Network Engineering and Implementation: S- and X-Band Feed System

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In support of the Mariner 1973 X-band experiment, it is necessary to implement a dual-frequency microwave feed system for the DSS 14 64-meter-diameter antenna. To fulfill this requirement, a particularly attractive approach, the reflex feed system, is being implemented. The reflex feed configuration and its calculated aperture efficiency performance were described in a previous reporting. Additionally, calculated radio frequency (RF) power dissipation data for the reflex feed were reported. In this article, two questions are analyzed: (1) the S-band effects of possible buckling of the dichroic flat plate caused by RF and solar heating, and (2) the effect of subreflector backscatter on the S-band focus characteristics of the antenna.

I. Effect of Flat-Plate Distortion

As described in the previous reporting (Ref. 1), when the antenna is transmitting at the 400-kilowatt level, approximately 50 watts are dissipated in the relatively thin dichroic flat plate, indicating a possible problem with physical distortion relative to the desired flat surface. An analysis has been performed to determine the effect of buckling on forward spillover and antenna gain. The configuration analyzed is shown in Fig. 1.

The essentially rigorous analysis technique utilized for computing scattered patterns and the results for no data distortion were previously reported (Ref. 1). Four additional cases have been computed: $h = -2.54$ cm, $h = -1.27$ cm, $h = +1.27$ cm, and $h = +2.54$ cm (see Fig. 1). Flat-plate scattered patterns for $m = 1$ ellipsoid illumination and for $h = -1.27$ cm, $h = 0$, and $h = +1.27$ cm are shown in Figs. 2, 3, and 4, respectively. By use of the efficiency program the gain loss as a function of buckling height h was computed; the result is shown in Fig. 5 together with the forward spillover as a function of buckling height. The effect of the forward spillover on gain is included in the gain loss curve of Fig. 5. A future reporting will discuss techniques which will be utilized to control flatness of the dichroic plate.

II. Effect of Subreflector Backscatter on the S-band Focus Characteristic

The antenna gain, as a function of the axial location of the feed system phase center, may be readily computed. For displacements relative to the paraboloid focus, which are small relative to the antenna physical dimensions, the gain loss is symmetrical with respect to the position which yields maximum gain. Moreover, for defocusing losses less than approximately 1 dB, the loss is almost exactly quadratic in focus position. Thus,

$$G_{DB}(x) \simeq G_{0DB} - A_2 (x - x_0)^2, \mathrm{dB} \qquad (1)$$

where

$G_{DB}(x)$ = antenna gain, dB

G_{0DB} = antenna gain at maximum, dB

A_2 = a constant

x = focus position

x_0 = focus position for maximum gain

When the gain of a cassegrainian antenna, such as the 64-meter-diameter antenna at DSS 14, is measured as a function of focus position of the subreflector, a curve is obtained which is not quadratic as predicted by simple analysis. As a pertinent example, a 64-meter S-band focus curve measured and reported by Levy, et al. (Ref. 2), is shown in Fig. 6. It can be seen in Fig. 6 that a rapidly varying gain loss component is superimposed on the expected variation given by Eq. (1). The effect is qualitatively predicted as follows: A part of the energy scattered by the subreflector is directed toward the feedhorn. Of the energy intercepted by the S-band feedhorn, approximately one-half is captured and appears at the horn output. The remainder is scattered by the feedhorn back toward the subreflector. The phase of this scattered energy relative to the original horn radiation varies cyclically with the horn-to-subreflector spacing (i.e., the focus position) with a period of 1 cycle for every half wavelength of focus movement.

The voltage magnitude of the reflected energy at the feedhorn output is (Ref. 3)

$$|\Gamma| = \frac{G_0}{8\pi M} \cdot \frac{\lambda}{c} \qquad (2)$$

where

$|\Gamma|$ = voltage reflection coefficient

G_0 = horn power gain

M = cassegrain magnification factor

$2c$ = cassegrain foci separation

λ = wavelength

For the 64-meter antenna at S-band, $|\Gamma| = 0.0247$, or -32 dB, a value which agrees with experimental tests.

If the horn scattering pattern were the same as the horn radiation pattern, Eq. (2) would predict a cyclical gain variation of 0.4 dB peak-to-peak as a function of focus position, a serious effect. An attempt was made, by hand calculation, to determine the cylical component in the *Surveyor* focus curve of Fig. 6.

The function which was selected for fitting to the *Surveyor* data was

$$G'DB(x) \equiv [A_0 + A_1 x + A_2 x^2] + [S_0 + S_1 x] \cos\left(\frac{4\pi x}{\lambda} - c\right) \qquad (3)$$

where A_0, A_1, A_2, S_0, S_1, and c were taken as unknown coefficients. As a fitting criterion, the coefficients were iteratively perturbed to minimize the rms error between Eq. (3) and the nine data points. The resulting coefficient values were

$A_0 = -0.01572679$ dB

$A_1 = -0.02980314$ dB/cm

$A_2 = -0.02403280$ dB/cm^2

$S_0 = 0.0527394$ dB

$S_1 = -0.00395247$ dB/cm

$c = 1.2879880$ radians

The resulting fit is shown in Fig. 7 and the two focus components in Fig. 8. As a partial check, the coefficient A_2 had been previously determined,[1] for uniform paraboloid illumination, with the Radiation Program as -0.02244 dB/cm^2. A recent computation for the 64-meter tricone system, including the phase and amplitude illumination functions, yielded a value of -0.02126 dB/cm^2.

As shown in Fig. 8, the reflection effect displaced the point of maximum gain by 0.6 cm. For the reflex feed, if the antenna were focused for S-band, a serious X-band gain loss could result. Thus, it would be desirable to be able to accurately determine the amplitude and phase of the cyclical component from focusing data and to have a means of adjusting the phase angle c to bring this component's maximum into alignment with the X-band focus maximum and essential alignment with the unperturbed S-band maximum. To achieve this objective, provision is being made for adjustment of the ellipsoid tilt and the dichroic flat-plate position and tilt to change the S-band

[1]M. S. Katow, JPL DSIF Engineering Section, private communication.

path length to the subreflector without focusing the subreflector.

It is presently planned to develop a curve-fitting computer program which will rapidly determine the amplitude and phase of the cyclical component from measured focus data and, from this information, determine the proper direction and magnitude of the reflex feed adjustments. Additionally, studies will be made of the best way to take the focus data (e.g., number of points and spacing) to minimize the station time and the error in the phase and amplitude determination.

References

1. Potter, P. D., "S- and X-Band RF Feed System," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. IX, pp. 141–146. Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1972.
2. Levy, G. S., et al., "Lunar Range Radiation Patterns of a 210-Foot Antenna at S-Band," *IEEE Transactions on Antennas and Propagation*, Vol. AP-15, No. 2, pp. 311–313, Mar. 1967. Also available as Technical Report 32-1079, Jet Propulsion Laboratory, Pasadena, Calif.
3. Rusch, W. V. T., and Potter, P. D., *Analysis of Reflector Antennas*, p. 106. Academic Press, Inc., New York, 1970.

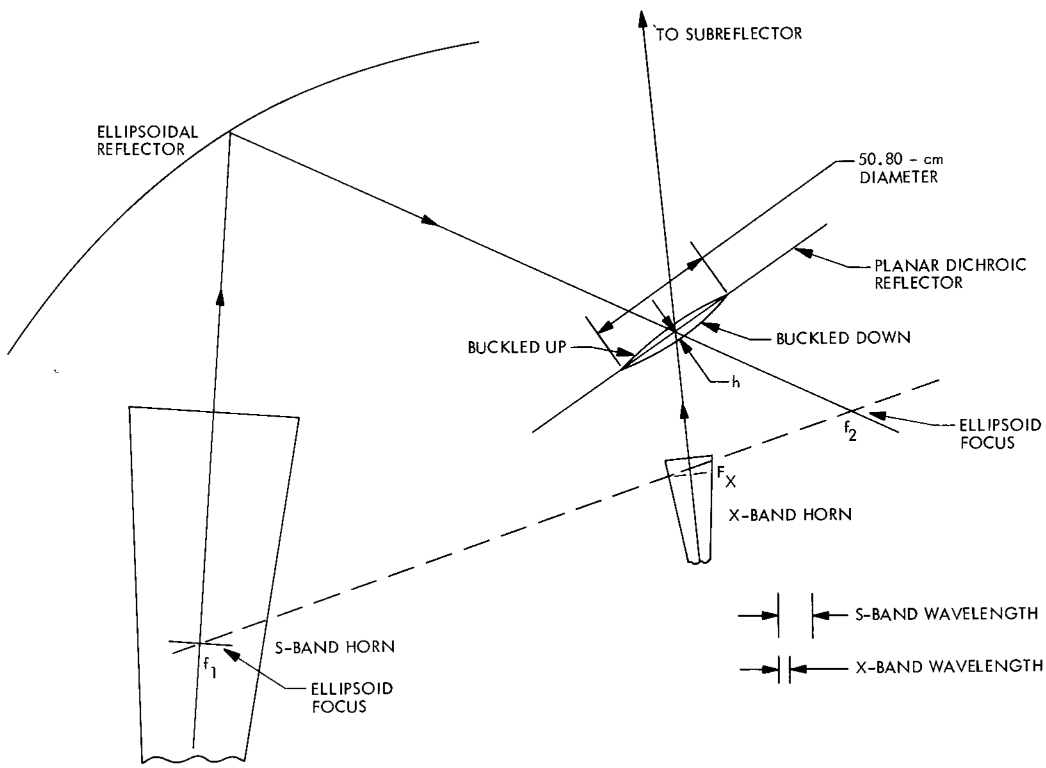

Fig. 1. Geometry of distorted flat plate

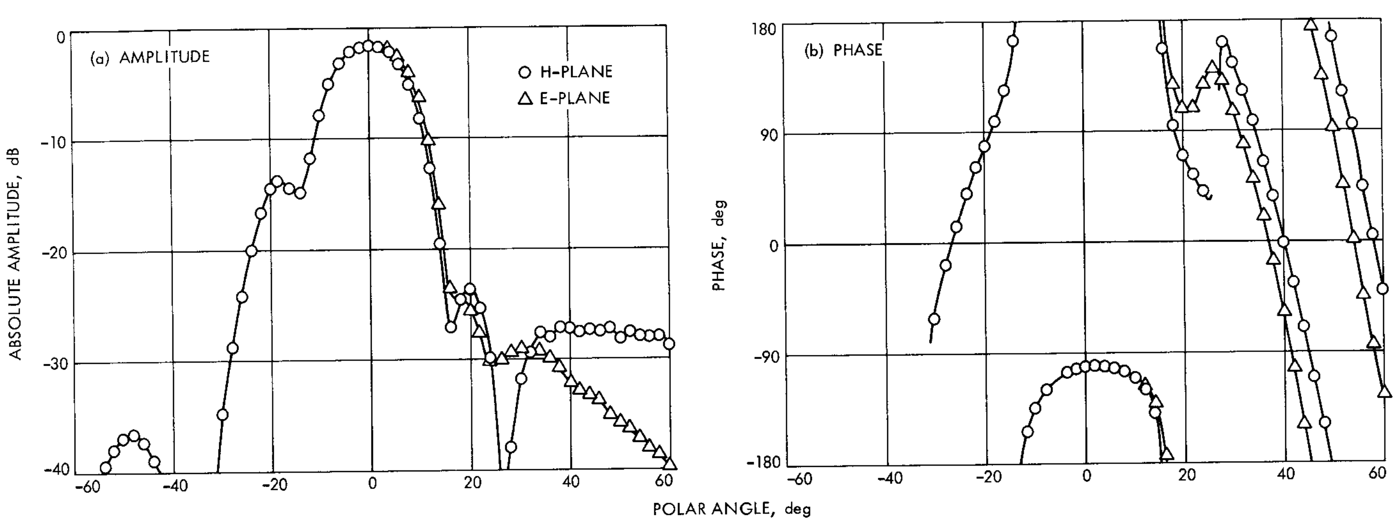

Fig. 2. Flat-plate scattered pattern, $h = -1.27$ cm

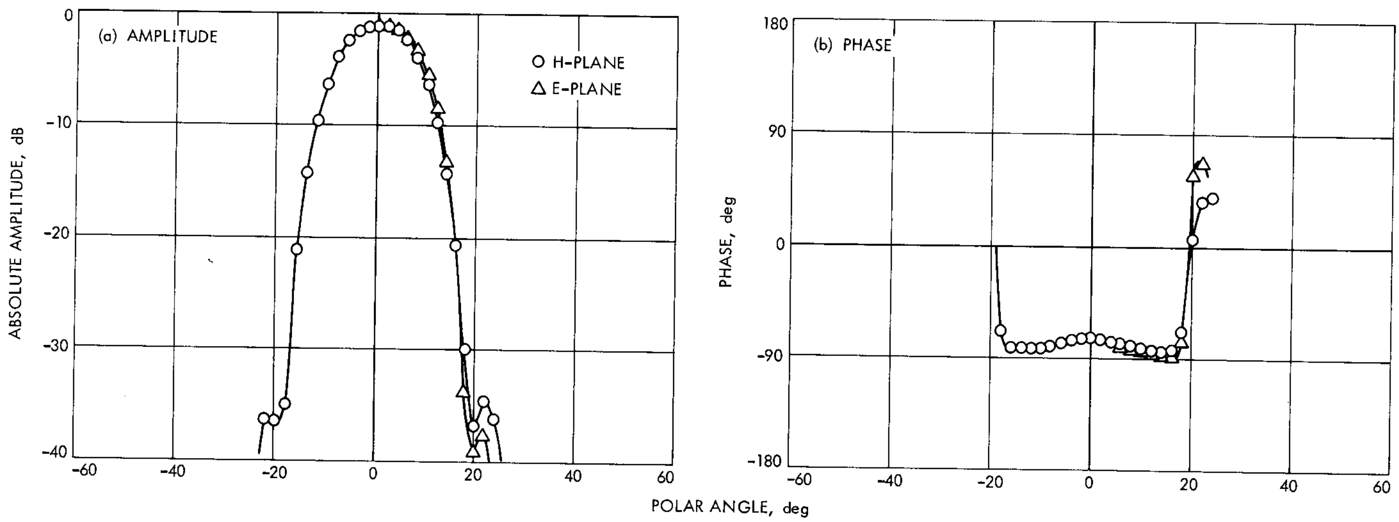

Fig. 3. Flat-plate scattered pattern, $h = 0$ cm

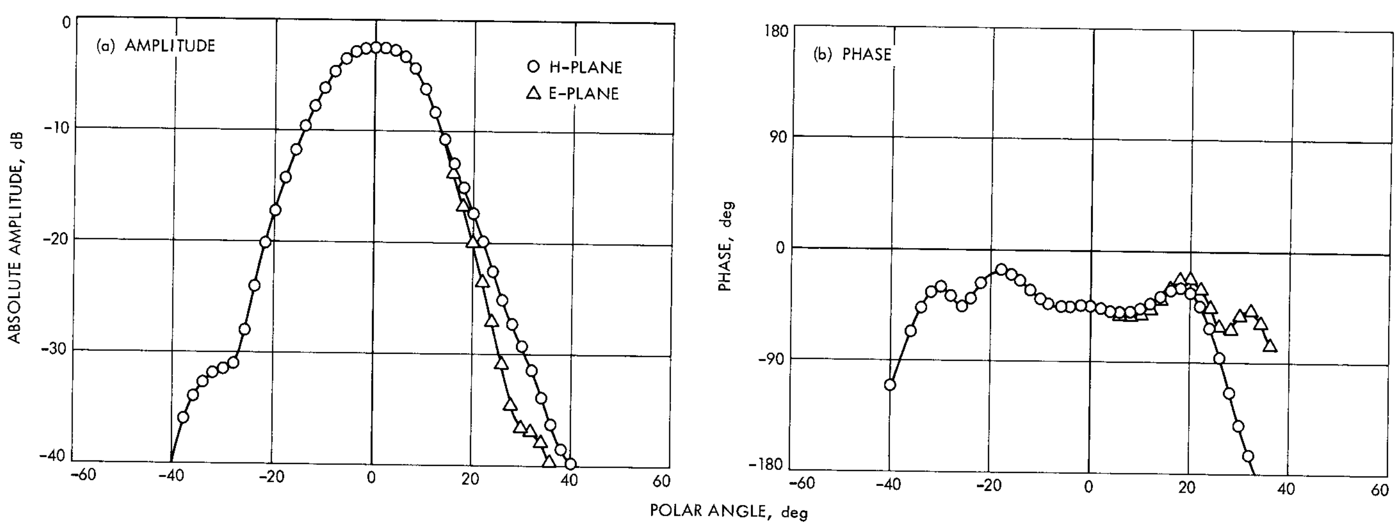

Fig. 4. Flat-plate scattered pattern, $h = +1.27$ cm

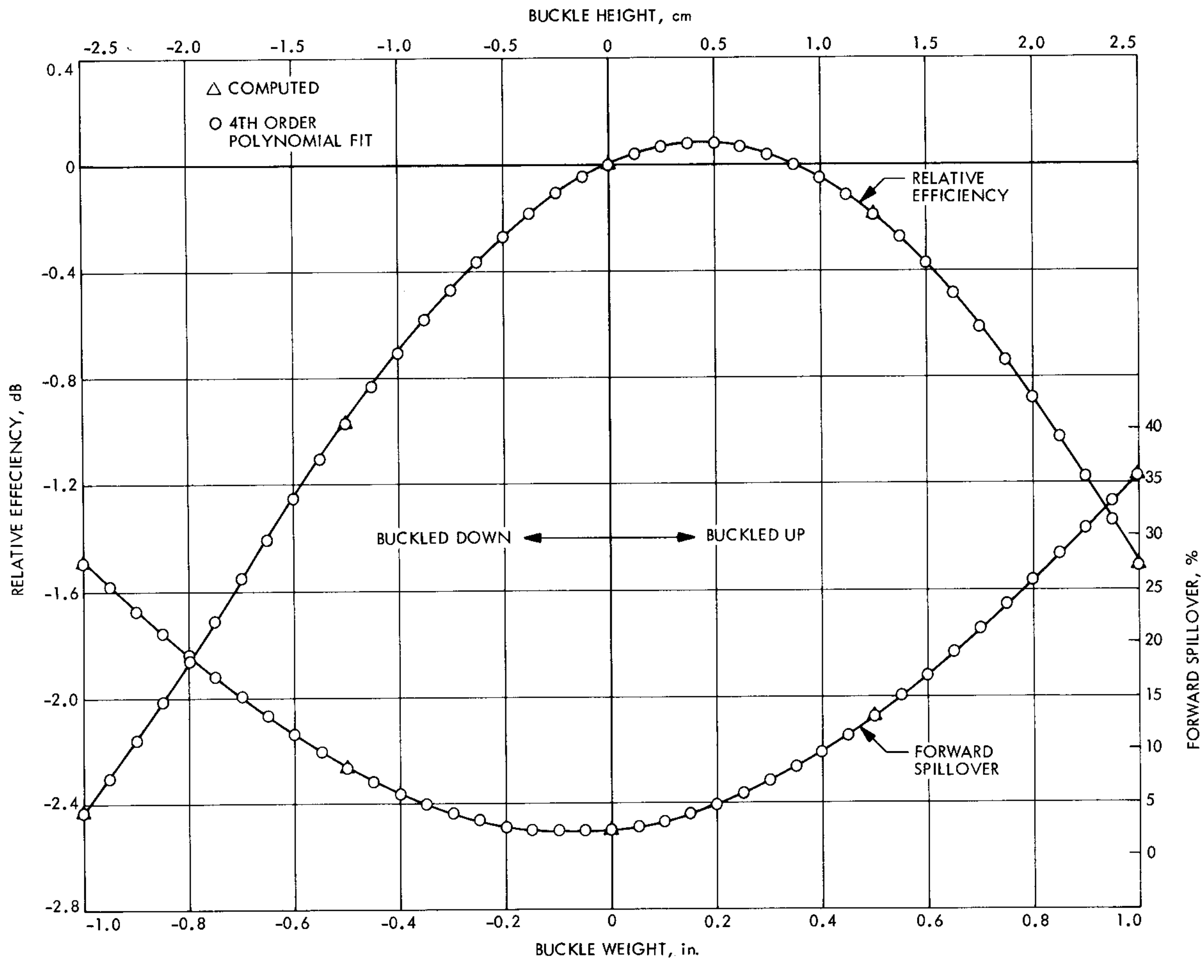

Fig. 5. Forward spillover and relative antenna efficiency vs dichroic plate buckling height

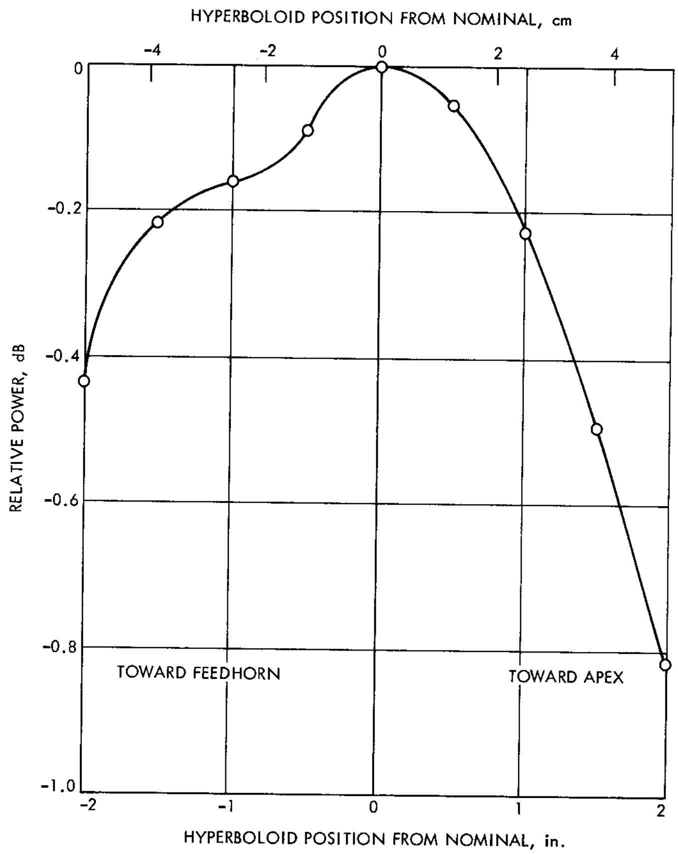

Fig. 6. 64-meter antenna *Surveyor* focus curve

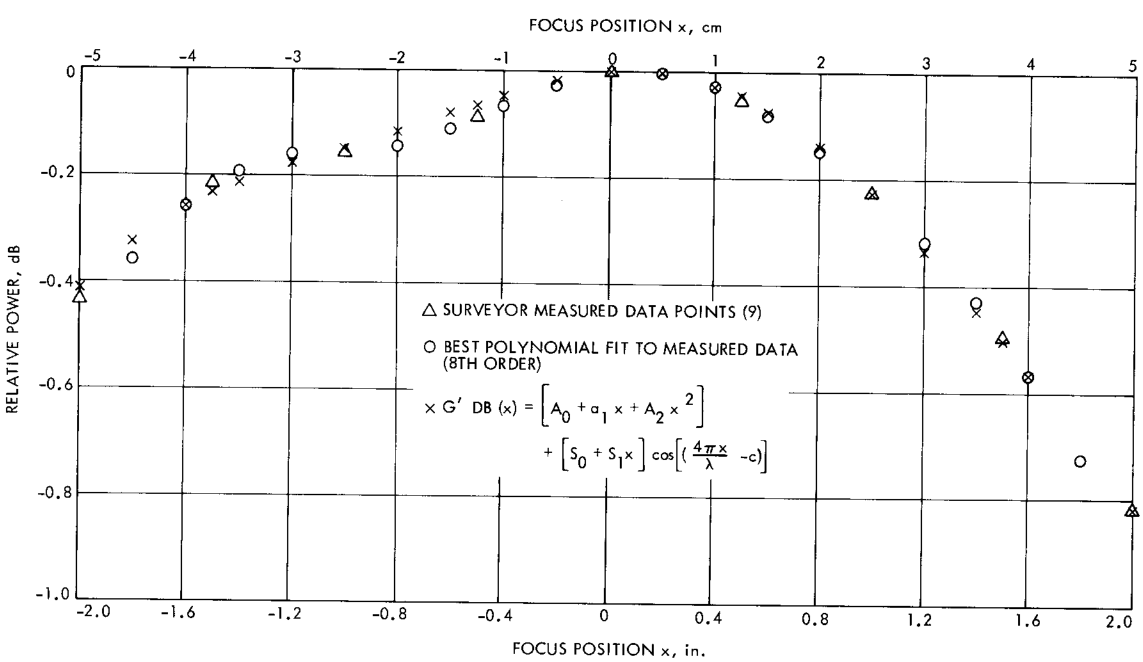

Fig. 7. *Surveyor* focus data fit

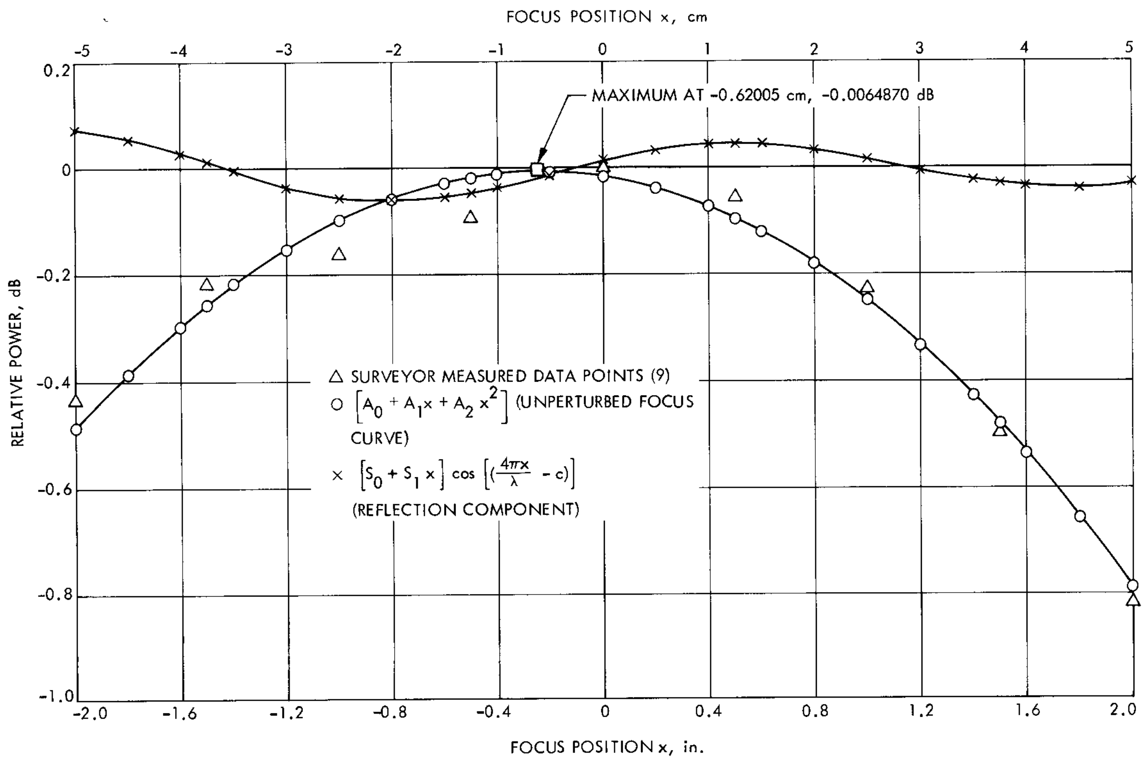

Fig. 8. *Surveyor* focus data components