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PROJECT STATUS REPORT

Monthly Progress Report No. 6 for December 1964

Project Title: Antenna Noise Temperature Study by Computer

Contract No.: NAS5-3909

Prepared for: NASA-Goddard Space Flight Center, Greenbelt, Maryland

Prepared by:
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Schenectady, New York

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General Electric Company
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Schedule:
Study - 30 June 1964 to 2 March 1965
Final Project Report - 30 April 1965

Objective of Contract and Technical Specifications (Abridged)

This is to be an analytical computer study of focal point monopulse tracking feeds for 85-foot diameter paraboloidal reflectors in order to establish the effect of the variation of design parameters on antenna noise temperature. It is to cover the frequency bands 136-137 Mc, 400-401 Mc, 1700-1710 Mc, and 4080-4170 Mc, and to consider both internal and external noise sources. Study tasks are: I - Determination of atmospheric, galactic, and sun noise; II - Determination of improvement of noise temperature with side lobe reduction, illumination taper, f/D ratio, and feed support design; III - Consideration of reflector edge diffraction; IV - Analysis of reflector surface tolerances; V - Experimental scale model antenna; and VI - Pattern measurements to confirm analytical results.

Work Performed During This Period

Work during December was principally on Task II. This consisted of compilation and calculation of the initial test case for the secondary pattern and gain program, additional trial calculations, completion of the composite antenna pattern program and start of checkout, selection of initial parameters, and completion of basic design for experimental scale model feed and start of construction.

The initial test case used to check out the secondary pattern and gain program was a theoretical primary feed pattern having uniform amplitude over the reflector illumination angle $2\psi_{max}$ and zero amplitude elsewhere. An f/D of 0.424, a frequency of 122.5 Mc, and polarization for a horn feed were used so that the results could be compared directly with the H-plane pattern given by W.V.T. Rusch in Figure 2 of JPL Technical Report No. 32-434. The initial results indicated excellent agreement with Rusch's pattern for the main beam and the first few side lobes out to about 30°, but considerable difference occurred for angles greater than 30° even though the pattern remained well defined. The program was revised to obtain greater accuracy at larger angles, but a departure from Rusch's pattern still exists.

An examination was made of the phase function used in the present computer program, and it appears that the number of integration points used are adequate to obtain the required accuracy. A plot of the phase path length across the reflector diameter in radial directions $\xi = 0^\circ$, 60°, and 90° is given in Figure 1 for pattern angles $\theta = 30^\circ$ and 90° in the plane $\phi = 0^\circ$. A corresponding plot of the phase path length around the edge of the reflector is given in Figure 2. In the present program, integration is performed first with respect to r from 0 to 42.5 feet for selected values of ξ between 0 and 2π. The greatest phase slope for the r integration is seen from Figure 1 to occur when $r = 42.5$ feet, $\xi = \pi$, and $\theta = 90^\circ$. At 136.5 Mc, this amounts to a phase slope of 1.27 radian per foot, which corresponds to an equivalent u_{max} of 26.9 (when the interval from 0 to 42.5 feet is normalized to -1 to +1) and indicates a required number of points for Gaussian quadrature integration equal to about 14 per radial.* In the actual calculations, 16 points in r were used initially (two sub-intervals of 8 points each).

If the integration with respect to ξ were performed first, the phase function would have its greatest slope when $r = 42.5$ feet, $\xi = \pm \pi/2$, and $\theta = 90^\circ$, as given in Figure 2. At 136.5 Mc, this amounts to a phase slope of 0.628 radian per degree in ξ, which corresponds to an equivalent u_{max} of 28.3 (when the interval from $\xi = 0^\circ$ to 90° is normalized to -1 to +1) and indicates a required number of Gaussian-quadrature-integration points equal to about 14 per quadrant. Since the r integrations are performed first in the present program and the phase of each of the resulting integrals will be that of a point at somewhat less than $r = 21.25$ feet on each radial (due to amplitude weighting favoring the smaller radii), the actual phase function for the ξ integration will have less than half the value given in Figure 2 and thus should require only about 7 Gaussian-quadrature-integration points per quadrant. In the actual calculations, 8 points in ξ per quadrant were used initially, making a total of 512 (r,ξ) points (16 x 8 x 4). Since the test case uses a frequency of 122.5 Mc instead of 136.5 Mc, even fewer integration points should be required.

Further computer calculations were made using a larger number of (r,ξ) points with some improvement in accuracy at angles near $\theta = 90^\circ$, but a departure from Rusch's pattern still occurred. The general characteristics of the pattern were the same, but the side lobe levels at angles from $\theta = 45^\circ$ to 120° were somewhat different and the pattern minima were displaced. It was concluded that something more basic than accuracy of

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* See: C. C. Allen, "Numerical Integration Methods for Antenna Pattern Calculations," IRE Transactions on Antennas and Propagation, vol. AP-7, Special Supplement, p. S396; December 1959.

integration was involved, and an examination of the basic formulations was made.

By definition, the test case set up to be calculated by the present program was intended to be the same as that calculated by Rusch, even though the specific mathematical formulations differ (Rusch assumes circular symmetry and reduces the double integral to a single integral involving Bessel functions). Actually, however, it appears that the two problems differ in the functions used for the feed polarization vector, $\overline{e}$, even though both are intended for a horn feed. Since the dot products of $\overline{i}_\theta$ and $\overline{i}_\phi$ are taken with $\overline{n} \times \overline{\rho}_1 \times \overline{e}$, the resulting pattern integrals will differ as a function of (θ,ϕ), thus affecting both the magnitude of the side lobes and the location of the minima, as observed. Since the feed polarization vector used for a horn feed in the present program has been verified experimentally by pattern measurements on horn feeds, it is assumed to be correct.

The computer programming for the composite antenna pattern (Step III) was completed and checkout started. This was done be incorporating the operations to be performed directly into the program for the secondary pattern, rather than writing a separate program which uses the secondary pattern as an input to be fed back into the computer. This was deemed advisable in view of the large amounts of data which would otherwise have to be saved from the secondary pattern program for use as input to the composite antenna pattern program. This composite antenna pattern program includes the shift in phase reference described in Report No. 4, the coordinate transformation described in Report No. 5, and provision for adding the primary feed pattern at all (θ,ϕ) angles to the transformed secondary pattern. As a minor correction, a minus sign should be added on page 3 of Report No. 5 as follows:

$$E_\phi(\theta,0) = -E_\Omega(\gamma,\pi).$$

The resulting composite antenna pattern is:

<u>Dipole Feed</u> -

$$\overline{E}_T(\theta,\phi) = \overline{i}_\gamma \left[(p_\gamma^t + H_\gamma \cos \Psi) + j(q_\gamma^t + H_\gamma \sin \Psi) \right]$$

$$+ \overline{i}_\Omega \left[p_\Omega^t + j\, q_\Omega^t \right]$$

<u>Horn Feed</u> -

$$\overline{E}_T(\theta,\phi) = \overline{i}_\Omega \left[(p_\Omega^t + H_\Omega \cos \Psi) + j\, (q_\Omega^t + H_\Omega \sin \Psi) \right]$$

$$+ \overline{i}_\gamma \left[p_\gamma^t + j\, q_\gamma^t \right]$$

where the first bracketed term in the principally polarized pattern in each case, and the second bracketed term is the cross polarized pattern.

Following some additional test runs of the combined secondary pattern and composite antenna pattern program, composite antenna pattern calculations will be made in January for the initial parameters and feed patterns. Values of f/D selected for the initial calculations are 0.375, 0.400, 0.423, and 0.450, which thus include the Rosman I value (0.423) and give nearly equal spacing. Larger or smaller values can be added based on evaluation of the initial results. Illumination tapers used in the initial calculations will be those produced by the various primary feed patterns without pattern scaling. Primary pattern angles can later be scaled to vary the illumination taper. Primary feed patterns available for initial calculations are the Rosman I patterns (principal planes only), the four-horn monopulse sum patterns, and the tri-mode feed sum patterns.

The basic design of the experimental feed for scale model tests was completed and construction was started. Some difficulty was experienced in scaling from the drawing furnished, because of a dimensional discrepancy between the detailed piece parts and the reference dimension on the assembled view. The scale model dimensions were adjusted to conform to the feed photograph and to the dipole spacings and ground plane dimensions furnished by Rantec in response to an inquiry made to resolve the discrepancy. Design of the balun and feed network is still in process. The 5-foot diameter scale model reflector was ordered. Upon completion of the experimental feed, primary pattern measurements will be made for use as inputs to the composite antenna pattern calculation program.

Results of the analysis of edge diffraction done on Task III were written up for inclusion in Report No. 5. This treated stationary phase regions of the first kind and showed that such regions on the reflector exactly cancelled direct feed radiation for directions from the feed to the shadow region of the reflector. The next step is to analyze stationary phase regions of the second kind, which occur at the edge of the reflector, but no further analysis was done on Task III in December.

Tabulation of noise sources on Task I, evaluation of strut effects on Task II(d), formulation of the noise temperature analysis on Task II (Step IV), and consideration of tolerance effects on Task IV are not yet completed.

Schedule Status

It has become apparent during December that all of the defined tasks cannot be completed as thoroughly as had been expected, due in part to problems encountered in obtaining a good checkout of the computer program with a high level of confidence in the accuracy obtained and also because of the delay in obtaining an extension to the contract to include Phase II work. What can be accomplished most effectively within the remaining time and funds is being re-evaluated. It is presently felt best to complete the composite antenna pattern calculations for all parameters even if very little noise temperature analysis is done, rather than to calculate only a few patterns and perform a preliminary noise temperature analysis on those. In that way, a basic foundation will have been laid that can be built upon later, rather than having one or two isolated cases carried through. Because of the areas of work that are common to this study of focal point fed antennas and to the planned study of Cassegrain antennas (Phase II), it had been initially anticipated that the two phases would overlap in order to take advantage of such common areas of work. It is believed that the present work can now be completed most effectively by integrating the two phases of the program.

Work Planned for Next Period

Complete checkout of composite antenna pattern program, and calculate patterns on computer for initial parameters and primary feed patterns.

Complete design and construction of experimental feed for scale model tests.

Continue formulation of noise temperature analysis on Task II.

Prepare tabulation of noise sources and results on Task I.

Evaluate measurements made on Task II(d) for analysis of strut effects.

Analyze stationary phase points of the second kind with regard to edge diffraction on Task III.

Continue consideration of tolerance effects on Task IV.

Project Engineer: C. C. Allen
C. C. Allen

Date: January 11, 1965

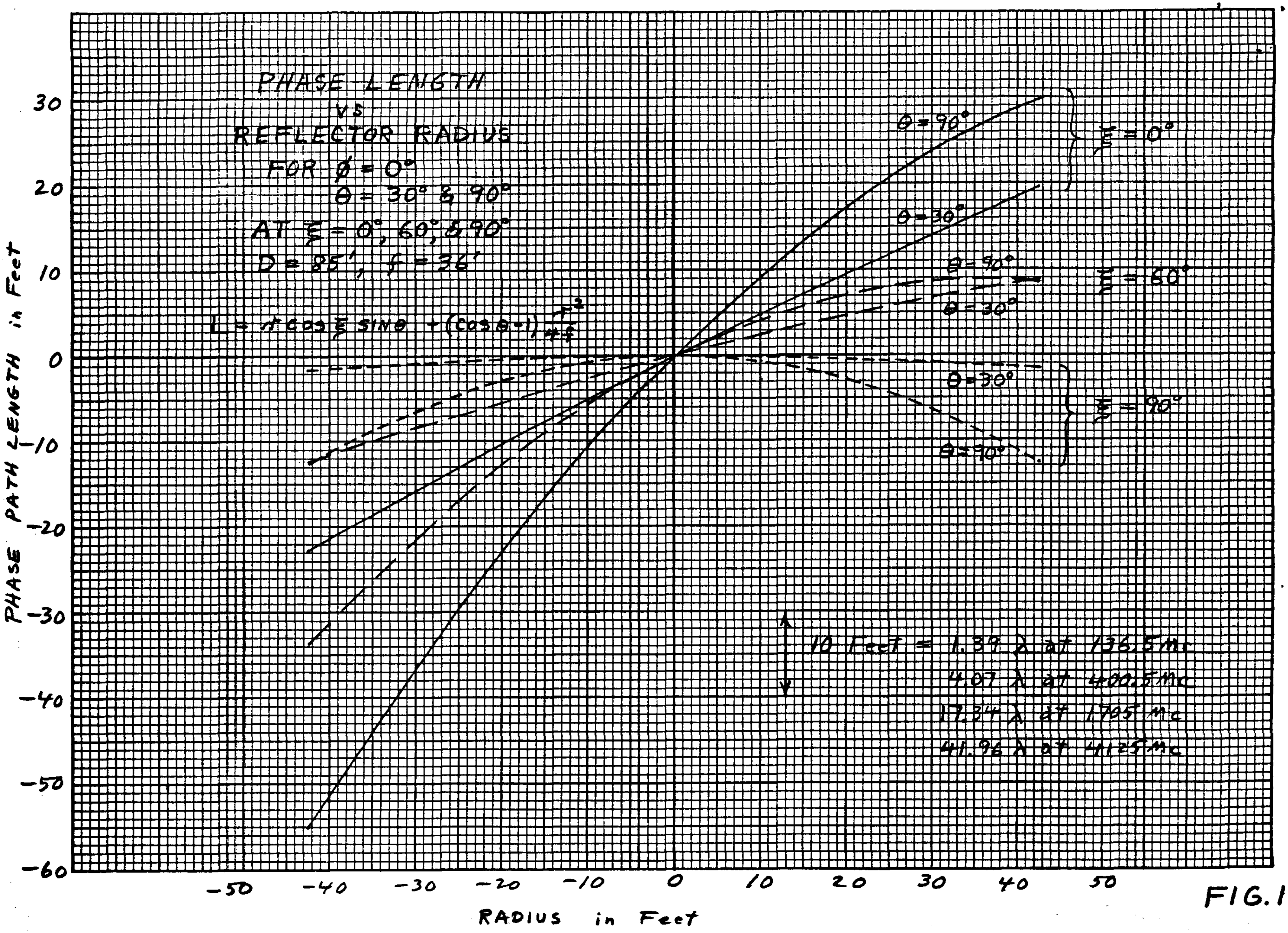
PHASE LENGTH
VS
REFLECTOR RADIUS
FOR $\phi = 0°$
$\theta = 30° \& 90°$
AT $\xi = 0°, 60°, \& 90°$
$D = 85'$, $f = 36'$
$L = r\cos\xi\sin\theta + (\cos\theta - 1)\frac{r^2}{4f}$
$\theta = 90°$
$\theta = 30°$
$\xi = 0°$
$\theta = 90°$
$\theta = 30°$
$\xi = 60°$
$\theta = 30°$
$\theta = 90°$
$\xi = 90°$
10 Feet = 1.39 λ at 136.5 Mc
4.07 λ at 400.5 Mc
17.34 λ at 1705 Mc
41.96 λ at 4125 Mc
30
20
10
0
-10
-20
-30
-40
-50
-60
PHASE PATH LENGTH in Feet
-50
-40
-30
-20
-10
0
10
20
30
40
50
RADIUS in Feet

FIG. 1

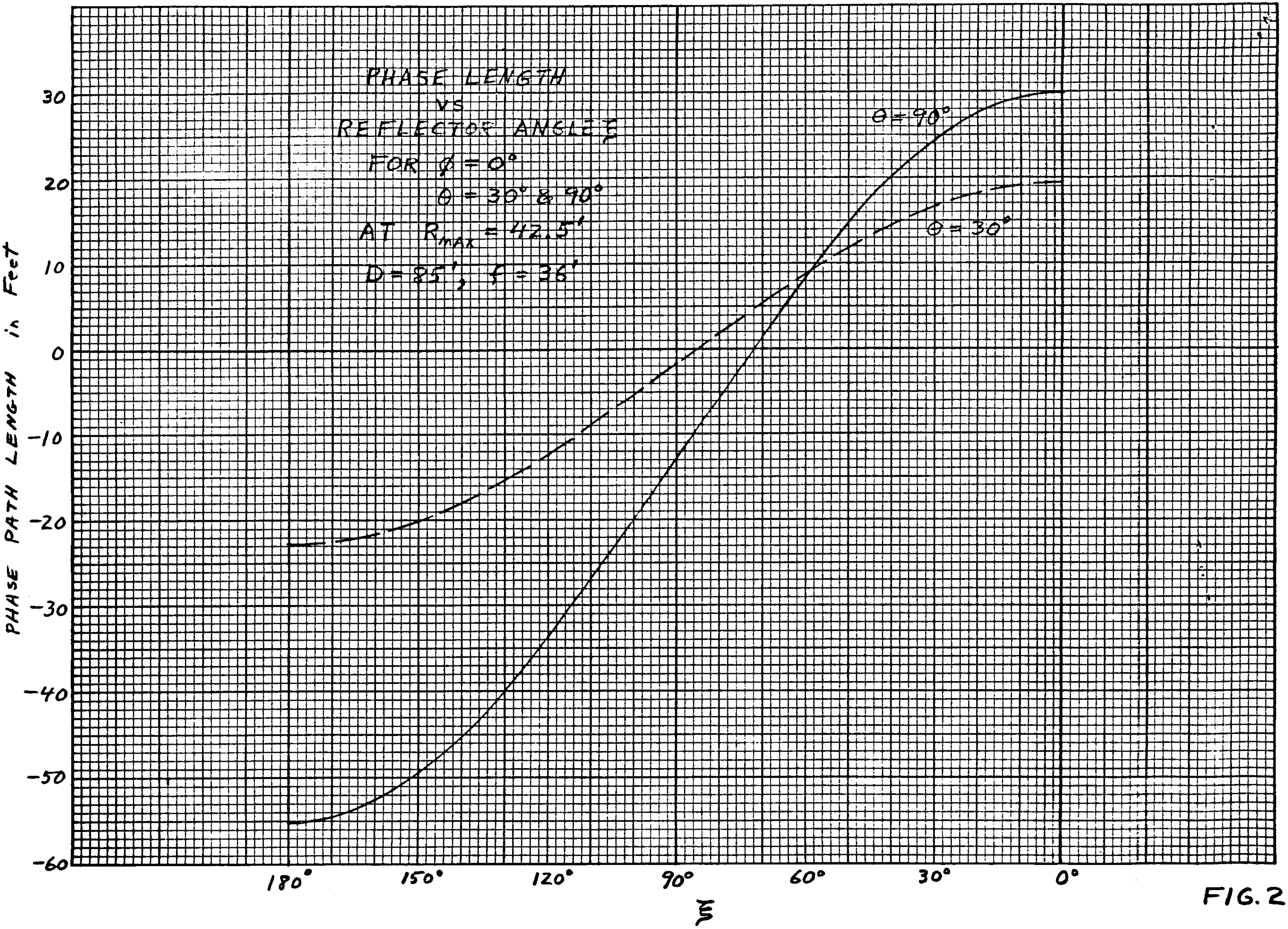
PHASE LENGTH
VS
REFLECTOR ANGLE Ξ
FOR ϕ = 0°
θ = 30° & 90°
AT R_MAX = 42.5'
D = 85', f = 36'
θ = 90°
θ = 30°
PHASE PATH LENGTH in Feet
30
20
10
0
-10
-20
-30
-40
-50
-60
180°
150°
120°
90°
60°
30°
0°
Ξ

FIG. 2