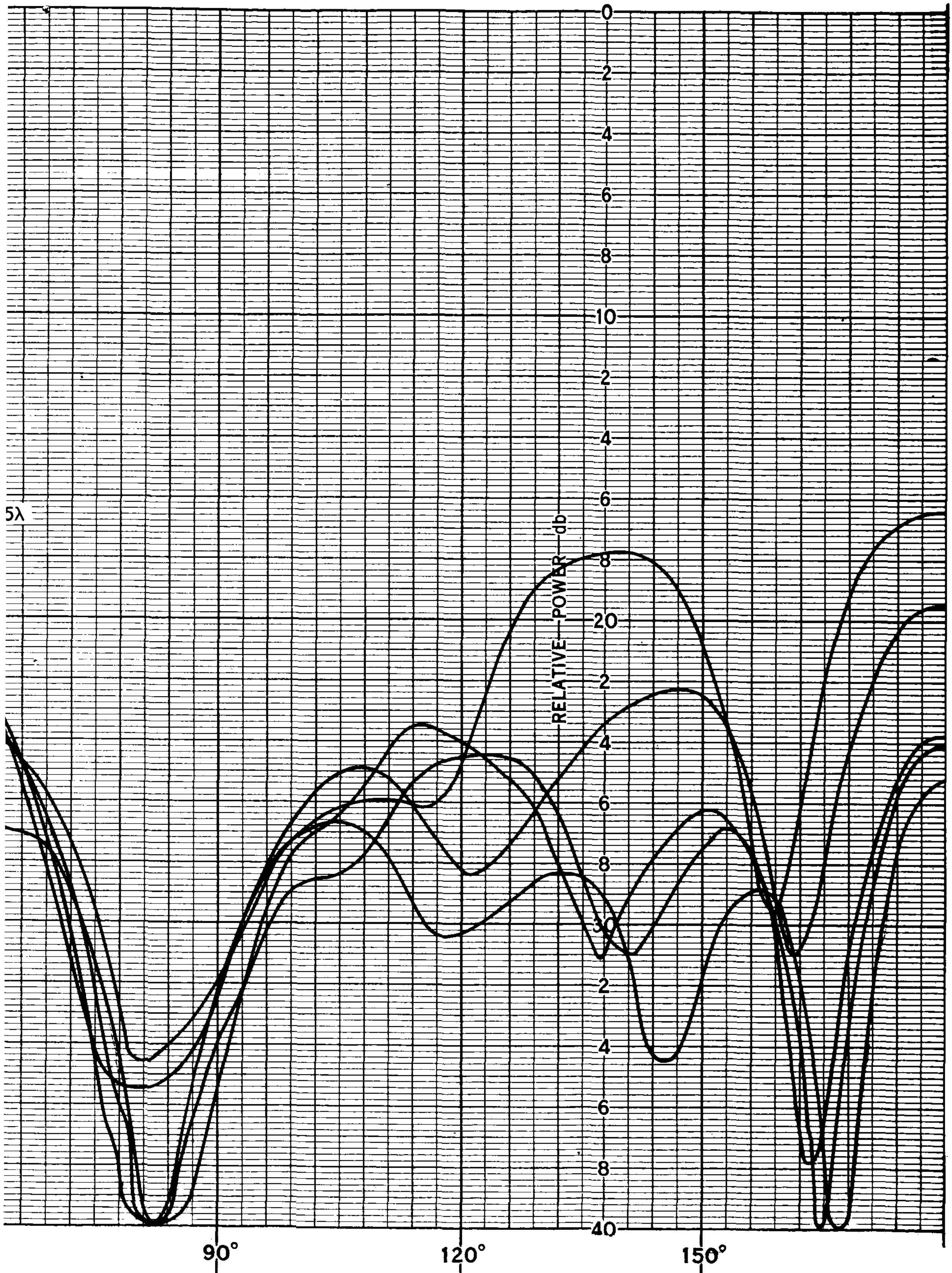

Figure 5. 1.0 λ Backfire E Plane Radiation Patterns for Variable Surface Wave Reflector Diameters with the Feed Dipole Located 0.2 λ from the Surface Wave Reflector

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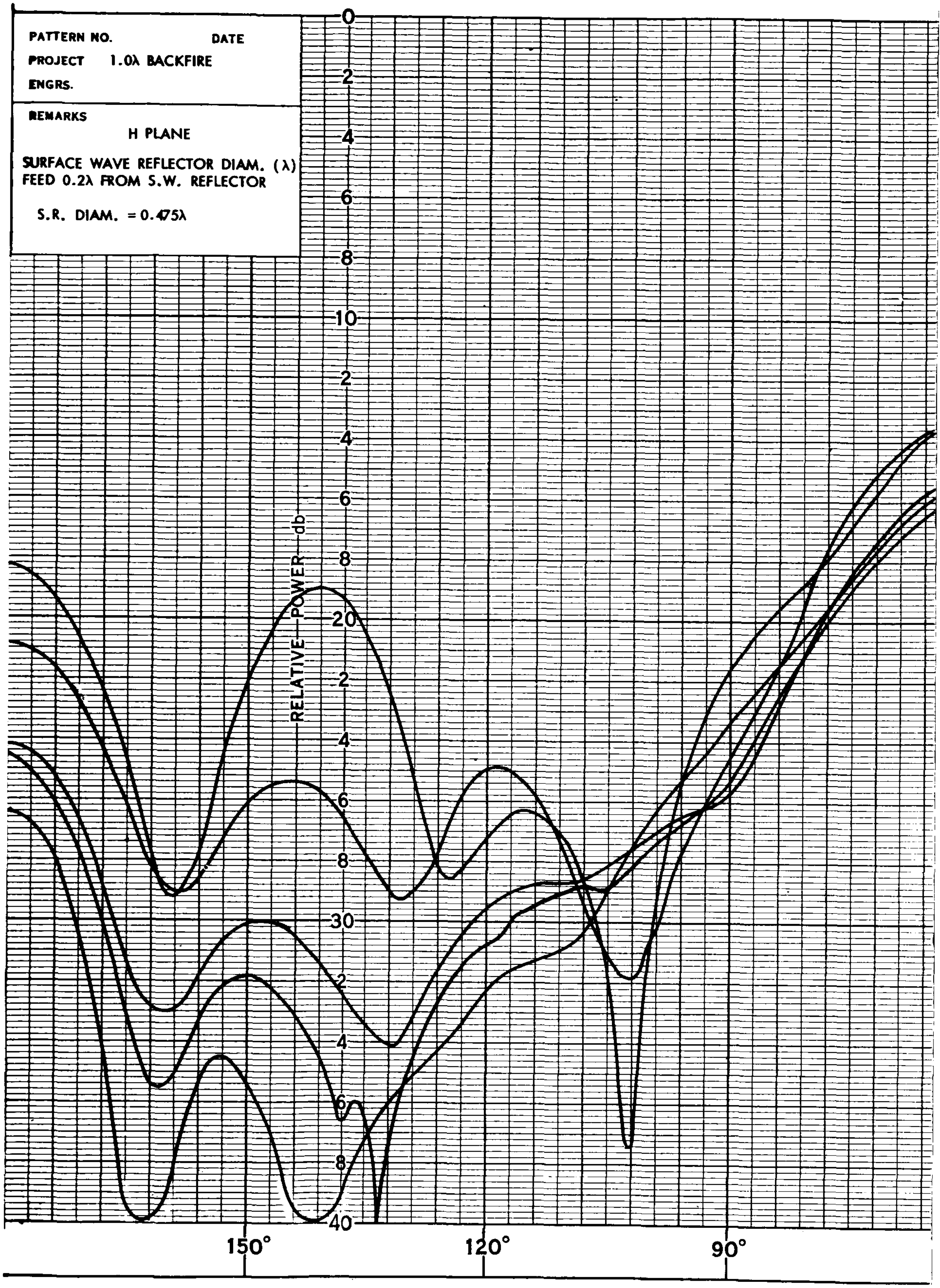

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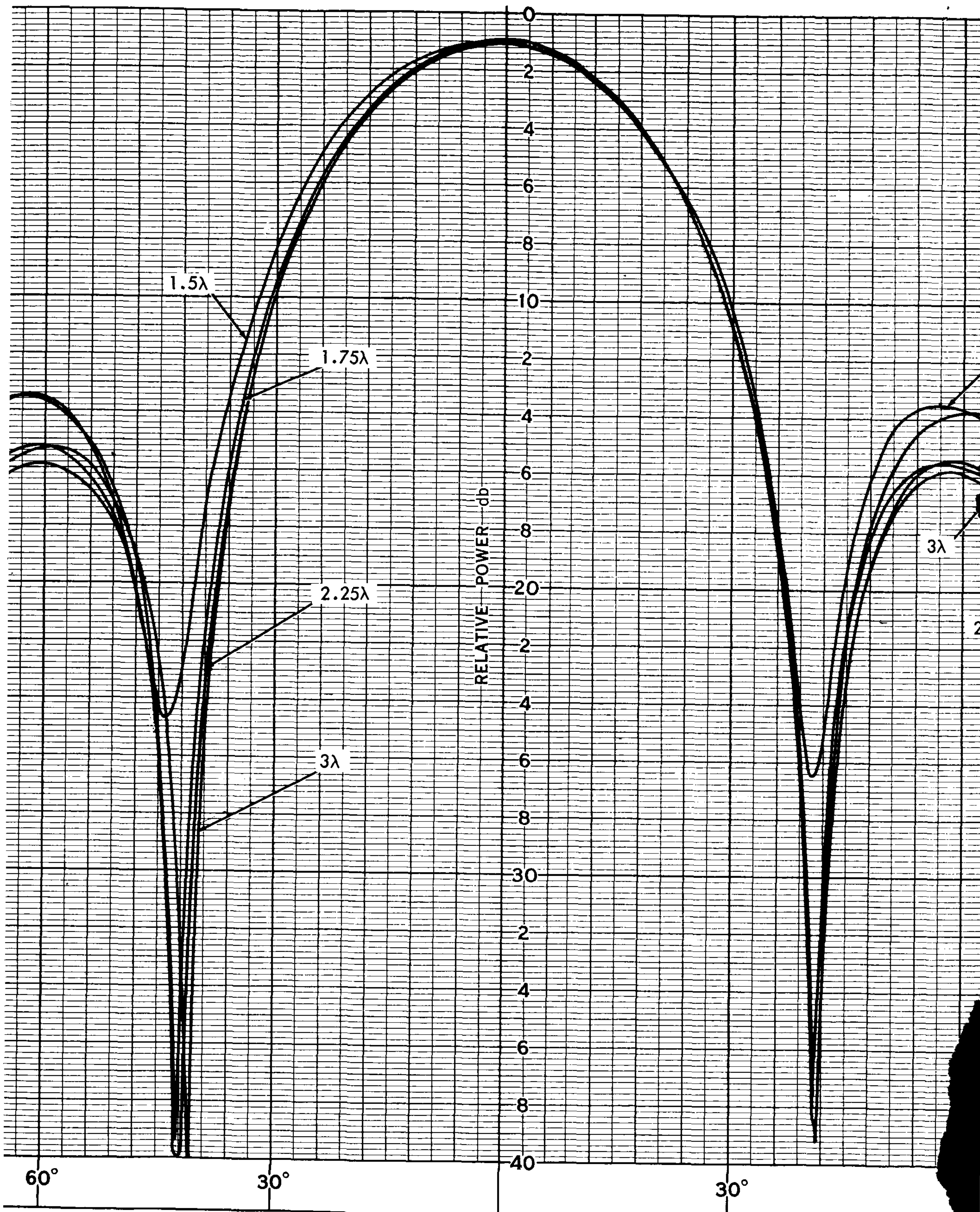

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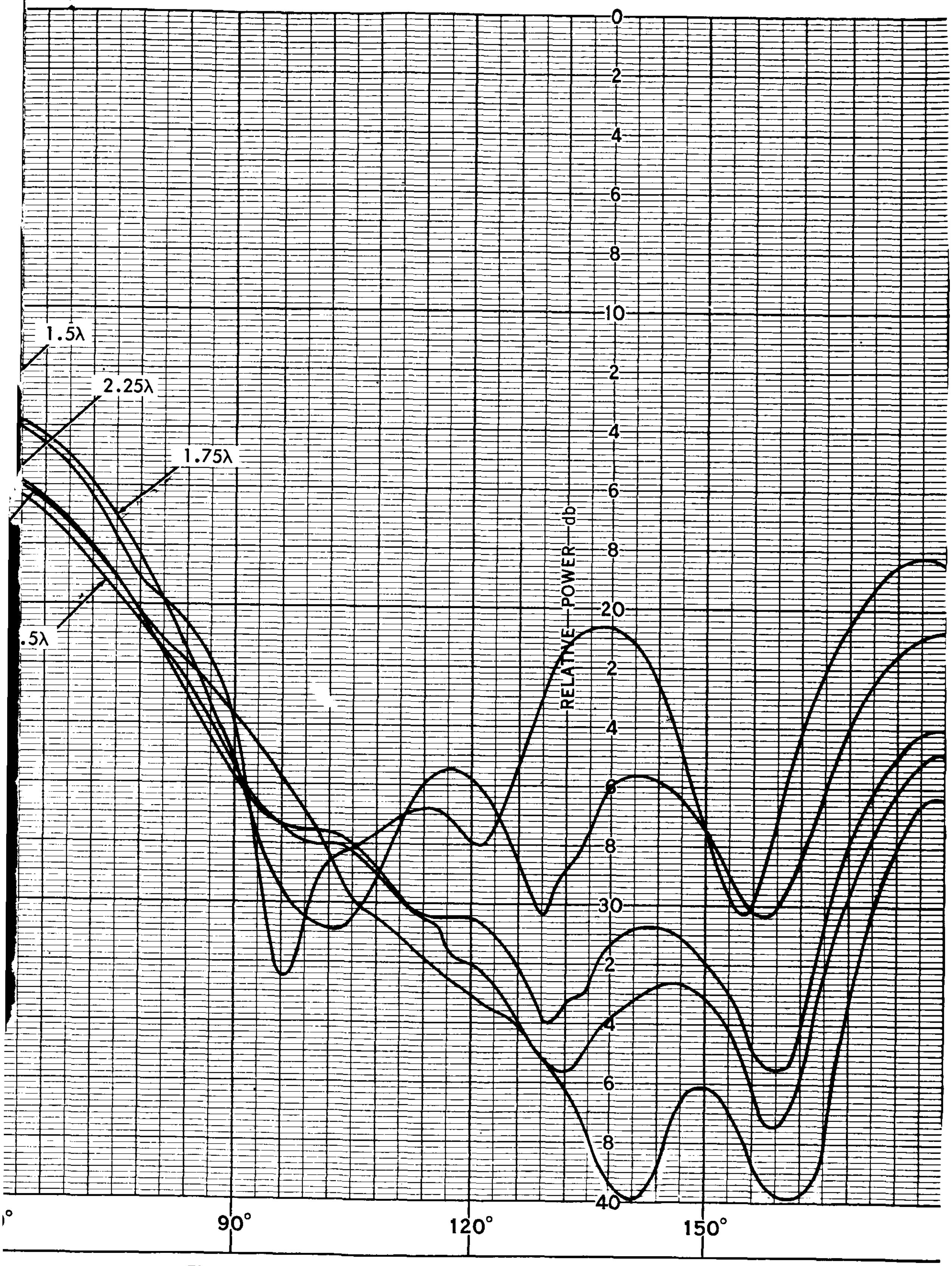
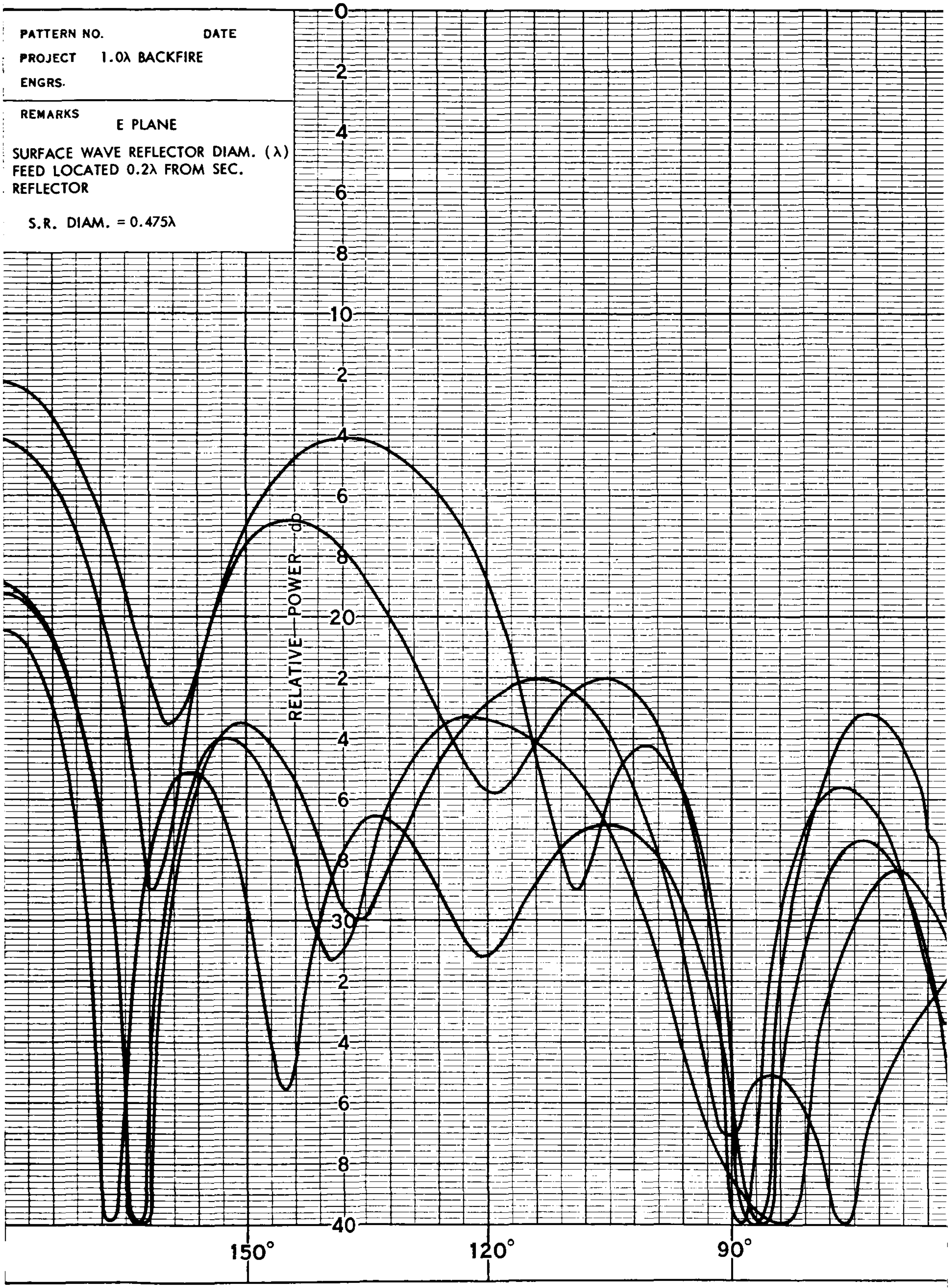


Figure 6. 1.0λ Backfire H Plane Radiation Patterns for Variable Surface Wave Reflector Diameters with the Feed Dipole Located 0.2 λ from the Surface Wave Reflector



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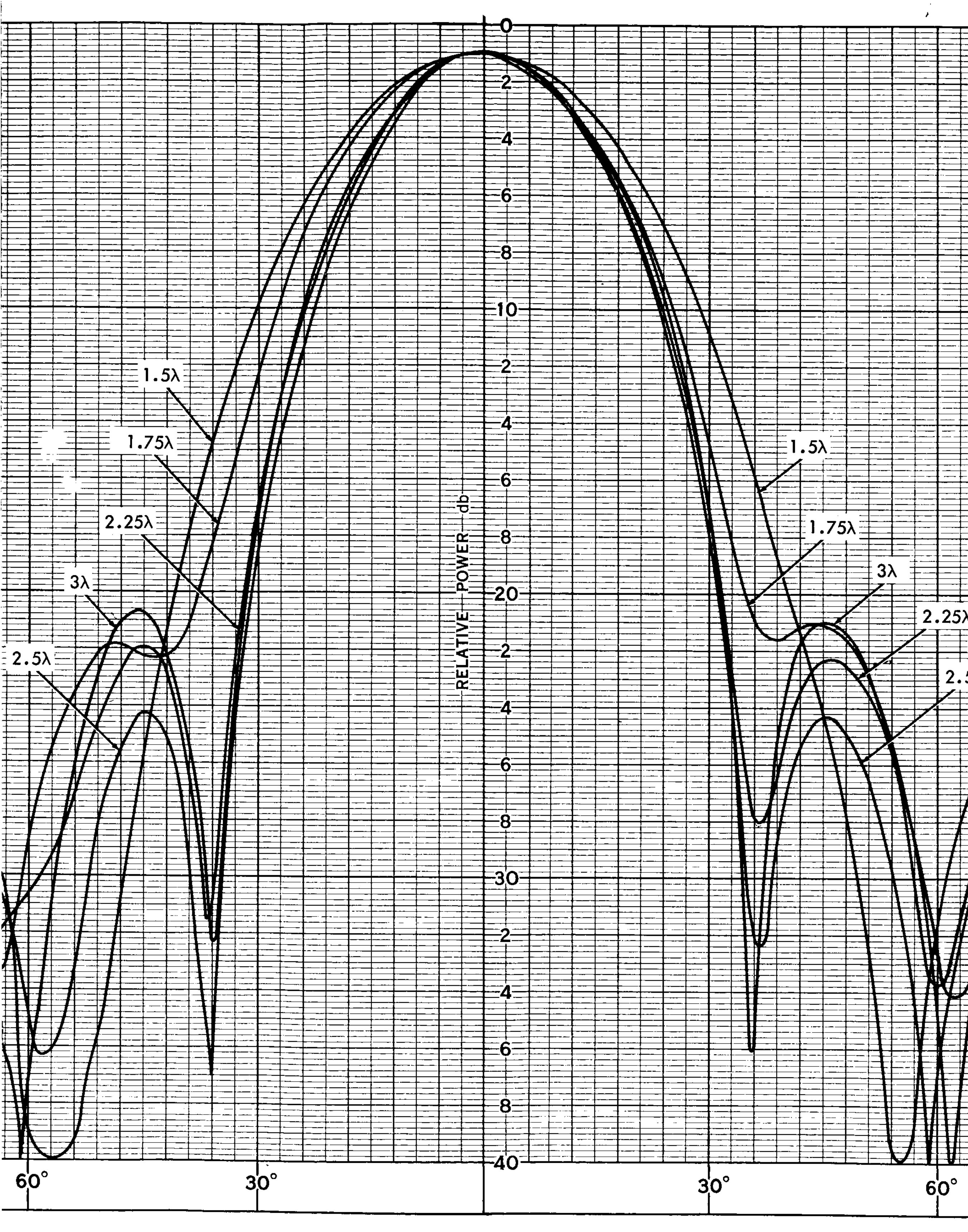

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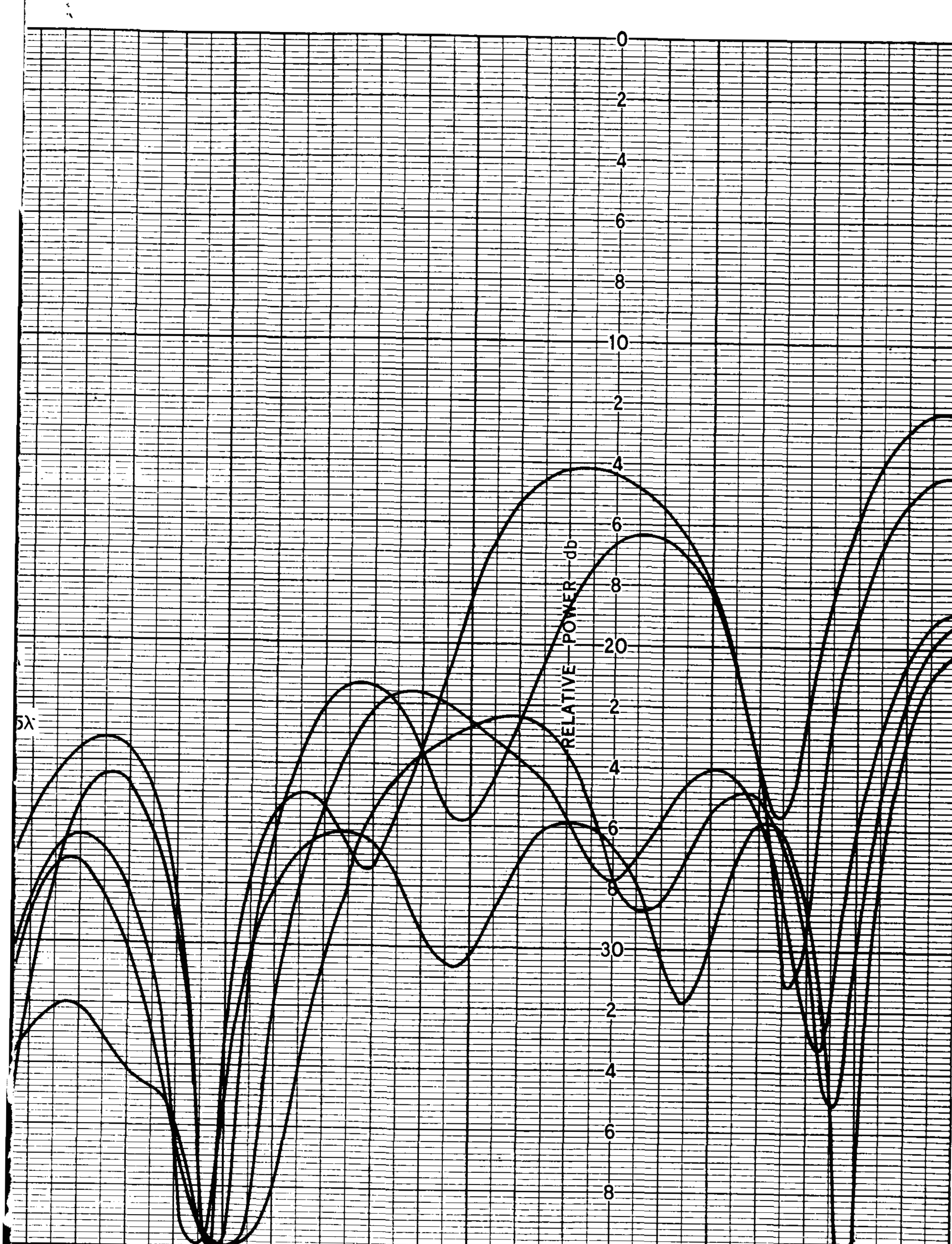
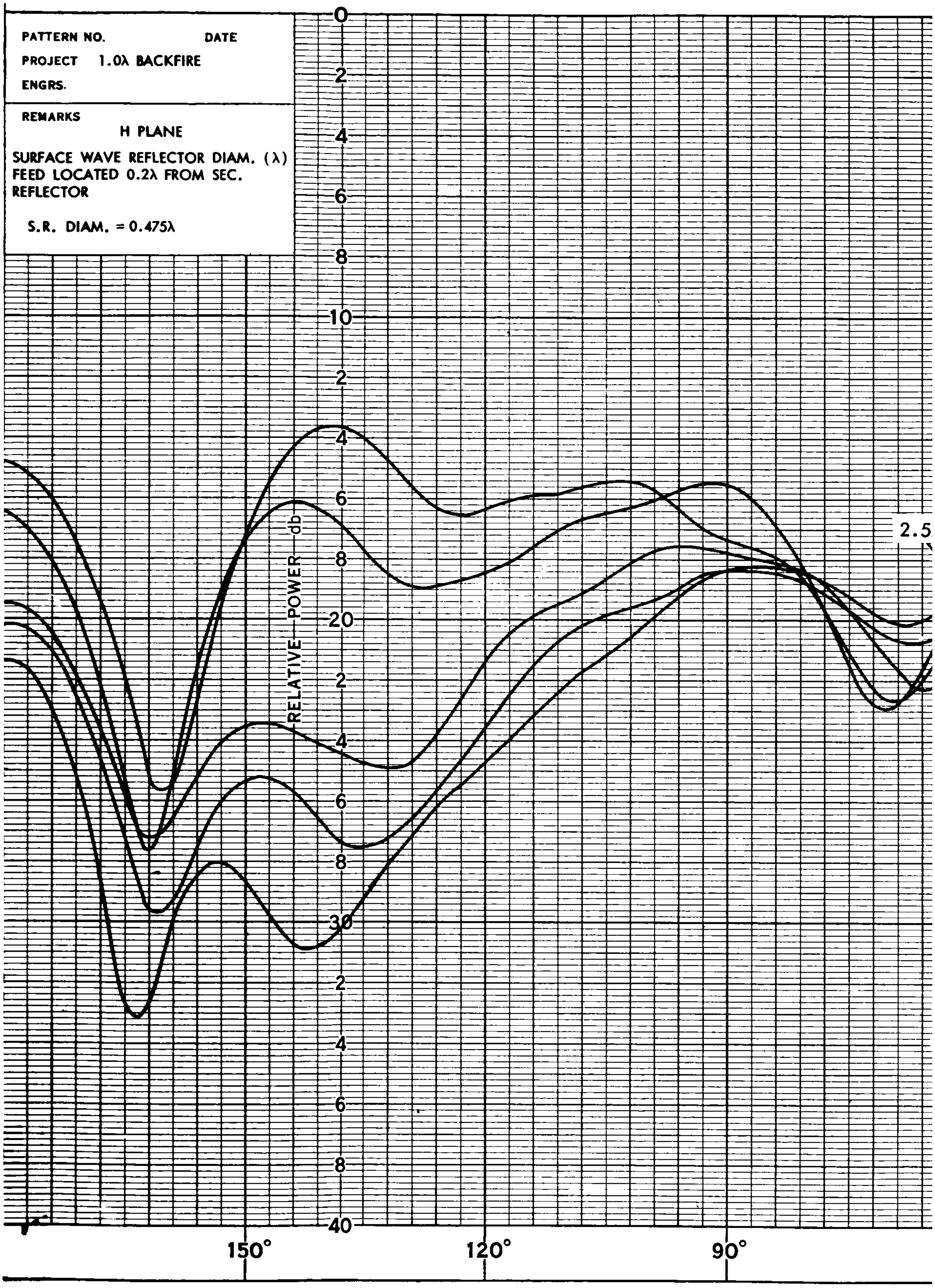


Figure 7. 1.0 λ Backfire E Plane Radiation Patterns for Variable Surface Wave Reflector Diameters with the Feed Dipole Located 0.2 λ from the Secondary Reflector



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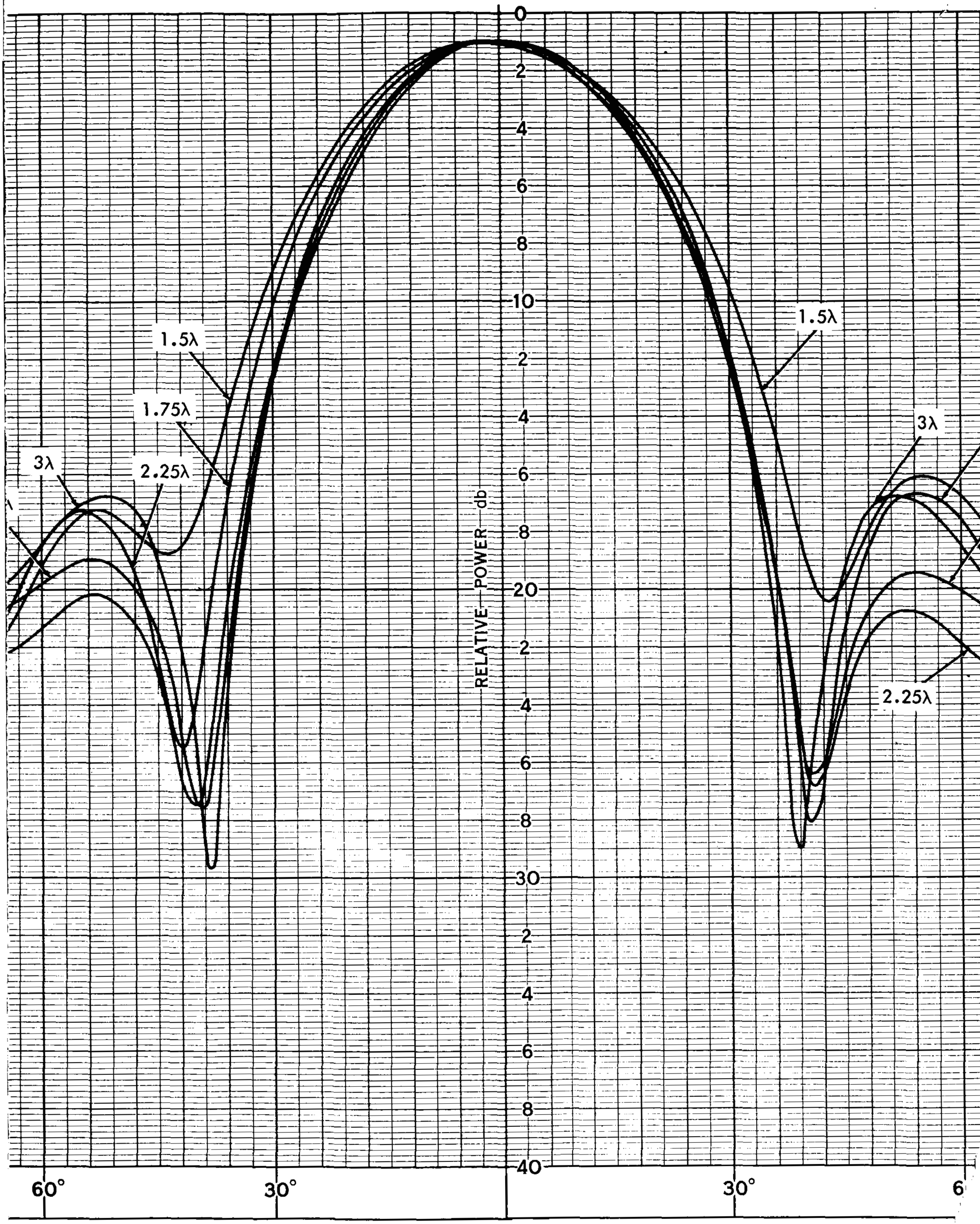

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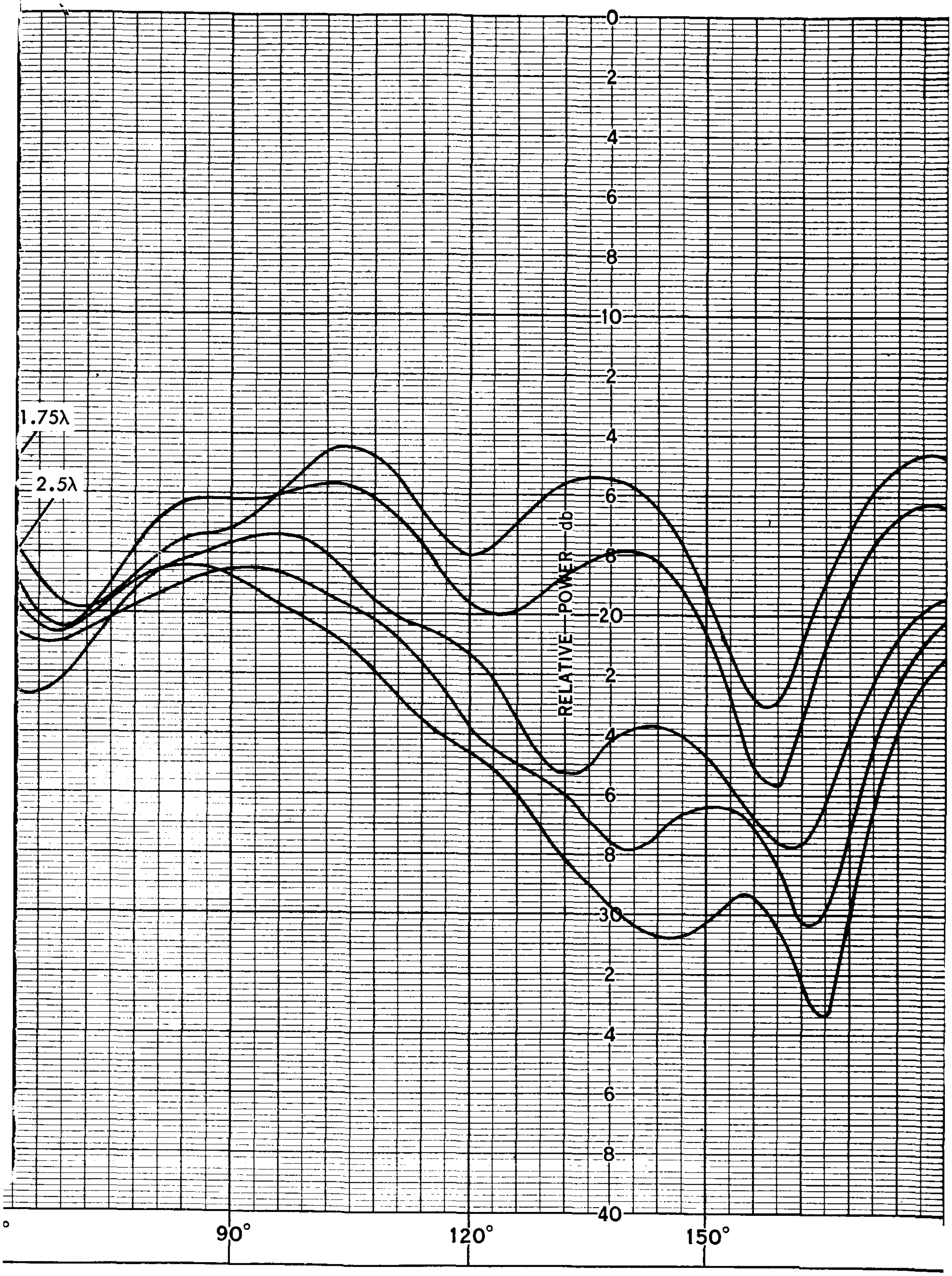

Figure 8. 1.0 λ Backfire H Plane Radiation Patterns for Variable Surface Wave Reflector Diameters with the Feed Dipole Located 0.2 λ from the Secondary Reflector

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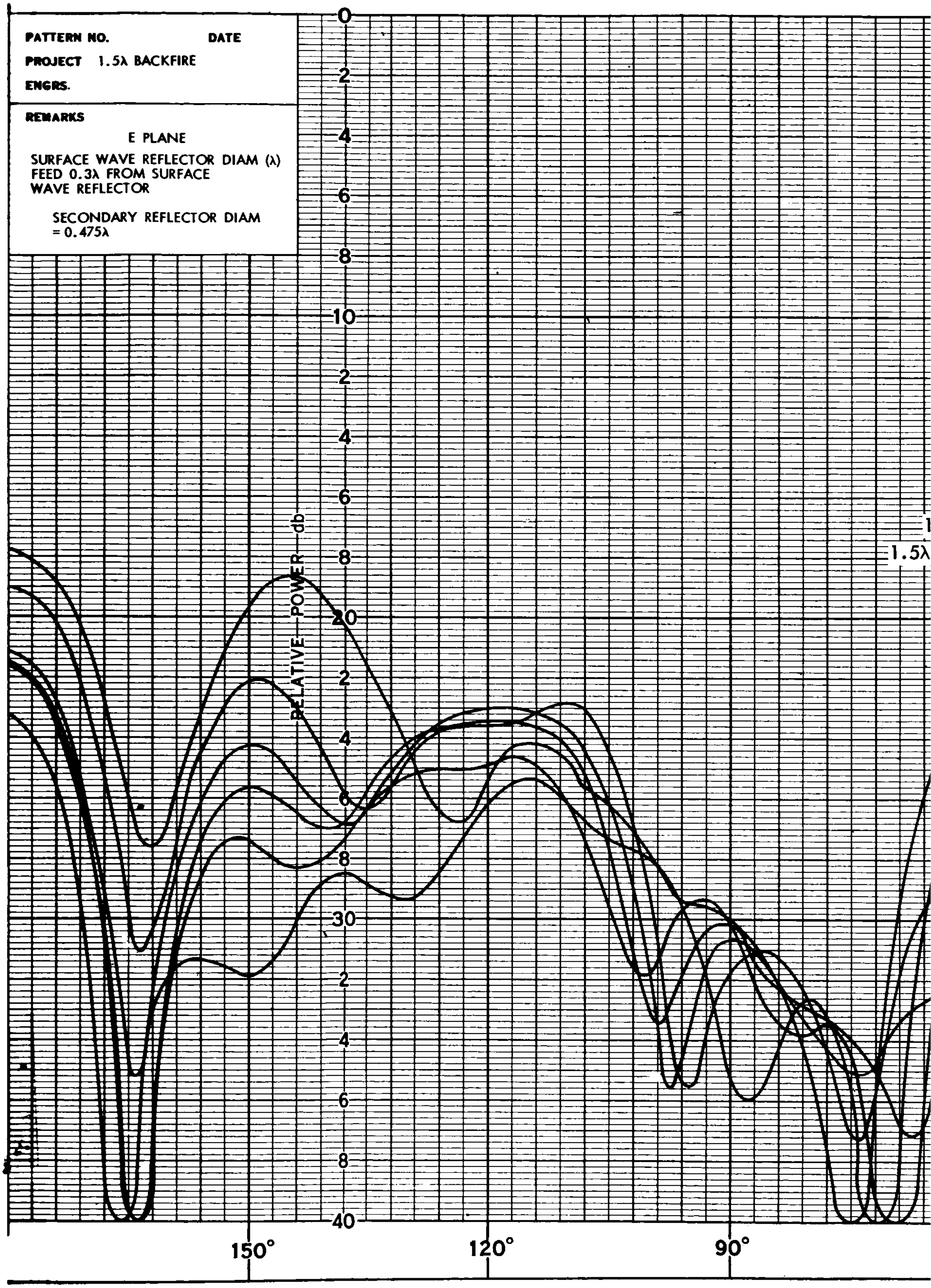

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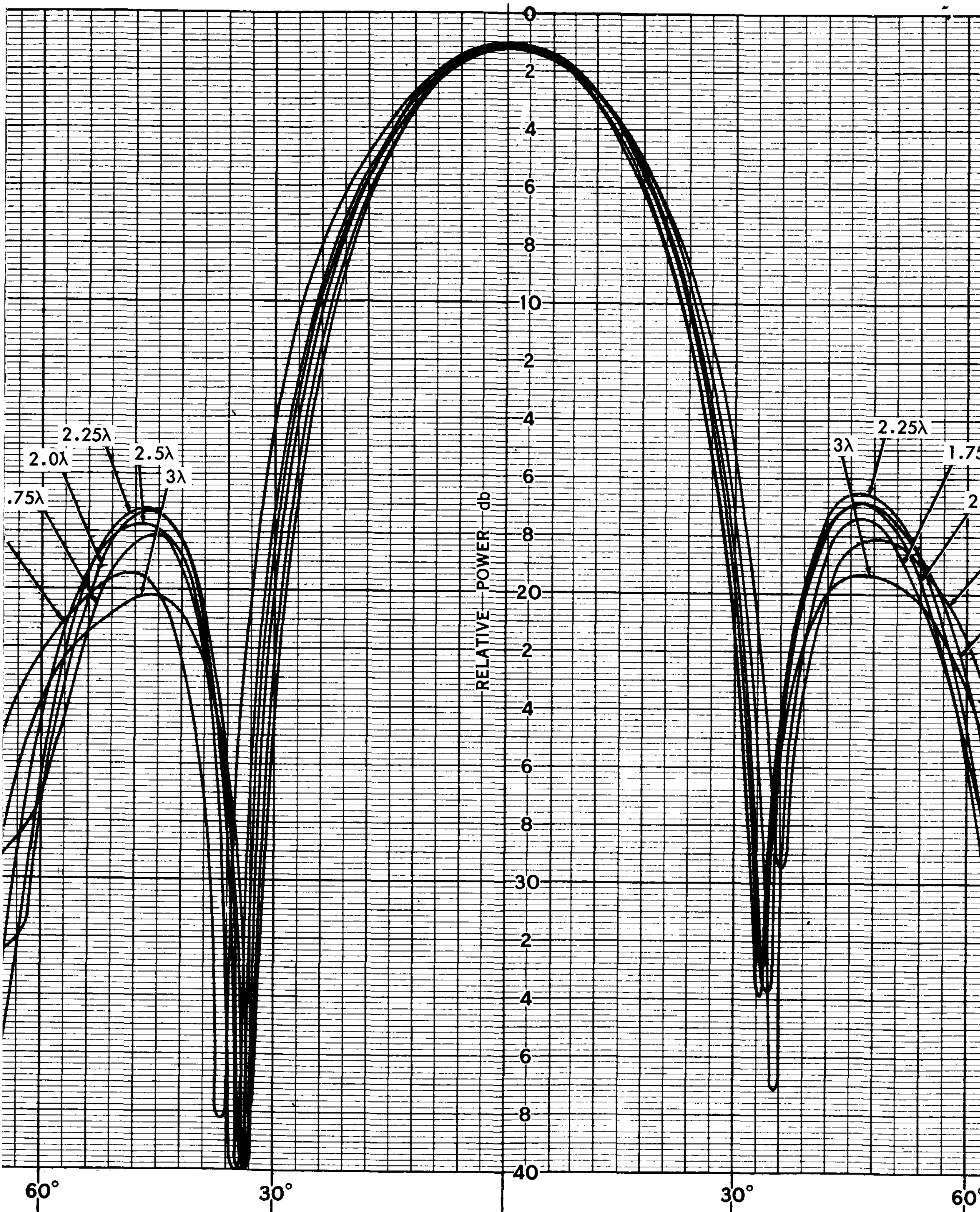

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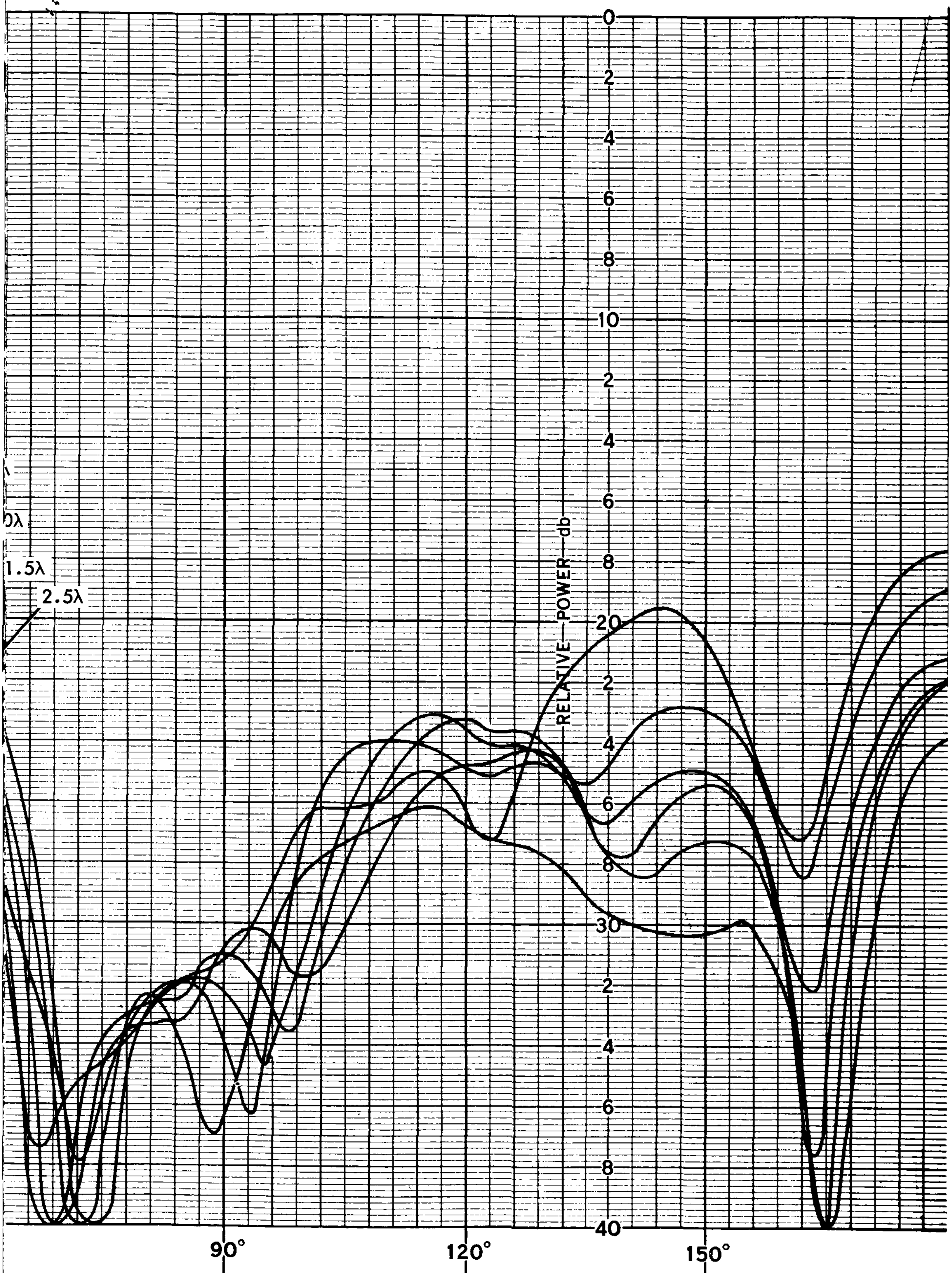
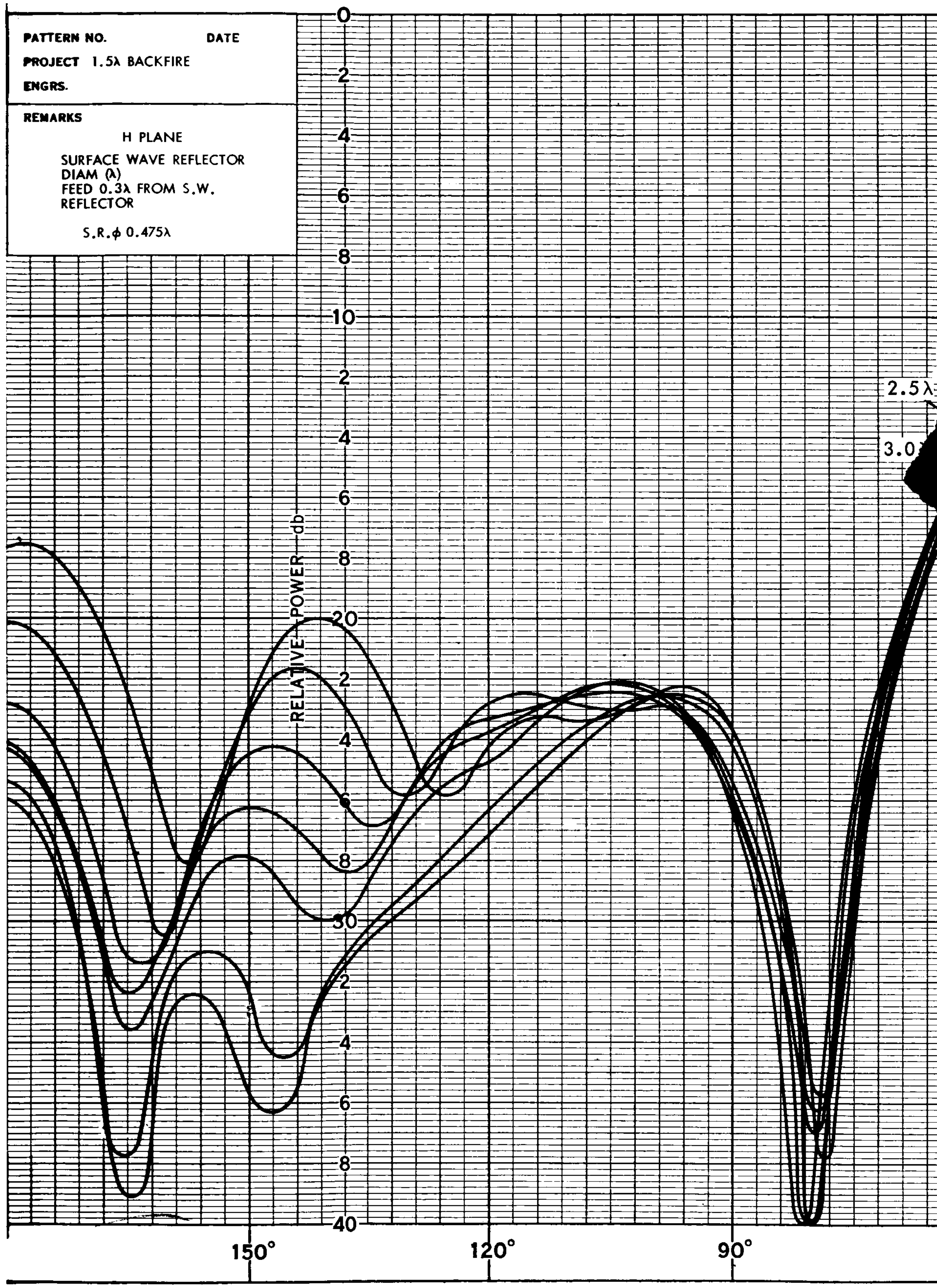


Figure 9. 1.5 λ Backfire E Plane Radiation Patterns for Variable Surface Wave Reflector Diameters with the Feed Dipole Located 0.3 λ from the Surface Wave Reflector



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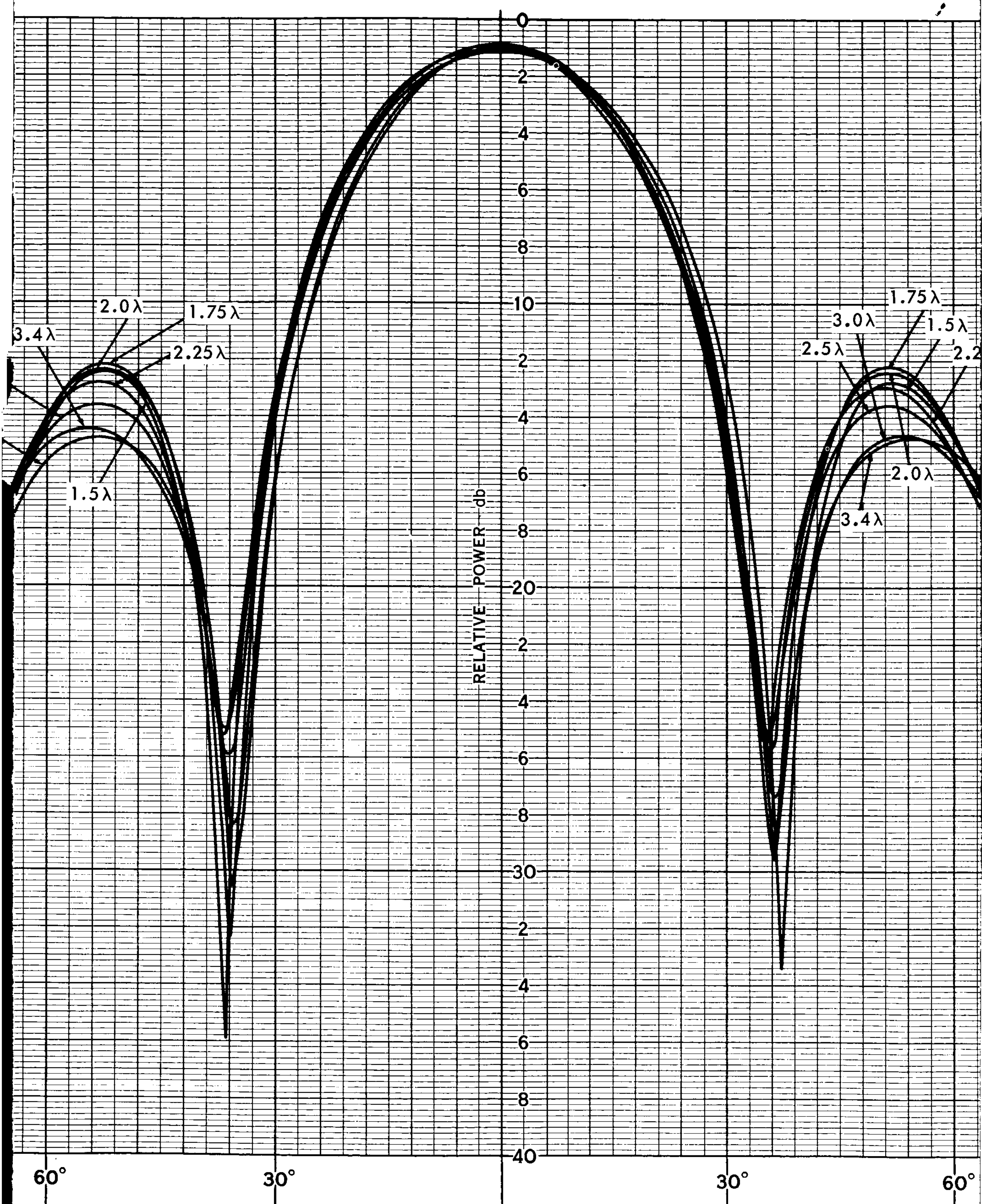

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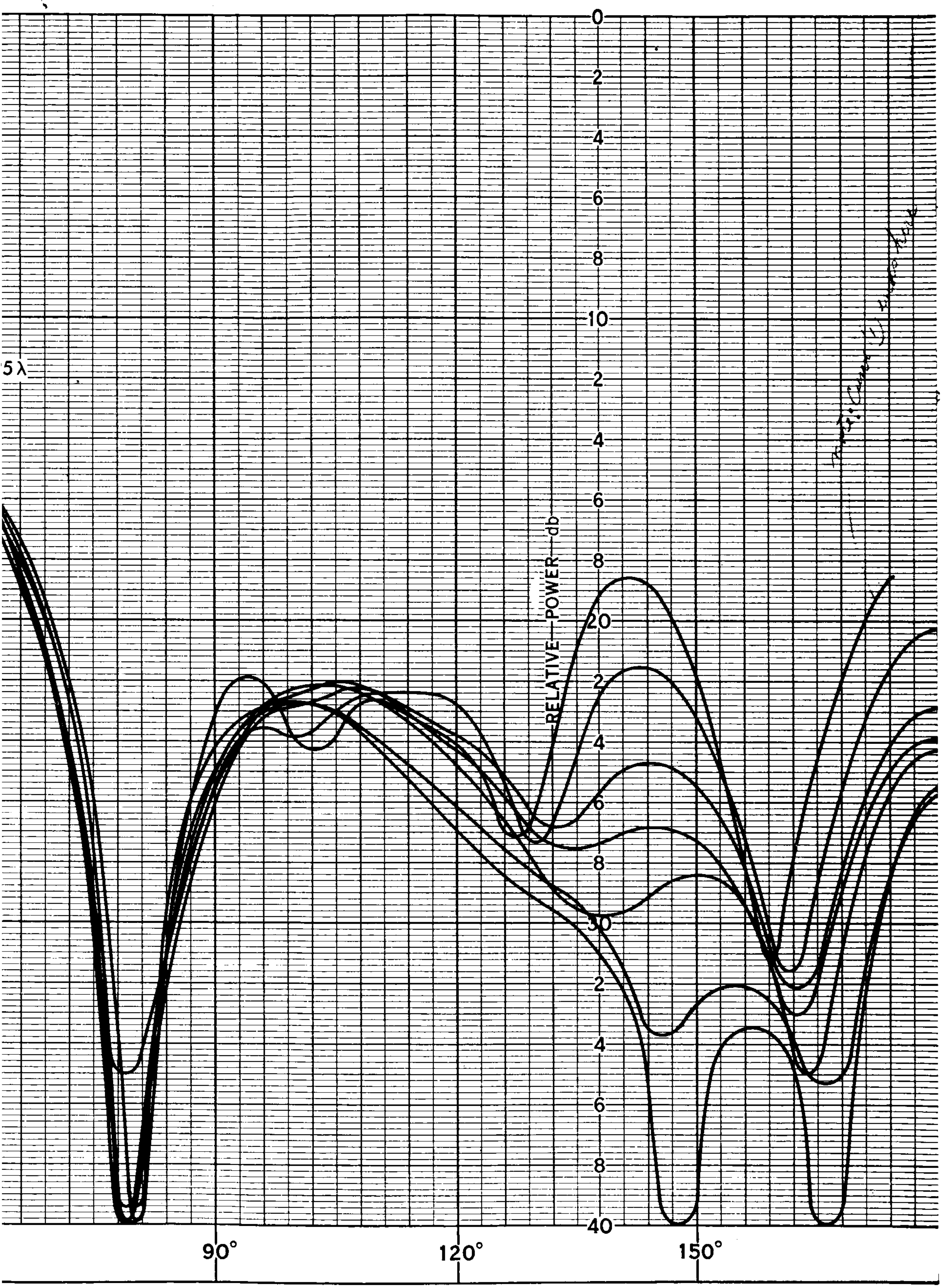
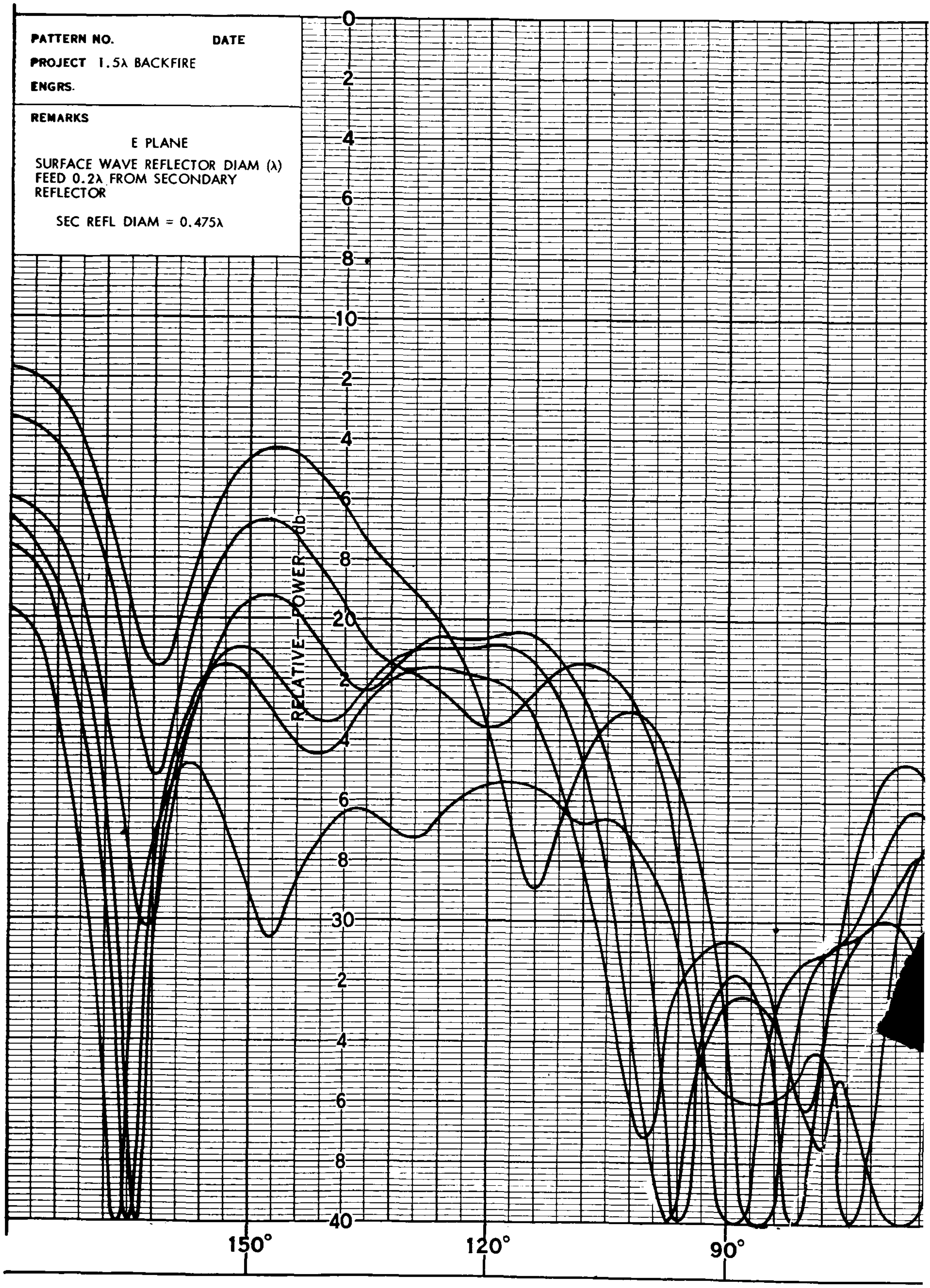


Figure 10. 1.5 λ Backfire H Plane Radiation Patterns for Variable Surface Wave Reflector Diameters with the Feed Dipole Located 0.3 λ from the Surface Wave Reflector



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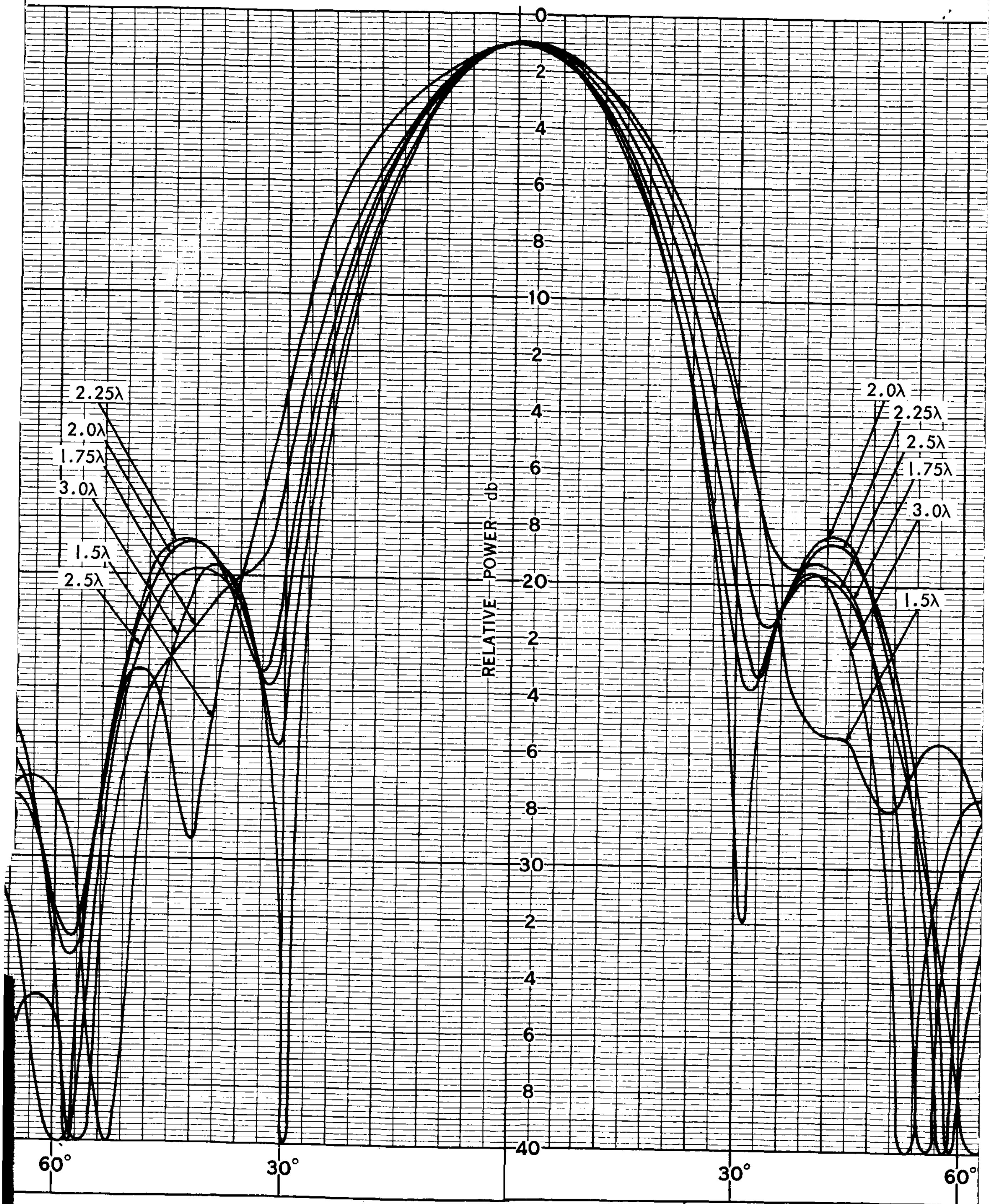

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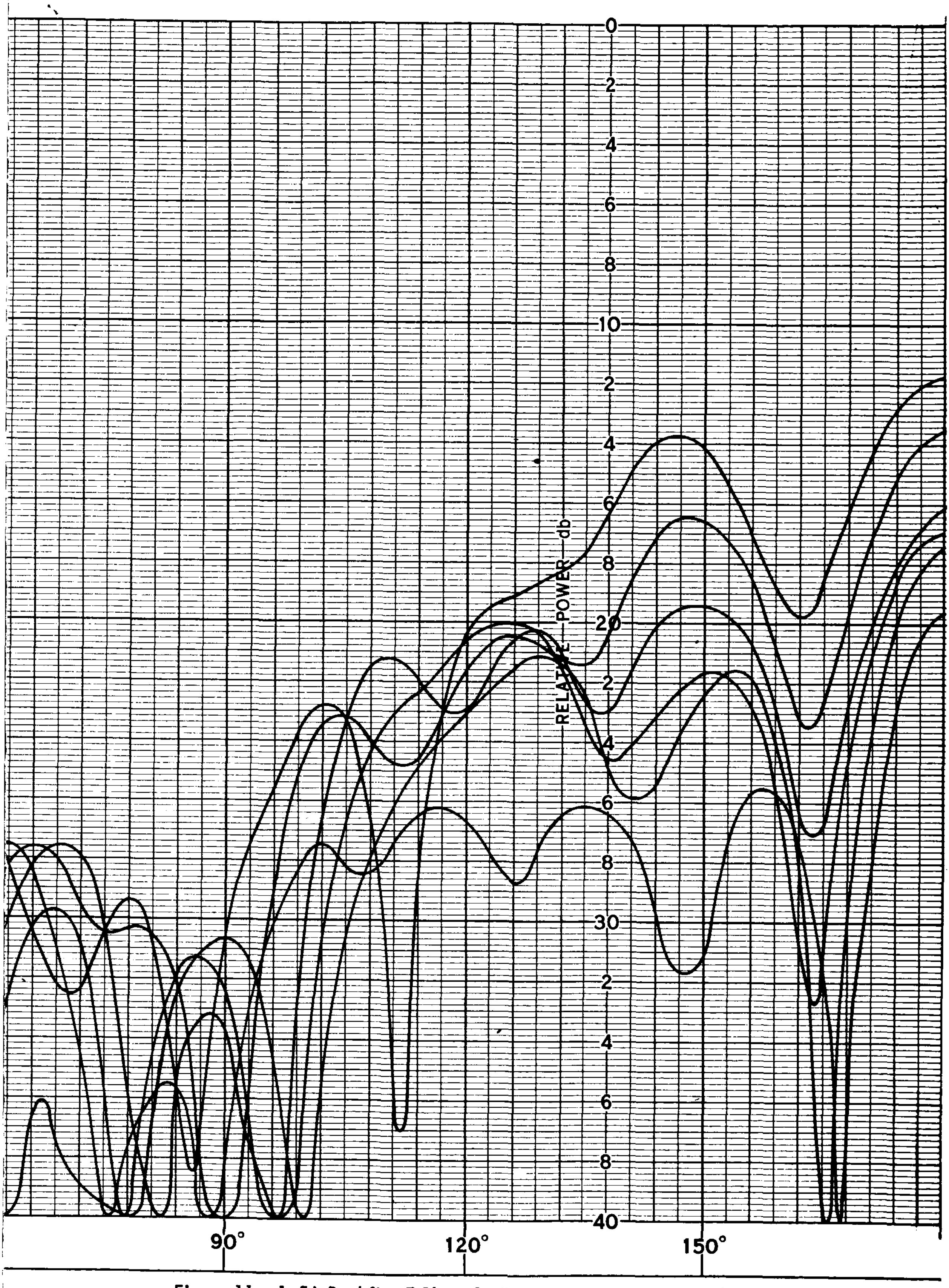

Figure 11. 1.5 λ Backfire E Plane Radiation Patterns for Variable Surface Wave Reflector Diameters with the Feed Dipole Located 0.2 λ from the Secondary Reflector

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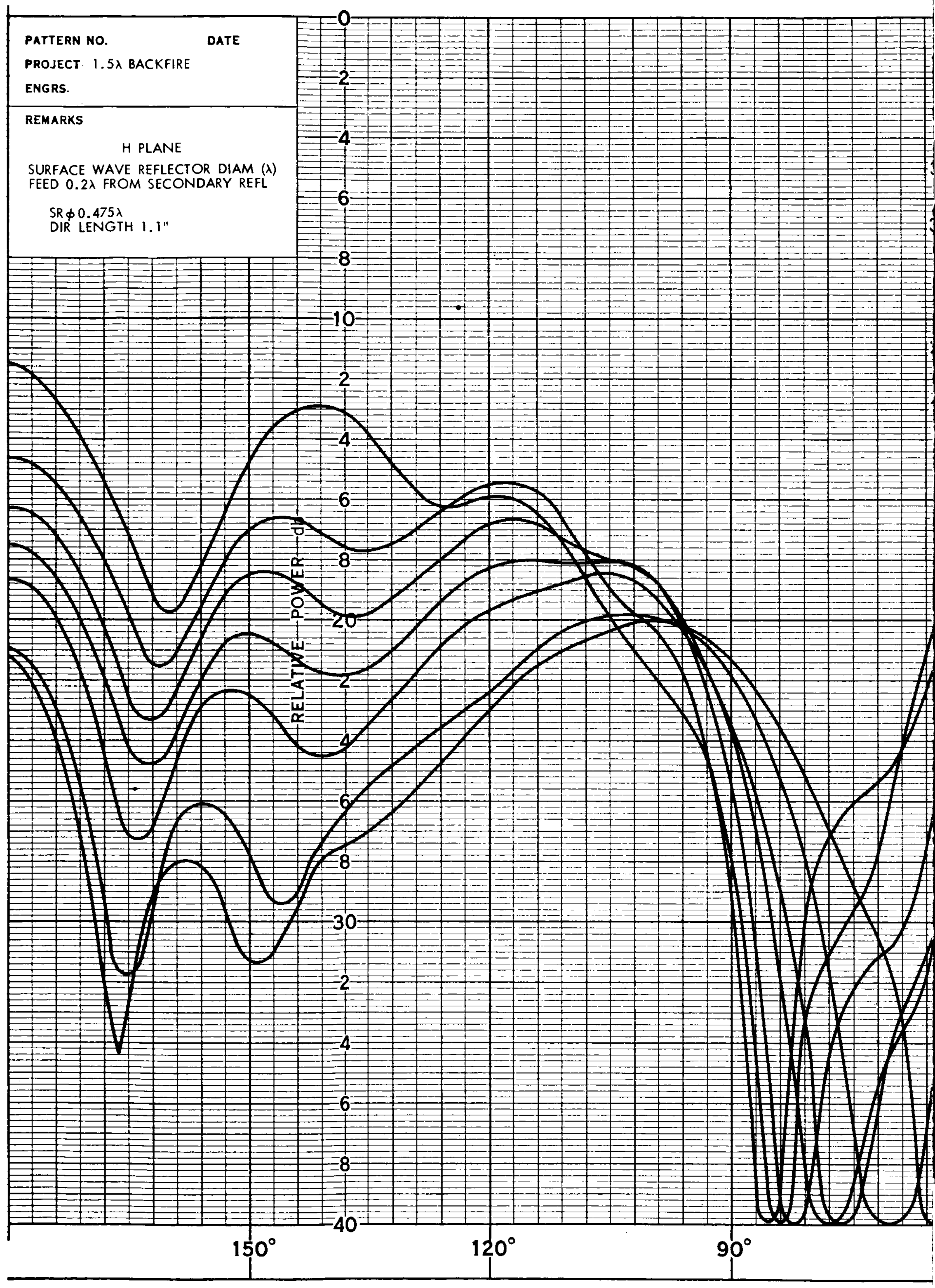

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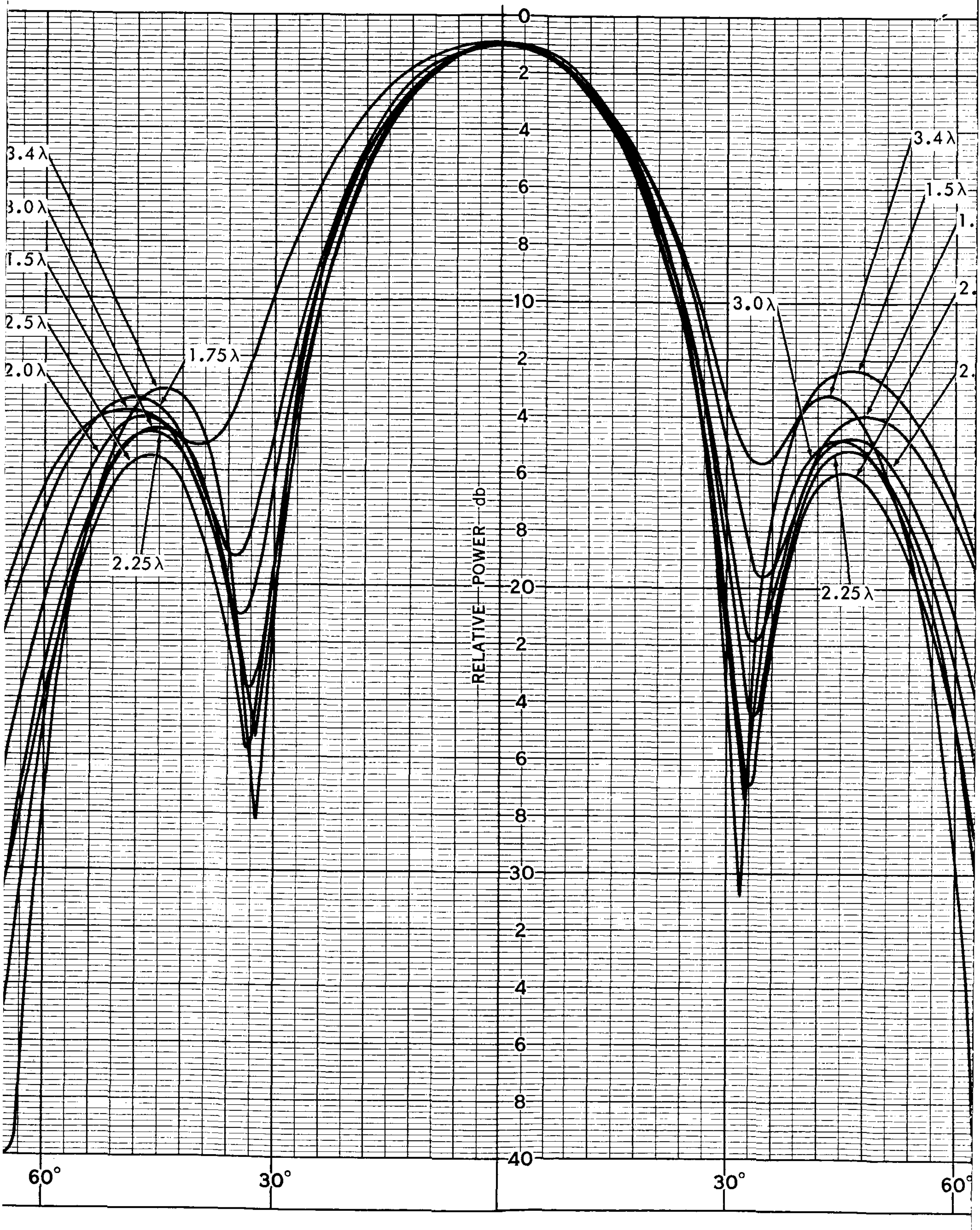

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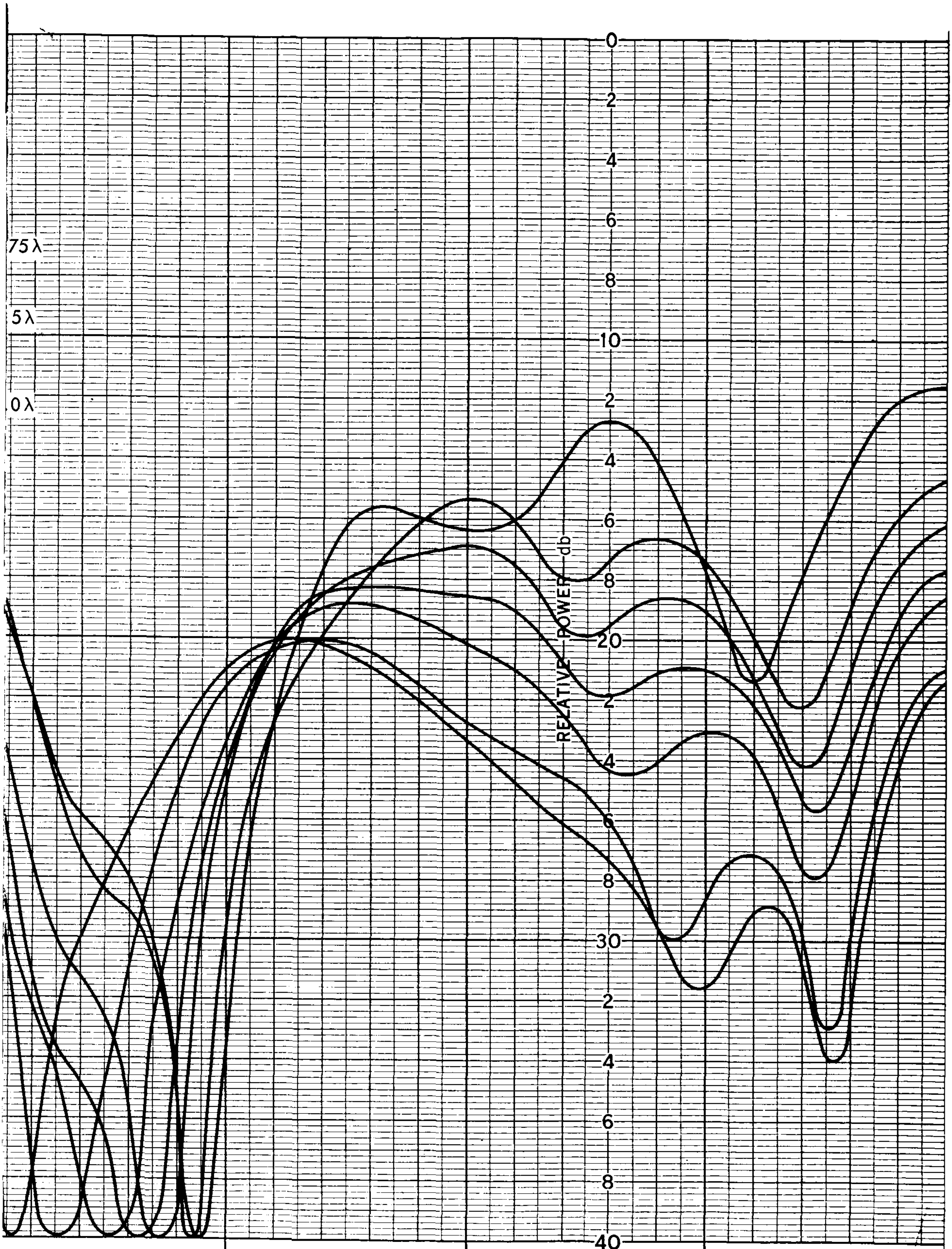

Figure 12. 1.5 λ Backfire H Plane Radiation Patterns for Variable Surface Wave Reflector Diameters with the Feed Dipole Located 0.2 λ from the Secondary Reflector

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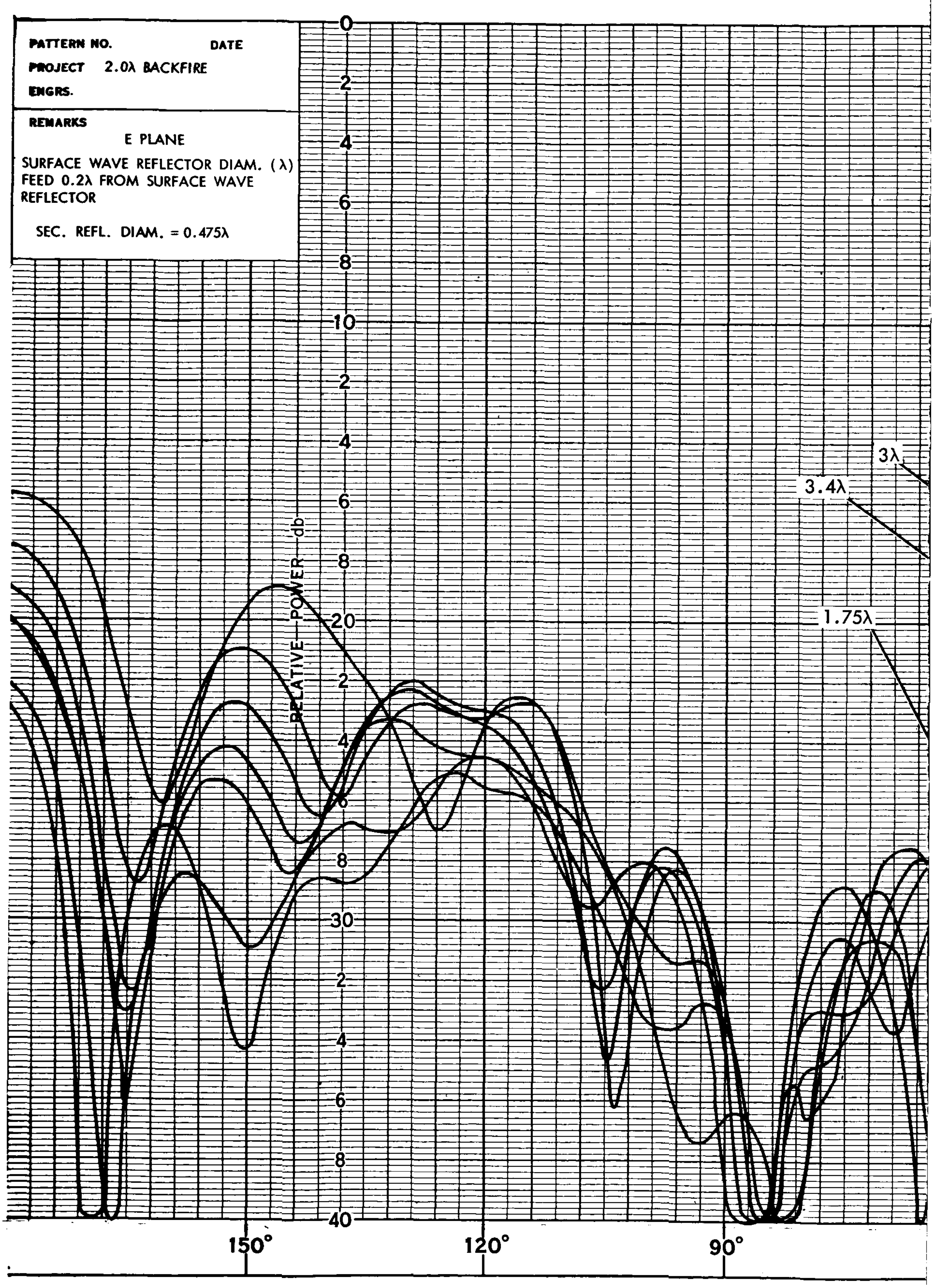

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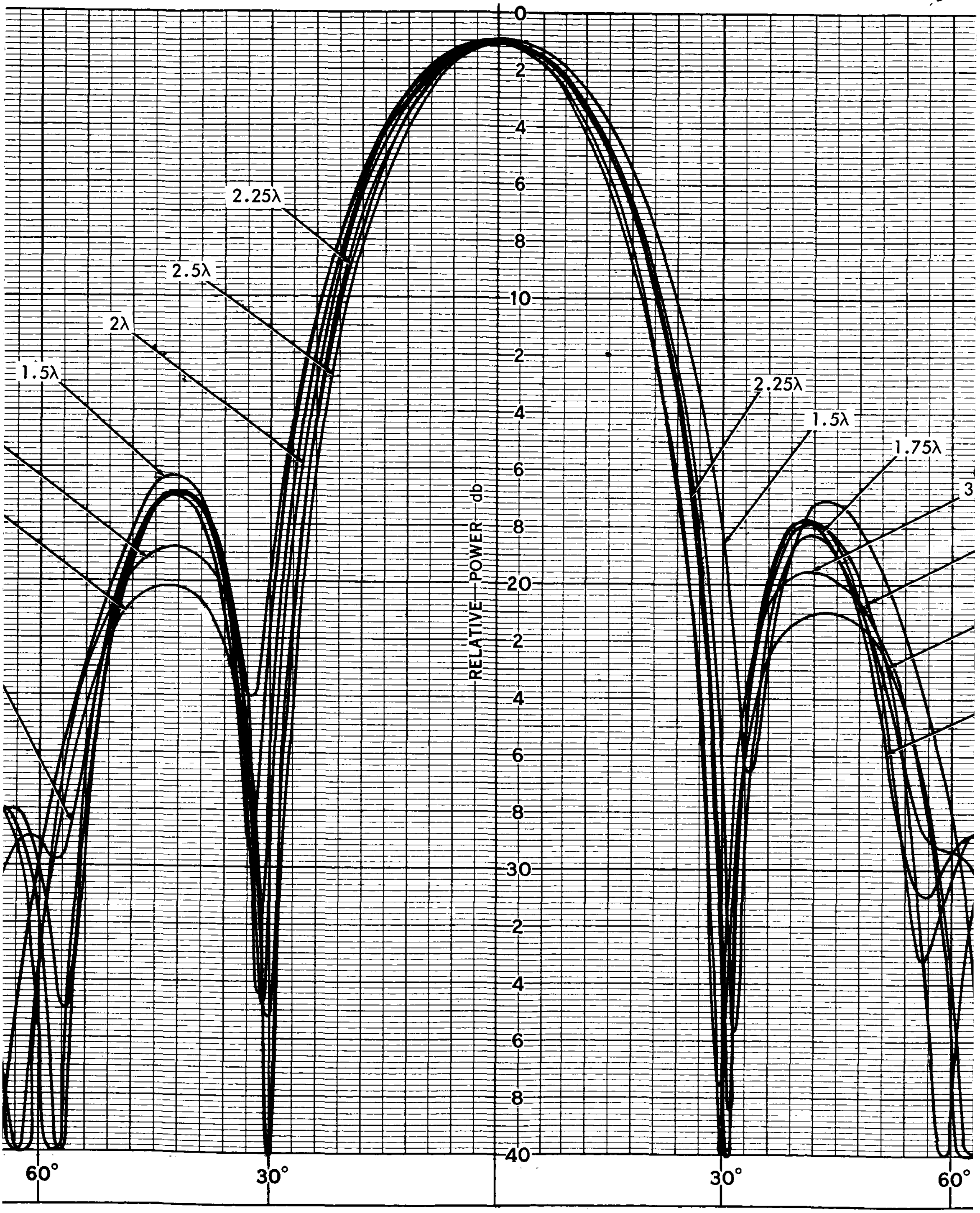

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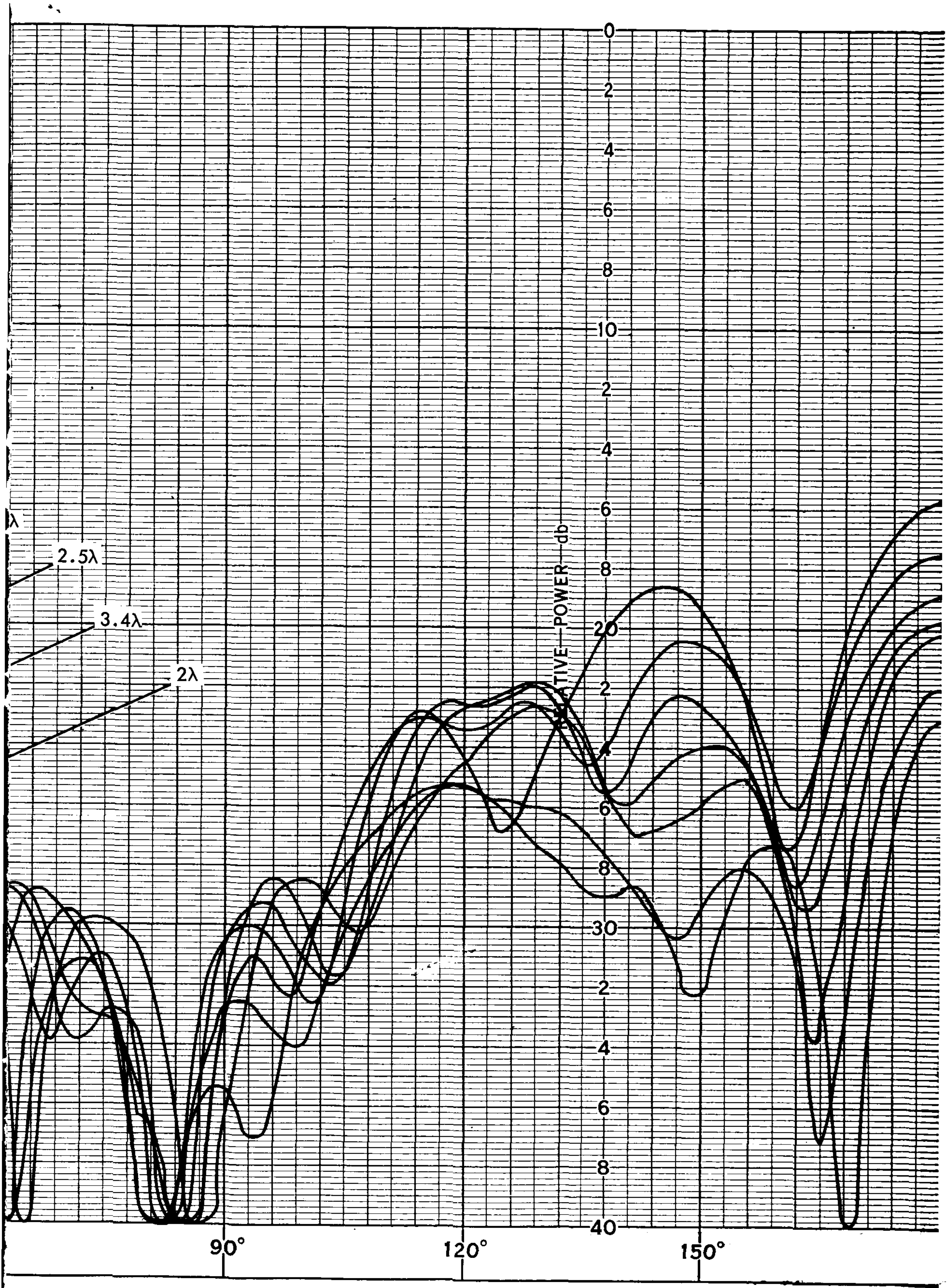
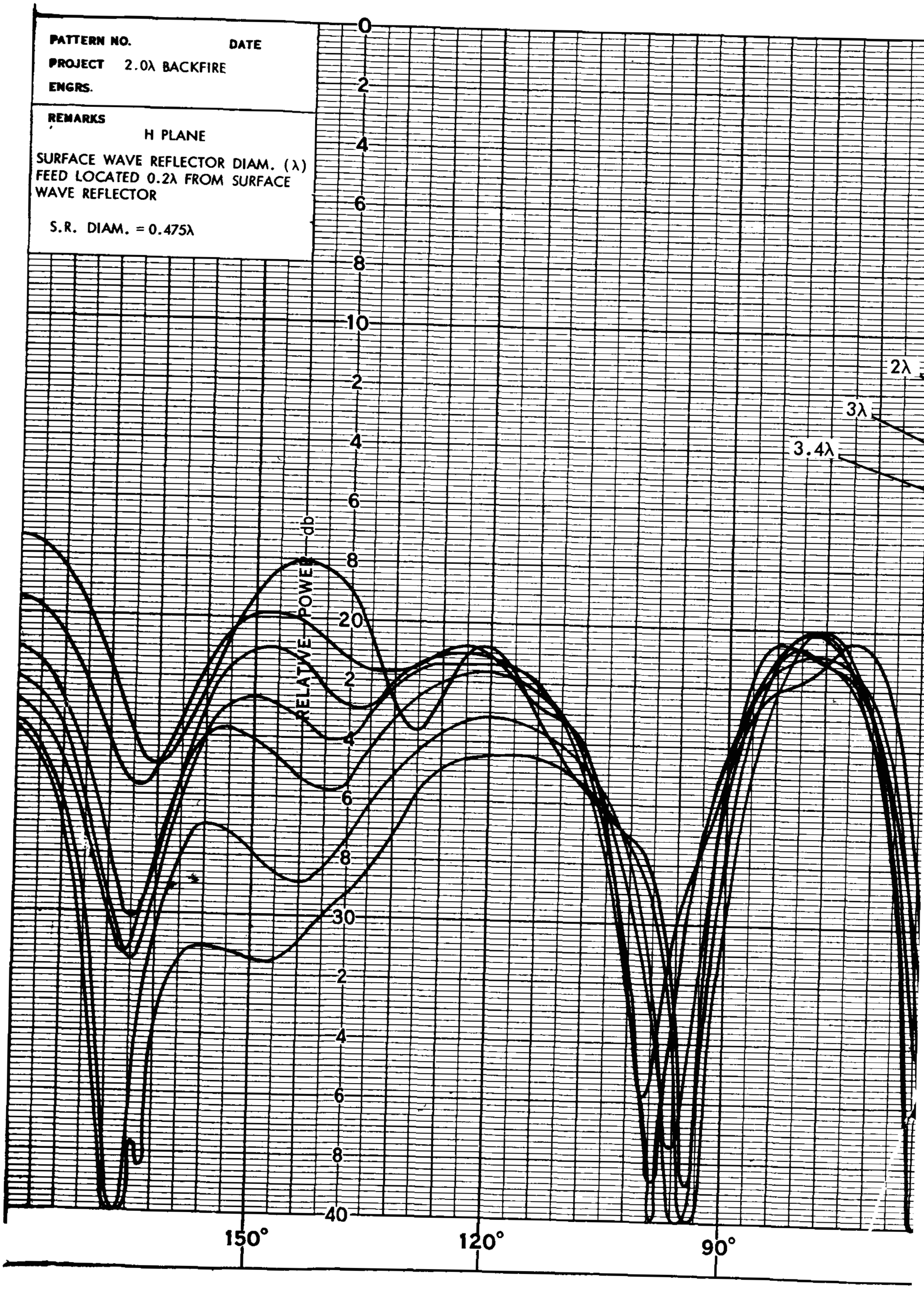


Figure 13. 2.0λ Backfire E Plane Radiation Patterns for Variable Surface Wave Reflector Diameters with the Feed Dipole Located 0.2 λ from the Surface Wave Reflector



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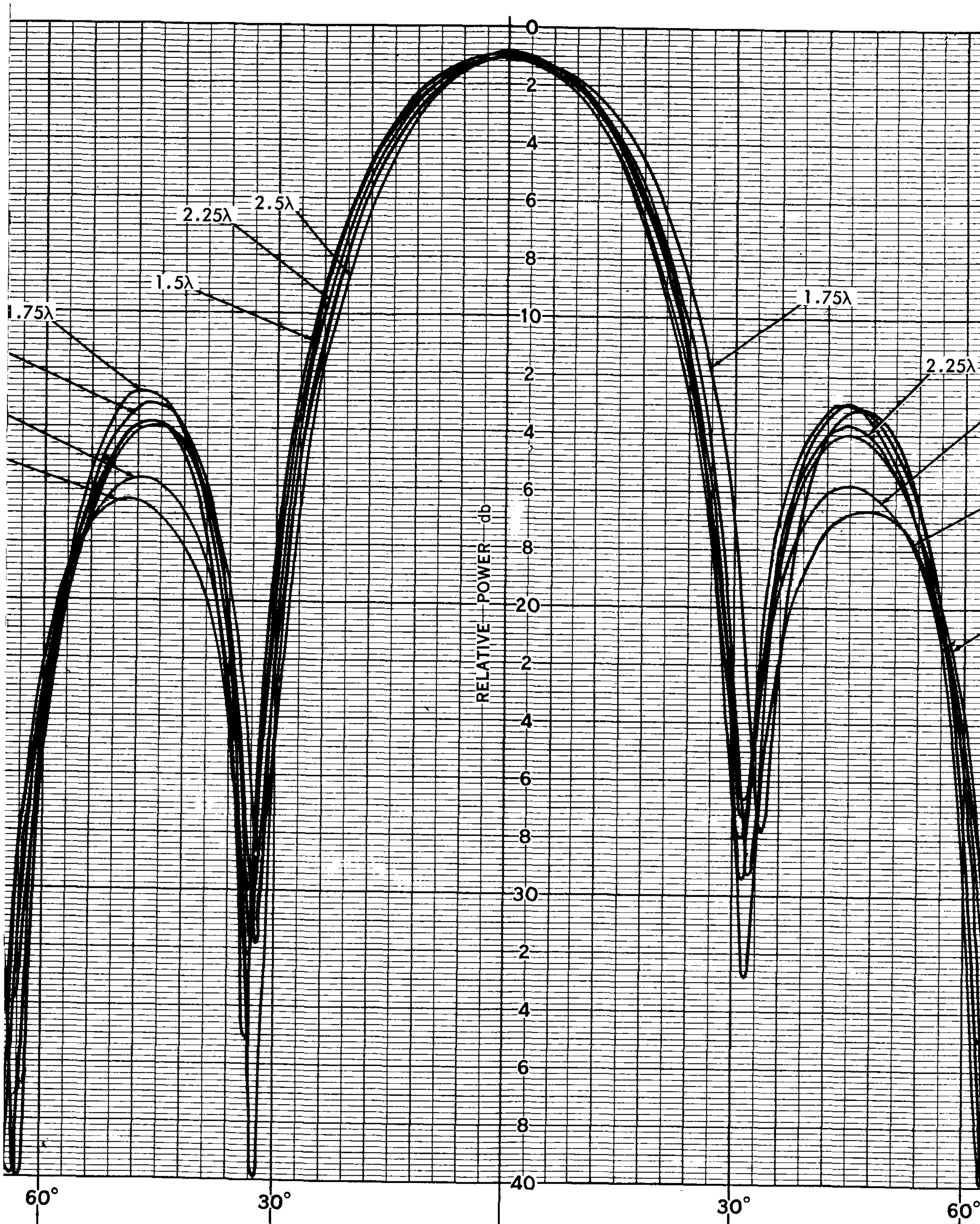

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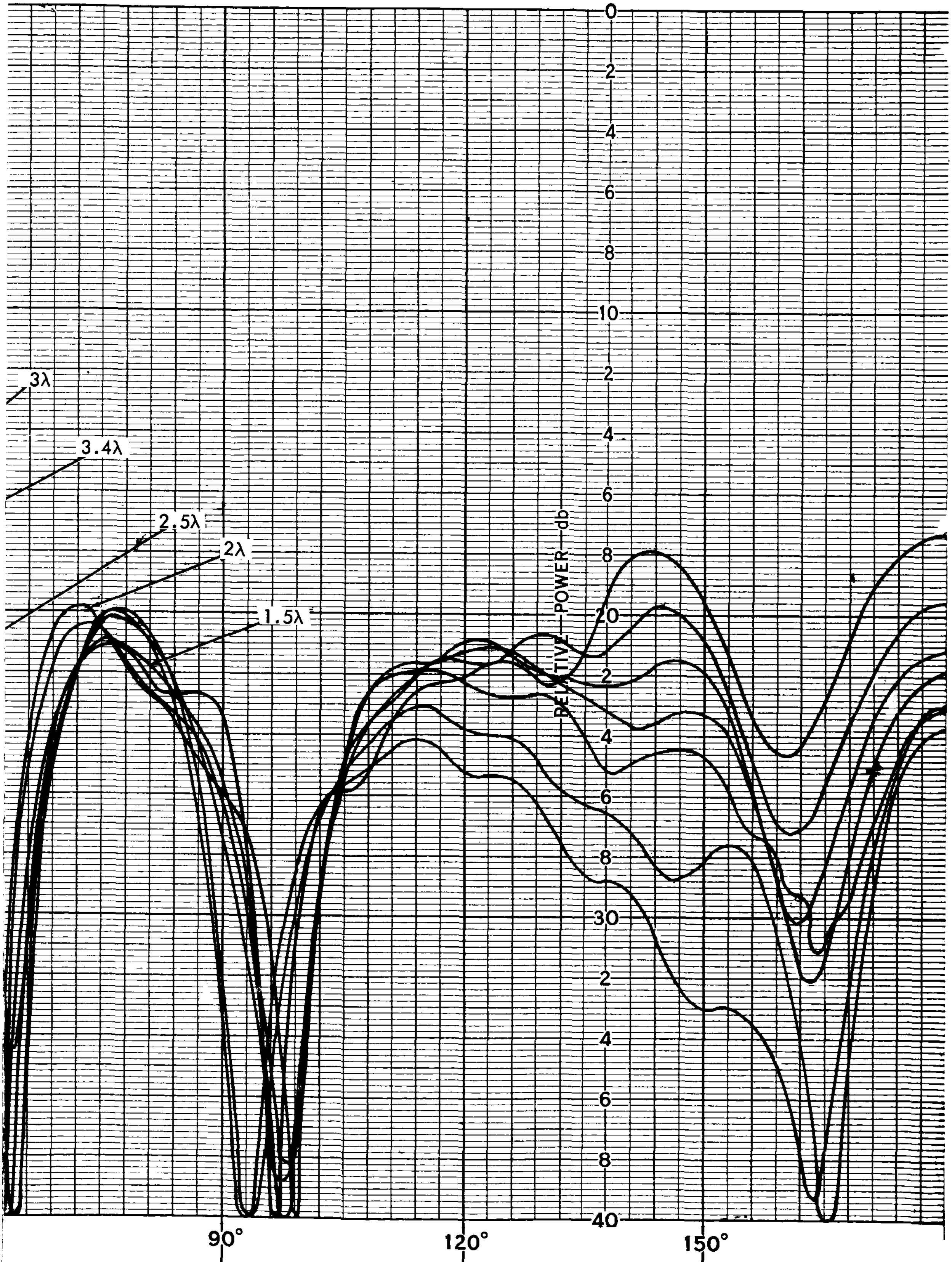

Figure 14. 2.0λ Backfire H Plane Radiation Patterns for Variable Surface Wave Reflector Diameters with the Feed Dipole Located 0.2λ from the Surface Wave Reflector

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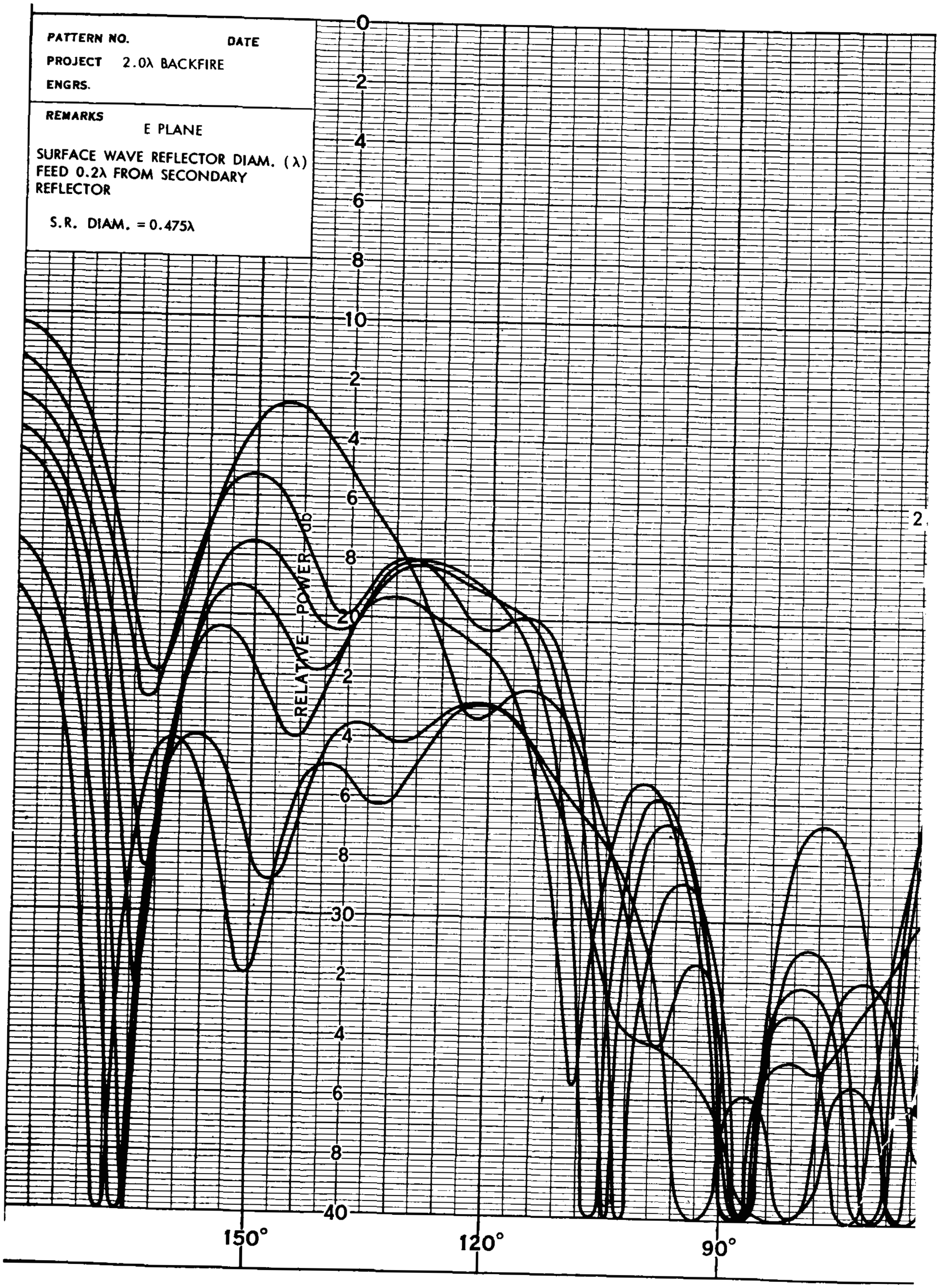

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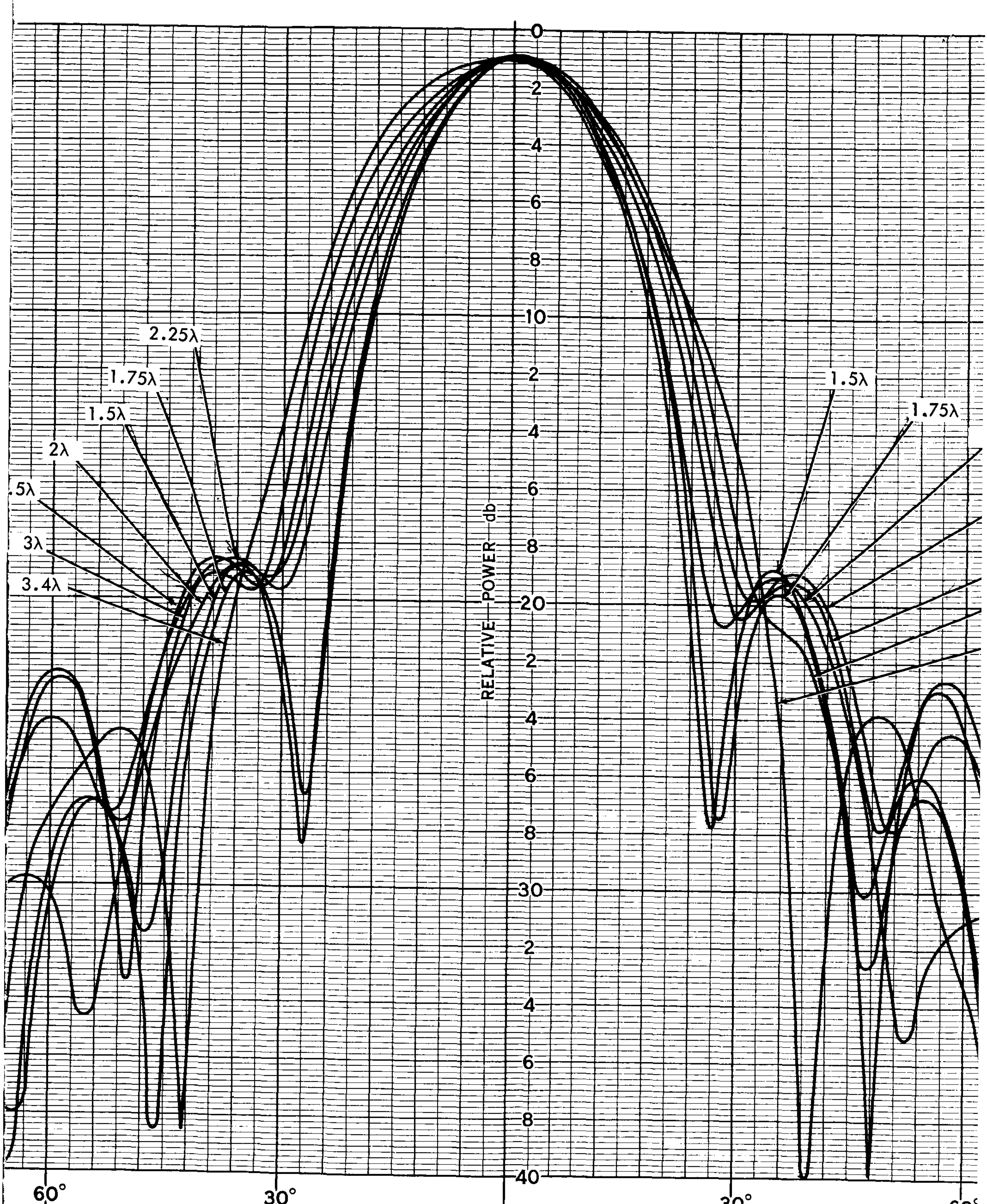

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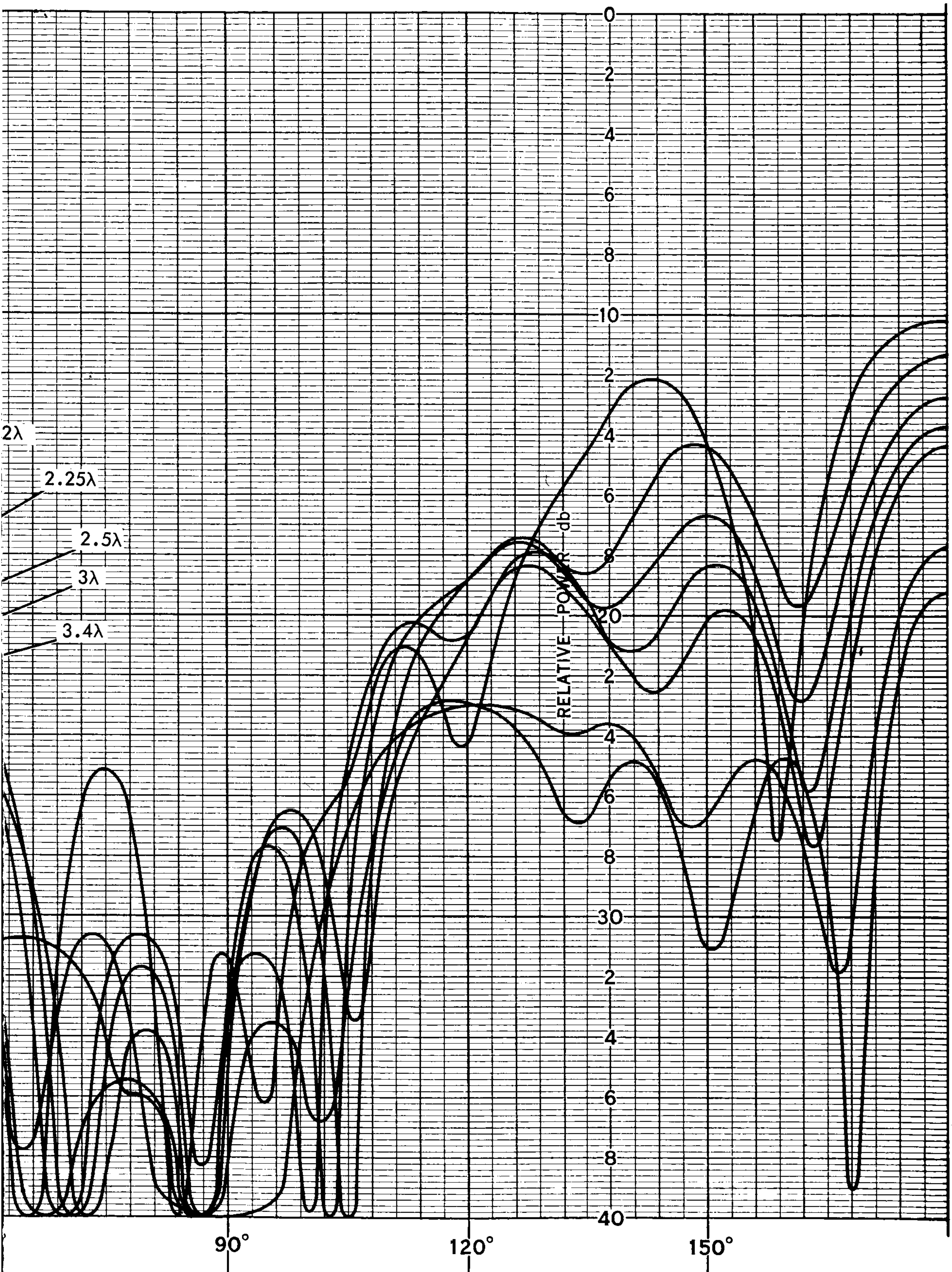

Figure 15. 2.0 λ Backfire E Plane Radiation Patterns for Variable Surface Wave Reflector Diameters with the Feed Dipole Located 0.2 λ from the Secondary Reflector

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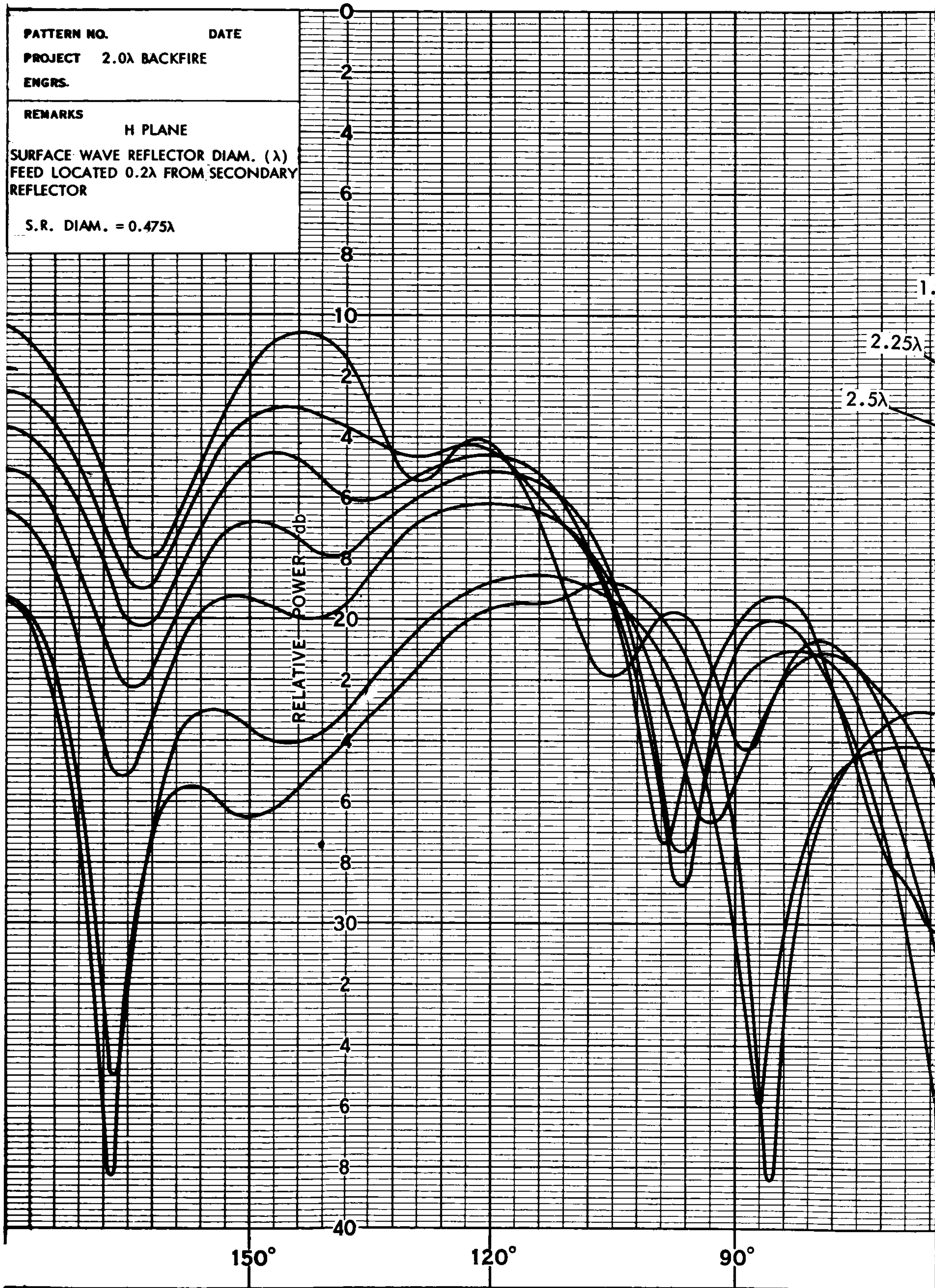

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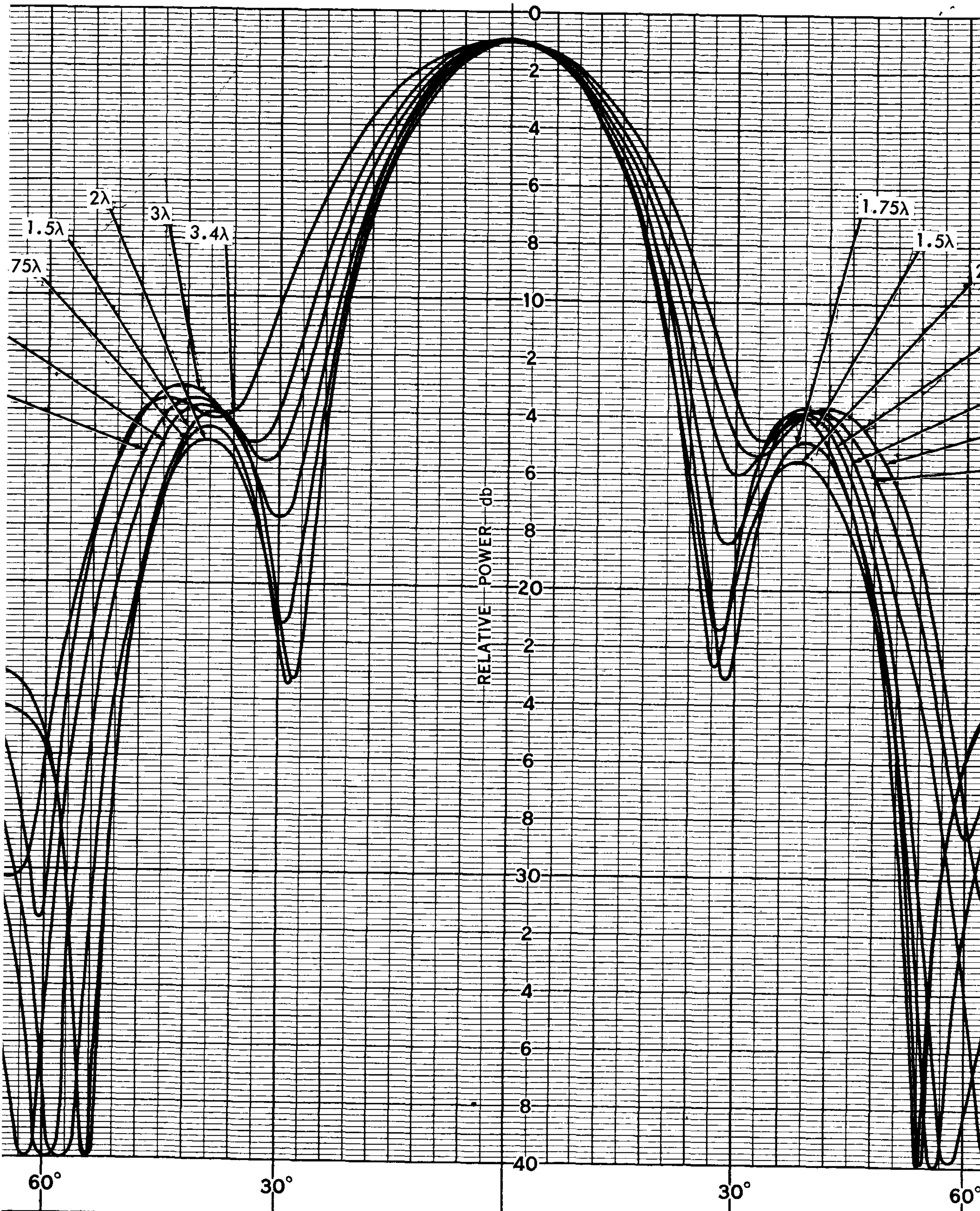

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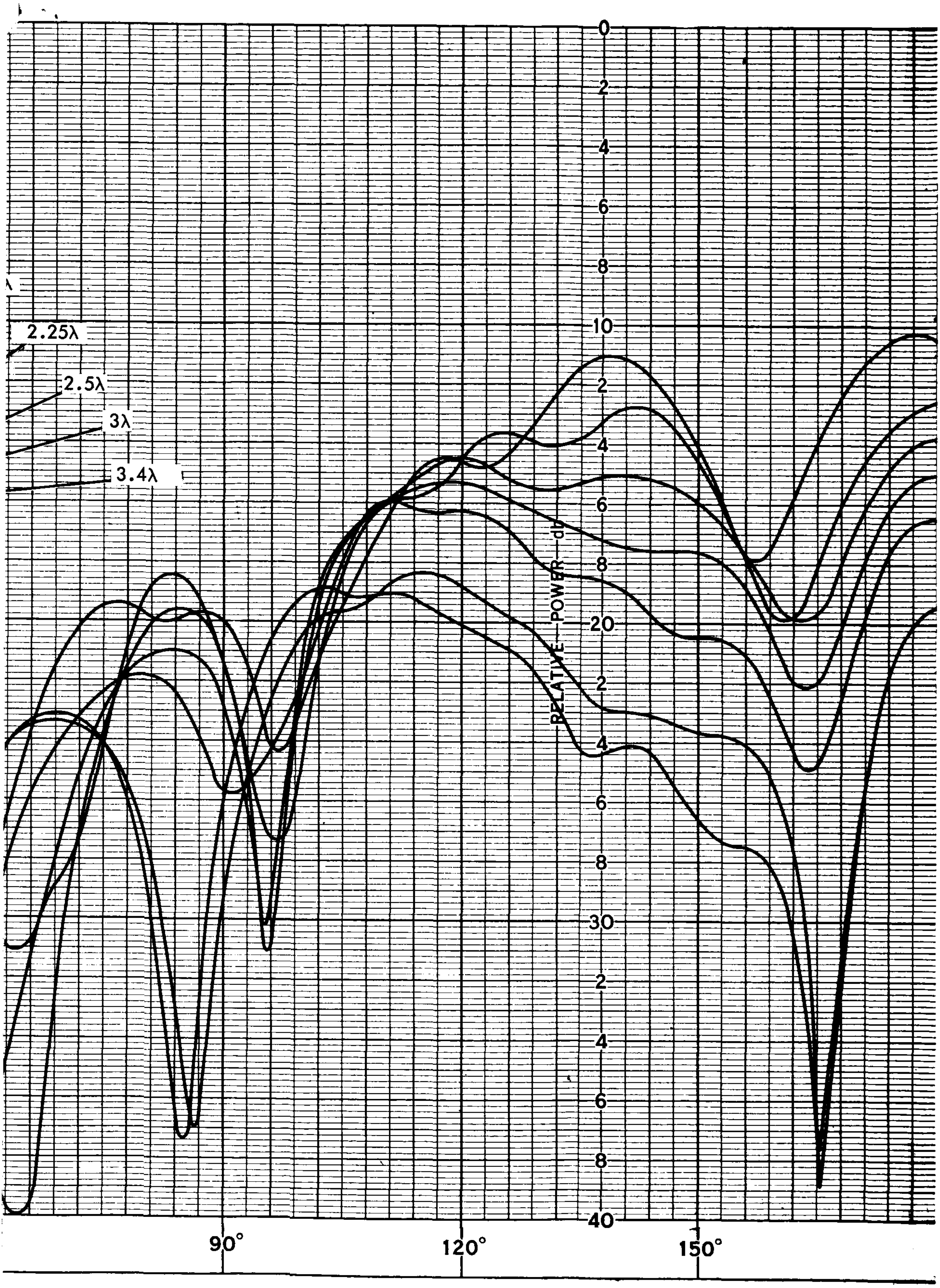

Figure 16. 2.0 λ Backfire H Plane Radiation Patterns for Variavble Surface Wave Reflector Diameters with the Feed Dipole Located 0.2 λ from the Secondary Reflector

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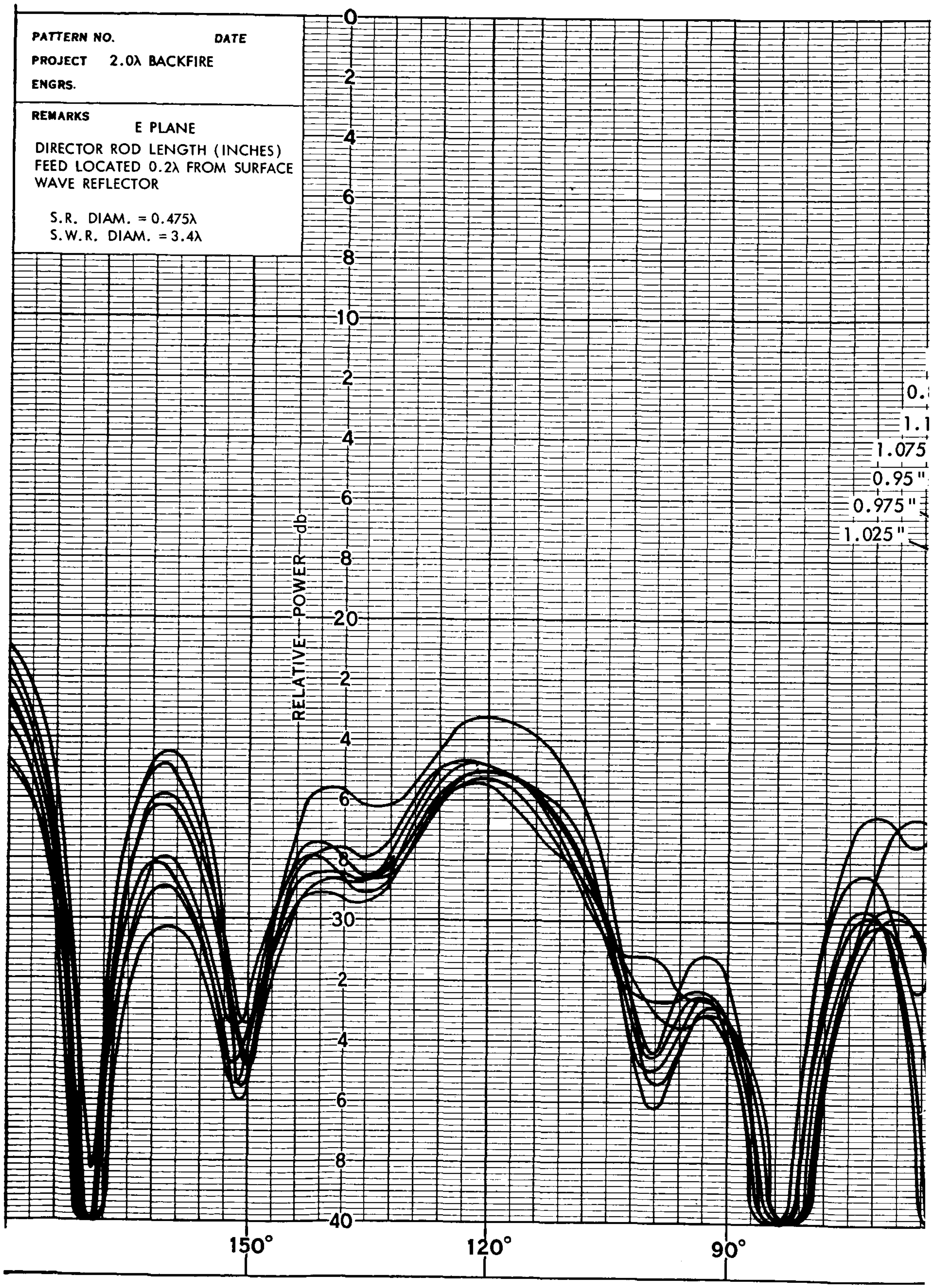

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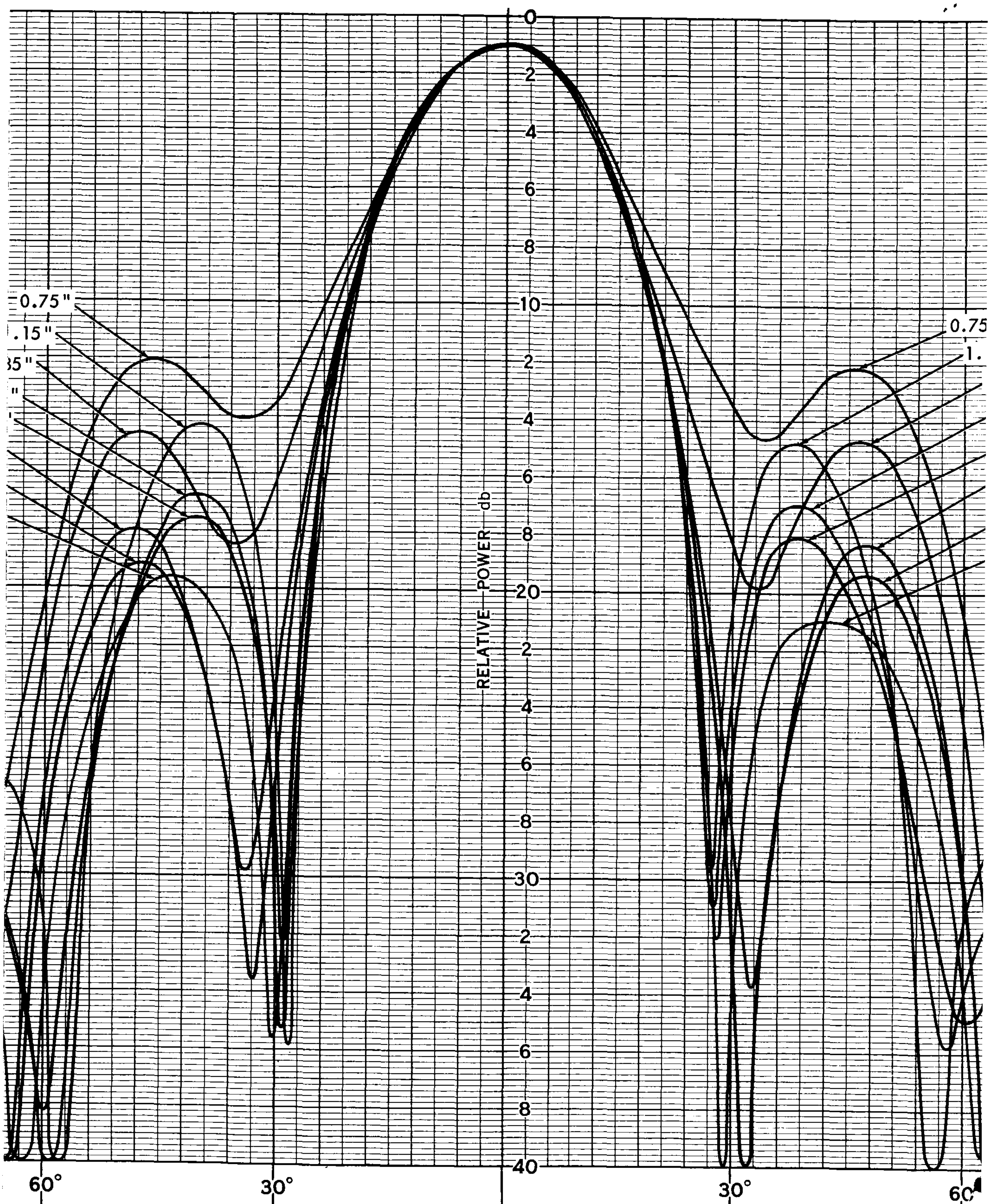

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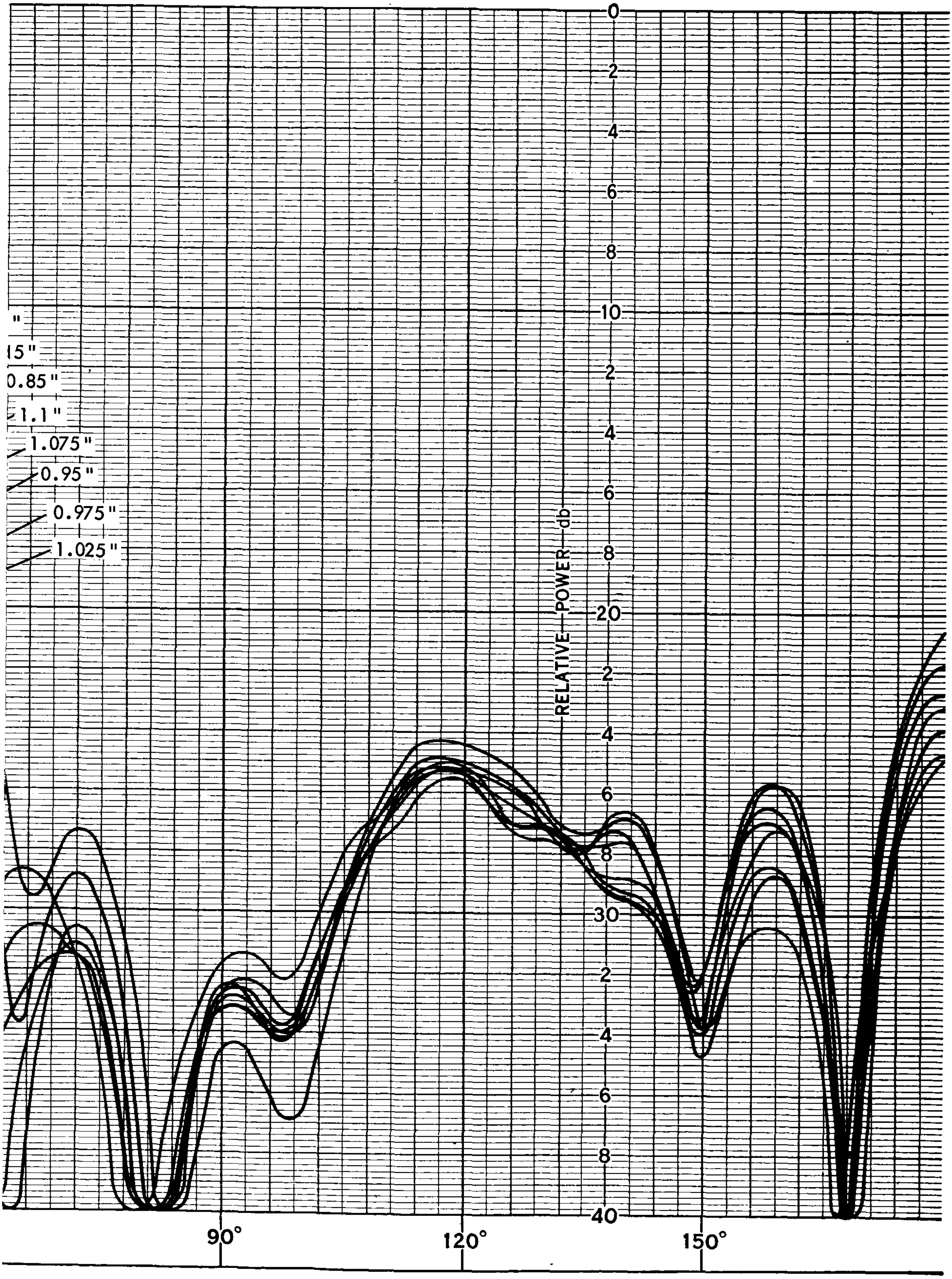

Figure 17. 2.0 λ Backfire E Plane Radiation Patterns for Variable Director Lengths With the Feed Dipole Located 0.2 λ from the Surface Wave Reflector

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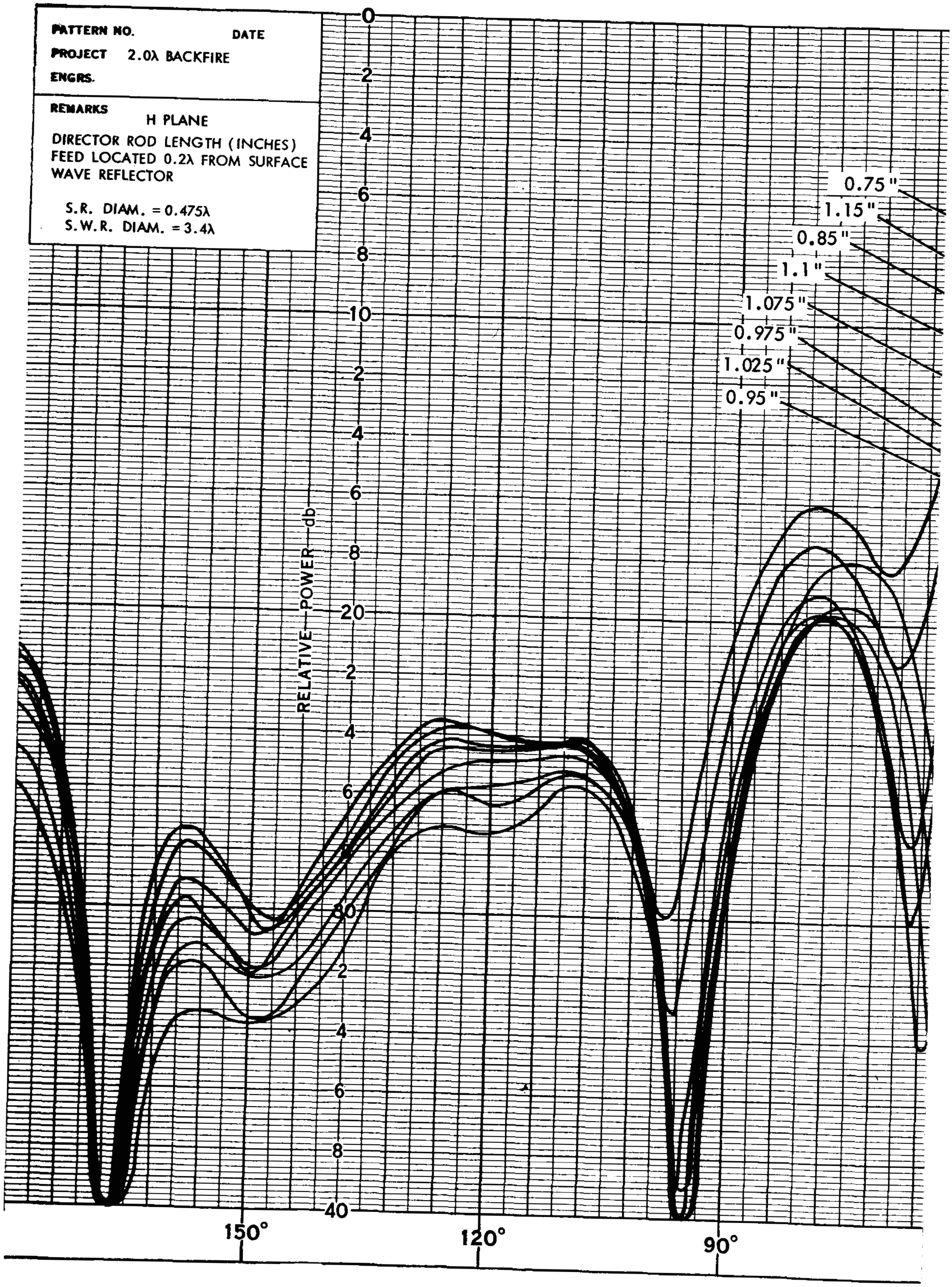

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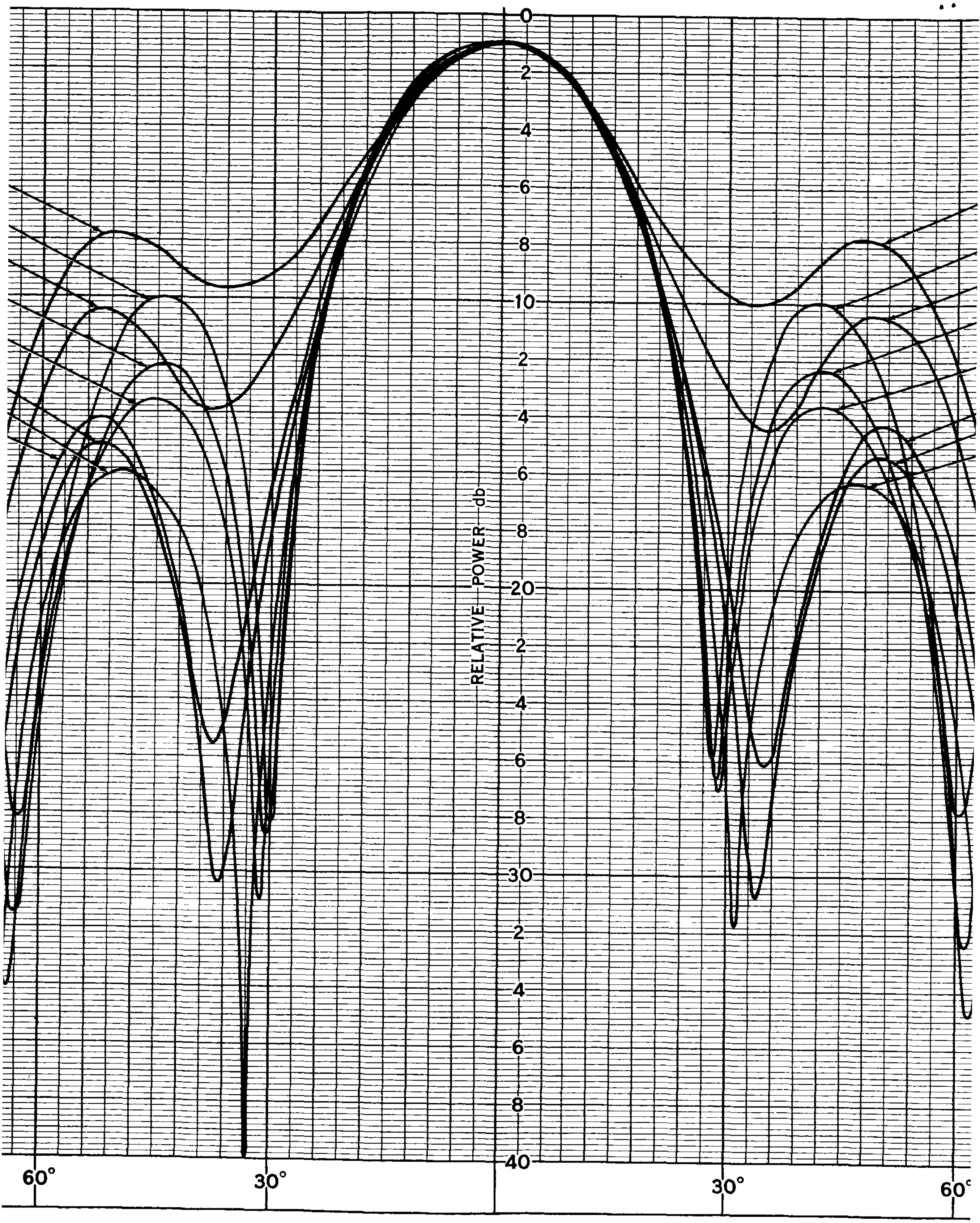

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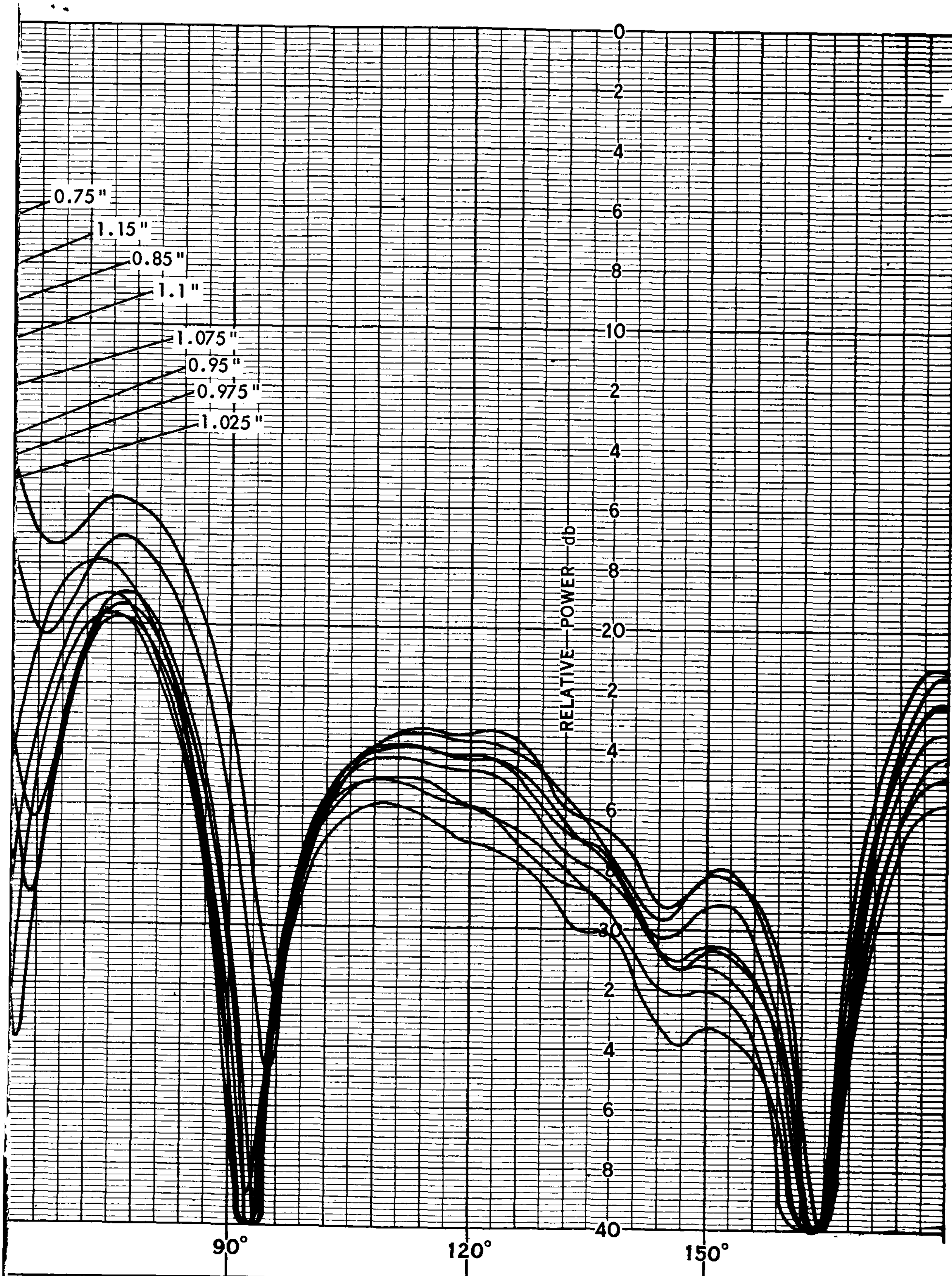

Figure 18. 2.0 λ Backfire H Plane Radiation Patterns for Variable Director Lengths With the Feed Dipole Located 0.2 λ from the Surface Wave Reflector

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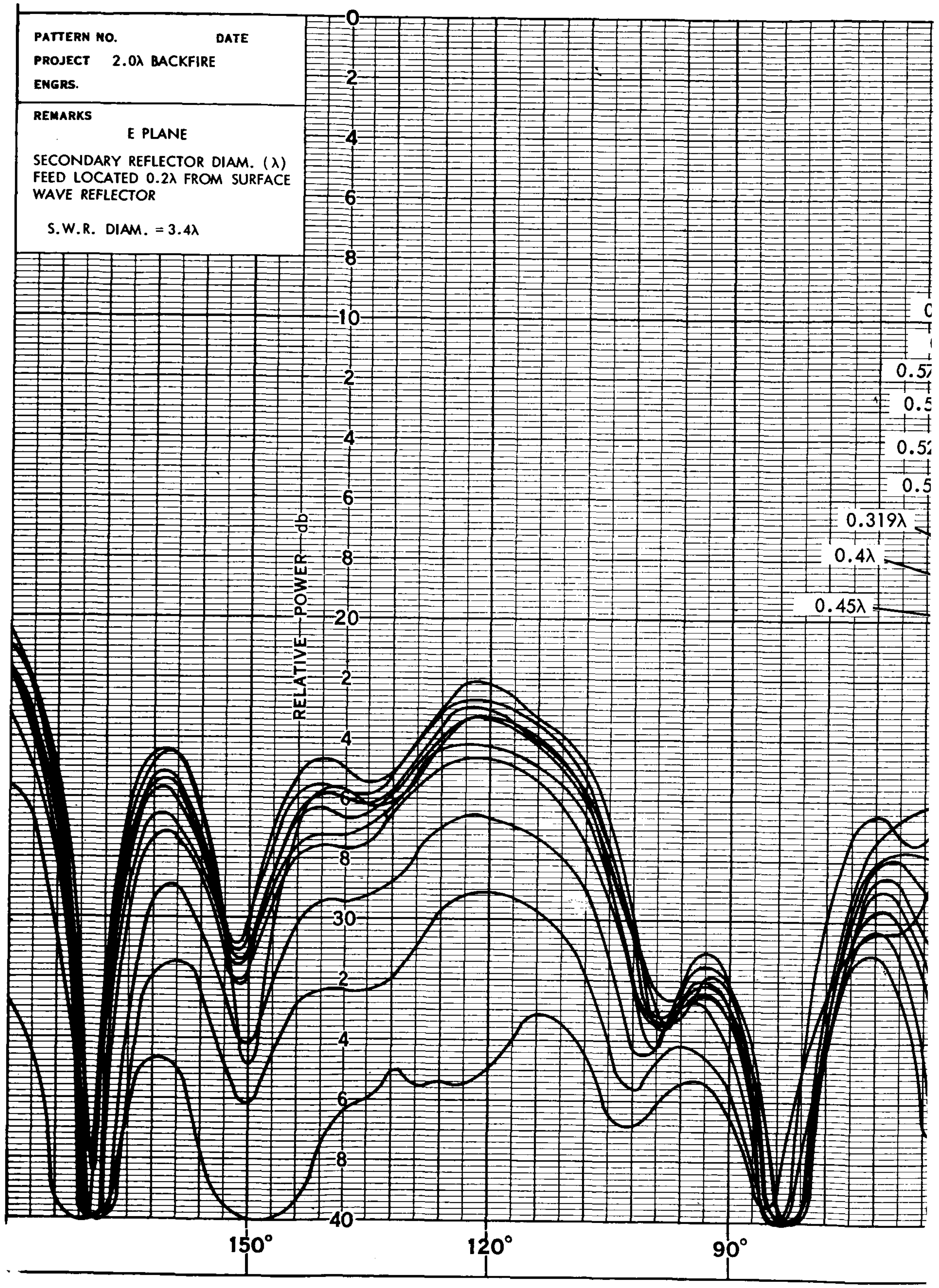

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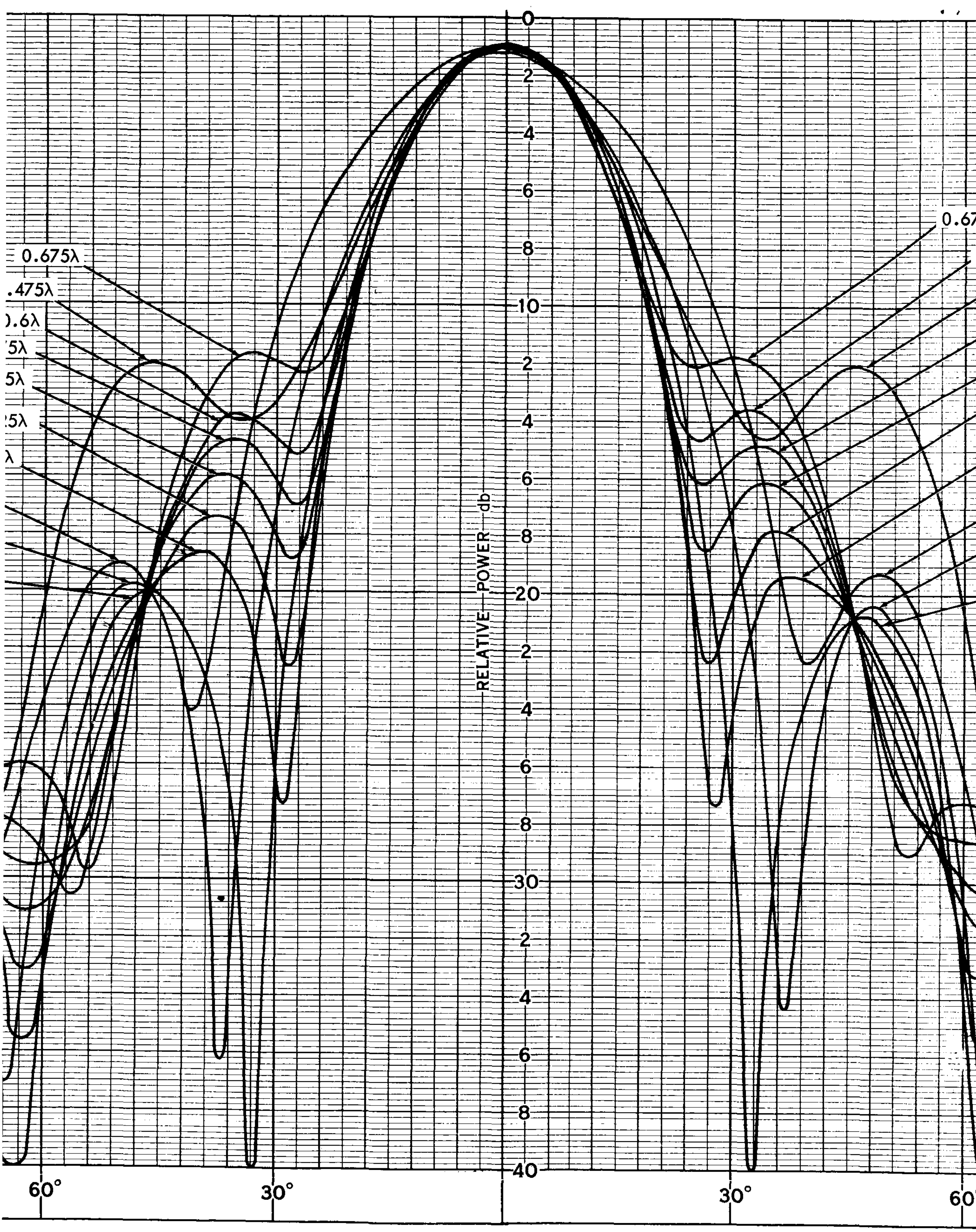

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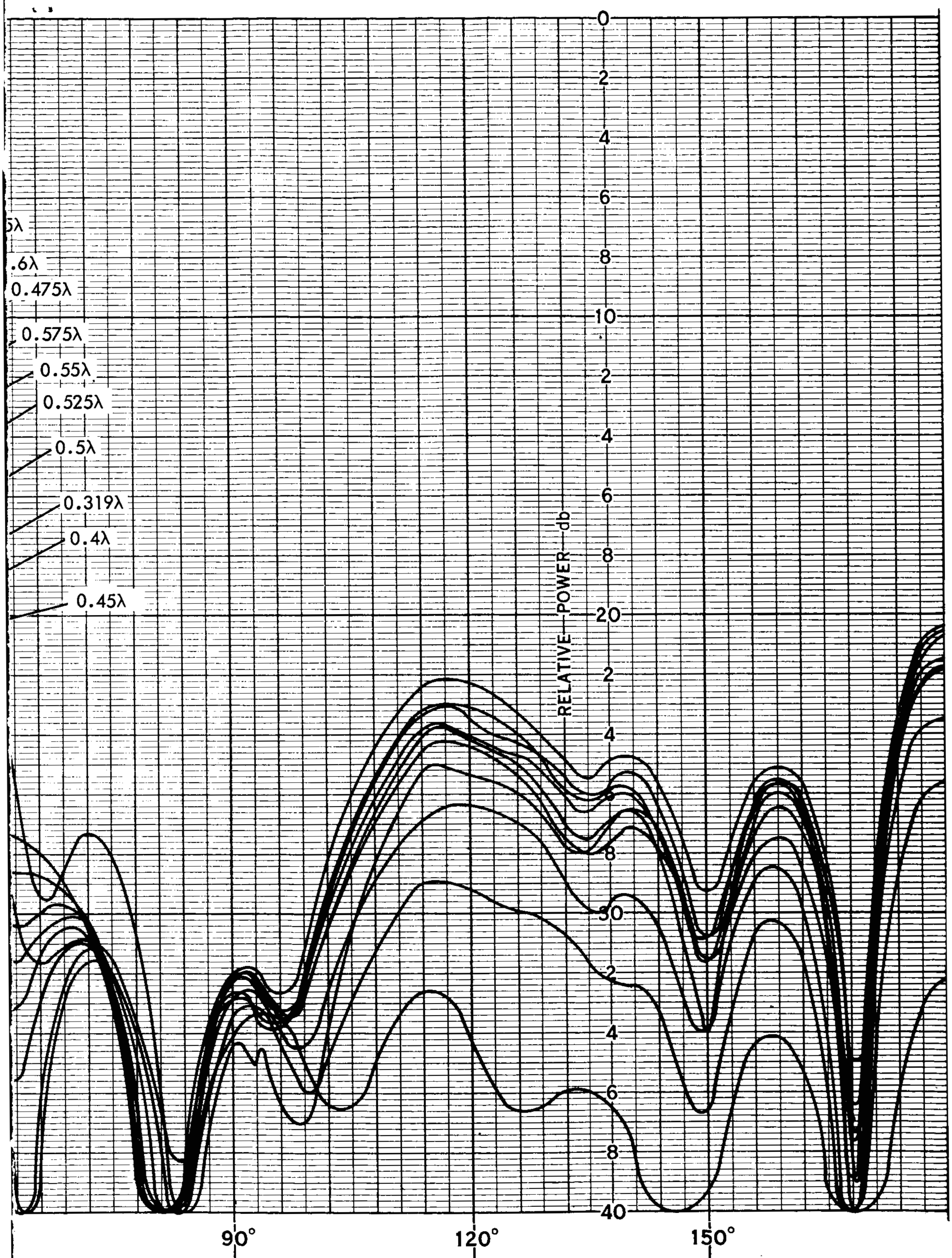

Figure 19. 2.0 λ Backfire E Plane Radiation Patterns for Variable Secondary Reflector Diameters with the Feed Dipole Located 0.2 λ from the Surface Wave Reflector

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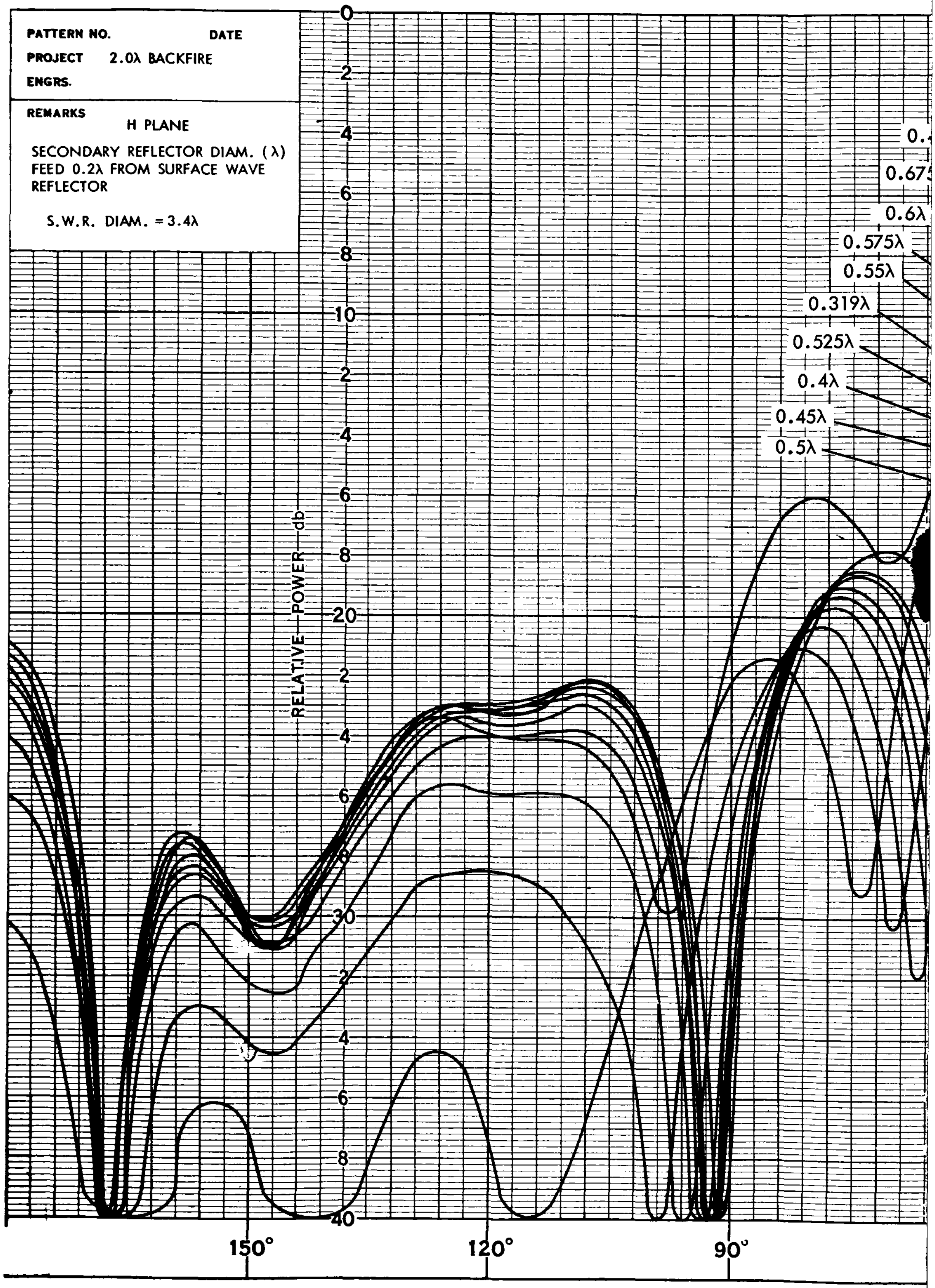

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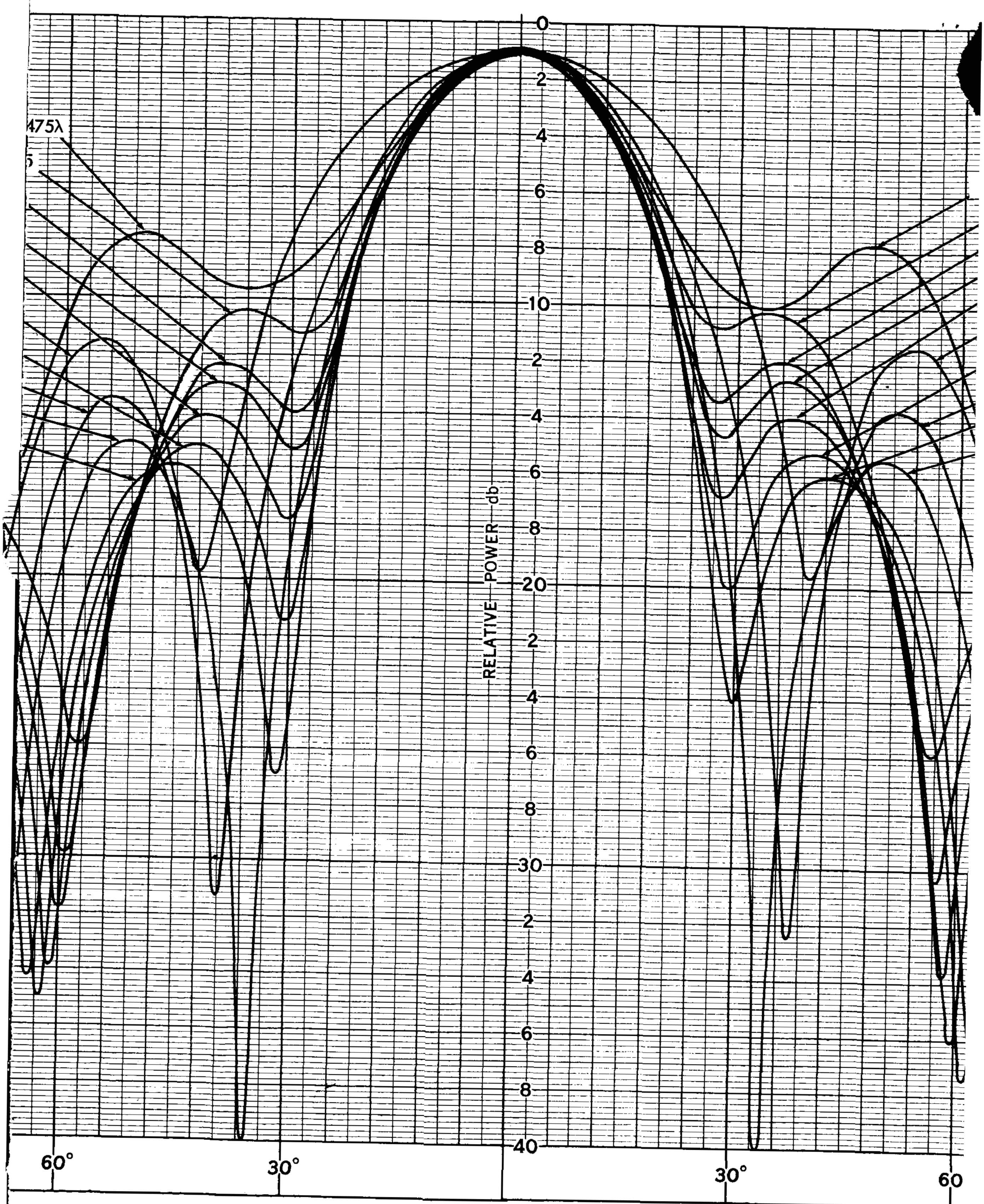

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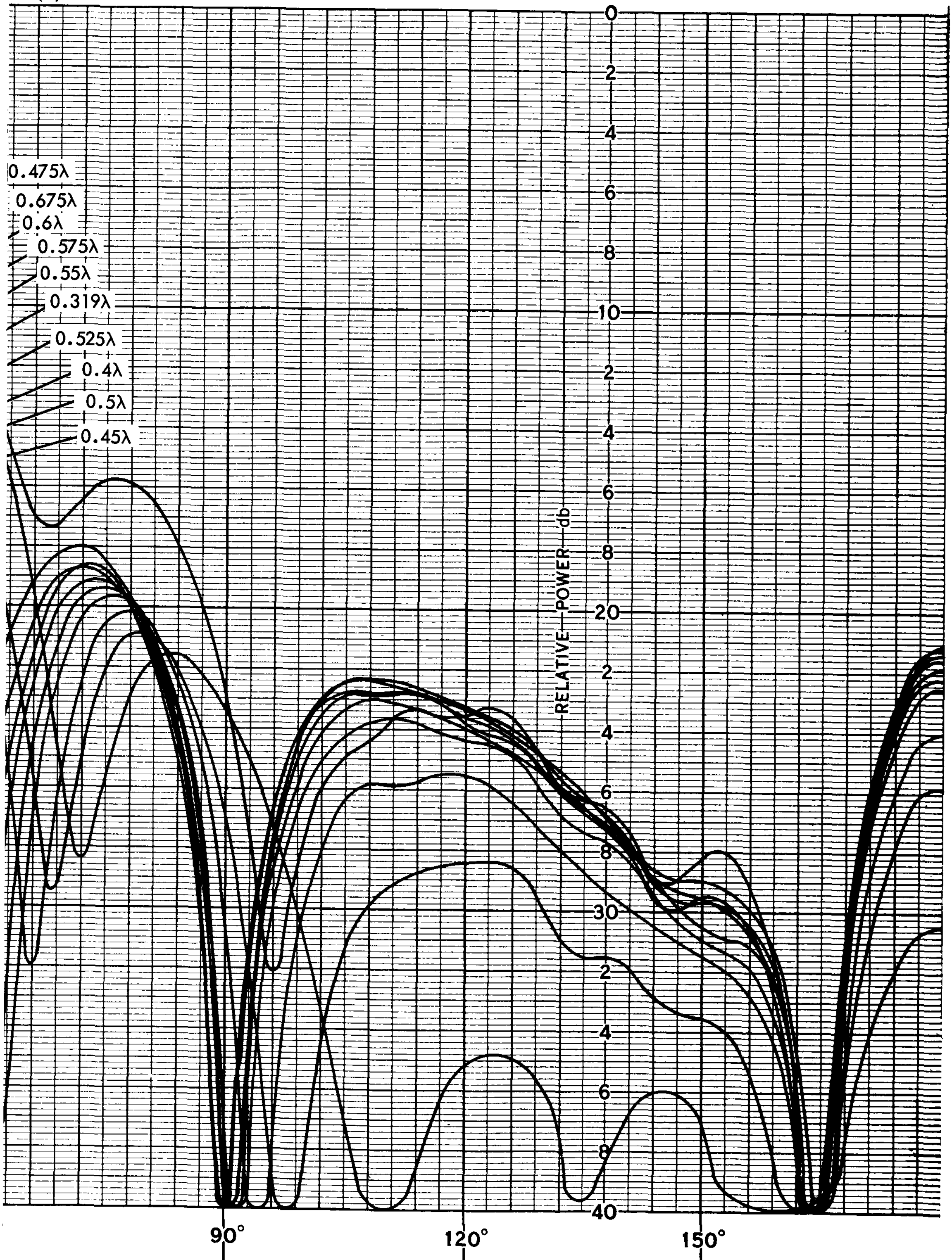

Figure 20. 2.0 λ Backfire H Plane Radiation Patterns for Variable Secondary Reflector Diameter with the Feed Dipole Located 0.2 λ from the Surface Wave Reflector

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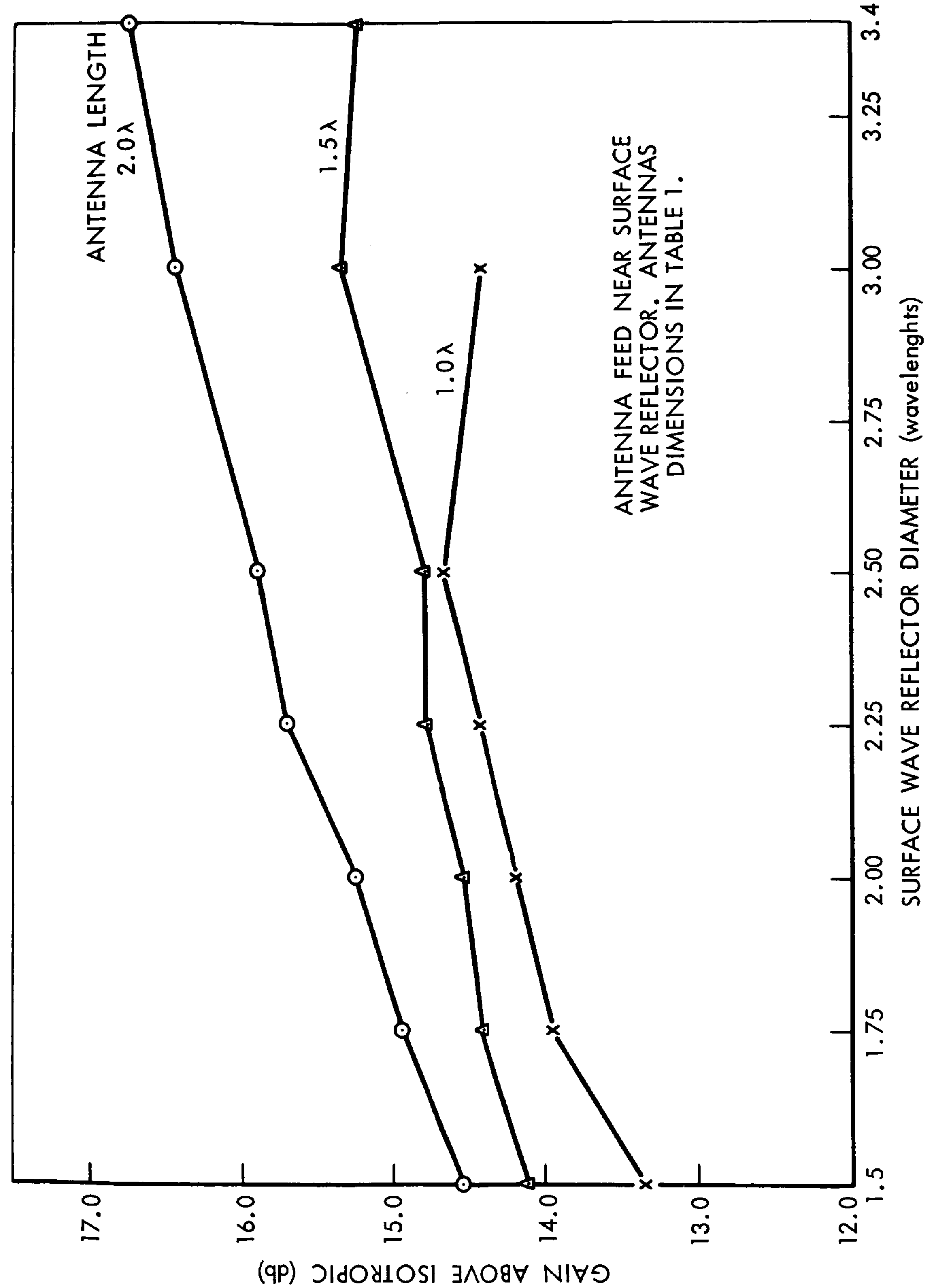


Figure 21. 1.0, 1.5, and 2.0λ Backfire Antenna Gain Versus the Diameter of the Surface Wave Reflector with the Feed Located Near the Surface Wave Reflector

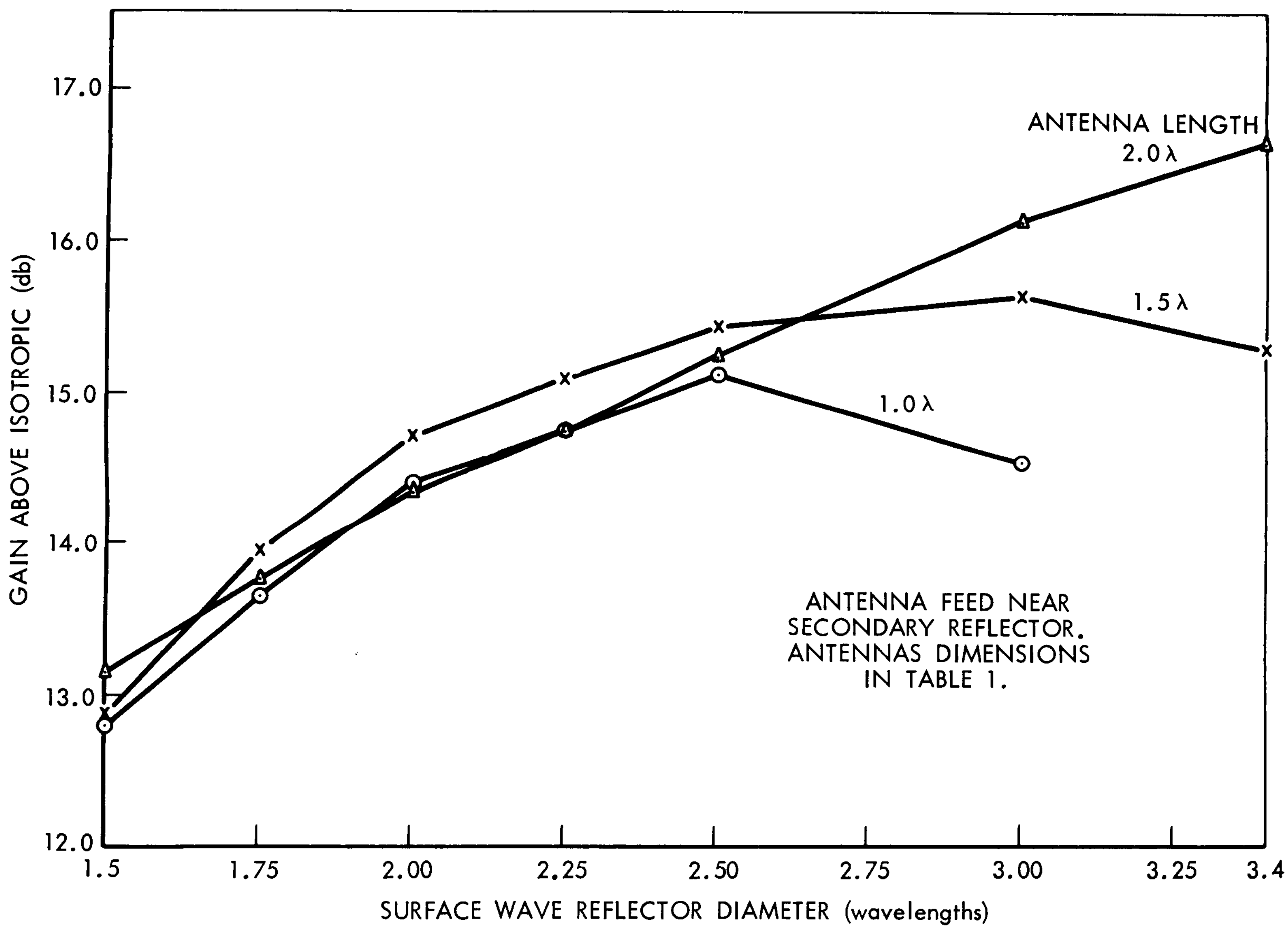
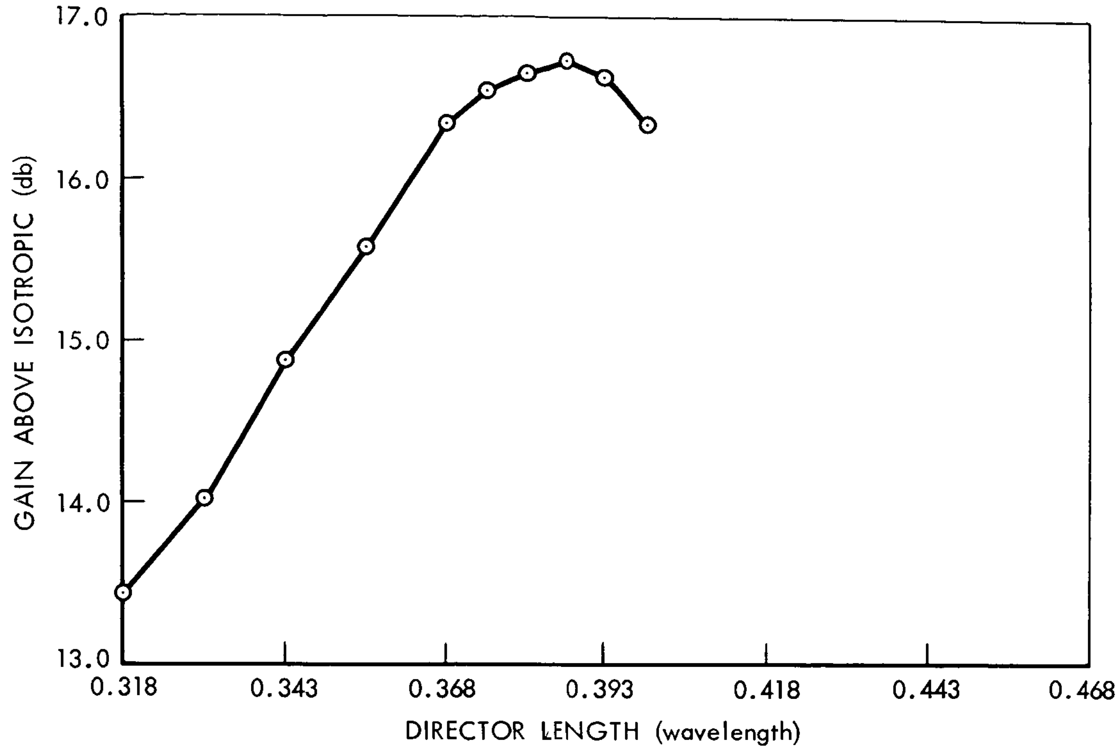


Figure 22. 1.0, 1.5, and 2.0λ Backfire Antenna Gain Versus the Diameter of the Surface Wave Reflector with the Feed Located Near the Secondary Reflector



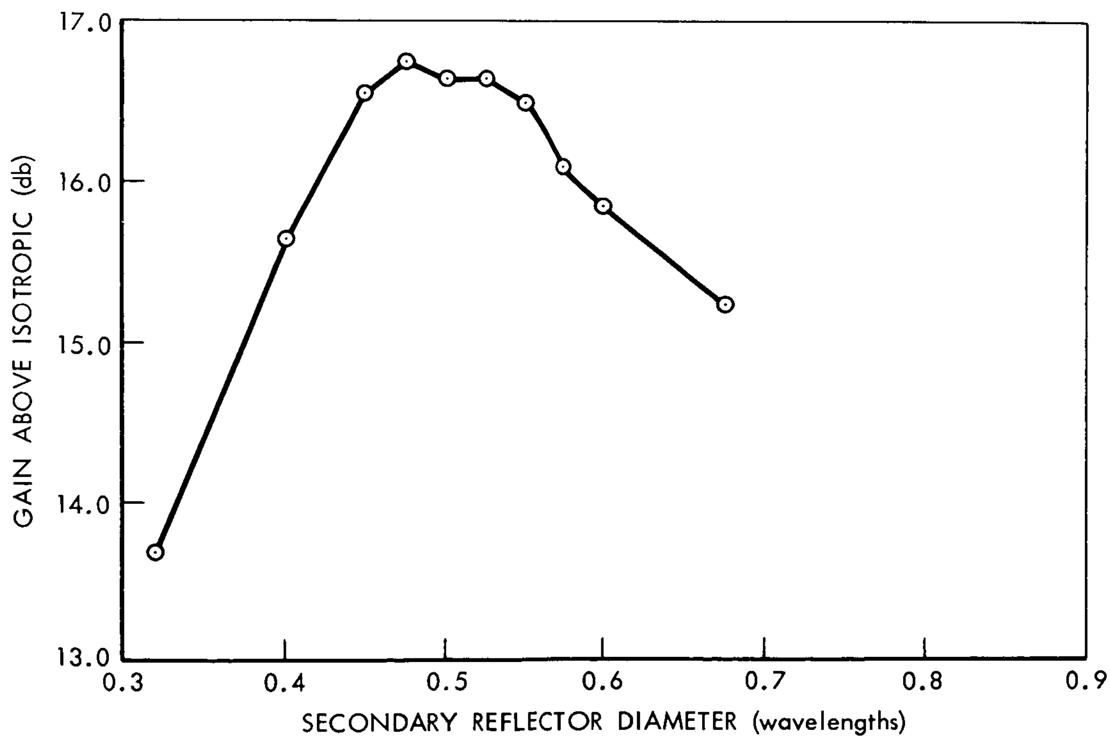


Figure 23. 2.0λ Backfire Antenna Gain Versus the Director Length Variation and Secondary Reflection Diameter