NASA CR-156780

Erwin Hirschmann
no NASA CR#

AMPLITUDE SCINTILLATION AT 2 AND 30 GHz ON EARTH SPACE PATHS

D. B. Hodge, D. M. Theobold, and D. M. J. Devasirvatham

The Ohio State University

ElectroScience Laboratory

Department of Electrical Engineering
Columbus, Ohio 43212

(NASA-CR-156780) AMPLITUDE SCINTILLATION AT 2 AND 30 GHz ON EARTH SPACE PATHS (Ohio State Univ., Columbus.) 9 p HC A02/MF A01 CSCL 20N

N78-28299

Unclas
G3/32 27057

Technical Report 4299-3

February 1977

Prepared for
National Aeronautics and Space Administration
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle AMPLITUDE SCINTILLATION AT 2 AND 30 GHz ON EARTH SPACE PATHS		5. Report Date February 1977 6. Performing Organization Code
7. Author(s) D.B. Hodge, D.M. Theobold, D.M.J. Devasirvatham		8. Performing Organization Report No. 4299-3
9. Performing Organization Name and Address The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering, Columbus, Ohio 43212		10. Work Unit No. 11. Contract or Grant No. NAS5-22575 13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address NASA, GSFC Greenbelt, Maryland 20771 E. Hirschmann, Code 951, Technical Officer		Type II Technical Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Extensive amplitude scintillation measurements have been made simultaneously at 2.075 and 30 GHz on earth-space propagation paths. These measurements were performed as the Applications Technology Satellite (ATS-6) was moved slowly from a synchronous position over India to a new synchronous position over the United States. The variance, path loss, covariance, and spectra are discussed as functions of the path elevation angle. These results are also compared with earlier simultaneous scintillation measurements at 20 and 30 GHz during the movement of ATS-6 to its position over India [1,2].

This report contains the text of a paper to be presented at the URSI Commission F Open Symposium on Propagation in Non-ionized Media at LaBaule, France, April 28-May 6, 1977.

17. Key Words (Selected by Author(s))	18. Distribution Statement
Millimeter wave ATS-6 Scintillation Earth-Space Propagation	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
U	U	5	

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

TABLE OF CONTENTS

AMPLITUDE SCINTILLATION AT 2 AND 30 GHz ON EARTH SPACE PATHS*

D. B. Hodge, D. M. Theobold and D. M. J. Devasirvatham
The Ohio State University ElectroScience Laboratory
Department of Electrical Engineering
Columbus, Ohio USA 43212

SUMMARY

Extensive amplitude scintillation measurements have been made simultaneously at 2.075 and 30 GHz on earth-space propagation paths. These measurements were performed as the Applications Technology Satellite (ATS-6) was moved slowly from a synchronous position over India to a new synchronous position over the United States. The variance, path loss, covariance, and spectra are discussed as functions of the path elevation angle. These results are also compared with earlier simultaneous scintillation measurements at 20 and 30 GHz during the movement of ATS-6 to its position over India [1,2].

1 - INTRODUCTION

The movement of ATS-6 from a synchronous position over India to a new synchronous position over the United States was such that the change in the elevation angle of the propagation path was less than one degree per day. Thus, a unique opportunity was presented to measure scintillation characteristics as a function of elevation angle. Phase-lock-loop receivers were implemented at Columbus, Ohio, U.S.A. to receive the 2.075 and 30 GHz ATS-6 beacon signals. 4.6 and 9.1 m Cassegrainian type horn fed parabolic reflector antennas were used. The measured system margins were 48 and 55 dB, respectively. The received signals were digitally recorded at a rate of 10 samples per second at all times during the experiment and at a rate of 200 samples per second on demand; all of the data presented in this paper were derived from the 10 sample per second recordings.

Thirty hours of simultaneous two frequency data were collected between August 29 and October 25, 1976; these data correspond to elevation angles ranging from -0.7° to 43.9° (not corrected for refraction). Samples of these raw data are shown in Figures 1, 2 and 3 for elevation angles of 0.38°, 2.82° and 22.34°, respectively; in these Figures the 2.075 and 30 GHz signals are shown with respect to the mean over the 30 minute data period presented. At the lower elevation angle the peak-to-peak scintillation exceeded 7 dB at 2.075 GHz and 20 dB at 30 GHz. These peak-to-peak scintillation values decreased with increasing elevation angle except that enhanced scintillations were often observed during the presence of non-precipitating cumulus clouds along the propagation path. Although the character of the scintillation appears to change as the elevation angle increases, examination of the spectra of these signals, presented later in this paper, do not show significant differences other than the general reduction of all frequency components. These scintillations were found to occur at all times during the experiment regardless of prevailing atmospheric conditions. All of the data presented in this paper correspond to times when there was no discernible precipitation on the propagation path.

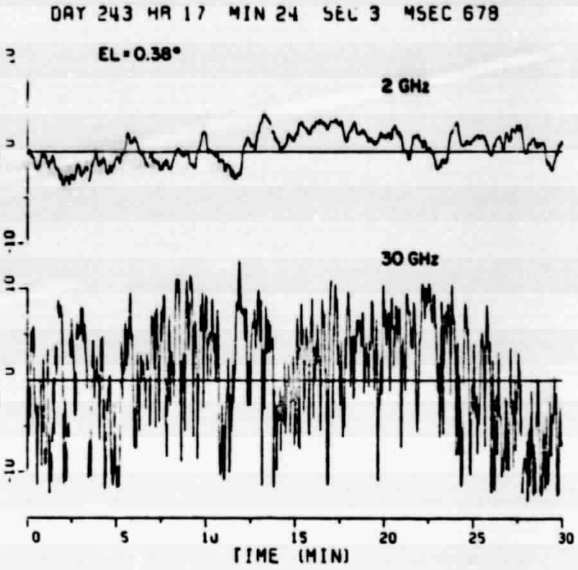

Figure 1. Received signal on day 243.

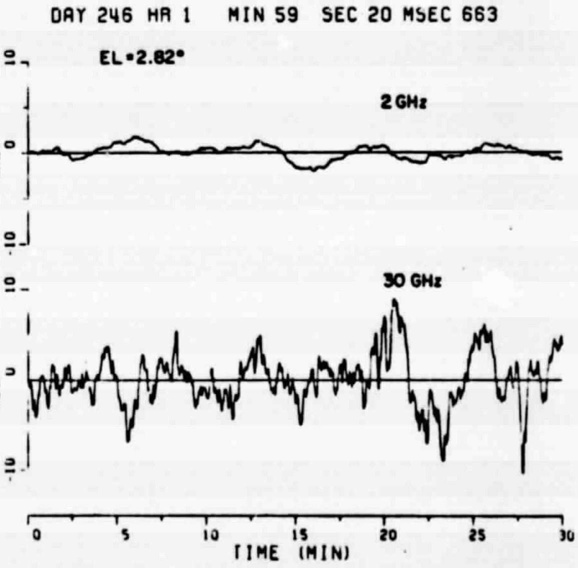

Figure 2. Received signal on day 246.

*The work reported in this paper was supported in part by Contract NAS5-25575 between National Aeronautics and Space Administration and The Ohio State University Research Foundation.

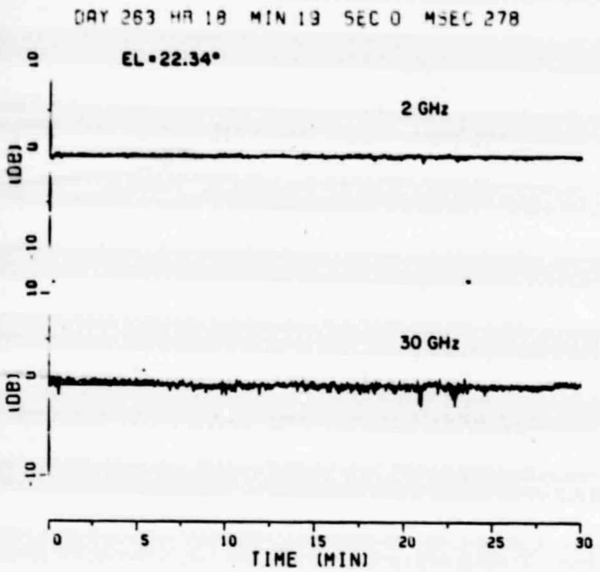

Figure 3. Received signal on day 263.

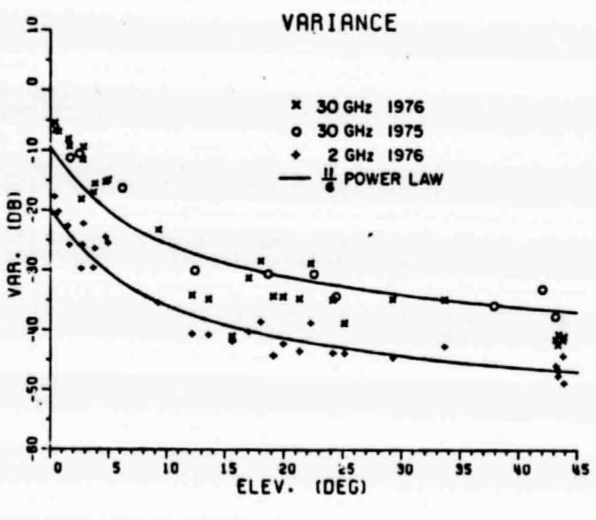

Figure 4. Variance of received signal amplitude.

The variances of these signals have been averaged over each data period and are shown in Figure 4 as functions of elevation angle. These variances were defined as

$$\sigma^2 = 10 \log_{10} \frac{\sum_{i=1}^{N} (V_i - \bar{V}_i)^2}{N \bar{V}_i^2} \qquad (1)$$

where the V_i are the samples of the received signal amplitude corrected for receiver nonlinearities and $\bar{V}_i$ is the average over the N samples. The variances were calculated for data intervals of 3.4 minutes, and these variances were then averaged over each data period of 30 to 60 minutes. The spread of the variance over such a data period was often as high as 10 dB. The variance defined in this manner represents the ratio of the power contained in the non-zero frequency components to the power contained in the zero frequency component of the signal. Also shown in Figure 4 are the 30 GHz variance data derived from the earlier set of measurements; these agree well with the current measurements. Theoretical curves have been included to demonstrate the variance behavior under the assumption that the variance is proportional to the 11/6 power of the path length through a 9 km spherical, homogeneous atmosphere. It can be noted that the measured variance agrees well with this model.

A plot of the variance of the log amplitude of the received signal is shown for comparison in Figure 5. Here the variance of the log amplitude is defined by

$$\sigma^2_{log} = \sum_{i=1}^{N} (V_{log_i} - \overline{V_{log_i}})^2 \Big/ N \qquad (2)$$

where $V_{log_i} = 20 \log_{10} V_i$; (3)

the subsequent processing was identical to that described above. It is interesting to note that the variance in log amplitude reveals a rather abrupt reduction in level for elevation angles above 6° that is not found in the variance of the amplitude presented earlier. This difference can lead to substantially different interpretations of the same data depending only on the method of data processing chosen.

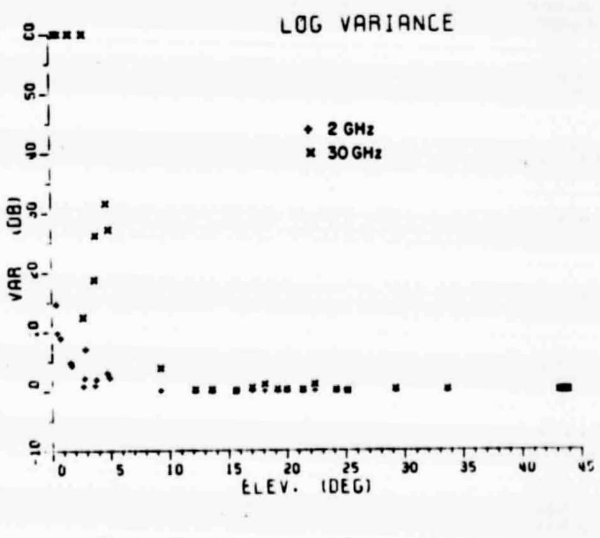

Figure 5. Variance of log amplitude.

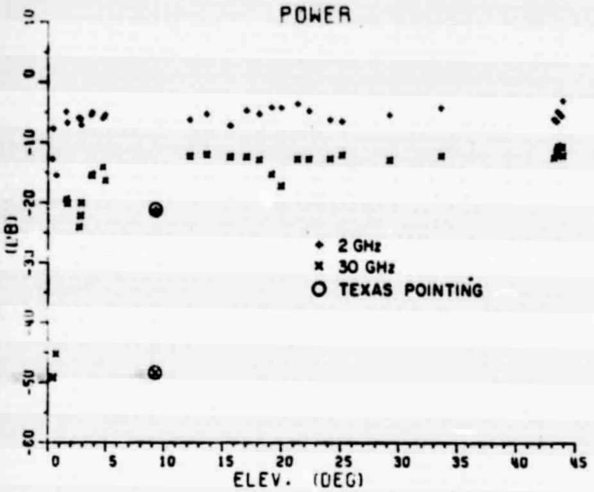

Figure 6. Average power in zero frequency component.

The average power contained in the zero frequency component of the received signal is plotted as a function of elevation angle in Figure 6; the reference in this figure is arbitrary. The dramatic reduction in level at an elevation of 9.3° is due to the fact that the spacecraft antennas were directed toward Texas rather than Ohio during this data period. A substantial reduction in the received power level below that predicted by simple atmospheric path loss calculations at lower elevation angles is also noted; this behavior has been observed earlier by McCormick and Maynard [3].

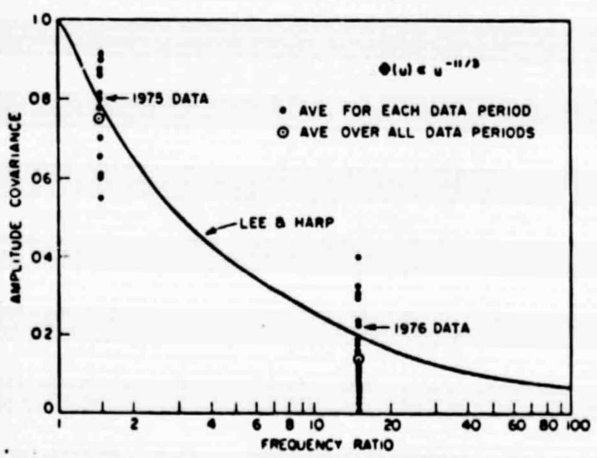

Figure 7. Covariance versus frequency ratio.

The covariance between the 2.075 and 30 GHz signals is shown in Figure 7 along with that for the 20 and 30 GHz data measured earlier [2] and the theoretical covariance predicted by Lee and Harp [4]. Although the spread of the covariance is large, the average over the entire data base agrees well with the theoretical prediction. The covariance is shown in Figure 8 as a function of elevation angle; here it is noted that the covariance decreases as the elevation angle increases. Both the covariance of the amplitudes and the covariance of the log amplitudes are shown in this figure for comparison; though some divergence is found at the lowest elevation angles they are found to agree well at higher elevation angles.

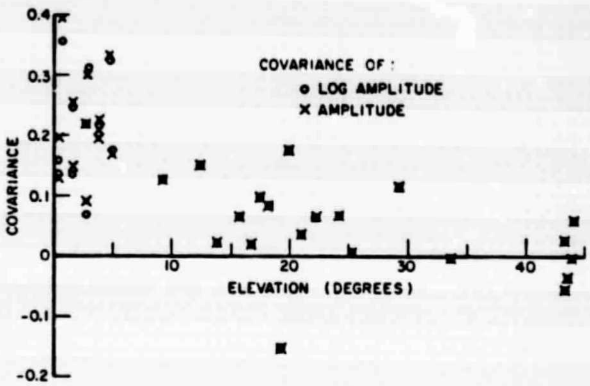

Figure 8. Covariance versus elevation angle.

Spectra of the received signals are shown in Figures 9, 10 and 11; these correspond to 3.4 minute intervals from the data periods shown in Figures 1, 2 and 3, respectively. These spectra all show a characteristic decay with frequency in the range from approximately 0.1 to 1.0 Hz. The spectra tend to be relatively flat for frequencies above and below that range.

Additional processing of these data is in progress and will be reported in a future publication.

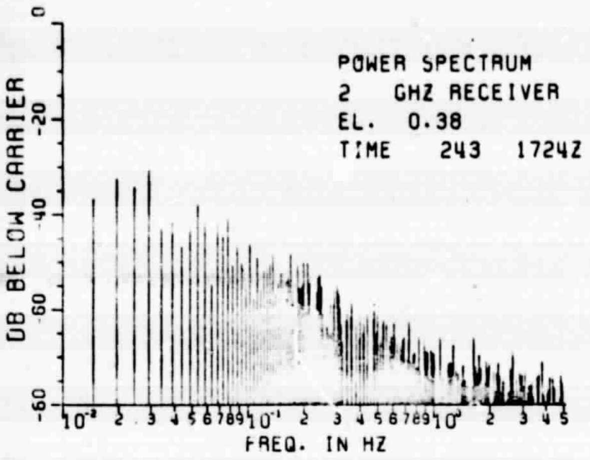

Figure 9a. Power spectrum - day 243.

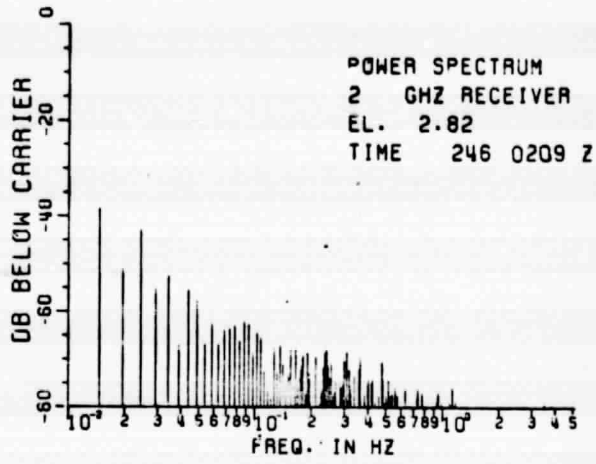

Figure 10a. Power spectrum - day 246.

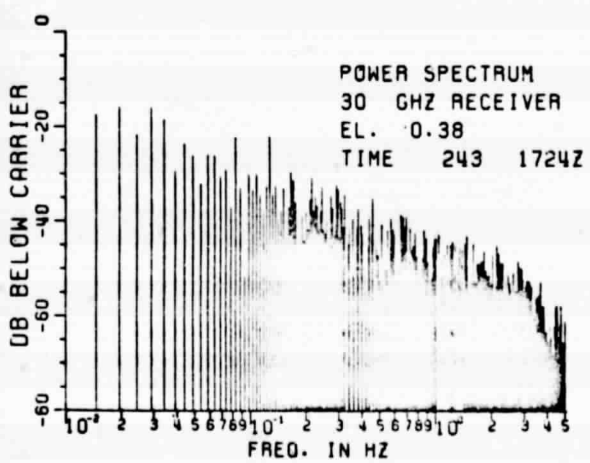

Figure 9b. Power spectrum - day 243.

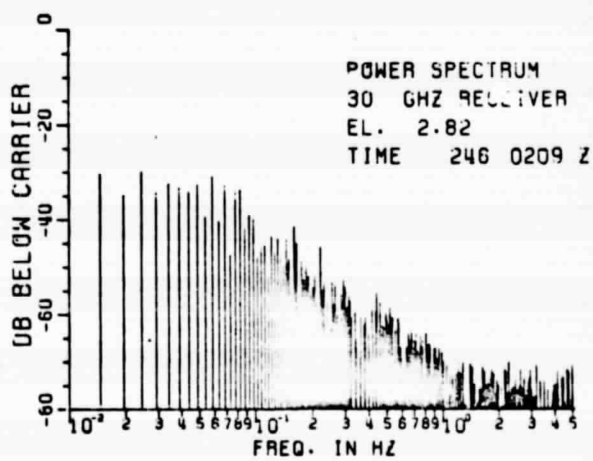

Figure 10b. Power spectrum - day 246.

REFERENCES

[1] "Scintillations Observed on the ATS-6 20 and 30 GHz Downlinks," D. B. Hodge and D. M. Theobold, URSI/USNC Meeting, Boulder, Colorado, October 1975.

[2] "ATS-6 Millimeter Wavelength Propagation Experiment," D. B. Hodge, D. M. Theobold, and R. C. Taylor, Ohio State University Electro-Science Report 3863-6, January 1976.

[3] "Measurements of S.H.F. Tropospheric Fading Along Earth-Space Paths at Low Elevation Angles," K. S. McCormick and L. A. Maynard, Electronics Letters, Vol. 8, p. 274, 1972.

[4] "Weak Scattering in Random Media, With Applications to Remote Probing," R. W. Lee and J. C. Harp, Proc. IEEE, Vol. 57, p. 375, 1969.

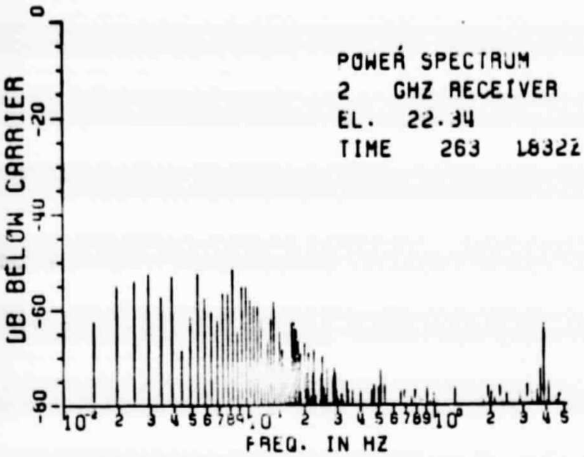

Figure 11a. Power spectrum - day 263.

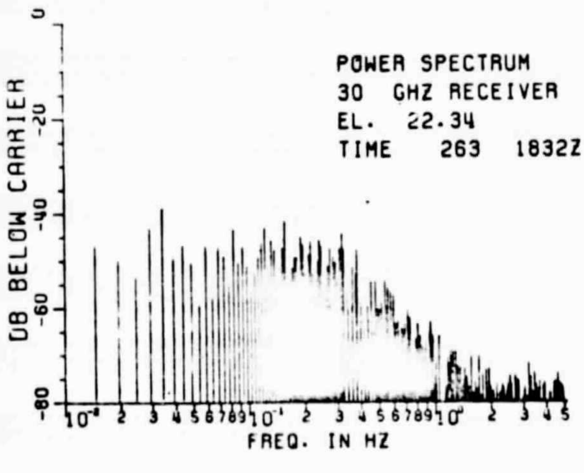

Figure 11b. Power spectrum - day 263.