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PROBABLE DEVIATIONS IN ALTITUDE READING GIVEN BY THE LM ALTIMETER FOR THE MOST ROUGH SURFACE ALONG A CERTAIN GIVEN TRAJECTORY*

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The spectrum of the backscattered energy for the Frequency Modulated Altimeter may be analyzed to obtain the target range variations versus the target surface conditions. And the expected frequency, and consequently the associate altitude may be calculated (Rice, 1944) as

$$\langle f_B \rangle = \left[\frac{\displaystyle\int_{\frac{2h\dot{f}}{c} - f_D}^{\frac{3h\dot{f}}{c} - f_D} \frac{G^2(\theta)\,\sigma(\theta)}{f_B}\, df_B}{\displaystyle\int_{\frac{2h\dot{f}}{c} - f_D}^{\frac{3h\dot{f}}{c} - f_D} \frac{G^2(\theta)\,\sigma(\theta)}{f_B^3}\, df_B} \right]^{\frac{1}{2}} \qquad (1)$$

where

f_B = the static beat frequency

h = the actual range

f_D = the doppler frequency

$\dot{f}$ = the FM slope

c = velocity of light

$G^2(\theta)$ = the two-way antenna gain

$\sigma(\theta)$ = the target scattering coefficient

For the Landing Module (LM), the radar has a beam width of 3.5° by 7° and the orientation of the beam on the landing track is as shown in Fig. 1 for vertical incidence case.

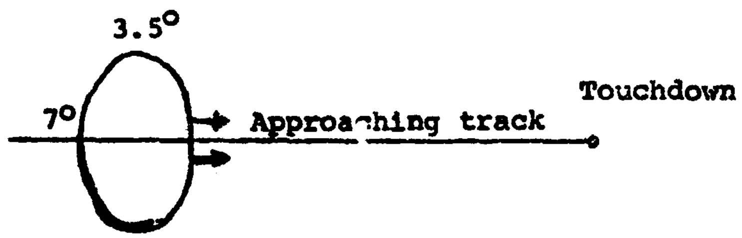

Fig. 1 The minor-axis of the radar beam parallel to the direction of motion.

The return signal is averaged over a period of 231 milliseconds along the trajectory. The horizontal velocity of the LM during landing is small, and the surface covered by the radar in one period is comparable to 150% of the beam cross-section (Tong and Hayre, 1967). Considering that the pitch angle of the vehicle, and the antenna angle do not vary within an averaging period, it suffices to treat the system as stationary with respect to the horizontal axis. If the width of the landing track scanned by the radar is normalized, the average beat frequency may be approximated using a one-dimensional profile.

In what follows the average beat frequency for $\theta = \theta_1$ at a fixed altitude is calculated.

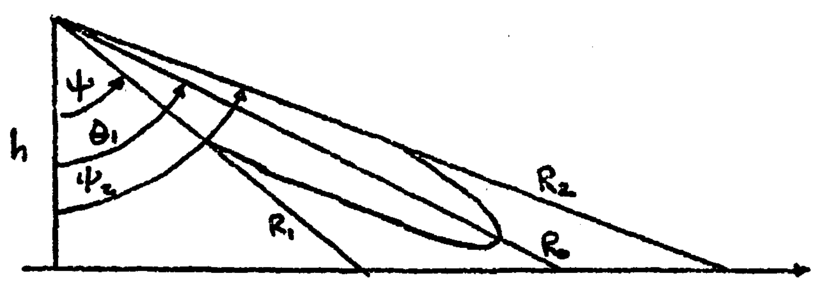

Fig. 2 Geometry of the Apollo radar-detection.

As shown in Fig. 2, the transformation of f_B to θ would be;

$$h = \frac{f_B c}{2\dot{f}} \quad \text{or} \quad f_B = \frac{2h\dot{f}}{c} \tag{2}$$

$$R_1 = \frac{f_1 c}{2\dot{f}} \quad \text{or} \quad f_1 = \frac{2h\dot{f}}{c \cos\psi_1} \tag{3}$$

$$R_2 = \frac{f_2 c}{2\dot{f}} \quad \text{or} \quad f_2 = \frac{2h\dot{f}}{c \cos\psi_2} \tag{4}$$

In general;

$$f_B = \frac{2h\dot{f}}{c\cos\theta} \tag{5}$$

and

$$df_B = \frac{2h\dot{f}}{c}\,\frac{\sin\theta}{\cos^2\theta}\,d\theta \tag{6}$$

Substituting (3), (4), (5) and (6) in (1), one obtains,

$$\langle f_B \rangle = \frac{2h\dot{f}}{c}\left[\frac{\int_{\psi_1}^{\psi_2} G^2(\theta)\,\sigma(\theta)\,\tan\theta\,d\theta}{\int_{\psi_1}^{\psi_2} G^2(\theta)\,\sigma(\theta)\cos\theta\sin\theta\,d\theta}\right]^{1/2} \tag{7}$$

The expression $\frac{2h\dot{f}}{c}$ in Eq. 7, is the beat frequency corresponding to the actual altitude of the transmitter, whereas the square root term is the ratio of the detected altitude to the actual altitude. Since the percent deviation in altitude is the essential information, one needs only to carry the calculation of the square root part of Eq. 7.

Based on the information of the radar beamwidth, the antenna gain is approximated to be

$$G^2(\theta) = \cos^4 13\theta \qquad (8)$$

and the scattering cross-section is chosen of point No. 8 Site P-II-6 of static runs of the acoustic simulation test and is shown in Fig. 3.

The percent deviation is plotted as shown in Fig. 4.

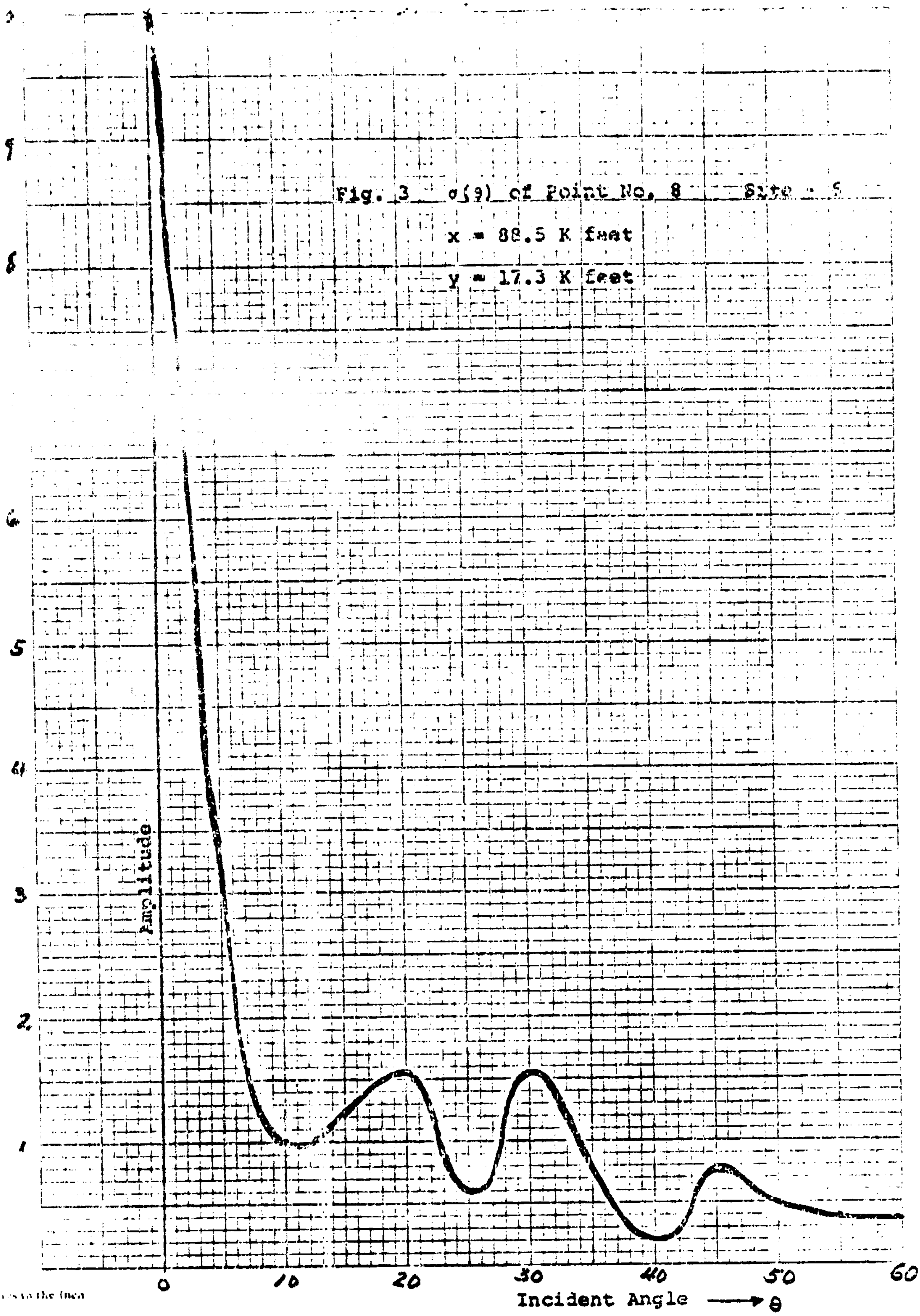

Fig. 3 σ(θ) of Point No. 8 Site - S

x = 88.5 K feet

y = 17.3 K feet

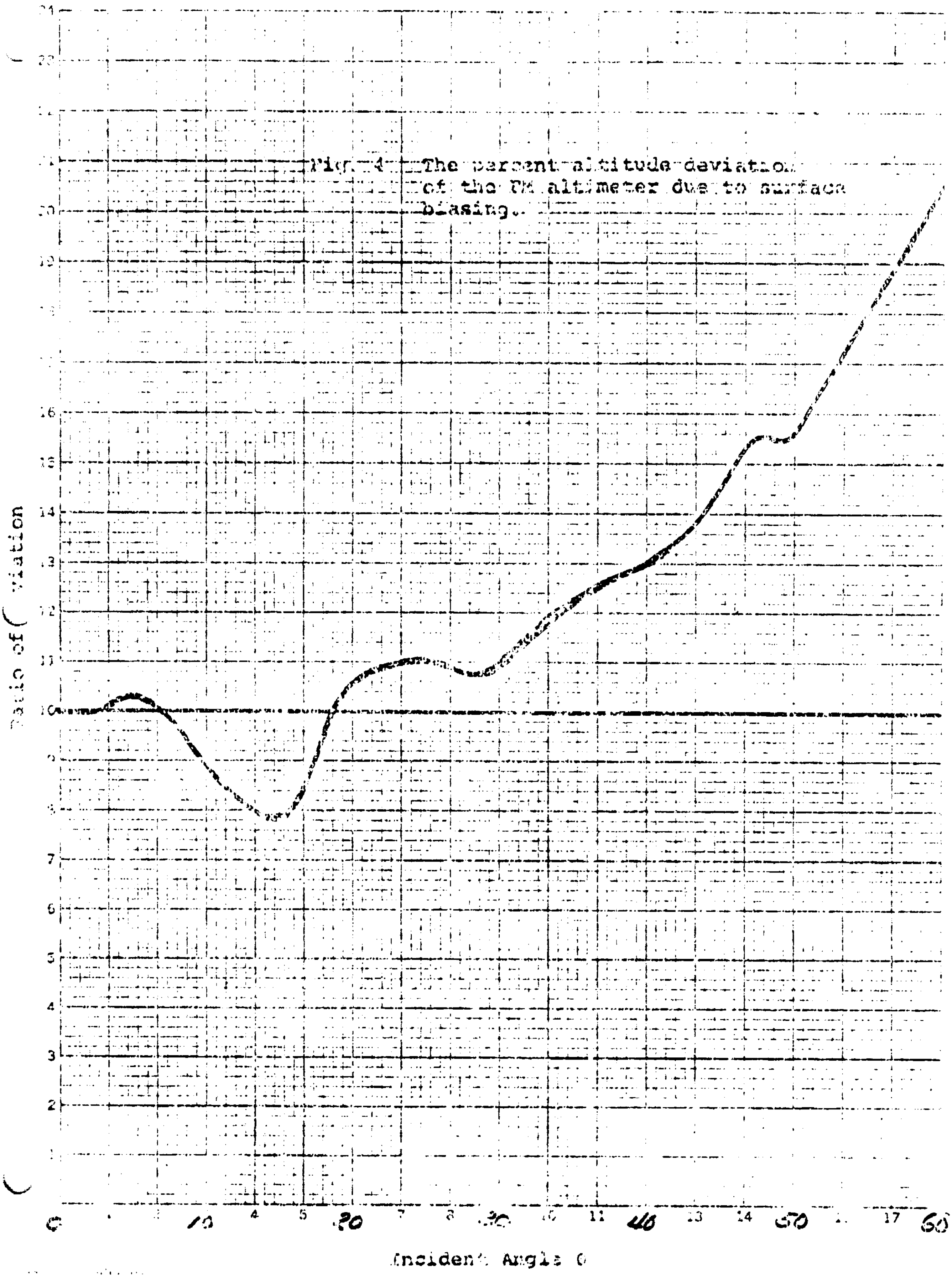

Fig. 4. The percent altitude deviation of the FM altimeter due to surface biasing.

CONCLUSION

This calculation shows that the percent deviation of the altitude reading from the actual would vary considerably from 79% to 203% corresponding to angles of incidence of 0° (vertical incidence) to 60° degrees. A close examination of these results indicate the variation to be within $\pm$ 10% for look angles of 0, 5°, 10°, 20°, 25°, and 30°, whereas for 15° angle of incidence it is -22% and for angles greater than 30°, it increases almost monotonically to +203% at $\theta = 60^{\circ}$

REFERENCES

1. Rice, S. O. "Mathematical Analysis of Random Noise," Bell Systems Tech. Journal, Vol. 23, No. 3, 1944, Bell P. 282; Vol. 24, No. 1, 1945, p. 46.

2. Tong, A. and H. S. Hayre. Lunar Surface Bias on Landing Module Altimeter Signal, Technical Report TR-67-19, University of Houston, Wave Propagation Laboratories, Electrical Engineering Department, October, 1967.