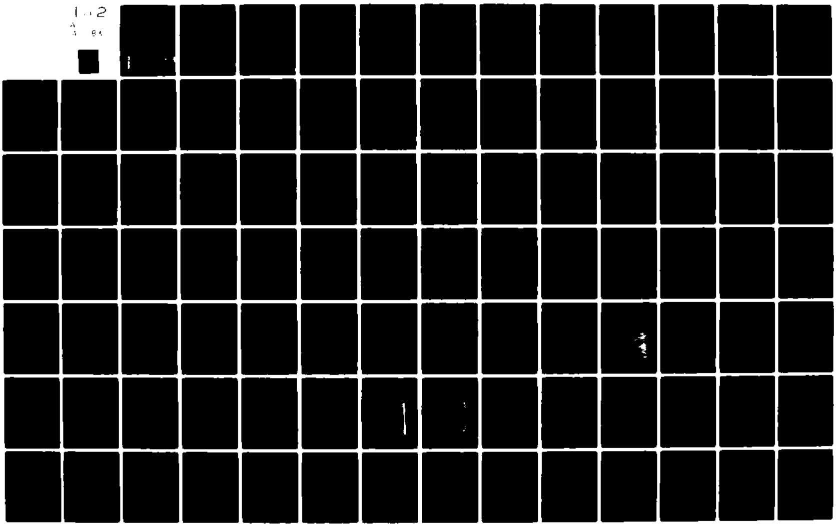
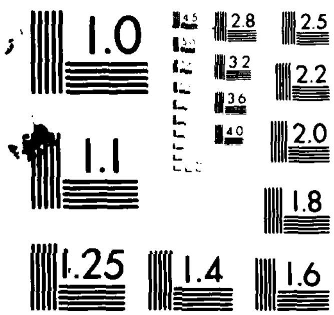
AD-A111 831   BEDFORD RESEARCH ASSOCIATES MA   F/G 20/14
STATISTICAL ANALYSIS OF SCINTILLATION DATA,(U)
SEP 81   S CHUA, J P NOONAN, S BASU   F19628-80-C-0216
UNCLASSIFIED   SCIENTIFIC-1   NL

1 of 2





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

AFGL-TR-81-0333

STATISTICAL ANALYSIS OF SCINTILLATION DATA

Siong-Huat, Chua
Joseph P. Noonan
Santimay Basu

Bedford Research Associates
2 DeAngelo Drive
Bedford, Massachusetts 01730

Scientific Report No. 1

September 1981

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFGL-TR-81-0333	2. GOVT ACCESSION NO. AD-A111831	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) STATISTICAL ANALYSIS OF SCINTILLATION DATA		5. TYPE OF REPORT & PERIOD COVERED Scientific Report No. 1
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Siong-Huat, Chua Joseph P. Noonan Santimay Basu *		8. CONTRACT OR GRANT NUMBER(s) F19628-80-C-0216
9. PERFORMING ORGANIZATION NAME AND ADDRESS Bedford Research Associates 2 DeAngelo Drive Bedford, MA. 01730		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62101F 9993XXXX 46430505
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory Hanscom AFB, MA. 01731 Monitor/A. Cosentino/SUNA		12. REPORT DATE September 1981
		13. NUMBER OF PAGES 136
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

* Emmanuel College
Physics Research Division
400 The Fenway
Boston, MA. 02115

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ionospheric scintillation, L-band, and UHF; Probability distribution, lognormal, Nakagami-m; Goodness-of-fit.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report investigates the goodness-of-fit of the Nakagami-m and lognormal distributions to ionospheric scintillation data at UHF and in the L-band.

DD FORM 1 JAN 73 1473

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

C O N T E N T S

Page No.

1.1 INTRODUCTION

The Nakagami-m distribution has traditionally been used successfully to model the probability characteristics of ionospheric scintillations at UHF. This report investigates the distribution properties of scintillation data in the L-band range. Specifically, the appropriateness of the Nakagmi-m and lognormal distributions is tested.

Briefly the results confirm that the Nakagami-m is appropriate for UHF but not for L-band scintillations. The lognormal provides a better fit to the distribution of L-band scintillations and is an adequate model allowing for an errof of $\pm$ 0.1 or smaller in predicted probability with a sample size of 256.

1.2 REMARKS ON NOTATION

The original data were recorded concurrently at the UHF and L-band channels at 36 observations per second in dB. The quantity whose distribution is under investigation here is the scintillation power, $S = 10^{dB/10}$. Plots of scintillation dB values however are dB values relative to the sample mean, μ_S. That is dB in the plots is defined as

$$dB = 10\log_{10}\left(\frac{S}{\mu_S}\right)$$

The original data at 36 observations/second were divided into segments of 1024 observations each and numbered chronologically. Each such segment is referred to as a <u>block</u> and corresponds to about 28.4 seconds of recorded data. Data are often sampled at reduced rates to obtain independent observations. To obtain a sample of size 1024 at the reduced rate of 6 observations/second would require selecting data from 6 of the original 1024 observation blocks (sampling rate = 36/second). If one begins sampling at block 25, data from blocks 26, 27, 28, 29 and 30 would be used to make up 1024 observations at one-sixth the original sampling rate, (approximately

170 seconds). Such a sample will however simply be denoted "block" 25; that is, in this notation all samples will be denoted by the first block where sampling began, although in each case both the sample size and sampling rate will be explicit.

Two blocks (sample size = 1024) of the original UHF scintillation power sampled at 36 observations per second are shown in Figures 1.1 and 1.2. The corresponding blocks for the L-band channel are plotted in Figures 1.3 and 1.4.

1.3 OUTLINE OF REPORT

Section 2 presents goodness-of-fit test results for the Nakagami-m to UHF scintillations. Section 3 discusses the results of similar tests with the Nakagami-m for scintillations in the L-band while section 4 presents the results of fitting the lognormal to the same data. An overall summary with additional recommendations is found in section 5.

2. GOODNESS OF FIT OF THE NAKAGAMI-M TO UHF SCINTILLATIONS

2.1 INTRODUCTION

The distribution properties of scintillation data at UHF are investigated here for comparison with test results with L-band data. Two goodness-of-fit tests, the Chi-squared and Kolmogorov-Smirnov were performed to test the appropriateness of the Nakagami-m distribution. Results are presented and discussed in sections 2.4 and 2.5 respectively. Section 2.6 presents the method of probability plotting which allows a visual examination of the goodness of fit.

The results confirm that the Nakagami-m models the sample distributions adequately.

2.2 PRE-WHITENING OF DATA

Previous investigators have indicated that sampling at 6 observations per second produces approximately independent samples, and stationarity can be assumed for 3-minute segments (corresponding to 6 "1024-observation" blocks) of the original data.

The power spectra of 2 blocks of the original 36 samples per second data are shown in Figures 2.1 and 2.2. Figures 2.3 and 2.4 show the spectrum of 2 samples (1024 observations per sample) at 6 observations per second. These figures confirm that sampling at 6 per second effectively whitens the data. Figures 2.5-2.8 which show the corresponding autocorrelations also confirm that autocorrelation is effectively removed at 6 observations per second.

A sampling rate of 6 per second and sample sizes of 1024 corresponding to about 3 minutes of the original data were used in the following tests.

2.3 NAKAGAMI-M: ESTIMATION OF PARAMETERS

The probability density function (pfd) of the Nakagami-m is

$$f_s(S) = \frac{m^m}{\Gamma(m)\,\Omega^m}\, S^{m-1} \exp\left(-\frac{mS}{\Omega}\right) \qquad 2.1$$

where

S = Signal power

Ω = Average power

$\Gamma(m)$ = Gamma function of m

The moment estimators of parameters Ω and m are

$$\Omega = E\,[S] = \mu_s$$

$$m = \frac{1}{S_4{}^2}$$

S_4 being the coefficient of variation or scintillation index

$$S_4 = \frac{\sigma_s}{\mu_s}$$

where σ_s and μ_s are the standard deviation and mean respectively. The moment extimators of m and Ω from sample statistics follow directly from these definitions.

The maximum likelihood estimates are

$$\hat{\Omega} = \frac{\Sigma S_i}{n} = \bar{S}$$

and

$$\frac{\Gamma'(m)}{\Gamma(m)} - \log m = \frac{\Sigma \log S_i}{n} - \log \bar{S}$$

where

$$\Gamma'(m) = \frac{d\,\Gamma(m)}{dm}$$

The moment estimators and maximum likelihood estimators are hence the same for Ω but differ for m .

Table 2.1 shows estimates of m from S_4 and using maximum likelihood for the UHF data under consideration. The difference between the two estimates and percentage differences (using the S_4 estimate as base) are also shown. Ignoring the first two blocks (1 and 7) where the scintillation data stream has not begun, it can be seen that 21 out of the 26 samples tested show differences in m estimates of less than 10%. Seventeen of the 26 differ by less than 5%. As will be seen in section 2.5 the results of goodness-of-fit tests using either estimator do not vary considerably either.

For theoretical reasons and because the additional effort in terms of computation time is negligible, the maximum likelihood estimator is recommended.

2.4 CHI-SQUARED TEST

This test compares the sample histogram to the fitted probability density function. In this application 20 histogram bins are defined by the equal probabilities method which avoids to some extent the arbitrariness inherent in defining histogram class intervals (Kendall and Stuart, 1961). The Chi-squared statistic is then computed from the difference between the observed or histogram frequency and the expected frequency which in this case is 0.05 for each of the 20 equi-probable bins. The parameter m is estimated using maximum likelihood.

Results are presented in Table 2.2. Again, the first 2 blocks are to be ignored leaving 26. From the table it can be seen that at the 0.01 significance level, 8 samples out of 26 (30.8%) will give positive (null hypothesis accepted) results. At the 0.005 significance level the breakdown is 10 out of 26 positive. This analysis is presented in Table 2.3. Figures 2.9-2.13 show plots of histogram and fitted Nakagami-m pdf for selected samples.

By themselves these results do not give enough acceptances to indicate that the Nakagami-m is an adequate model for the observed distribution. The Chi-squared test however is affected by the somewhat arbitrary way in which the number and class intervals of histogram bins are defined. These limitations are transcended by the Kolmogorov-Smirnov test presented next.

2.5 KOLMOGOROV-SMIRNOV TEST

This test compares the fit of the experimental to population cumulative distribution functions (cdf). It establishes confidence intervals on the sample or experimental cumulative distribution function (ecdf), $F_n(x) \pm d_\alpha$ so that there is an α chance of some hypothesized distribution $F(x)$ falling outside the confidence bounds, $\pm d_\alpha$, if, under the null hypothesis, $F(x)$ is the underlying population distribution function. That is, if D is the maximum absolute difference between experimental and hypothesized cdf's

$$D = \sup_X \left| F_n(x) - F(x) \right|$$

then there is an α-chance of $D \geq d_\alpha$ if the null hypothesis is true. The value d_α is computed from knowledge of the properties of the sample order statistics and is a distribution independent parameter (Gibbons, 1971). For large samples ($n > 30$), the following values of d_α apply.

Significance level, α	Confidence level $(1-\alpha)$	d_α
0.10	.90	$1.22/\sqrt{n}$
0.05	.95	$1.36/\sqrt{n}$
0.01	.99	$1.63/\sqrt{n}$

The results of the Kolmogorov-Smirnov test with the Nakagami-m as the hypothesized distribution are presented in Table 2.4. Parameter m is again estimated by the method of maximum likelihood. Table 2.5 shows the breakdown of these results by significance level. From the table it can be seen that the percent acceptances are close to the theoretical values. Hence at 0.01 significance there is theoretically a 99% chance of acceptance while the number of acceptances from the test is 1 out of 26 or 96.1%. From these results, it is possible to conclude that the Nakagami-m is an adequate model to at least the 0.05 significance level.

Plots of experimental and hypothesized cdf's and the confidence intervals for selected blocks are shown in Figures 2.14-2.18.

For comparison purposes, the Kolmogorov-Smirnov test was rerun with m estimated now from S_4. The results in Table 2.6 and 2.7 are not significantly different from the earlier results using maximum likelihood estimation. This is to be expected given the large sample size and the fact that the Nakagami-m is an appropriate model for the data.

2.6 PROBABILITY PLOTTING

From Figures 2.14-2.18 it can be seen that the fit between experimental and hypothesized distributions is generally good throughout the range of the observations. Another good visual representation of the fit (or the lack of it) is the method of probability plotting, (Wilk, et al. 1962).

Briefly, the method involves plotting the ordered observations against the corresponding quantiles of the hypothesized distribution.

Suppose $Y_1 \leq Y_2 \leq \ldots Y_n$ represents an ordered random sample of n observations and $b_1, b_2 \ldots b_n$ are fractions of some hypothesized distribution "corresponding" to the order statistics. Then if $\tilde{Y}_i$, $i = 1, 2 \ldots n$ are quantiles of the hypothesized distribution such that

$$F(\tilde{Y}_i) = b_i \quad i = 1, 2 \ldots n$$

and $Y_i \ldots Y_n$ is indeed an ordered sample from the hypothesized distribution the points $(\tilde{Y}_i, Y_i), i = 1, 2 \ldots n$ will tend to fall along a straight line with slope 1 through the origin.

In this case the hypothesized distribution is the Nakagami-m

$$F(\tilde{Y}; m, \Omega) = \int_0^{\tilde{Y}} f(S; m, \Omega)\, dS$$

where the pdf is defined in (2.1).

A "standard" form of the distribution is obtained by the transformation

$$\tilde{X} = \frac{\tilde{Y}}{\Omega}$$

so that the standard cdf is

$$F(\tilde{X}; m, 1) = \int^{\tilde{X}} f(S; m, 1)\, dS$$

Hence if

$$F(\tilde{X}_i; m, 1) = b_i \quad i=1, 2 \ldots n$$

then a plot of $(\tilde{X}_i, Y_i)$, $i = 1, 2 \ldots n$ will tend to fall along a straight line with intercept, Ω. Deviations from the straight line will indicate where the lack of fit occurs.

Note that in this application of probability plotting it is necessary to estimate the parameter m of the hypothesized distribution in order to plot the quantiles $\tilde{X}_i$. As recommended by Wilt, et al. (1962) the fractions b_i are computed from

$$b_i = \frac{i - \frac{1}{2}}{n} \quad i = 1, 2 \ldots n$$

Figures 2.19-2.23 are the probability plots of the "blocks" whose cdf's were plotted in Figures 2.13-2.18. The least squares line has been drawn through each set of points. As can be seen the points do follow closely the least squares line. The small deviations at the lower tail-end are here accentuated by the conversion to dB values. Also as a result of this conversion, the relationship

$$Y = \Omega X$$

is now $10 \log_{10} \frac{Y}{\hat{\Omega}} = 10 \log_{10} \Omega + 10 \log_{10} \frac{X}{\hat{\Omega}}$

or

$$Y_{dB} = 10 \log_{10} \Omega + X_{dB}$$

Although not shown the slope and intercept of the least squares line are respectively close to 1 and $10 \log_{10} \Omega$ respectively, again confirming the good fit to the Nakagami-m.

3. GOODNESS OF FIT OF THE NAKAGAMI-M TO L-BAND SCINTILLATIONS

3.1 PRE-WHITENING

Figures 3.1 and 3.2 are the power spectra of two representative segments of 1024 observations of the original L-band scintillations at 36 observations per second. Figures 3.3 and 3.4 show the 6 observations per second power spectra. Compared to the corresponding 6 per second spectra of the UHF data (Figures 2.3-2.4) which are approximately white the power in the L-band spectra is more concentrated in the lower frequencies, indicating longer time autocorrelations than in the UHF case. Halfing the sampling rate to 3 observations per second, Figure 3.5, does not "whiten" the data sufficiently. At 1.5 observations per second, Figures 3.6 and 3.7, the spectra resembles more closely white noise. The corresponding autocorrelations at 36, 6, 3 and 1.5 observations per second are shown in Figures 3.9-3.11. The progressive removal of autocorrelation in this series of figures is evident although less obvious than in the spectra plots.

In the tests that follow, a sampling rate of 1.5 per second is assumed to yield independent observations.

3.2 STATIONARITY CONSIDERATIONS

To test the assumption of stationarity within 3 minute segments, the Kruskal-Wallis one-way analysis of variance test was implemented.

A brief description of this test follows. Details can be found in Gibbons (1971).

Suppose that there are K samples of size n_i, $i=1, \ldots K$, such that there are N observations in all. That is

$$\sum_{i=1}^{K} n_i = N$$

The null hypothesis, H_o, is that all K samples are drawn from some common population. Hence under H_o, there is a single sample of size N, each observation of which ordered from smallest to largest can be assigned a rank r_j from 1 to N. If the N observations are from a single population, it would be expected that adjacent ranks are well distributed among the K samples. This criterion is tested by noting that the average sum of ranks

$\bar{R}_i = \sum_{j=1}^{n_i} r_j/n_i$ for each sample of size, n_i will have moments

$$E[\bar{R}_i] = \frac{N+1}{2} \quad \text{and var } [\bar{R}_i] = \frac{(N+1)(N-n_i)}{12\, n_i}$$

The Kruskal-Wallis statistic can then be formed

$$H = \sum_{i=1}^{K} \frac{12n_i\,[\bar{R}_i - (N+1)/2]^2}{N\,(N+1)}$$

which is distributed as a Chi-squared variable. The rejection region for H_o is then $H \geq \chi^2_{\alpha,K-1}$ where α is the significance level and K-1 the degrees of freedom.

The Kruskal-Wallis test is applied to test the hypothesis that 256 observations of L-band scintillations at 1.5 observations per second (about 2.8 minutes of data) constitute a sample from a single population. Table 3.1 shows the result of testing this hypothesis by dividing the 256 observations into equi-size samples of 128 observations each. Table 3.2 shows the results of hypothesis testing with the same 256-observation blocks divided into 4 samples each of size 64. For each set of results, 22 out of 26 (ignoring again "blocks" 1 and 7) give positive outcomes at the 0.90 significance level and better. From these results, it can be concluded that 256 observations (at 1.5 samples per second) constitute a stationary (and uncorrelated) sample. Note that no assumptions have been made about the probability distribution of the samples and the Kruskal-Wallis test is in fact independent of distribution assumptions.

3.3 NAKAGAMI-m

3.3.1 CHI-SQUARED TEST

Samples of 256 observations at the sampling rate of 1.5 per second are now tested for goodness-of-fit to the Nakagami-m using the Chi-squared test. Results are in Table 3.3 and the breakdown of these results by the number of acceptances at fixed significance levels are presented in Table 3.4. As with the UHF data m is estimated by the maximum likelihood method and 20 equiprobable bins were defined for the histogram.

The results in Tables 3.2 and Table 3.3 indicate that fits are not as good as was obtained with UHF data. Referring to Tables 3.3 and 2.3, the number accepted at the 0.005 significance level is 8 for L-band and 10 for UHF. At 0.01 it is 4 for L-band versus 8 for UHF. The differences are however not significant and the results by themselves are inconclusive. At issue again are the weaknesses of the Chi-squared test mentioned previously.

Histograms and fitted pdf's are plotted in Figures 3.12-3.16 for selected blocks.

3.4 KOLMOGOROV-SMIRNOV

The test results with the Nakagami-m as the hypothesized distribution are in Table 3.5 and the breakdown of these results by significance levels are in Table 3.6. At the 0.01 significance level, the percentage acceptance is 57.7 (15 out of 26) and at the 0.10 level only 11.5 (3 out of 26). These figures compare poorly with the UHF case - 96.1% acceptance at the 0.01 level, 80.8% at the 0.10 level, and are certainly far from their expected values of 99.0% and 90% respectively.

Plots of the cdf's and confidence bands for selected blocks (25, 55, 85, 109, 145) are shown in Figures 3.17-3.21. The null hypothesis was accepted at the 0.05 and 0.01 significance levels for blocks 25 and 55 respectively and rejected at 0.01 significance for the remaining three blocks. It can be seen from these plots that the maximum deviations between sample and hypothesized cdf's occur very close to dB = 0; this feature is also discernible in Figures 3.17 and 3.18 (blocks 25 and 55) where H_o was accepted. Table 3.5 also shows that the maximum deviations for all "rejected blocks" occur at negative dB values less than 1, (which translates to within 1.25 times the sample mean value below the sample mean). Around these values, the sample cdf also tends to be higher in all blocks tested than that predicted by the fitted Nakagami-m. These features are also evident in the probability plots discussed in the next section.

3.5 PROBABILITY PLOTS

As was done with the UHF data, the ordered observations (y-axis) for each block (sample) are plotted against the corresponding quantiles (x-axis) of a Nakagami-m distribution with maximum likelihood m estimated from the sample and $\Omega = 1$. The points are converted to dB so that the x-y relationship if the sample is Nakagami-m distributed, should be

$$Y_{dB} = 10 \log_{10} \Omega + X_{dB}$$

These probability plots for the blocks 25,55,85,109,145, depicted earlier are shown in Figures 3.22-3.26. The poor fit to the Nakagami for blocks 85, 109 and 145 is evident in the departure from the straight line both at the upper and lower tail ends (somewhat exaggerated because of the conversion to dB) and especially in the "kink" formed by the sample points just below 0 dB (y-axis). This "kink" corresponds to the maximum deviations between sample and hypothesized cdfs noted in the previous section. Even in the samples which yielded better fits (Blocks 25 and 55), this departure from the straight line close to dB = 0 is also discernible.

3.6 CONCLUSION

The results of the Kolmogorov-Smirnov tests bolstered by the evidence from probability plotting leads one to reject the Nakagami-m as an adequate distribution model for the L-band data. For the sake of completeness the results of Kolmogorov-Smirnov test runs with m estimated from S_4 are also presented here (Table 3.7). As is evident there are minor variations from block to block when compared to maximum likelihood results but the overall picture in terms of number of rejections is not significantly different. Table 3.8 compares the estimates of m from S_4 and using maximum likelihood for L-band scintillations. Maximum likelihood consistently gives higher estimates than S_4 and differences are larger (greater than 10% in all cases except 1) than the corresponding UHF results. This result may reflect partly the smaller sample size (256 for L-band versus 1024 for UHF) but are certainly another indication that the Nakagami-m is not an appropriate distribution. (The maximum likelihood method estimates m and Ω conditioned upon the Nakagami-m being the true distribution).

4. GOODNESS OF FIT OF THE LOGNORMAL TO L-BAND SCINTILLATIONS

4.1 INTRODUCTION

Having rejected the Nakagami-m for L-band scintillations the choice of the lognormal was natural given previous experience in the field of scintillation data.

The pdf of the lognormal can be written as:

$$P_s(S) = \frac{1}{(S-\theta)\sqrt{2\pi}\,\sigma} \exp\left[-\frac{1}{2}\frac{\left\{\log(S-\theta) - \zeta\right\}^2}{\sigma^2}\right] \quad (4.1)$$

where

$$\zeta = E[Z] \quad (4.2)$$

$$\sigma = \mathrm{Var}\,[Z] \quad (4.3)$$

Z being the logarithm (base e) of $(S - \theta)$, i.e. $Z = \log(S - \theta)$.
θ is usually assumed to be zero as it is in this application.

The moment estimators of ζ and σ follow directly from the definitions 4.2 and 4.3. Z being normal, the moment estimators are also the maximum likelihood estimators.

The Chi-squared and Kolmogorov-Smirnov tests were rerun with the null hypothesis, H_o now being lognormality of the samples. The results follow in the next 2 sections. A third goodness-of-fit test designed particularly for testing normality has also been run on the data. Details and results are in Section 4.4. Probability plots follow in Section 4.5.

4.2 CHI-SQUARED TEST

The results are shown in Table 4.1 and Table 4.2 gives a breakdown by discrete significance levels. At every level of significance the percentage acceptance of H_o show an improvement over the corresponding results with the Nakagami as the hypothesized distribution (Table 3.4). For example, at 0.01 significance the number of acceptances is 9 out of 26 compared to 4 out of 26 for the Nakagami-m. The percentage of acceptances also compares favorably with the UHF-Nakagami Chi-squared results (see Table 2.3), although the apparent differences here are much less significant. Nevertheless, if Chi-squared test results alone are considered,the lognormal would appear to fit the L-band distribution at least as well as the Nakagami-m modelled scintillation distributions at UHF.

Plots of histogram and fitted pdf's are shown in Figures 4.1-4.5.

4.3 KOLMOGOROV-SMIRNOV TESTS

The test results are in Table 4.3 and the percentage acceptances at discrete significance levels tabulated in Table 4.4. The improvement over the corresponding results with the Nakagami-m (Tables 3.5 and 3.6) is immediately evident. For example there is 92.0% acceptance of lognormality at 0.01 significance compared to 57.7% for the Nakagami-m. These results, though an improvement, are still not entirely satisfactory. At 0.10, 0.05 and 0.01 significance, there is theoretically a 10%, 5% and 1% chance respectively of the hypothesized distribution falling outside the Kolmogorov-Smirnov bands. The percentage rejection at these levels of significance are much higher; respectively they are 42.3, 34.6 and 8.0%. For comparison, the corresponding figures for UHF data with the Nakagami-m as the hypothesized distribution are 19.2, 7.7 and 3.9% rejection. Certainly these figures indicate that the lognormal models the cdf of L-band scintillations less successfully than the Nakagami-m vis-a-vis UHF.

Plots of cdf's and confidence bands for selected blocks are shown in Figures 4.6-4.10. The improvement in fit compared with the Nakagami-m is obvious although deviations between sample and hypothesized distributions are still apparent. Discussion of maximum deviations and where they occur will be taken up when probability plots are considered.

4.4 SKEWNESS-KURTOSIS TEST

This test is designed specifically to test for normality and proves more sensitive in testing for lognormality (normality of the logarithm of the scintillations) than either the Kolmogorov-Smirnov or the Chi-squared.

The skewness and kurtosis are shape parameters defined respectively as:

$$\sqrt{\beta_1} = \frac{\mu_3}{\mu_2^{3/2}}$$

$$\beta_2 = \frac{\mu_4}{\mu_2^{2}}$$

where μ_k is the k^{th} central moment.

β_1 is a measure of symmetry. The normal density distribution being symmetric has $\sqrt{\beta_1} = 0$. β_2 is a measure of curvature (or kurtosis). The normal has a $\beta_2 = 3$.

To test for lognormality then (the null hypothesis) the skewness and kurtosis of the log of the observations are estimated directly from the central moments of the log sample according to the above definitions. For large normally distributed samples of size n, say, the estimate $\sqrt{b_1}$ of $\sqrt{\beta_1}$ is approximately normally distributed with mean 0 and standard deviation $\sqrt{6/n}$. The estimate b_2 of the kurtosis β_2 is also approximately normal with mean 3 and standard deviation $\sqrt{24/n}$. b_1 and b_2 are uncorrelated. The above implies that

$$T = \frac{nb_1}{6} + \frac{n(b_2 - 3)^2}{24}$$

has approximately a chi-squared distribution with two degrees of freedom. The test is based on the statistic T.

The results of hypothesis testing (Table 4.5) gives the percentage acceptances by significance levels in Table 4.6. As is evident the percentage acceptances are significantly less at every significance level compared to Kolmogorov-Smirnov results. In particular, at 0.01 significance, the number of acceptances is about halved.

Also significant is the fact that the skewness and kurtosis of the majority of the samples are less than zero and greater than 3 respectively. This indicates a tendency for the samples (converted to their logs) to have longer lower tails than the normal (skewness = 0) and to be thicker in both tails (and hence more peaked in the middle) than the normal (kurtosis = 3).

Overall, the skewness-kurtosis test indicates a smaller likelihood of lognormality than did the Kolmogorov-Smirnov test.

4.5 PROBABILITY PLOTS

For a visual inspection of where lack of fit occurs probability plots are again useful. As before, the ordered observations, say, $y_i, i=1,\ldots n$ are used to define the corresponding fractions $b_i, i=1\ldots n$ of the standard normal N(0,1) distribution through the relationship

$$b_i = \frac{i - \frac{1}{2}}{n} \qquad i=1,2\ldots n$$

Hence if $x_i, i=1,2,\ldots n$ are standard normal variates such that

$$F(x_i) = b_i$$

and y_i is truly lognormally distributed with parameters ζ and σ, then the relationship

$$\frac{\log_e y_i - \zeta}{\sigma} = x_i \qquad i=1,2\ldots n$$

should hold.

Plots of log y against x should yield straight lines with slopes σ and intercepts ζ. In this application, the observations are plotted in dB hence the x-y relationship in the plots is actually

$$Y_{dB} = 10 \log_{10} y/\hat{\mu} = (10 \log_{10} e)\, \sigma x - (10 \log_{10} e\zeta - 10 \log_{10} \hat{\mu})$$

where $\hat{\mu}$ is the sample mean.

Probability plots for the blocks whose cdf's were shown in Figures 4.6-4.10 are found in Figures 4.11-4.15. The samples under discussion are blocks 25,55,85,109,145. The Kolmogorov-Smirnov test gave H_o accepted at 0.10 significance for blocks 25,55 and 145. H_o was accepted at 0.05 for block 109 and at 0.01 for block 85. The confidence bands shown correspond to the respective significance level of acceptance.

At the 0.10 significance level, both cdf and probability plots for blocks 25,55 and 145 show generally good fits throughout the range of sample values. The experimental points in the probability plot of block 145 (Fig. 4.15) dip slightly below the least squares straight line around dB = 0. This translates into a lognormal cdf value smaller than sample values in that region of the sample (Fig. 4.10). This effect is more pronounced in block 109 (Figures 4.14 and 4.9, H_o accepted at 0.05) and is more prominent still in block 85 (Figures 4.13 and 4.8; H_o accepted at 0.01). Recall that this feature was previously observed as the characteristic "kink" in the probability plots with the Nakagami as the hypothesized distribution. With the lognormal probability plots, this effect is less pronounced and observable in only some of the blocks suggesting that the lognormal is more successful in modelling the distribution of values around the mean. However, values of kurtosis greater than 3 observed earlier for many of the blocks do indicate probability densities of the log sample greater than predictable with the normal.

4.6 DB DEVIATIONS

A further examination of where "lack of fit" occurs is to consider the deviations between theoretical and observed dB values at various percentile levels. Say at the 10th percentile the closest ordered sample value to satisfy the relation

$$\frac{i}{N} = p$$

is $S_i(p)$ while the theoretical value, $\hat{S}(p)$ is the quantile that satisfies the hypothesized cumulative distribution.

$$\int_0^{\hat{s}} P_s\ (s)\ dS = p$$

where N is the sample size, $P_s(s)$ is the hypothesized distribution density function. Converting these values to their respective dB (relative to the mean) values, the dB deviation is computed as

$$\hat{S}_{dB}(p) - S_{dB}(p) = \Delta_{dB}\ (p)$$

Tables 4.7 - 4.10 present these dB deviations at the 1st, 5th, 10th and 50th percentiles respectively for the fitting of both the lognormal and the Nakagami-m to UHF and L-band channel scintillations. An examination of the figures in these tables confirm the earlier results that show that the lognormal fits sample distributions much better than the Nakagami-m in the case of L-band scintillations while the reverse is true for UHF data. Additionally these results hold true over the four percentile levels investigated.

4.7 INFLUENCE OF S_4

The value of the scintillation index, S_4, has been included in all preceding tables. It can be noted that the UHF samples correspond to high S_4 values ($S_4 > 0.6$); in fact all UHF S_4 values are greater than 0.8. L-band S_4 values on the other hand fall below 0.8 for many samples and for the "block" 67 and for "blocks" 85 to 121, they are less than 0.6.

S_4 is a measure of variation about the mean value, being the ratio of the standard deviation to the mean. It may be thought that S_4 would have some effect on sample distribution properties. In particular UHF samples, all with high S_4 values are modelled well by the Nakagami-m while the greater variation in S_4 for L-band samples may have some bearing on the less satisfactory performance of the Nakagami-m.

An examination of the results however indicates that no direct link exists between the value of S_4 and the tendency of L-band sample distribution to follow either a Nakagami or lognormal model. For example, referring to the Kolmogorov-Smirnov results for goodness-of-fit to the Nakagami-m (Table 3.5), "blocks" 85-121, corresponding to low S_4 show 4 rejections out of seven at the 0.01 significance level; "blocks" 25-61, on the other hand all with S_4 above 0.7 show 2 out of 7 rejections, not a significantly dramatic improvement. The corresponding results with the lognormal (Table 4.3) indicate no rejections for both sets of samples at the 0.01 level, while at 0.05 significance there are 3 (out of 7) rejections for the low S_4 samples ("blocks: 85-121), and again all acceptances for the high S_4 samples ("blocks" 35-61).

The overall picture for L-band samples appears to be that distributions with low S_4 values tend to be more poorly modelled than those with high S_4 by both the Nakagami-m and the lognormal. It remains true nevertheless that independent of the value of S_4, L-band samples conform more closely to the lognormal than to the Nakagami-m.

4.8 CONCLUSIONS

It is evident from the foregoing results that the lognormal fits L-band distributions better than the Nakagami-m. This is in sharp contrast to the case of UHF scintillations whose frequency distributions are adequately modelled by the Nakagami (section 2) but not the lognormal (see Appendix).

In the L-band range however, Kolmogorov-Smirnov test outcomes of 92% acceptances at 0.01 significance level indicate that the lognormal is adequate within an error allowance of approximately $\pm$ 0.1 in predicted probability with a sample size of 256. The lognormal fails more often than would be expected of an "Adequate" model when greater accuracy than $\pm$ 0.1 (with 256 observations) is sought. This is reflected in the Kolmogorov-Smirnov outcomes (65.4% acceptance for an error interval of 0.085) and also indicated by the result of the skewness-kurtosis test which is more sensitive to the characteristics of normal probability density (of the log observations). Probability and cdf plots indicate that poor fit occurs generally close to and less than 2 dB values (dB relative to the mean) below the sample mean.

5. SUMMARY AND RECOMMENDATIONS

UHF Scintillations: Observations at 6 samples per second give independent samples. 3 minute segments of data can be considered stationary. The Nakagami-m is an adequate model for scintillation distributions at 0.05 significance. With a sample size of 1024, the maximum likelihood method for parameter estimation and estimation by the method of moments (S_4) give results which do not differ significantly.

L-Band Scintillations: The recommended sampling rate for independent observations is 1.5 per second. Stationarity within 3 minute segments is confirmed by the Kruskal-Wallis test.

Table 4.11 summarizes the average dB deviations at all 4 percentile levels for all the various distribution-data channel combinations. Average dB deviations were computed in the following manner. DB deviation expressed in terms of scintillation power is

$$\Delta_{dB}(p) = 10 \log_{10} \frac{\hat{S}(p)}{\mu} - 10 \log_{10} \frac{S(p)}{\mu}$$

$$= 10 \log_{10} \frac{\hat{S}(p)}{S(p)}$$

Average dB deviation is computed by first finding the arithmetic average of the ratio $\frac{\hat{S}}{S}$ for all the blocks (except 1 and 7) and then taking logarithmic values. Hence, average dB is expressed as

$$\bar{\Delta}_{dB}(p) = 10 \log_{10} \frac{\sum_{k}^{n} \left(\frac{\hat{S}(p)}{S(p)}\right)_k}{n}$$

where n is the number of blocks over which averaging was performed.

As before, the average dB values confirm that the lognormal is more appropriate than the Nakagami-m for L-band data (and the reverse for UHF) at all percentile levels. Also, in terms of dB deviations it is noted that at the 1st and 5th percentiles, the Nakagami seems to fit UHF sample distributions better than the case of the lognormal with L-band data, while the reverse becomes true at the 10th and 50th percentiles. These observations however must take into account the fact that L-band samples were smaller (256 observations) than UHF samples (1024 observations). Consequently, more uncertainty is associated with the L-band probabilities, or expressed another way, confidence bounds on L-band probabilities will tend to be larger.

Nevertheless, it is noteworthy that in both the L-band/lognormal and UHF/Nakagami cases, average deviations at the 50th percentile are very small indicating good fits at the median.

The lognormal performs better than the Nakagami-m in modelling the probability distribution of the data. The lognormal is an adequate model at 0.01 significance with less than $\pm$ 0.1 error in predicted probability with sample sizes of 256. The lognormal fails to achieve the desired accuracy at higher significance levels. Poor fits at these levels occur close to and less than the sample mean, with the lognormal predicting lower probabilities than the sample frequencies.

Other recommendations: It is clear from this work that the Chi-squared test is less than adequate for goodness-of-fit tests with scintillation data. Not only is there inherent arbitrariness in the way the number and values of histogram class intervals are defined, Chi-squared test results do not provide adequate information regarding where lack of fit occurs. The Kolmogorov-Smirnov test which defines confidence interval criteria is recommended instead. Together with cdf and/or probability plots it can provide good indications of where and how badly poor fits occur both statistically (with reference to confidence intervals) and visually.

REFERENCES

1) Kendall, M.G. and Stuart, A., (1961) - The Advanced Theory of Statistics, Volume 2, Hafner Publishing Co.

2) Gibbons, J.D. (1971) Nonparametric Statistical Inference - McGraw Hill Book Company, New York

3) Wilt, W.B., Granadesikan, R. and Huyett, M.J., (1962) - "Probability Plots for the Gamma Distribution", Technometrics, Volume 4 (1), pp 1-15.

APPENDIX - Goodness of Fit of the Lognormal to UHF Scintillations

For the sake of completeness, two goodness-of-fit tests were run to check the appropriateness of the lognormal for modelling the distribution of UHF scintillations. These are the familiar Chi-squared test and the skewness-kurtosis test described in 4.4. In both cases the null hypothesis H_o is that the lognormal is an appropriate distribution model for the samples. As is evident from Tables A.1 and A.2, the results of both tests show negligible chance of accepting H_o for all blocks tested. (As before, blocks 1 and 7 containing invalid data are to be discounted).

Figures A.1 - A.4 showing cdf and probability plots for 2 representative blocks indicate quite clearly the considerable deviation between sample and hypothesized distributions.

These results leave little doubt that the lognormal is inappropriate for UHF distributions.

LIST OF TABLES

Problem 3044

* * *

LIST OF FIGURES

COMPARISON OF S4 AND MAX. LIKELIHOOD ESTIMATES FOR UHF DATA

SAMPLING RATE IS: 4.0 PER SEC.

SAMPLE SIZE IS: 1024

BLOCK	MEAN	STD. DEV.	S/4	m S/4	m M/L	m M/L - m S/4	DIFF. %
1	0.107999	0.009399	0.087028	132.055511	6.999985	**********	24.699
7	0.110310	0.046652	0.422916	5.571033	3.332536	-2.258497	40.395
13	0.068476	0.063273	0.924020	1.171210	1.274330	0.103113	8.804
19	0.074434	0.066081	0.887770	1.268818	1.444252	0.175435	13.827
25	0.096081	0.077096	0.802413	1.553113	1.589464	0.036351	2.341
31	0.078129	0.071830	0.919240	1.183432	1.407949	0.224517	18.972
37	0.068850	0.062877	0.913533	1.198255	1.293595	0.095339	7.957
43	0.063619	0.055181	0.867361	1.329234	1.471001	0.141766	10.665
49	0.065696	0.057954	0.882163	1.285001	1.342045	0.057045	4.439
55	0.082718	0.071051	0.858948	1.355392	1.316828	0.038564	2.845
61	0.070402	0.063155	0.897040	1.242676	1.274330	0.031654	2.547
67	0.071379	0.062596	0.876955	1.300305	1.261893	-0.038412	-2.954
73	0.061439	0.055442	0.902400	1.228013	1.259643	0.031630	2.576
79	0.072942	0.067127	0.920279	1.180760	1.238317	0.057557	4.875
85	0.066105	0.063827	0.965538	1.072657	1.111385	0.038728	3.610
91	0.080135	0.074901	0.934697	1.144615	1.102582	0.042032	3.672
97	0.075243	0.070775	0.953086	1.100869	1.229216	0.128347	11.659
103	0.076166	0.069692	0.914999	1.194423	1.210575	0.016152	1.352
109	0.085102	0.075200	0.883647	1.280682	1.247128	-0.033554	-2.620
115	0.086631	0.082307	0.950110	1.107776	1.100565	-0.007211	-0.651
121	0.084096	0.082375	0.979766	1.041729	1.129157	0.087428	8.393
127	0.067584	0.060710	0.898291	1.239271	1.227309	-0.011962	0.965
133	0.058709	0.054888	0.934921	1.144065	1.177077	0.033012	2.885
139	0.059216	0.052998	0.894984	1.248444	1.264838	0.016394	1.313
145	0.075019	0.068714	0.915952	1.191941	1.235551	0.043610	3.659
151	0.081745	0.079921	0.777688	1.046166	1.332843	0.286677	27.403
157	0.067130	0.059817	0.891062	1.259462	1.304487	0.045025	3.575
163	0.089076	0.079214	0.889287	1.264488	1.368981	0.104493	8.264

TABLE 2.1

CHI SQUARED TEST FOR UHF DATA

NULL HYPOTHESIS, Ho: SAMPLE IS DISTRIBUTED AS NAKAGAMI-m

SAMPLING RATE IS: 6.0 PER SEC

SAMPLE SIZE IS : 1024

NO. OF CELLS = 20 DEGREES OF FREEDOM OF CHI SQUARED STATISTIC = 17

BLOCK	S4	OMEGA	MAX.LIK. m	CHI2 STAT.	PROB Ho TRUE
1	0.08703	0.109E+00	0.700E+01	0.219E+04	0.000E+00
7	0.42292	0.110E+00	0.333E+01	0.129E+04	0.000E+00
13	0.92402	0.685E-01	0.127E+01	0.374E+02	0.300E-02
19	0.88777	0.744E-01	0.144E+01	0.432E+02	0.351E-03
25	0.80241	0.961E-01	0.159E+01	0.430E+02	0.475E-03
31	0.91924	0.781E-01	0.141E+01	0.353E+02	0.569E-02
37	0.91353	0.688E-01	0.129E+01	0.316E+02	0.167E-01
43	0.86736	0.636E-01	0.147E+01	0.375E+02	0.289E-02
49	0.88216	0.657E-01	0.134E+01	0.406E+02	0.106E-02
55	0.85895	0.827E-01	0.132E+01	0.365E+02	0.387E-02
61	0.89706	0.704E-01	0.127E+01	0.649E+02	0.179E-06
67	0.87696	0.714E-01	0.126E+01	0.327E+02	0.124E-01
73	0.90240	0.614E-01	0.126E+01	0.306E+02	0.223E-01
79	0.92028	0.729E-01	0.124E+01	0.621E+02	0.477E-06
85	0.96554	0.661E-01	0.111E+01	0.247E+02	0.101E+00
91	0.93470	0.801E-01	0.110E+01	0.298E+02	0.282E-01
97	0.95309	0.952E-01	0.123E+01	0.404E+02	0.113E-02
103	0.91500	0.769E-01	0.121E+01	0.220E+02	0.184E+00
109	0.88365	0.851E-01	0.125E+01	0.476E+02	0.988E-04
115	0.95011	0.866E-01	0.110E+01	0.235E+02	0.135E+00
121	0.97977	0.841E-01	0.117E+01	0.402E+02	0.121E-02
127	0.92829	0.676E-01	0.123E+01	0.433E+02	0.439E-03
133	0.93499	0.587E-01	0.118E+01	0.210E+02	0.228E+00
139	0.89498	0.599E-01	0.126E+01	0.369E+02	0.343E-02
145	0.91595	0.750E-01	0.124E+01	0.337E+02	0.908E-02
151	0.97769	0.817E-01	0.133E+01	0.520E+02	0.204E-04
157	0.89106	0.671E-01	0.130E+01	0.414E+02	0.831E-03
163	0.88929	0.871E-01	0.133E+01	0.415E+02	0.800E-03

TABLE 2.2

TABLE 2.3

CHI-SQUARE TEST: NAKAGAMI FIT TO UHF

PERCENT ACCEPTANCE BY SIGNIFICANCE LEVEL

Significance Level	No. Accepted	No. Rejected	Total	Percent Acceptance
0.005	10	16	26	38.5
0.01	8	18	26	31.8
0.05	4	22	26	15.4
0.10	4	22	26	15.4

KOLMOGOROV SMIRNOV TEST FOR [illegible] DATA

SAMPLING RATE IS: 6.0 PER SEC

SAMPLE SIZE IS: 1024

NULL HYPOTHESIS, Ho: SAMPLE IS DISTRIBUTED AS NAKAGAMI M

BLOCK	SA	OMEGA	M/L m	MAX. DEV.	Q X VALUE	Q DF VALUE	K S STAT.	SIG. LEV.	**Ho**
1	0.087	0.108E+00	0.700E+01	0.351E+00	0.930E-01	0.647E+00	0.509E-01	0.100E-01	REJECT
7	0.423	0.110E+00	0.333E+01	0.243E+00	0.108E+00	0.961E-01	0.509E-01	0.100E-01	REJECT
13	0.924	0.685E-01	0.127E+01	0.339E-01	0.677E-01	0.494E-01	0.381E-01	0.100E+00	ACCEPT
19	0.888	0.744E-01	0.144E+01	0.474E-01	0.791E-01	0.266E+00	0.509E-01	0.100E-01	ACCEPT
25	0.802	0.961E-01	0.159E+01	0.249E-01	0.395E-01	0.386E+01	0.381E-01	0.100E+00	ACCEPT
31	0.919	0.781E-01	0.141E+01	0.329E-01	0.795E-01	0.739E-01	0.381E-01	0.100E+00	ACCEPT
37	0.914	0.688E-01	0.129E+01	0.170E-01	0.825E-01	0.785E+00	0.381E-01	0.100E+00	ACCEPT
43	0.847	0.636E-01	0.147E+01	0.380E-01	0.311E-01	-0.311E+01	0.381E-01	0.100E+00	ACCEPT
49	0.882	0.657E-01	0.134E+01	0.308E-01	0.314E-01	0.321E+01	0.381E-01	0.100E+00	ACCEPT
55	0.859	0.827E-01	0.132E+01	0.322E-01	0.352E-01	0.371E+01	0.381E-01	0.100E+00	ACCEPT
61	0.897	0.704E-01	0.127E+01	0.366E-01	0.769E-01	0.385E+00	0.381E-01	0.100E+00	ACCEPT
67	0.877	0.714E-01	0.126E+01	0.221E-01	0.298E-01	0.329E+01	0.381E-01	0.100E+00	ACCEPT
73	0.902	0.614E-01	0.126E+01	0.249E-01	0.308E-01	0.300E+01	0.381E-01	0.100E+00	ACCEPT
79	0.920	0.729E-01	0.124E+01	0.396E-01	0.325E-01	-0.352E+01	0.425E-01	0.500E-01	ACCEPT
85	0.966	0.661E-01	0.111E+01	0.242E-01	0.297E-01	0.348E+01	0.381E-01	0.100E+00	ACCEPT
91	0.935	0.801E-01	0.110E+01	0.220E-01	0.482E-01	0.221E+01	0.381E-01	0.100E+00	ACCEPT
97	0.953	0.952E-01	0.123E+01	0.281E-01	0.793E-01	0.795E+00	0.381E-01	0.100E+00	ACCEPT
103	0.915	0.762E-01	0.121E+01	0.223E-01	0.307E-01	0.395E+01	0.381E-01	0.100E+00	ACCEPT
109	0.884	0.851E-01	0.125E+01	0.399E-01	0.420E-01	0.240E+01	0.425E-01	0.500E-01	ACCEPT
115	0.950	0.866E-01	0.110E+01	0.181E-01	0.279E-01	-0.493E+01	0.381E-01	0.100E+00	ACCEPT
121	0.980	0.841E-01	0.113E+01	0.492E-01	0.776E-01	0.352E+00	0.425E-01	0.500E-01	ACCEPT
127	0.898	0.676E-01	0.123E+01	0.319E-01	0.326E-01	-0.316E+01	0.381E-01	0.100E+00	ACCEPT
133	0.935	0.587E-01	0.118E+01	0.308E-01	0.259E-01	0.355E+01	0.381E-01	0.100E+00	ACCEPT
139	0.895	0.592E-01	0.126E+01	0.228E-01	0.760E-01	0.108E+01	0.381E-01	0.100E+00	ACCEPT
145	0.916	0.750E-01	0.124E+01	0.363E-01	0.768E-01	0.100E+00	0.381E-01	0.100E+00	ACCEPT
151	0.978	0.817E-01	0.133E+01	0.557E-01	0.811E-01	-0.356E-01	0.509E-01	0.100E-01	REJECT
157	0.821	0.671E-01	0.130E+01	0.334E-01	0.341E-01	0.294E+01	0.381E-01	0.100E+00	ACCEPT
163	0.889	0.891E-01	0.137E+01	0.276E-01	0.827E-01	-0.322E+00	0.381E-01	0.100E+00	ACCEPT

TABLE 2.4

TABLE 2.5

KOLMOGOROV SMIRNOV TEST: NAKAGAMI-M FIT TO

UHF: PERCENT ACCEPTANCE BY SIGNIFICANCE LEVEL

($\hat{M}$ FROM MAXIMUM LIKELIHOOD)

Significance Level	No. Accepted	No. Rejected	Total	Percent Acceptance
0.01	25	1	26	96.1
0.05	24	2	26	92.3
0.10	21	5	26	80.8

KOLMOGOROV SMIRNOV TEST FOR UHF DATA

SAMPLING RATE IS: 6.0 PER SEC

SAMPLE SIZE IS: 1024

NULL HYPOTHESIS, H0: SAMPLE IS DISTRIBUTED AS NAKAGAMI M

BLOCK	S4	OMEGA	m S/4	MAX. DEV.	@ X VALUE	@ DB VALUE	K S STAT.	SIG. LEV.	**DEC
1	0.997	0.108E+00	0.200E+02	0.239E+00	0.977E-01	0.435E+00	0.509E-01	0.100E-01	REJECT
7	0.423	0.110E+00	0.559E+01	0.222E+00	0.109E+00	0.441E-01	0.509E-01	0.100E-01	REJECT
13	0.924	0.685E-01	0.117E+01	0.320E-01	0.203E-01	0.528E+01	0.381E-01	0.100E+00	ACCEPT
19	0.888	0.744E-01	0.122E+01	0.421E-01	0.727E-01	0.226E+00	0.425E-01	0.500E-01	ACCEPT
25	0.802	0.961E-01	0.155E+01	0.222E-01	0.195E+00	0.306E+01	0.381E-01	0.100E+00	ACCEPT
31	0.919	0.781E-01	0.118E+01	0.429E-01	0.126E-01	0.[illegible]E+01	0.509E-01	0.100E-01	ACCEPT
37	0.914	0.688E-01	0.120E+01	0.307E-01	0.204E-01	0.529E+01	0.381E-01	0.100E+00	ACCEPT
43	0.867	0.636E-01	0.133E+01	0.340E-01	0.198E-01	0.507E+01	0.381E-01	0.100E+00	ACCEPT
49	0.882	0.657E-01	0.129E+01	0.225E-01	0.314E-01	0.321E+01	0.381E-01	0.100E+00	ACCEPT
55	0.857	0.827E-01	0.136E+01	0.380E-01	0.352E-01	0.371E+01	0.381E-01	0.100E+00	ACCEPT
61	0.897	0.704E-01	0.124E+01	0.357E-01	0.769E-01	0.385E+00	0.381E-01	0.100E+00	ACCEPT
67	0.877	0.714E-01	0.130E+01	0.281E-01	0.298E-01	0.372E+01	0.381E-01	0.100E+00	ACCEPT
73	0.902	0.614E-01	0.123E+01	0.225E-01	0.204E-01	0.478E+01	0.381E-01	0.100E+00	ACCEPT
79	0.920	0.729E-01	0.118E+01	0.302E-01	0.325E-01	0.352E+01	0.381E-01	0.100E+00	ACCEPT
85	0.966	0.661E-01	0.107E+01	0.232E-01	0.952E-01	0.158E+01	0.381E-01	0.100E+00	ACCEPT
91	0.935	0.801E-01	0.114E+01	0.245E-01	0.963E-02	0.920E+01	0.381E-01	0.100E+00	ACCEPT
97	0.953	0.952E-01	0.110E+01	0.404E-01	0.204E-01	0.670E+01	0.425E-01	0.500E-01	ACCEPT
103	0.915	0.762E-01	0.119E+01	0.196E-01	0.307E-01	0.395E+01	0.381E-01	0.100E+00	ACCEPT
109	0.884	0.851E-01	0.128E+01	0.354E-01	0.470E-01	0.240E+01	0.381E-01	0.100E+00	ACCEPT
115	0.950	0.866E-01	0.111E+01	0.195E-01	0.279E-01	0.473E+01	0.381E-01	0.100E+00	ACCEPT
121	0.980	0.841E-01	0.104E+01	0.338E-01	0.776E-01	0.352E+00	0.381E-01	0.100E+00	ACCEPT
127	0.898	0.476E-01	0.124E+01	0.337E-01	0.326E-01	0.316E+01	0.381E-01	0.100E+00	ACCEPT
133	0.935	0.587E-01	0.114E+01	0.251E-01	0.252E-01	0.355E+01	0.381E-01	0.100E+00	ACCEPT
139	0.895	0.572E-01	0.125E+01	0.228E-01	0.760E-01	0.108E+01	0.381E-01	0.100E+00	ACCEPT
145	0.916	0.750E-01	0.119E+01	0.343E-01	0.768E-01	0.100E+00	0.381E-01	0.100E+00	ACCEPT
151	0.978	0.817E-01	0.105E+01	0.449E-01	0.193E-01	0.427E+01	0.509E-01	0.100E-01	REJECT
157	0.891	0.671E-01	0.126E+01	0.269E-01	0.341E-01	0.294E+01	0.381E-01	0.100E+00	ACCEPT
163	0.887	0.821E-01	0.126E+01	0.239E-01	0.243E-01	0.564E+01	0.381E-01	0.100E+00	ACCEPT

TABLE 2.6

TABLE 2.7

KOLMOGOROV-SMIRNOV TEST: NAKAGAMI-M FIT TO UHF: PERCENT ACCEPTANCE BY SIGNIFICANCE LEVEL ($\hat{M}$ FROM S4)

Significance Level	No. Accepted	No. Rejected	Total	Percent Acceptance
0.01	25	1	26	96.1(5)
0.05	24	2	26	92.3
0.10	22	4	26	84.6

KRUSKAL WALLIS ANALYSIS OF VARIANCE TEST FOR L BAND DATA

NULL HYPOTHESIS Ho: ALL SAMPLES DRAWN FROM THE SAME POPULATION

TOTAL OBSERVATIONS = 256

OBSERVATIONS PER SAMPLE = 128

TOTAL SAMPLES IN ALL = 2

BLOCK	K/W STAT.	DEG. FREE.	PROB Ho TRUE	R_1*	R_2*
1	0.314E+01	1.	0.755E-01	17501.00	15395.00
7	0.345E-01	1.	0.853E+00	16550.00	16338.00
13	0.000E+00	1.	0.100E+01	16451.50	16444.50
19	0.432E+01	1.	0.377E-01	15217.00	17679.00
25	0.209E+00	1.	0.647E+00	16177.00	16719.00
31	0.467E-01	1.	0.829E+00	16576.00	16320.00
37	0.981E+01	1.	0.174E-02	14593.00	18303.00
43	0.299E-02	1.	0.956E+00	16480.50	16415.50
49	0.105E+00	1.	0.746E+00	16256.00	16640.00
55	0.507E-02	1.	0.943E+00	16405.50	16490.50
61	0.279E+00	1.	0.597E+00	16135.00	16761.00
67	0.338E+01	1.	0.661E-01	17536.50	15359.50
73	0.841E+01	1.	0.374E-02	18165.50	14730.50
79	0.380E-01	1.	0.845E+00	16563.50	16332.50
85	0.873E+00	1.	0.350E+00	15894.50	17001.50
91	0.265E+01	1.	0.103E+00	17413.00	15483.00
97	0.129E-01	1.	0.909E+00	16515.50	16380.50
103	0.525E-02	1.	0.942E+00	16405.00	16491.00
109	0.277E+00	1.	0.598E+00	16760.00	16136.00
115	0.149E+00	1.	0.699E+00	16219.00	16677.00
121	0.776E-01	1.	0.781E+00	16613.00	16283.00
127	0.448E+00	1.	0.503E+00	16844.50	16051.50
133	0.110E+01	1.	0.293E+00	17070.50	15825.50
139	0.641E-01	1.	0.800E+00	16598.00	16298.00
145	0.123E+01	1.	0.267E+00	17105.00	15791.00
151	0.230E+00	1.	0.632E+00	16164.00	16732.00
157	0.421E+00	1.	0.516E+00	16063.50	16832.50
163	0.732E-03	1.	0.978E+00	16432.00	16464.00

*Ri = SUM OF RANKS FOR INDIVIDUAL SAMPLE

TABLE 3.1

KRUSKAL WALLIS ANALYSIS OF VARIANCE TEST FOR I BAND DATA

NULL HYPOTHESIS Ho: ALL SAMPLES DRAWN FROM THE SAME POPULATION

TOTAL OBSERVATIONS = 256

OBSERVATIONS PER SAMPLE = 64

TOTAL SAMPLES IN ALL = 4

BLOCK	K/W STAT.	DEG. FREE.	PROB Ho TRUE	R_1*	R_2*	R_3*	R_4*
1	0.405E+01	3.	0.257E+00	8359.00	9142.00	7742.50	7652.50
7	0.104E+02	3.	0.154E-01	7233.50	9324.50	9018.00	7320.00
13	0.170E+01	3.	0.636E+00	8345.50	8106.00	7689.00	8755.50
19	0.609E+01	3.	0.107E+00	7283.50	7933.50	8386.00	9293.00
25	0.694E+01	3.	0.737E-01	7209.50	8967.50	8999.00	7720.00
31	0.413E+01	3.	0.248E+00	7577.50	8998.50	7700.00	8620.00
37	0.179E+02	3.	0.460E-03	6116.00	8477.00	9317.00	8986.00
43	0.276E-01	3.	0.999E+00	8224.50	8256.00	8271.50	8144.00
49	0.657E+00	3.	0.883E+00	8432.00	7824.00	8254.00	8386.00
55	0.396E+00	3.	0.941E+00	8264.00	8141.50	8500.00	7990.50
61	0.464E+00	3.	0.927E+00	8042.00	8093.00	8558.50	8202.50
67	0.123E+02	3.	0.653E-02	8627.50	8909.00	8920.50	6439.00
73	0.917E+01	3.	0.271E-01	8761.50	9404.00	7541.00	7189.50
79	0.118E+01	3.	0.759E+00	8225.50	8338.00	8609.50	7723.00
85	0.136E+01	3.	0.714E+00	7654.50	8240.00	8517.00	8484.50
91	0.114E+02	3.	0.997E-02	9203.50	8209.50	8874.00	6609.00
97	0.250E-01	3.	0.999E+00	8272.50	8243.00	8293.50	8087.00
103	0.116E+01	3.	0.763E+00	7836.50	8560.50	7984.00	8507.00
109	0.174E+01	3.	0.628E+00	8308.00	8452.00	7566.50	8569.50
115	0.118E+01	3.	0.757E+00	7950.00	8267.00	7944.00	8733.00
121	0.194E+00	3.	0.979E+00	8165.50	8447.50	8163.00	8120.00
127	0.189E+01	3.	0.596E+00	8635.50	8289.00	7571.00	8400.50
133	0.195E+01	3.	0.582E+00	8797.50	8273.00	8196.00	7629.50
139	0.104E+01	3.	0.791E+00	8260.50	8337.50	8561.50	7736.50
145	0.407E+01	3.	0.254E+00	8111.00	8994.00	7345.50	8445.50
151	0.165E+01	3.	0.648E+00	7626.50	8537.50	8162.50	8569.50
157	0.316E+01	3.	0.368E+00	7509.00	8554.50	7961.00	8871.50
163	0.159E+01	3.	0.661E+00	8732.00	7750.00	8482.00	7932.00

Ri = SUM OF RANKS FOR INDIVIDUAL SAMPLE

TABLE 3.2

CHI SQUARED TEST FOR L BAND DATA

NULL HYPOTHESIS, Ho: SAMPLE IS DISTRIBUTED AS NAKAGAMI m

SAMPLING RATE IS: 1.5 PER SEC

SAMPLE SIZE IS : 254

NO. OF CELLS = 20   DEGREES OF FREEDOM OF CHI SQUARED STATISTIC = 17

BLOCK	S4	OMEGA	MAX LIK m	CHI SQ STAT.	PROB Ho TRUE
1	0.06008	0.208E 01	0.700E+01	0.834E+03	0.000E+00
7	0.31331	0.145E 01	0.700E+01	0.301E+03	0.000E+00
13	0.81677	0.155E 01	0.174E+01	0.429E+02	0.413E-04
19	1.14511	0.207E 01	0.126E+01	0.412E+02	0.878E-03
25	0.92625	0.361E 01	0.150E+01	0.309E+02	0.207E-01
31	0.99267	0.223E 01	0.141E+01	0.346E+02	0.697E-02
37	0.86715	0.307E 01	0.182E+01	0.381E+02	0.241E-02
43	0.90917	0.345E 01	0.171E+01	0.354E+02	0.550E-02
49	0.95471	0.351E 01	0.150E+01	0.581E+02	0.221E-05
55	0.99238	0.357E 01	0.127E+01	0.507E+02	0.327E-04
61	0.85751	0.342E 01	0.173E+01	0.390E+02	0.179E-02
67	0.52530	0.321E 01	0.418E+01	0.610E+02	0.715E-06
73	0.77495	0.207E 01	0.212E+01	0.249E+02	0.961E-01
79	0.66980	0.214E 01	0.270E+01	0.513E+02	0.260E-04
85	0.57784	0.343E 01	0.346E+01	0.595E+02	0.131E-05
91	0.52346	0.325E 01	0.442E+01	0.645E+02	0.179E-06
97	0.40314	0.326E 01	0.700E+01	0.404E+02	0.113E-02
103	0.43193	0.337E 01	0.525E+01	0.346E+02	0.697E-02
109	0.49722	0.347E 01	0.505E+01	0.434E+02	0.423E-03
115	0.41110	0.337E 01	0.652E+01	0.304E+02	0.218E-02
121	0.40268	0.344E 01	0.515E+01	0.351E+02	0.605E-02
127	0.70371	0.356E 01	0.287E+01	0.592E+02	0.143E-05
133	0.81079	0.363E 01	0.204E+01	0.579E+02	0.232E-05
139	0.76696	0.351E 01	0.231E+01	0.242E+02	0.115E+00
145	0.77540	0.350E 01	0.236E+01	0.465E+02	0.145E-03
151	1.04115	0.387E 01	0.131E+01	0.540E+02	0.745E-05
157	0.77452	0.370E 01	0.205E+01	0.410E+02	0.714E-03
163	0.90569	0.374E 01	0.154E+01	0.320E+02	0.159E-01

TABLE 3.3

TABLE 3.4

CHI-SQUARE TEST: NAKAGAMI-M FIT TO L-BAND: PERCENT ACCEPTANCE BY SIGNIFICANCE LEVEL

Significance Level	No Accepted	No. Rejected	Total	Percent Acceptance
0.005	8	18	26	30.8
0.01	4	22	26	15.4
0.05	2	24	26	7.69
0.10	1	25	26	3.85

KOLMOGOROV SMIRNOV TEST FOR L BAND DATA

SAMPLING RATE IS: 1.5 PER SEC

SAMPLE SIZE IS: 256

NULL HYPOTHESIS, Ho: SAMPLE IS DISTRIBUTED AS NAKAGAMI M

BLOCK	S4	OMEGA	M/I m	MAX. DEV.	@ X VALUE	@ DB VALUE	K S STAT.	SIG. LEV.	**Ho**
1	0.060	0.208E 01	0.700E+01	0.409E+00	0.187E 01	-0.466E+00	0.102E+00	0.100E 01	REJECT
7	0.313	0.145E 01	0.700E+01	0.204E+00	0.161E-01	0.441E+00	0.102E+00	0.100E 01	REJECT
13	0.817	0.155E 01	0.176E+01	0.657E 01	0.695E 02	0.342E+01	0.763E 01	0.100E+00	ACCEPT
19	1.145	0.207E 01	0.126E+01	0.916E 01	0.273E-01	0.121E+01	0.102E+00	0.100E 01	ACCEPT
25	0.926	0.361E-01	0.150E+01	0.839E-01	0.331E-01	-0.373E+00	0.850E-01	0.500E 01	ACCEPT
31	0.993	0.223E 01	0.141E+01	0.785E 01	0.284E 01	0.105E+01	0.850E 01	0.500E 01	ACCEPT
37	0.867	0.307E 01	0.182E+01	0.972E 01	0.314E 01	0.246E 01	0.102E+00	0.100E 01	ACCEPT
43	0.909	0.345E-01	0.171E+01	0.114E+00	0.321E-01	-0.315E+00	0.102E+00	0.100E 01	REJECT
49	0.955	0.351E 01	0.150E+01	0.140E+00	0.321E-01	0.308E+00	0.102E+00	0.100E 01	REJECT
55	0.972	0.357E 01	0.127E+01	0.277E 01	0.384E 01	0.317E+00	0.102E+00	0.100E 01	ACCEPT
61	0.858	0.342E 01	0.173E+01	0.824E 01	0.303E 01	-0.777E+00	0.102E+00	0.100E 01	ACCEPT
67	0.525	0.321E-01	0.410E+01	0.109E+00	0.326E-01	0.707E 01	0.102E+00	0.100E 01	REJECT
73	0.775	0.207E 01	0.212E+01	0.729E 01	0.300E 01	0.160E+01	0.763E-01	0.100E+00	ACCEPT
79	0.670	0.216E 01	0.270E+01	0.652E-01	0.311E-01	0.158E+01	0.763E-01	0.100E+00	ACCEPT
85	0.570	0.343E-01	0.366E+01	0.134E+00	0.316E-01	0.345E+00	0.102E+00	0.100E 01	REJECT
91	0.523	0.325E 01	0.442E+01	0.122E+00	0.321E-01	0.522E 01	0.102E+00	0.100E 01	REJECT
97	0.403	0.326E-01	0.700E+01	0.117E+00	0.315E-01	-0.144E+00	0.102E+00	0.100E 01	REJECT
103	0.432	0.337E 01	0.595E+01	0.916E 01	0.319E-01	0.238E+00	0.102E+00	0.100E 01	ACCEPT
109	0.497	0.343E-01	0.505E+01	0.113E+00	0.316E 01	-0.351E+00	0.102E+00	0.100E 01	REJECT
115	0.411	0.337E 01	0.652E+01	0.859E-01	0.294E-01	-0.590E+00	0.102E+00	0.100E-01	ACCEPT
121	0.483	0.344E 01	0.515E+01	0.903E 01	0.298E-01	-0.622E+00	0.102E+00	0.100E 01	ACCEPT
127	0.704	0.356E 01	0.287E+01	0.148E+00	0.321E 01	0.442E+00	0.102E+00	0.100E 01	REJECT
133	0.811	0.343E-01	0.206E+01	0.111E+00	0.319E-01	0.559E+00	0.102E+00	0.100E 01	REJECT
139	0.767	0.351E 01	0.231E+01	0.831E 01	0.333E 01	0.224E+00	0.850E-01	0.500E 01	ACCEPT
145	0.775	0.350E 01	0.236E+01	0.115E+00	0.301E 01	0.655E+00	0.102E+00	0.100E 01	REJECT
151	1.041	0.387E-01	0.131E+01	0.118E+00	0.316E-01	0.874E+00	0.102E+00	0.100E 01	REJECT
157	0.775	0.370E 01	0.205E+01	0.928E 01	0.319E-01	-0.648E+00	0.102E+00	0.100E 01	ACCEPT
163	0.906	0.374E 01	0.156E+01	0.922E-01	0.321E 01	0.656E+00	0.102E+00	0.100E 01	ACCEPT

TABLE 3.5

TABLE 3.6

KOLMOGOROV-SMIRNOV TEST: NAKAGAMI-M FIT TO L-BAND
PERCENT ACCEPTANCE BY SIGNIFICANCE LEVEL

Significance Level	No. Accepted	No. Rejected	Total	Percent Acceptance
0.01	15	11	26	57.7
0.05	6	20	26	23.1
0.10	3	23	26	11.5

KOLMOGOROV SMIRNOV TEST FOR L BAND DATA

SAMPLING RATE IS: 1.5 PER SEC

SAMPLE SIZE IS: 758

NULL HYPOTHESIS, Ho: SAMPLE IS DISTRIBUTED AS NAKAGAMI M

ORDER	S4	OMEGA	m S4	MAX. DEV.	@ X VALUE	@ DB VALUE	K S STAT.	SIG. LEV.	**Ho**
1	0.060	0.208E 01	0.200E+02	0.315E+00	0.187E 01	0.466E+00	0.102E+00	0.100E-01	REJECT
7	0.313	0.145E 01	0.103E+02	0.192E+00	0.161E-01	0.441E+00	0.102E+00	0.100E-01	REJECT
13	0.817	0.155E 01	0.150E+01	0.569E 01	0.363E 02	0.631E+01	0.763E 01	0.100E+00	ACCEPT
19	1.145	0.207E 01	0.763E+00	0.138E+00	0.426E 02	0.686E+01	0.102E+00	0.100E 01	REJECT
25	0.924	0.361E-01	0.117E+01	0.836E 01	0.144E 01	0.397E+01	0.850E-01	0.500E-01	ACCEPT
31	0.993	0.323E 01	0.101E+01	0.888E 01	0.457E 02	0.682E+01	0.102E+00	0.100E 01	ACCEPT
37	0.867	0.307E 01	0.133E+01	0.104E+00	0.118E 01	0.415E+01	0.102E+00	0.100E 01	REJECT
43	0.909	0.345E 01	0.121E+01	0.937E 01	0.894E 02	0.582E+01	0.102E+00	0.100E-01	ACCEPT
49	0.955	0.351E 01	0.110E+01	0.115E+00	0.321E 01	0.388E+00	0.102E+00	0.100E 01	REJECT
55	0.992	0.357E 01	0.102E+01	0.872E 01	0.384E 01	0.317E+00	0.102E+00	0.100E-01	ACCEPT
61	0.858	0.362E 01	0.136E+01	0.719E 01	0.966E-02	0.574E+01	0.763E-01	0.100E+00	ACCEPT
67	0.525	0.321E 01	0.362E+01	0.106E+00	0.326E-01	0.707E 01	0.102E+00	0.100E 01	REJECT
73	0.775	0.207E 01	0.167E+01	0.860E 01	0.133E 01	0.124E+01	0.102E+00	0.100E 01	ACCEPT
79	0.670	0.216E-01	0.223E+01	0.851E-01	0.119E-01	0.241E+01	0.102E+00	0.100E-01	ACCEPT
85	0.578	0.343E-01	0.299E+01	0.121E+00	0.316E 01	0.345E+00	0.102E+00	0.100E-01	REJECT
91	0.523	0.325E-01	0.365E+01	0.119E+00	0.321E 01	0.522E 01	0.102E+00	0.100E-01	REJECT
97	0.403	0.326E-01	0.615E+01	0.112E+00	0.315E 01	0.144E+00	0.102E+00	0.100E 01	REJECT
103	0.432	0.337E 01	0.536E+01	0.859E-01	0.319E-01	0.238E+00	0.102E+00	0.100E 01	ACCEPT
109	0.497	0.343E-01	0.404E+01	0.986E 01	0.316E-01	0.351E+00	0.102E+00	0.100E 01	ACCEPT
115	0.411	0.337E-01	0.592E+01	0.770E-01	0.294E-01	0.590E+00	0.850E-01	0.500E 01	ACCEPT
121	0.483	0.344E-01	0.429E+01	0.738E-01	0.354E 01	0.119E+00	0.763E 01	0.100E+00	ACCEPT
127	0.704	0.356E 01	0.202E+01	0.122E+00	0.321E 01	0.442E+00	0.102E+00	0.100E-01	REJECT
133	0.811	0.363E 01	0.152E+01	0.102E+00	0.992E-02	0.563E+01	0.102E+00	0.100E-01	REJECT
139	0.767	0.351E 01	0.170E+01	0.112E+00	0.168E-01	0.319E+01	0.102E+00	0.100E 01	REJECT
145	0.775	0.350E-01	0.166E+01	0.116E+00	0.139E 01	0.400E+01	0.102E+00	0.100E 01	REJECT
151	1.041	0.387E-01	0.923E+00	0.121E+00	0.129E 01	0.478E+01	0.102E+00	0.100E 01	REJECT
157	0.776	0.370E 01	0.167E+01	0.801E 01	0.326E 01	0.551E+00	0.850E 01	0.500E 01	ACCEPT
163	0.906	0.374E 01	0.122E+01	0.892E 01	0.992E 02	0.576E+01	0.102E+00	0.100E 01	ACCEPT

TABLE 3.7

Copy available to DTIC does not permit fully legible reproduction

COMPARISON OF S4 AND MAX. LIKELIHOOD ESTIMATES FOR L BAND DATA

SAMPLING RATE IS: 1.5 PER SEC.

SAMPLE SIZE IS: 256

BLOCK	MEAN	STD. DEV.	S/4	m S/4	m M/L	m M/L - m S/4	DIFF. %
1	0.020845	0.001252	0.060084	276.871185	7.000000	**********	97.472
7	0.014510	0.004546	0.313311	10.187069	7.000000	3.187069	31.205
13	0.015515	0.012672	0.814746	1.499010	1.757025	0.258016	17.212
19	0.020661	0.023659	1.145105	0.762622	1.262955	0.500334	65.607
25	0.036061	0.033402	0.926250	1.165502	1.504089	0.339307	29.111
31	0.022262	0.022098	0.992666	1.014831	1.413854	0.399024	39.319
37	0.030714	0.026634	0.867148	1.329084	1.815234	0.485350	36.496
43	0.034536	0.031329	0.909168	1.209793	1.711028	0.501235	41.431
49	0.035120	0.033529	0.954706	1.097136	1.498647	0.401510	36.596
55	0.035202	0.035430	[illegible]	1.015420	1.269705	0.254285	25.042
61	0.036239	0.031075	0.857508	1.359953	1.731909	0.371956	27.351
67	0.032072	0.014848	0.525301	3.623934	4.175175	0.551241	15.211
73	0.020736	0.016070	0.774955	1.665125	2.122744	0.457618	27.483
79	0.021640	0.014495	0.662226	2.229020	2.697175	0.468155	21.003
85	0.034260	0.019797	0.572844	2.994871	3.658997	0.664125	22.175
91	0.032510	0.017018	0.524459	3.649496	4.423993	0.774497	21.222
97	0.032577	0.013133	0.403141	6.152976	7.000000	0.847024	13.766
103	0.033671	0.014543	0.431928	5.360169	5.953613	0.593443	11.071
109	0.034305	0.017057	0.497216	4.044907	5.046267	1.001359	24.756
115	0.033653	0.013035	0.411098	5.917119	6.519328	0.602210	10.177
121	0.034430	0.016618	0.402679	4.292228	5.147339	0.855111	19.922
127	0.035561	0.025025	0.703712	2.019337	2.868675	0.849338	42.060
133	0.036258	0.029398	0.810793	1.521175	2.057839	0.536664	35.280
139	0.035096	0.026917	0.766958	1.700031	2.305702	0.605671	35.627
145	0.034971	0.027117	0.775396	1.663231	2.357161	0.693930	41.722
151	0.030695	0.040208	1.041150	0.922515	1.307393	0.384078	41.721
157	0.037005	0.028661	0.774525	1.666275	2.050558	0.383584	23.011
163	0.037757	0.033834	0.895491	1.219100	1.555754	0.336654	27.615

TABLE 3.8

CHI SQUARED TEST FOR L BAND DATA

NULL HYPOTHESIS, Ho: SAMPLE IS DISTRIBUTED AS LOGNORMAL

SAMPLING RATE IS: 1.5 PER SEC

SAMPLE SIZE IS : 256

NO. OF CELLS = 20 DEGREES OF FREEDOM OF CHI SQUARED STATISTIC = 17

BLOCK	S4	MEAN LN(X)	VAR LN(X)	CHI2 STAT.	PROB Ho TRUE
1	0.06008	0.392E+01	0.361E 02	0.306E+03	0.224E 01
7	0.31331	0.427E+01	0.842E 01	0.197E+03	0.000E+00
13	0.81677	0.448E+01	0.723E+00	0.501E+02	0.408E 04
19	1.14511	0.432E+01	0.998E+00	0.367E+02	0.375E 02
25	0.92625	0.369E+01	0.808E+00	0.251E+02	0.926E-01
31	0.92267	0.420E+01	0.863E+00	0.360E+02	0.454E 02
37	0.86715	0.378E+01	0.656E+00	0.404E+02	0.113E 02
43	0.90917	0.369E+01	0.648E+00	0.234E+02	0.137E+00
49	0.95471	0.372E+01	0.778E+00	0.454E+02	0.212E 03
55	0.99238	0.379E+01	0.102E+01	0.387E+02	0.198E 02
61	0.85751	0.363E+01	0.674E+00	0.284E+02	0.407E-01
67	0.52530	0.356E+01	0.203E+00	0.795E+02	0.000E+00
73	0.77495	0.413E+01	0.568E+00	0.482E+02	0.795E 04
79	0.66980	0.403E+01	0.410E+00	0.385E+02	0.208E 02
85	0.57784	0.352E+01	0.285E+00	0.487E+02	0.674E 04
91	0.52346	0.354E+01	0.233E+00	0.463E+02	0.153E 03
97	0.40714	0.349E+01	0.131E+00	0.398E+02	0.139E 02
103	0.43123	0.340E+01	0.177E+00	0.379E+02	0.254E 02
109	0.49722	0.347E+01	0.200E+00	0.259E+02	0.769E 01
115	0.41110	0.347E+01	0.157E+00	0.345E+02	0.730E-02
121	0.48268	0.347E+01	0.174E+00	0.199E+02	0.277E+00
127	0.70371	0.352E+01	0.345E+00	0.398E+02	0.137E 02
133	0.81079	0.358E+01	0.552E+00	0.306E+02	0.226E 01
139	0.76676	0.358E+01	0.529E+00	0.357E+02	0.500E 02
145	0.77540	0.358E+01	0.442E+00	0.265E+02	0.658E 01
151	1.04115	0.368E+01	0.232E+00	0.367E+02	0.375E 02
157	0.77452	0.356E+01	0.541E+00	0.259E+02	0.768E 01
163	0.90569	0.366E+01	0.284E+00	0.213E+02	0.211E+00

TABLE 4.1

TABLE 4.2

CHI-SQUARE TEST: LOGNORMAL FIT TO L-BAND
PERCENT ACCEPTANCE BY SIGNIFICANCE LEVEL

Significance Level	No. Accepted	No. Rejected	Total	Percent Acceptance
0.005	11	15	26	42.3
0.01	9	17	26	34.6
0.05	7	19	26	26.9
0.10	3	23	26	13.0

KOLMOGOROV-SMIRNOV TEST FOR L-BAND DATA

SAMPLING RATE IS: 1.5 PER SEC

SAMPLE SIZE IS: 256

NULL HYPOTHESIS, Ho: SAMPLE IS DISTRIBUTED AS LOGNORMAL

BLOCK	S4	MEAN LN(X)	VAR LN(X)	MAX. DEV.	@ X VALUE	@ DB VALUE	K-S STAT.	SIG. LEV.	**Ho**
1	0.060	-0.387E+01	0.361E-02	0.353E-01	0.199E-01	-0.207E+00	0.763E-01	0.100E+00	ACCEPT
7	0.313	-0.427E+01	0.842E-01	0.171E+00	0.161E-01	0.441E+00	0.102E+00	0.100E-01	REJECT
13	0.817	-0.448E+01	0.723E+00	0.767E-01	0.137E-01	-0.525E+00	0.850E-01	0.500E-01	ACCEPT
19	1.145	-0.432E+01	0.988E+00	0.772E-01	0.126E-01	-0.216E+01	0.850E-01	0.500E-01	ACCEPT
25	0.926	-0.369E+01	0.808E+00	0.568E-01	0.159E-01	-0.357E+01	0.763E-01	0.100E+00	ACCEPT
31	0.993	-0.420E+01	0.863E+00	0.573E-01	0.105E-01	-0.326E+01	0.763E-01	0.100E+00	ACCEPT
37	0.867	-0.378E+01	0.656E+00	0.609E-01	0.184E-01	-0.222E+01	0.763E-01	0.100E+00	ACCEPT
43	0.909	-0.369E+01	0.648E+00	0.590E-01	0.321E-01	-0.315E+00	0.763E-01	0.100E+00	ACCEPT
49	0.955	-0.372E+01	0.778E+00	0.824E-01	0.321E-01	-0.388E+00	0.850E-01	0.500E-01	ACCEPT
55	0.992	-0.378E+01	0.102E+01	0.722E-01	0.203E-01	-0.246E+01	0.763E-01	0.100E+00	ACCEPT
61	0.858	-0.363E+01	0.674E+00	0.494E-01	0.234E-01	-0.191E+01	0.763E-01	0.100E+00	ACCEPT
67	0.525	-0.356E+01	0.283E+00	0.106E+00	0.231E-01	-0.142E+01	0.102E+00	0.100E-01	REJECT
73	0.775	-0.413E+01	0.568E+00	0.905E-01	0.133E-01	-0.194E+01	0.102E+00	0.100E-01	ACCEPT
79	0.670	-0.403E+01	0.410E+00	0.692E-01	0.120E-01	-0.257E+01	0.763E-01	0.100E+00	ACCEPT
85	0.578	-0.352E+01	0.285E+00	0.973E-01	0.316E-01	-0.345E+00	0.102E+00	0.100E-01	ACCEPT
91	0.523	-0.354E+01	0.233E+00	0.895E-01	0.321E-01	-0.522E-01	0.102E+00	0.100E-01	ACCEPT
97	0.403	-0.349E+01	0.131E+00	0.937E-01	0.315E-01	-0.144E+00	0.102E+00	0.100E-01	ACCEPT
103	0.432	-0.348E+01	0.177E+00	0.694E-01	0.249E-01	-0.131E+01	0.763E-01	0.100E+00	ACCEPT
109	0.497	-0.347E+01	0.200E+00	0.822E-01	0.316E-01	-0.351E+00	0.850E-01	0.500E-01	ACCEPT
115	0.411	-0.347E+01	0.157E+00	0.611E-01	0.294E-01	-0.590E+00	0.763E-01	0.100E+00	ACCEPT
121	0.483	-0.347E+01	0.194E+00	0.624E-01	0.298E-01	-0.622E+00	0.763E-01	0.100E+00	ACCEPT
127	0.704	-0.352E+01	0.345E+00	0.104E+00	0.321E-01	-0.442E+00	0.102E+00	0.100E-01	REJECT
133	0.811	-0.358E+01	0.552E+00	0.626E-01	0.365E-01	0.239E-01	0.763E-01	0.100E+00	ACCEPT
139	0.767	-0.358E+01	0.529E+00	0.768E-01	0.168E-01	-0.319E+01	0.850E-01	0.500E-01	ACCEPT
145	0.775	-0.358E+01	0.442E+00	0.680E-01	0.301E-01	-0.656E+00	0.763E-01	0.100E+00	ACCEPT
151	1.041	-0.368E+01	0.932E+00	0.633E-01	0.129E-01	-0.478E+01	0.763E-01	0.100E+00	ACCEPT
157	0.775	-0.356E+01	0.541E+00	0.477E-01	0.319E-01	-0.648E+00	0.763E-01	0.100E+00	ACCEPT
163	0.906	-0.364E+01	0.784E+00	0.478E-01	0.384E-01	0.120E+00	0.763E-01	0.100E+00	ACCEPT

>

TABLE 4.3

TABLE 4.4

KILGOMOROV-SMIRNOV TEST: LOGNORMAL FIT TO
L-BAND: PERCENT ACCEPTANCES BY SIGNIFICANCE LEVEL

Significance Level	No. Accepted	No. Rejected	Total	Percent Acceptance
0.01	24	2	26	92.0
0.05	17	9	26	65.4
0.10	15	11	26	57.7

TEST OF GOODNESS OF FIT TO LOGNORMAL DISTRIBUTION FOR L BAND DATA

SAMPLING RATE IS 1.5 PER SEC

SAMPLE SIZE IS 256
NULL HYPOTHESIS: SAMPLE IS LOGNORMALLY DISTRIBUTED

******************************STATISTICS OF LN(X)******************************

BLOCK	S4	MEAN	VARIANCE	SKEWNESS	KURTOSIS	STAT. T	PROB Ho TRUE
1	0.060	-0.387E+01	0.359E-02	0.570E-01	0.275E+01	0.782E+00	0.676E+00
7	0.313	0.427E+01	0.838E-01	0.691E+00	0.904E+01	0.409E+03	0.000E+00
13	0.817	0.448E+01	0.720E+00	0.659E+00	0.410E+01	0.314E+02	0.179E-06
19	1.145	-0.432E+01	0.984E+00	-0.460E+00	0.371E+01	0.145E+02	0.724E-03
25	0.926	-0.369E+01	0.805E+00	-0.349E+00	0.330E+01	0.618E+01	0.456E-01
31	0.993	-0.420E+01	0.859E+00	0.374E+00	0.355E+01	0.920E+01	0.100E-01
37	0.867	-0.378E+01	0.654E+00	-0.464E+00	0.405E+01	0.209E+02	0.293E-04
43	0.909	-0.369E+01	0.645E+00	0.268E-01	0.305E+01	0.576E-01	0.972E+00
49	0.955	-0.372E+01	0.775E+00	0.232E+00	0.365E+01	0.606E+01	0.324E-01
55	0.992	-0.378E+01	0.101E+01	0.495E+00	0.382E+01	0.175E+02	0.155E-03
61	0.858	0.363E+01	0.671E+00	-0.234E+00	0.307E+01	0.240E+01	0.302E+00
67	0.525	-0.356E+01	0.282E+00	0.122E+01	0.907E+01	0.457E+03	0.000E+00
73	0.775	-0.413E+01	0.566E+00	-0.578E+00	0.387E+01	0.224E+02	0.142E-04
79	0.670	0.403E+01	0.408E+00	0.233E+00	0.352E+01	0.518E+01	0.751E-01
85	0.578	0.352E+01	0.284E+00	0.434E-02	0.324E+01	0.592E+00	0.744E+00
91	0.523	-0.354E+01	0.232E+00	0.282E-03	0.381E+01	0.704E+01	0.296E-01
97	0.403	-0.349E+01	0.130E+00	0.439E+00	0.318E+01	0.856E+01	0.137E-01
103	0.432	-0.348E+01	0.176E+00	0.264E+00	0.443E+01	0.247E+02	0.370E-05
109	0.497	-0.347E+01	0.199E+00	0.101E+00	0.406E+01	0.124E+02	0.202E-02
115	0.411	0.347E+01	0.157E+00	0.611E-01	0.296E+01	0.179E+00	0.914E+00
121	0.483	0.347E+01	0.193E+00	0.303E+00	0.277E+01	0.446E+01	0.107E+00
127	0.704	-0.352E+01	0.344E+00	0.382E+00	0.313E+01	0.641E+01	0.405E-01
133	0.811	0.358E+01	0.550E+00	0.529E+00	0.659E+01	0.150E+03	0.000E+00
139	0.767	-0.358E+01	0.526E+00	0.123E+01	0.106E+02	0.684E+03	0.000E+00
145	0.775	-0.358E+01	0.440E+00	0.708E-01	0.362E+01	0.434E+01	0.114E+00
151	1.041	0.368E+01	0.928E+00	0.377E+00	0.425E+01	0.234E+02	0.805E-05
157	0.775	0.356E+01	0.538E+00	0.319E-01	0.276E+01	0.674E+00	0.714E+00
163	0.906	-0.364E+01	0.780E+00	0.487E+00	0.442E+01	0.316E+02	0.119E-06

TABLE 4.5

TABLE 4.6

SKEWNESS-KURTOSIS TEST: LOGNORMAL FIT TO L-BAND

PERCENT ACCEPTANCE BY SIGNIFICANCE LEVEL

Significance Level	No. Accepted	No. Rejected	Total	Percent Acceptance
0.01	14	12	26	53.8
0.025	12	14	26	46.1(5)
0.05	8	18	26	30.8
0.10	7	19	26	26.9

	L - BAND		UHF	
BLOCK	LOGNORMAL	NAKAGAMI	LOGNORMAL	NAKAGAMI
1				
7				
13	3.89	1.34	3.10	-0.559
19	2.18	-2.18	2.51	-0.907
25	0.696	-2.76	2.90	0.050
31	0.956	-2.82	1.55	-1.99
37	0.046	-2.64	2.43	-1.19
43	0.488	-2.74	2.67	-0.548
49	1.43	-2.224	3.10	-0.384
55	1.65	-2.51	2.54	-0.939
61	0.742	-2.22	2.59	-1.10
67	3.55	-2.79	4.40	0.980
73	0.016	-2.06	4.05	0.460
79	-0.0004	-1.72	2.20	-1.72
85	0.490	-0.787	4.22	-0.100
91	0.319	-1.36	4.28	0.232
97	-0.480	-1.30	5.30	1.62
103	1.75	-1.08	3.15	-0.679
109	1.29	0.367	4.85	1.43
115	-0.135	-0.779	5.06	0.919
121	-0.197	-1.12	2.97	-1.38
127	-0.221	-2.13	1.95	-1.84
133	-0.338	-2.74	1.39	-2.75
139	1.50	-0.284	2.43	-1.20
145	0.942	-1.33	1.94	-1.89
151	1.91	-2.35	1.88	-2.03
157	-0.565	-3.07	2.74	-0.881
163	1.44	-1.84	2.65	-0.787
AVERAGE ABS VALUES	1.04	1.16	3.17	0.520

TABLE 4.7 - DB DEVIATIONS AT 1ST PERCENTILE

	L - BAND		UHF	
BLOCK	LOGNORMAL	NAKAGAMI	LOGNORMAL	NAKAGAMI
1				
7				
13	-0.22	-.854	1.13	-0.014
19	0.572	-1.05	0.654	-0.525
25	0.870	-0.397	0.372	-0.543
31	0.206	-1.20	0.870	-0.359
37	0.696	-0.272	1.24	-0.096
43	0.414	-0.869	0.803	-0.265
49	0.509	-0.901	0.722	-0.380
55	0.047	-1.44	1.18	-0.113
61	0.913	-0.197	0.833	-0.328
67	-0.531	-0.724	0.955	0.006
73	1.02	0.016	1.47	0.398
79	1.05	0.407	0.859	-0.408
85	-0.084	-0.593	0.955	-0.379
91	-0.177	-0.596	1.74	0.611
97	-0.091	-0.492	1.11	0.001
103	-0.090	-0.339	0.847	-0.313
109	-0.419	-0.800	1.42	0.488
115	-0.280	-0.533	1.23	0.041
121	-0.306	-0.697	1.04	-0.344
127	-0.542	-1.36	1.31	0.149
133	-0.814	-1.72	1.35	0.019
139	0.187	-0.385	1.19	0.087
145	-0.455	-1.39	0.800	-0.401
151	-0.249	-1.85	0.918	-0.474
157	-0.001	-0.974	0.815	-0.340
163	0.618	-0.569	1.07	-0.035
AVERAGE ABS VALUES	0.148	0.716	1.04	0.108

TABLE 4.8 - DB DEVIATIONS AT 5th PERCENTILE

	L - BAND		UHF	
BLOCK	LOGNORMAL	NAKAGAMI	LOGNORMAL	NAKAGAMI
1				
7				
13	-0.129	-0.364	0.435	0.161
19	0.039	-0.602	0.197	-0.196
25	0.531	-0.044	0.220	-0.027
31	-0.010	-0.652	0.394	-0.021
37	0.488	0.131	0.315	-0.029
43	-0.112	-0.684	0.297	-0.022
49	0.293	-0.304	0.346	0.063
55	0.334	-0.207	0.231	-0.011
61	-0.236	-0.681	0.308	0.018
67	-0.483	-0.485	0.250	0.132
73	0.734	0.518	0.0628	-0.148
79	0.151	-0.104	0.325	-0.026
85	-0.248	-0.471	0.491	0.180
91	-0.334	-0.521	0.895	0.752
97	-0.056	-0.289	0.0700	-0.144
103	-0.223	-0.317	0.528	0.278
109	-0.324	-0.500	0.358	0.264
115	-0.208	-0.316	0.178	-0.013(5)
121	-0.166	-0.354	0.439	0.071
127	-0.293	-0.704	0.940	0.676
133	-0.284	-0.649	0.778	0.419
139	-0.734	-0.882	0.830	0.590
145	-0.360	-0.799	0.438	0.140
151	-0.385	-1.04	0.085	-0.419
157	-0.139	-0.555	0.143	-0.161
163	-0.707	-1.15	0.322	0.0245
AVERAGE ABS VALUES	0.099	0.445	0.387	0.108

TABLE 4.9 - *DB DEVIATIONS AT 10th PERCENTILE*

	L - BAND		UHF	
BLOCK	LOGNORMAL	NAKAGAMI	LOGNORMAL	NAKAGAMI
13	-0.612	-0.854	-0.768	-0.079
19	-0.457	-1.05	-0.436	0.161
25	-0.232	-0.397	-0.388	0.146
31	-0.514	-1.20	-0.432	0.182
37	-0.113	-0.272	-0.642	0.035
43	0.076	-0.869	-0.620	-0.038
49	0.210	-0.901	-0.754	-0.104
55	0.398	-1.44	-0.618	0.047
61	0.066	-0.197	-0.798	-0.110
67	-0.042	-0.724	-0.850	-0.152
73	-0.382	0.316	-0.743	-0.044
79	-0.097	0.407	-0.688	0.0241
85	0.235	-0.593	-0.866	-0.058
91	0.102	-0.596	-1.00	-0.188
97	0.134	-0.492	-0.679	0.039
103	0.184	-0.339	-0.763	-0.032
109	0.162	-0.800	-0.747	-0.042
115	0.265	-0.533	-0.916	-0.101
121	0.237	-0.697	-0.540	0.252
127	0.368	-1.36	-0.915	-0.195
133	0.014	-1.72	-0.760	-0.005
139	-0.117	-0.385	-0.763	-0.069
145	0.231	-1.39	-0.748	-0.035
151	-0.056	-1.85	-0.368	0.285
157	0.198	-0.974	-0.591	0.080
163	-0.005	-0.569	-0.562	0.072
AVERAGE ABS VALUES	0.013	0.366	0.688	0.046

TABLE 4.10 - DB DEVIATIONS AT 50th PERCENTILE

PERCENTILE	L-BAND		VHF	
	LOGNORMAL	NAKAGAMI	LOGNORMAL	NAKAGAMI
1	1.04	1.16	3.17	0.520
5	0.148	0.716	1.04	0.108
10	0.099	0.445	0.387	0.108
50	0.013	0.366	0.688	0.046

TABLE 4.11 AVERAGE DB DEVIATIONS

KOLMOGOROV SMIRNOV TEST FOR UHF DATA

SAMPLING RATE IS: 6.9 PER SEC

SAMPLE SIZE IS: 1024

NULL HYPOTHESIS, Ho: SAMPLE IS DISTRIBUTED AS LOGNORMAL

BLOCK	S4	MEAN LN(X)	VAR LN(X)	MAX. DEV.	@ X VALUE	@ DD VALUE	K S STAT.	SIG. LEV.	**Ho**
1	0.087	0.223E 01	0.760E-02	0.163E-01	0.977E-01	0.435E 00	0.381E-01	0.100E 00	ACCEPT
7	0.423	0.276E 01	0.470E 00	0.266E 00	0.105E 00	-0.211E 00	0.509E-01	0.100E-01	REJECT
13	0.924	0.312E 01	0.111E 01	0.224E-01	0.468E-01	-0.166E 01	0.509E-01	0.100E-01	REJECT
19	0.888	0.290E 01	0.889E 00	0.498E-01	0.546E-01	0.135E 01	0.509E-01	0.100E-01	ACCEPT
25	0.802	0.262E 01	0.824E 00	0.429E-01	0.556E-01	-0.238E 01	0.509E-01	0.100E-01	ACCEPT
31	0.919	-0.294E 01	0.914E 00	0.600E-01	0.511E-01	0.185E 01	0.509E-01	0.100E-01	REJECT
37	0.914	0.311E 01	0.108E 01	0.642E-01	0.468E-01	0.168E 01	0.509E-01	0.100E-01	REJECT
43	0.867	-0.313E 01	0.892E 00	0.601E-01	0.504E-01	0.101E 01	0.509E-01	0.100E-01	REJECT
49	0.882	0.314E 01	0.103E 01	0.698E-01	0.461E-01	0.154E 01	0.509E-01	0.100E-01	REJECT
55	0.859	0.292E 01	0.107E 01	0.6[illegible]E-01	0.542E-01	0.184E 01	0.509E-01	0.100E-01	REJECT
61	0.897	0.309E 01	0.110E 01	0.807E-01	0.500E-01	0.148E 01	0.509E-01	0.100E-01	REJECT
67	0.877	0.309E 01	0.118E 01	0.761E-01	0.530E-01	0.123E 01	0.509E-01	0.100E-01	REJECT
73	0.907	0.324E 01	0.115E 01	0.705E-01	0.518E-01	0.238E 00	0.509E-01	0.100E-01	REJECT
79	0.920	-0.307E 01	0.113E 01	0.710E-01	0.523E-01	-0.145E 01	0.509E-01	0.100E-01	REJECT
85	0.966	-0.323E 01	0.134E 01	0.759E-01	0.469E-01	0.149E 01	0.509E-01	0.100E-01	REJECT
91	0.935	0.304E 01	0.142E 01	0.888E-01	0.482E-01	-0.221E 01	0.509E-01	0.100E-01	REJECT
97	0.953	-0.281E 01	0.119E 01	0.760E-01	0.519E-01	0.263E 01	0.509E-01	0.100E-01	REJECT
103	0.915	0.304E 01	0.120E 01	0.[illegible]E-01	0.469E-01	0.211E 01	0.509E-01	0.100E-01	REJECT
109	0.884	0.292E 01	0.121E 01	0.103E 00	0.490E-01	-0.240E 01	0.509E-01	0.100E-01	REJECT
115	0.950	0.296E 01	0.141E 01	0.850E-01	0.513E-01	0.228E 01	0.509E-01	0.100E-01	REJECT
121	0.980	0.298E 01	0.128E 01	0.659E-01	0.449E-01	0.273E 01	0.509E-01	0.100E-01	REJECT
127	0.898	0.315E 01	0.117E 01	0.802E-01	0.517E-01	0.116E 01	0.509E-01	0.100E-01	REJECT
133	0.935	-0.332E 01	0.121E 01	0.620E-01	0.447E-01	0.119E 01	0.509E-01	0.100E-01	REJECT
139	0.895	0.327E 01	0.113E 01	0.730E-01	0.514E-01	0.614E 00	0.509E-01	0.100E-01	REJECT
145	0.916	0.305E 01	0.115E 01	0.745E-01	0.516E-01	0.1[illegible]E 01	0.509E-01	0.100E-01	REJECT
151	0.970	0.292E 01	0.958E 00	0.527E-01	0.496E-01	0.212E 01	0.509E-01	0.100E-01	REJECT
157	0.991	0.313E 01	0.106E 01	0.607E-01	0.537E-01	-0.922E 00	0.509E-01	0.100E-01	REJECT
163	0.882	0.283E 01	0.994E 00	0.629E-01	0.564E-01	0.1[illegible]E 01	0.509E-01	0.100E-01	REJECT

TABLE A.1

TEST OF GOODNESS OF FIT TO LOGNORMAL DISTRIBUTION FOR UHF DATA

SAMPLING RATE IS 6.0 PER SEC

SAMPLE SIZE IS 1024
NULL HYPOTHESIS: SAMPLE IS LOGNORMALLY DISTRIBUTED

*******************************STATISTICS OF LN(X)*****************************

BLOCK	S4	MEAN	VARIANCE	SKEWNESS	KURTOSIS	STAT. T	PROB Ho TRUE
1	0.887	-0.223E+01	0.760E-01	0.772E-01	0.301E+01	0.102E+01	0.601E+00
7	0.423	0.236E+01	0.477E+00	0.222E+01	0.824E+01	0.234E+04	0.000E+00
13	0.924	-0.312E+01	0.111E+01	0.765E+00	0.325E+01	0.124E+03	0.000E+00
19	0.888	-0.298E+01	0.888E+00	0.480E+00	0.324E+01	0.418E+02	0.000E+00
25	0.802	0.269E+01	0.823E+00	0.524E+00	0.320E+01	0.630E+02	0.000E+00
31	0.919	-0.294E+01	0.913E+00	0.475E+00	0.315E+01	0.325E+02	0.000E+00
37	0.914	-0.311E+01	0.108E+01	0.714E+00	0.354E+01	0.993E+02	0.000E+00
43	0.867	0.317E+01	0.871E+00	0.599E+00	0.353E+01	0.730E+02	0.000E+00
49	0.882	0.314E+01	0.103E+01	0.680E+00	0.354E+01	0.913E+02	0.000E+00
55	0.859	0.322E+01	0.107E+01	0.704E+00	0.342E+01	0.922E+02	0.000E+00
61	0.897	0.309E+01	0.110E+01	0.703E+00	0.353E+01	0.965E+02	0.000E+00
67	0.877	0.309E+01	0.118E+01	-0.922E+00	0.402E+01	0.192E+03	0.000E+00
73	0.902	-0.324E+01	0.115E+01	-0.834E+00	0.379E+01	0.143E+03	0.000E+00
79	0.920	0.307E+01	0.112E+01	0.649E+00	0.343E+01	0.797E+02	0.000E+00
85	0.966	-0.323E+01	0.133E+01	0.772E+00	0.359E+01	0.117E+03	0.000E+00
91	0.935	-0.304E+01	0.142E+01	0.914E+00	0.371E+01	0.164E+03	0.000E+00
97	0.953	0.281E+01	0.119E+01	0.924E+00	0.442E+01	0.231E+03	0.000E+00
103	0.915	-0.304E+01	0.120E+01	0.740E+00	0.775E+01	0.114E+03	0.000E+00
109	0.884	-0.292E+01	0.121E+01	0.981E+00	0.424E+01	0.229E+03	0.000E+00
115	0.950	0.296E+01	0.140E+01	0.907E+00	0.390E+01	0.176E+03	0.000E+00
121	0.930	-0.298E+01	0.128E+01	0.726E+00	0.360E+01	0.106E+03	0.000E+00
127	0.898	-0.315E+01	0.117E+01	0.704E+00	0.323E+01	0.862E+02	0.000E+00
133	0.935	-0.332E+01	0.121E+01	0.635E+00	0.313E+01	0.695E+02	0.000E+00
139	0.895	-0.327E+01	0.113E+01	0.758E+00	0.352E+01	0.109E+03	0.000E+00
145	0.916	-0.305E+01	0.115E+01	-0.714E+00	0.348E+01	0.770E+02	0.000E+00
151	0.928	-0.292E+01	0.957E+00	0.441E+00	0.332E+01	0.353E+02	0.000E+00
157	0.891	0.313E+01	0.106E+01	0.667E+00	0.347E+01	0.855E+02	0.000E+00
163	0.889	-0.283E+01	0.993E+00	0.644E+00	0.332E+01	0.766E+02	0.000E+00

TABLE A.2

FIGURE 1.1

Scintillation Intensity at UHF Sampled at
36 Observations per second: Block 25

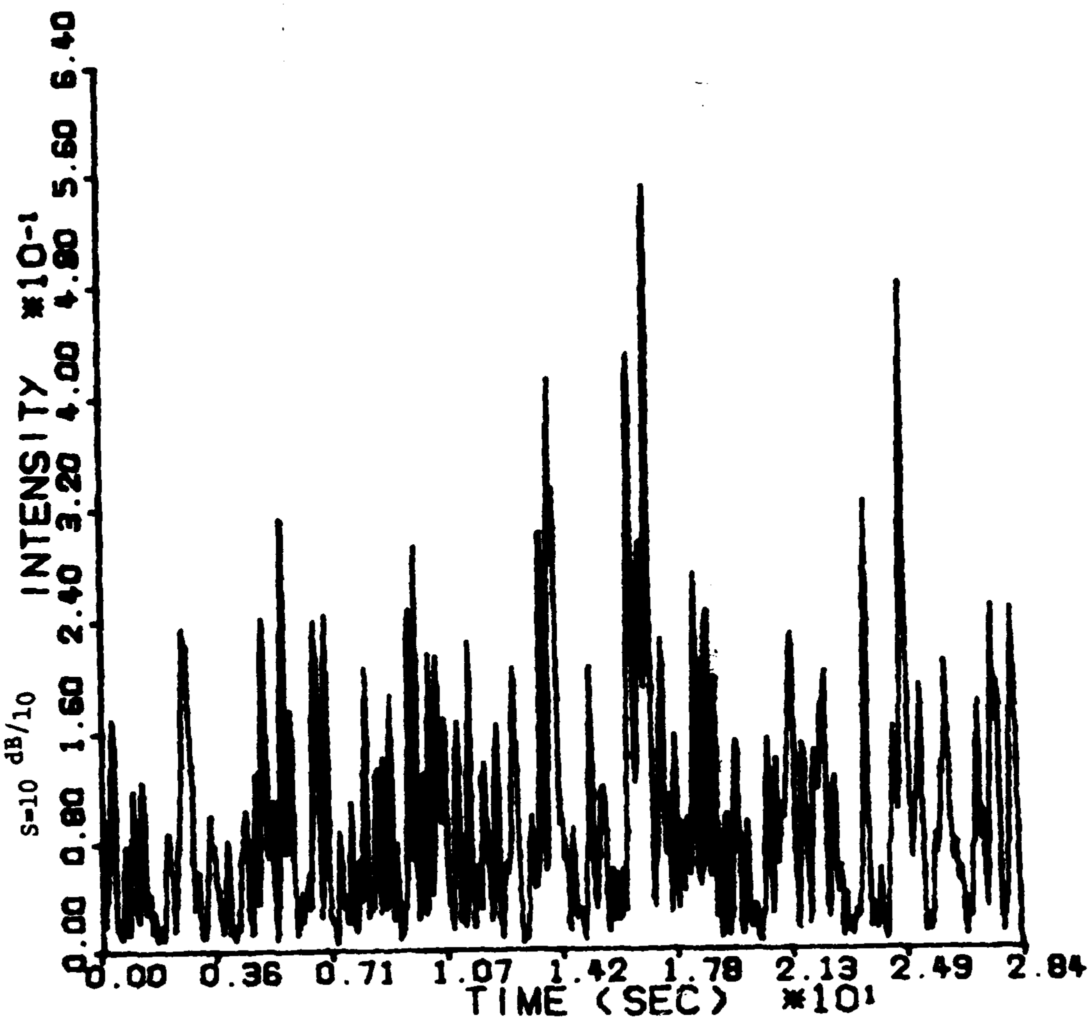


FIGURE 1.2

Scintillation Intensity at UHF Sampled at 36 Observations per second: Block 85

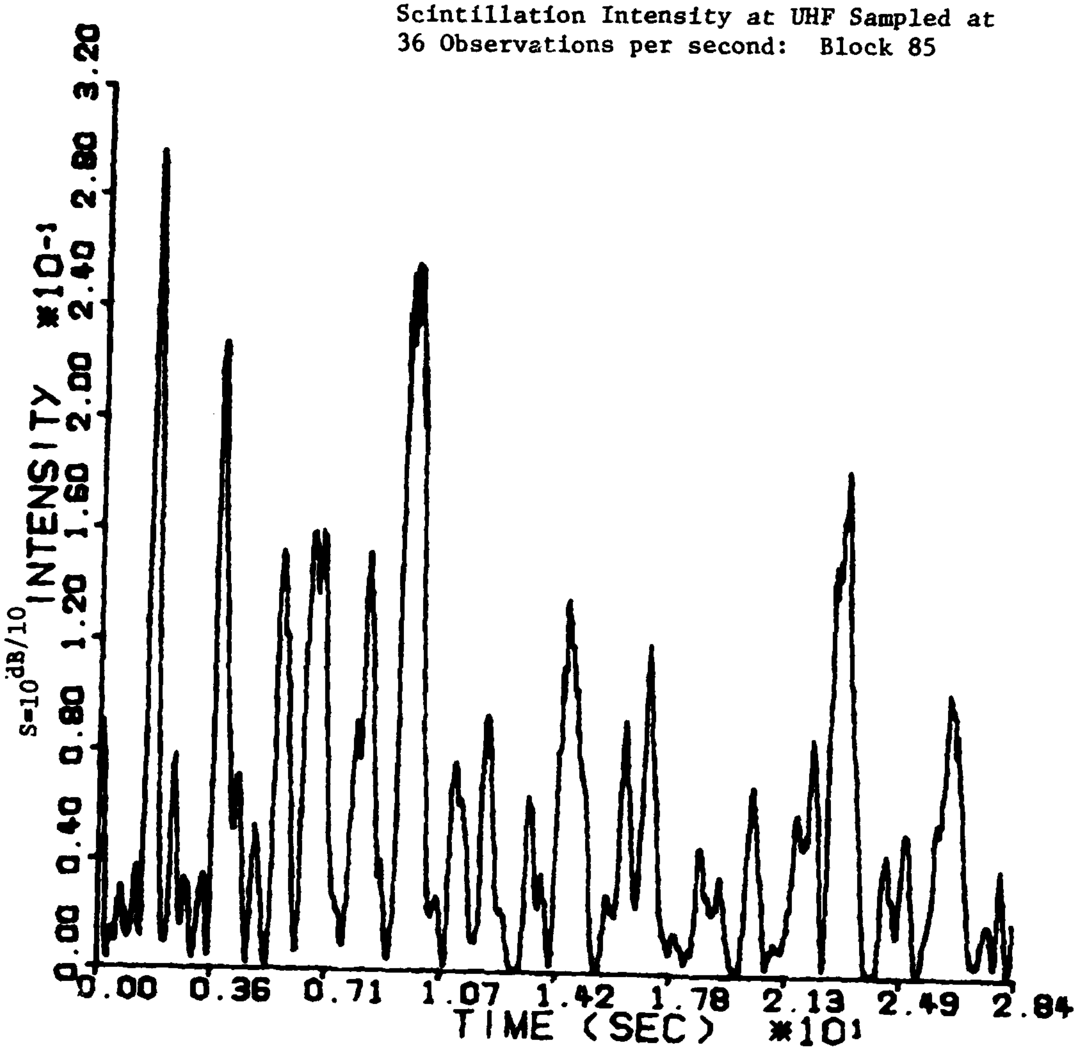


FIGURE 1.3

Scintillation *Intensity at L-Band Sampled* at 36 Observations per second: Block 25

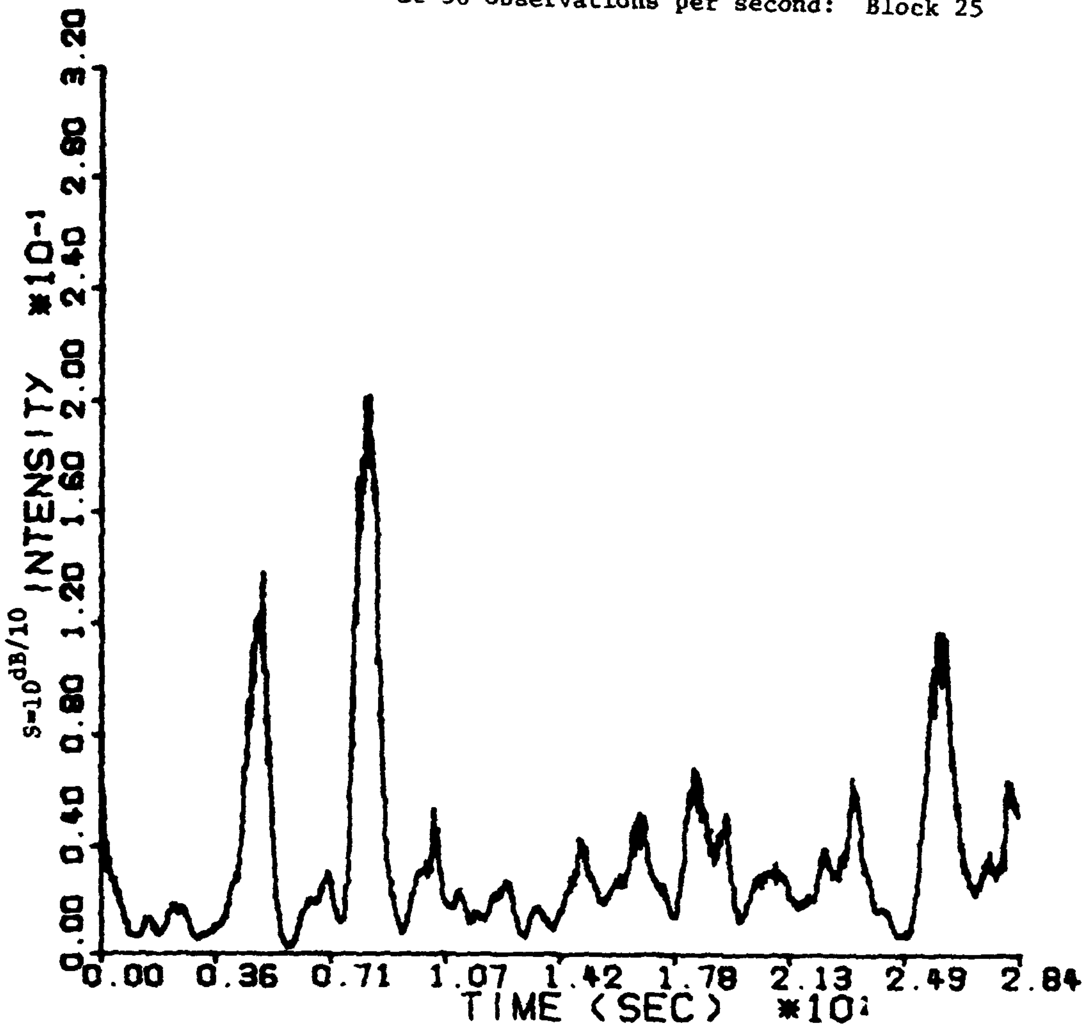


FIGURE 1.4

Scint'llation Intensity at L-Band Sampled
at 36 Observations per second: Block 85

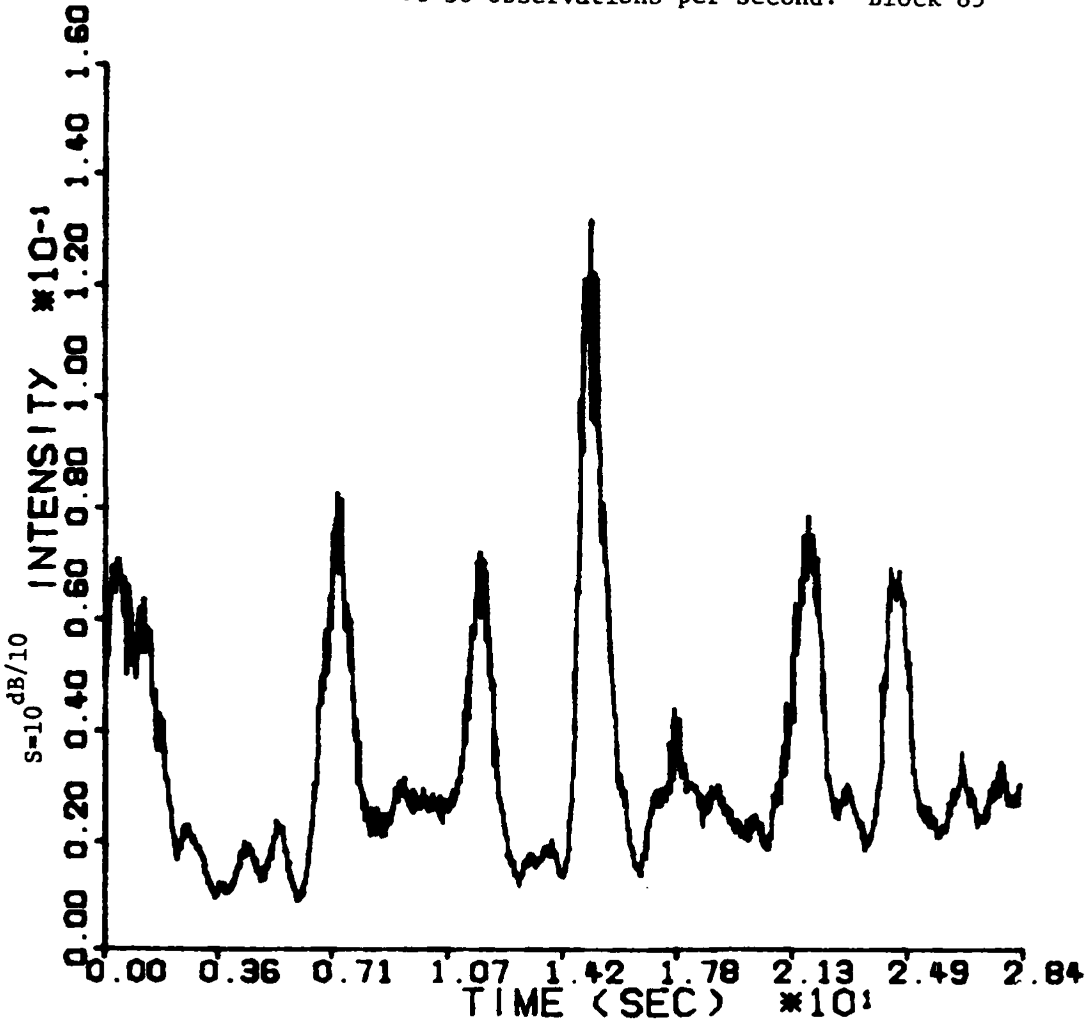


FIGURE 2.1

Power Spectrum of UHF Scintillations at 36 per second: Block 25

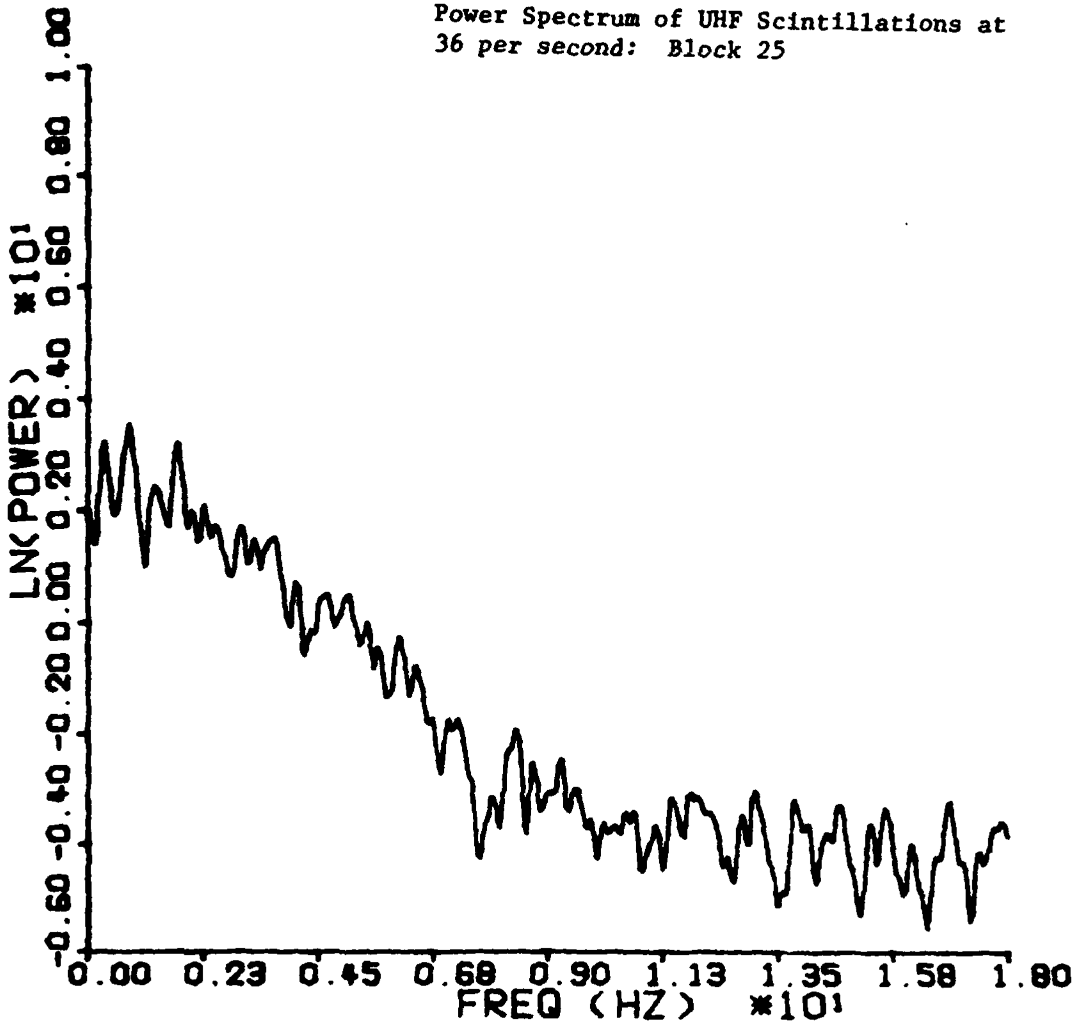


FIGURE 2.2

Power Spectrum of UHF Scintillations at
36 per second: Block 85

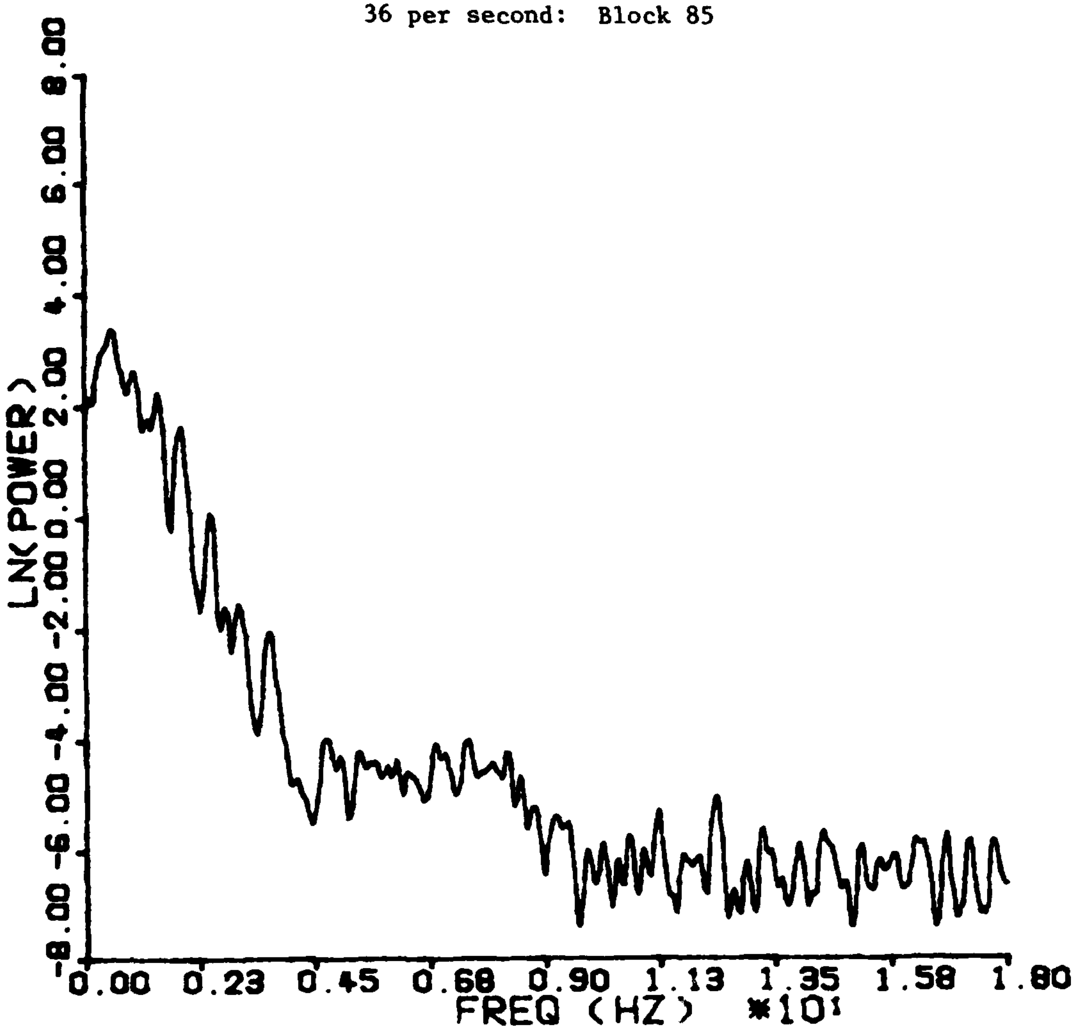


FIGURE 2.3

Power Spectrum of UHF Scintillations at
6 per second: Block 25

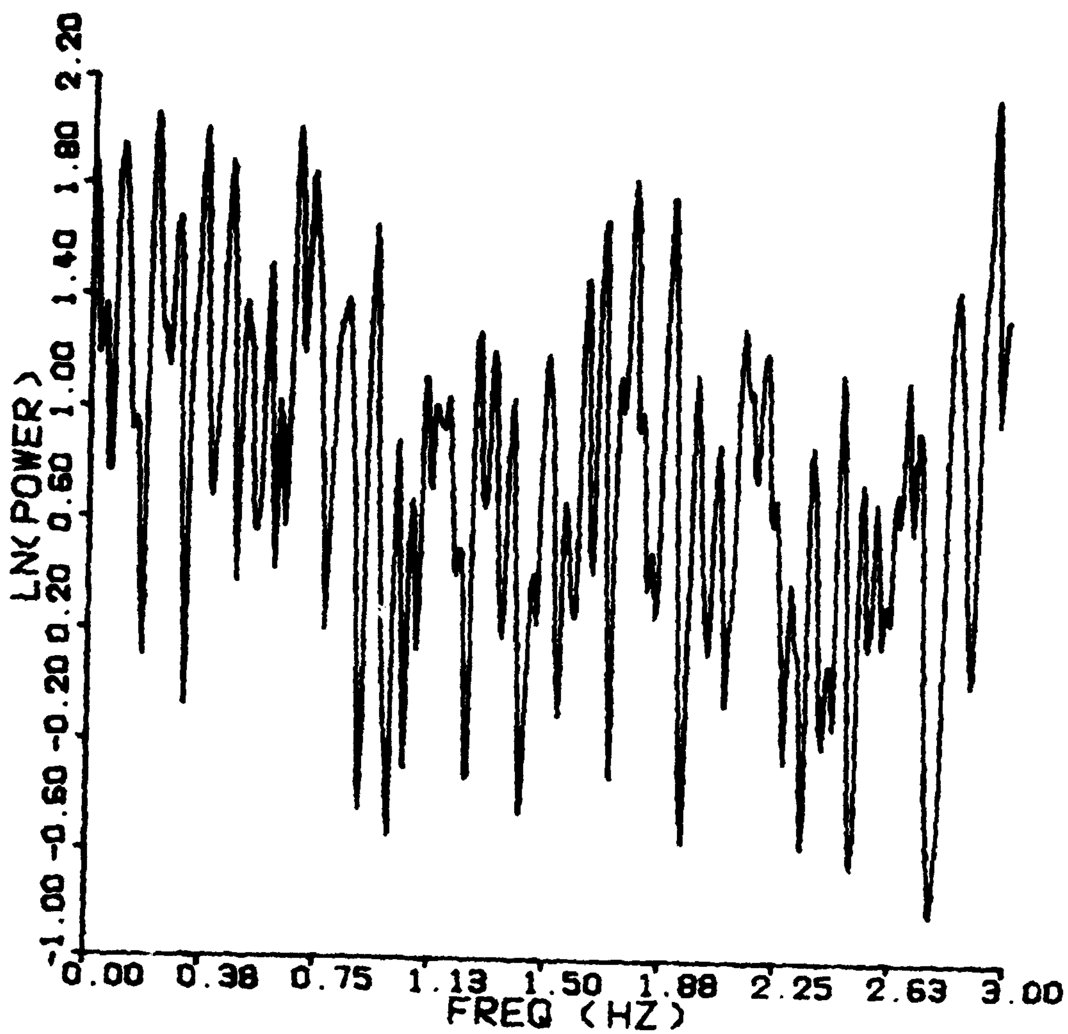


FIGURE 2.4

Power Spectrum of UHF Scintillations at 6 per second: Block 85

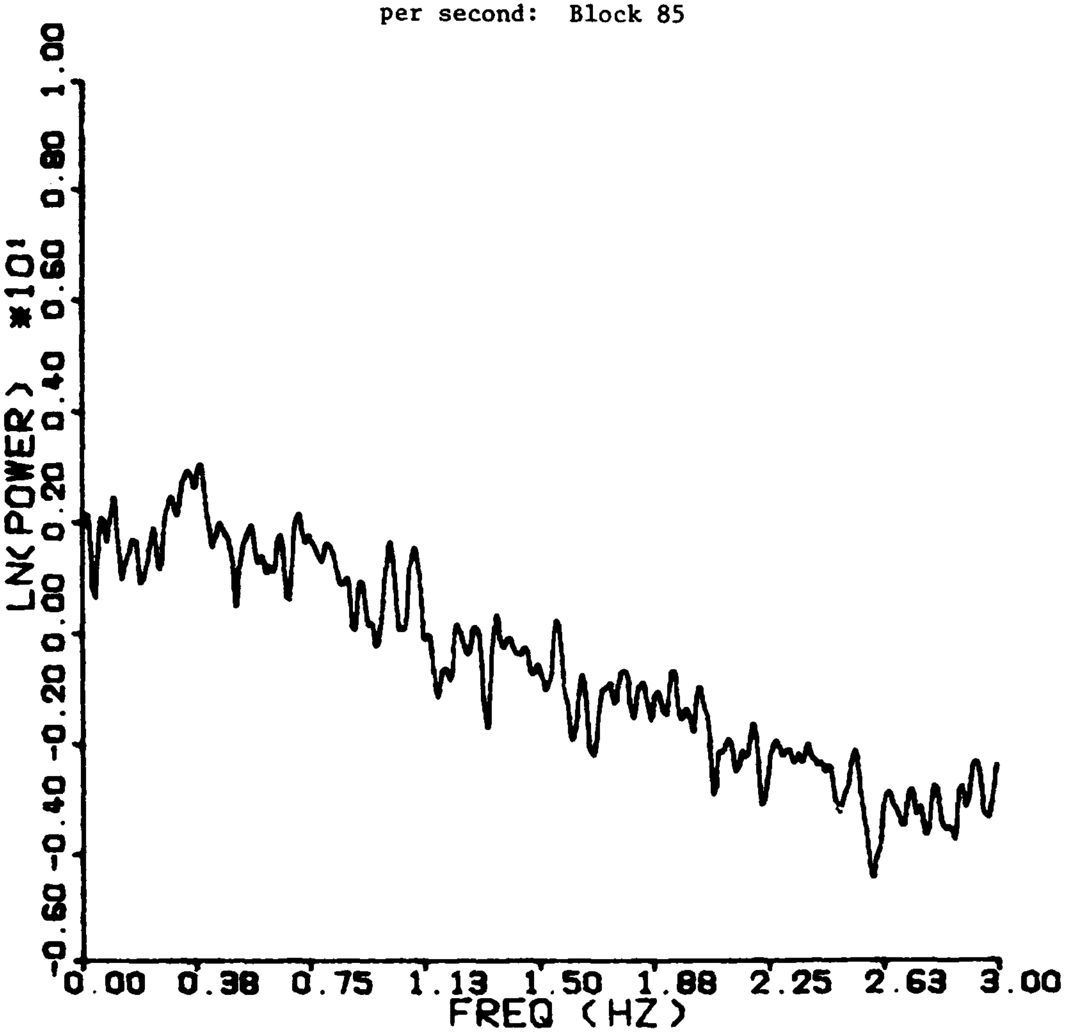


FIGURE 2.5

Autocorrelation of UHF Scintillations at
36 per second: Block 25

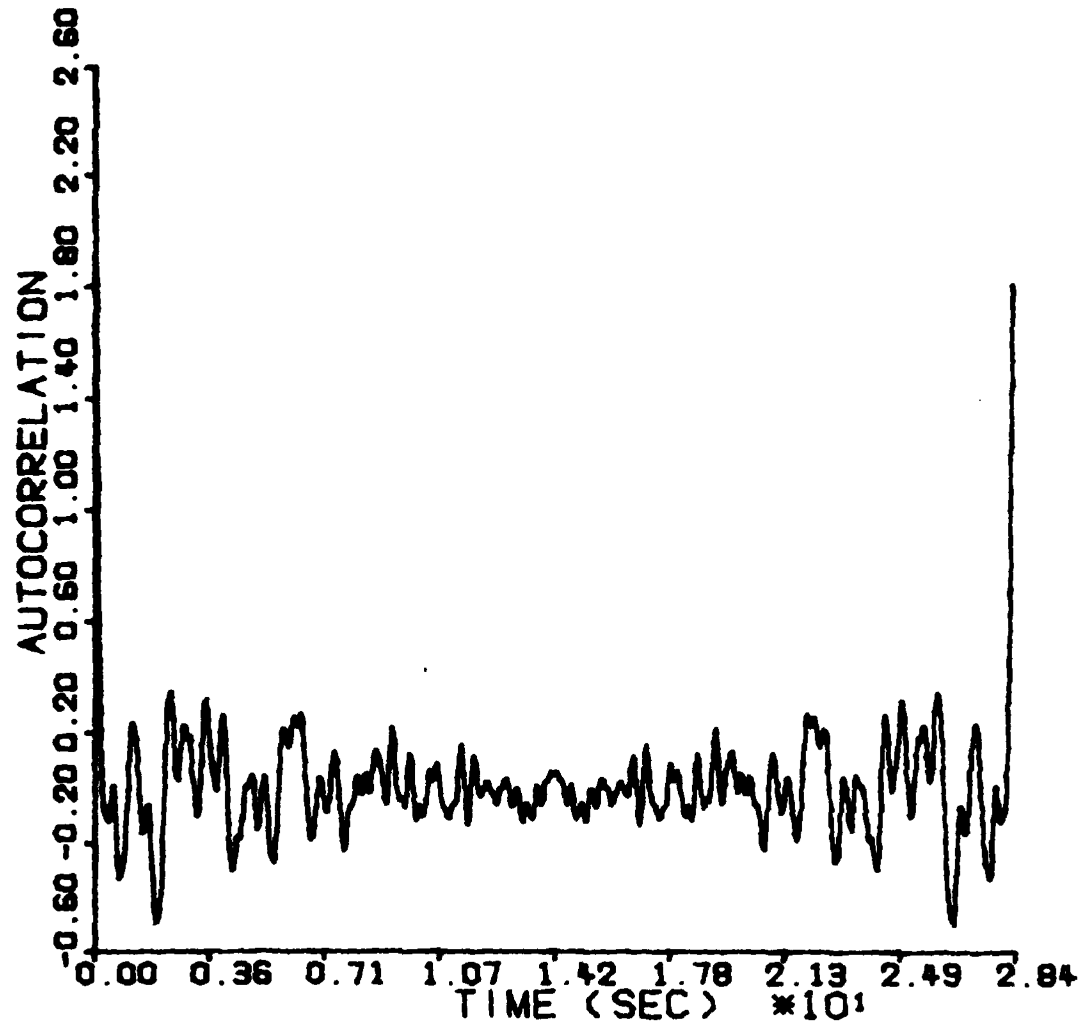


FIGURE 2.6

Autocorrelation of UHF Scintillations at
36 per second: Block 85

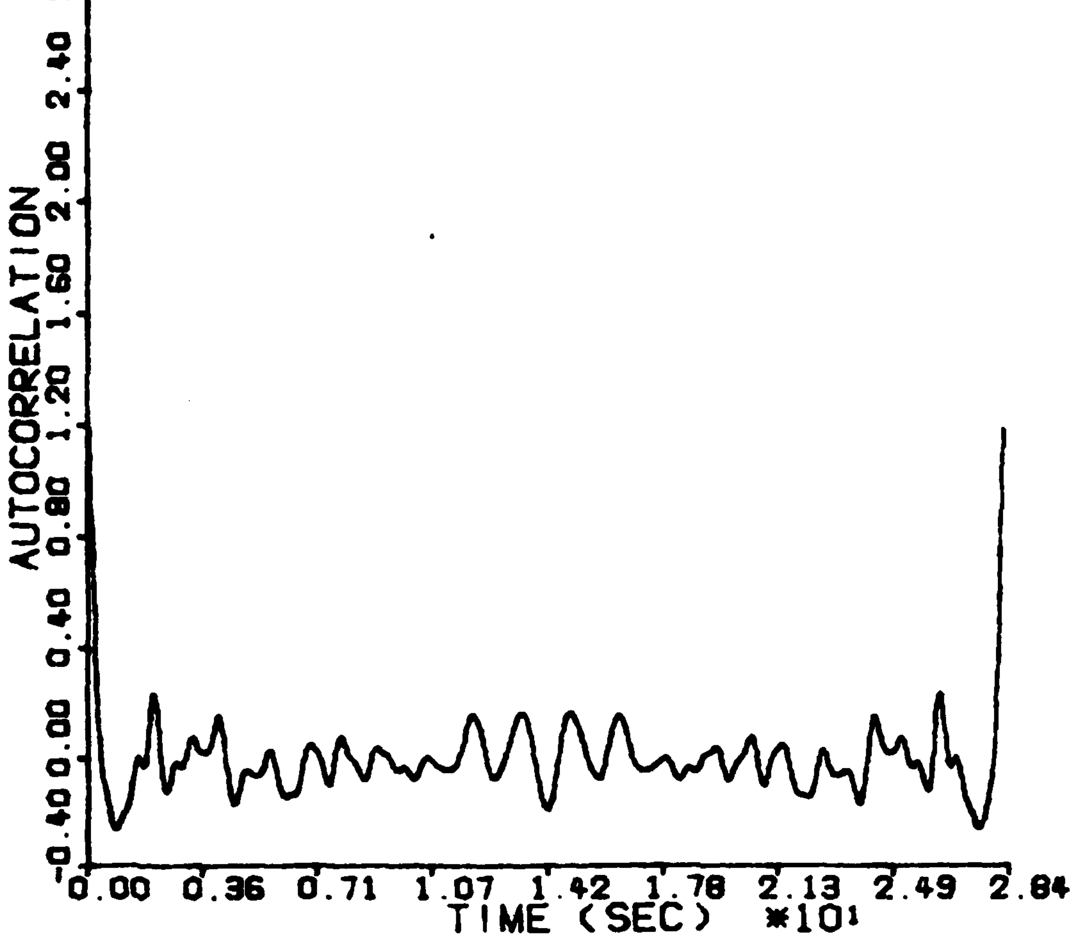


FIGURE 2.7

Autocorrelation of UHF Scintillations at 6 per second: Block 25

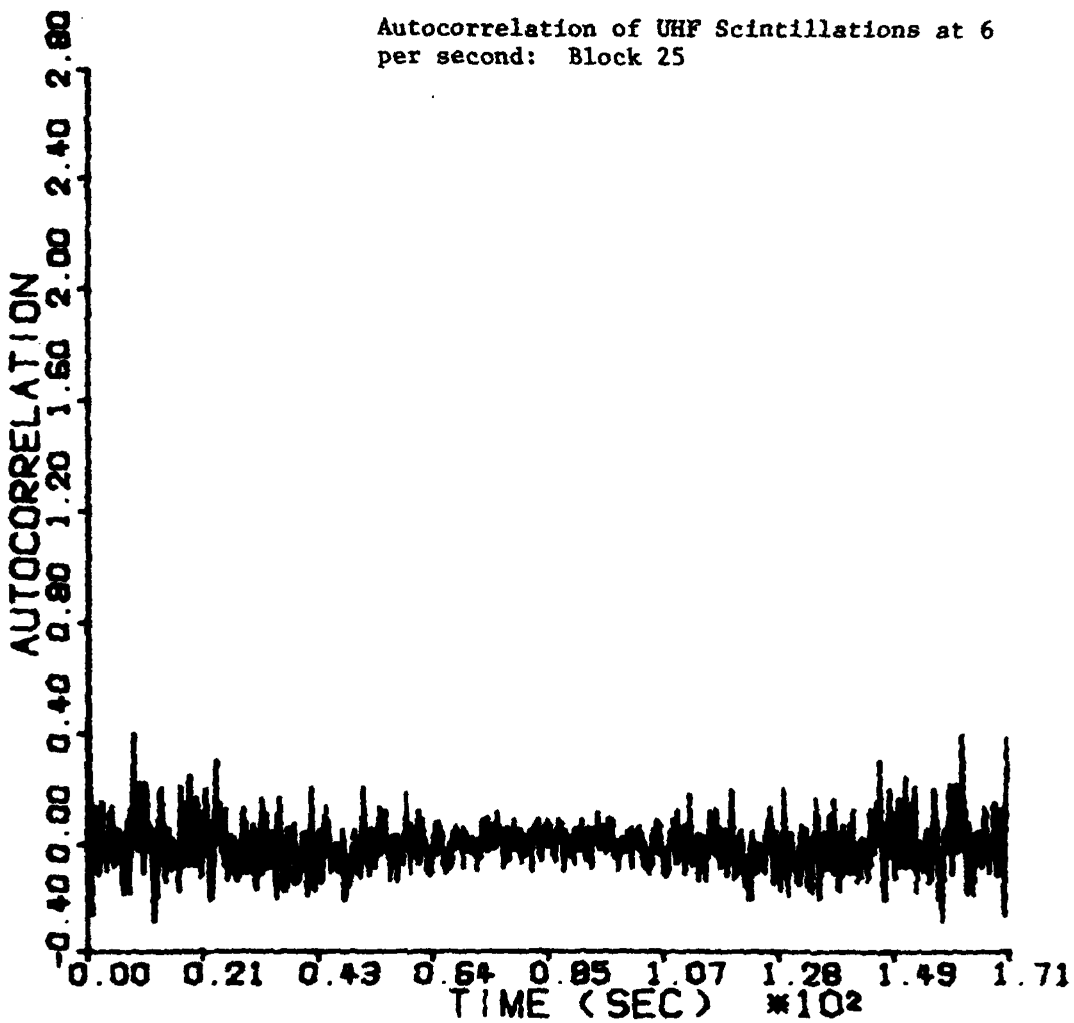


FIGURE 2.8

Autocorrelation of UHF Scintillations at
6 per second: Block 85

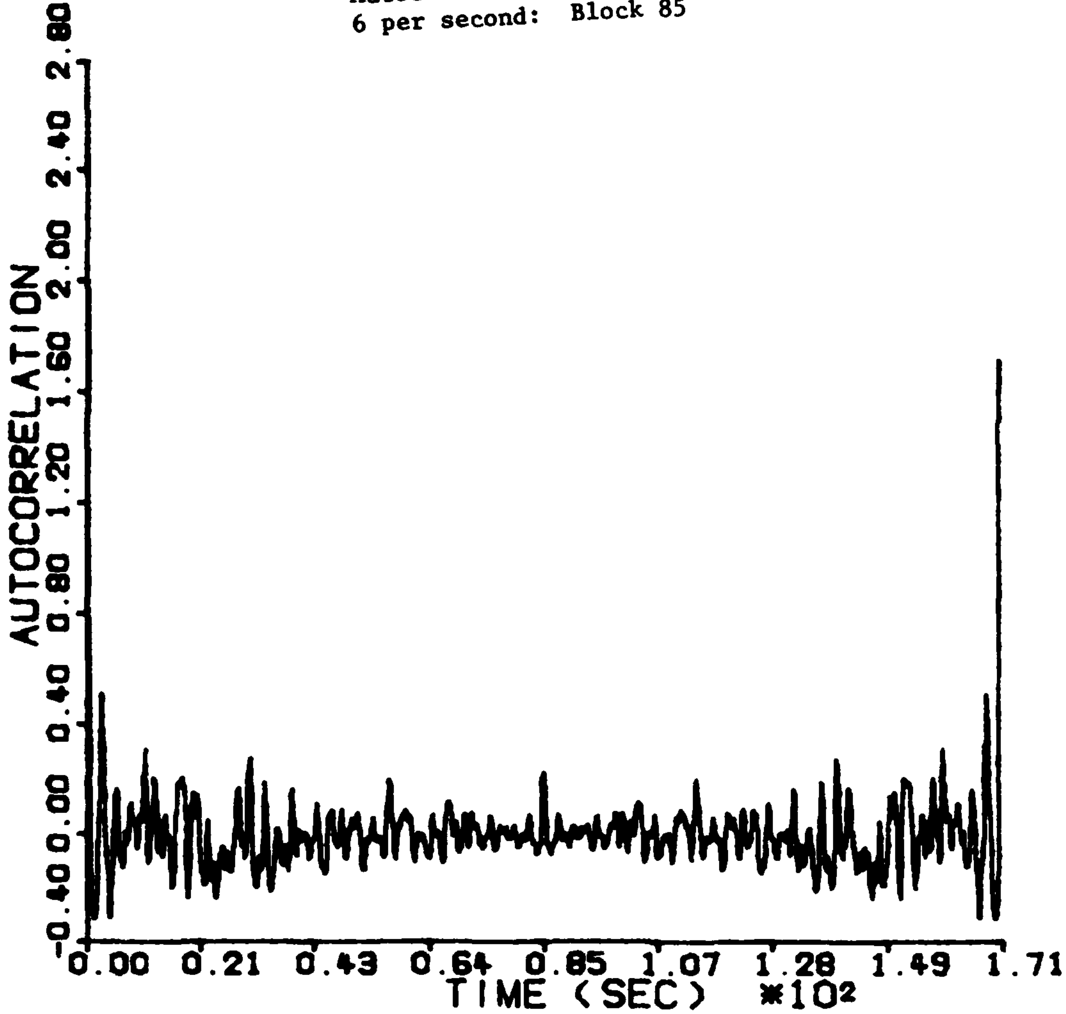


FIGURE 2.9

HISTOGRAM AND NAKAGAMI PDF

UHF BLOCK 25 S4 = 0.802

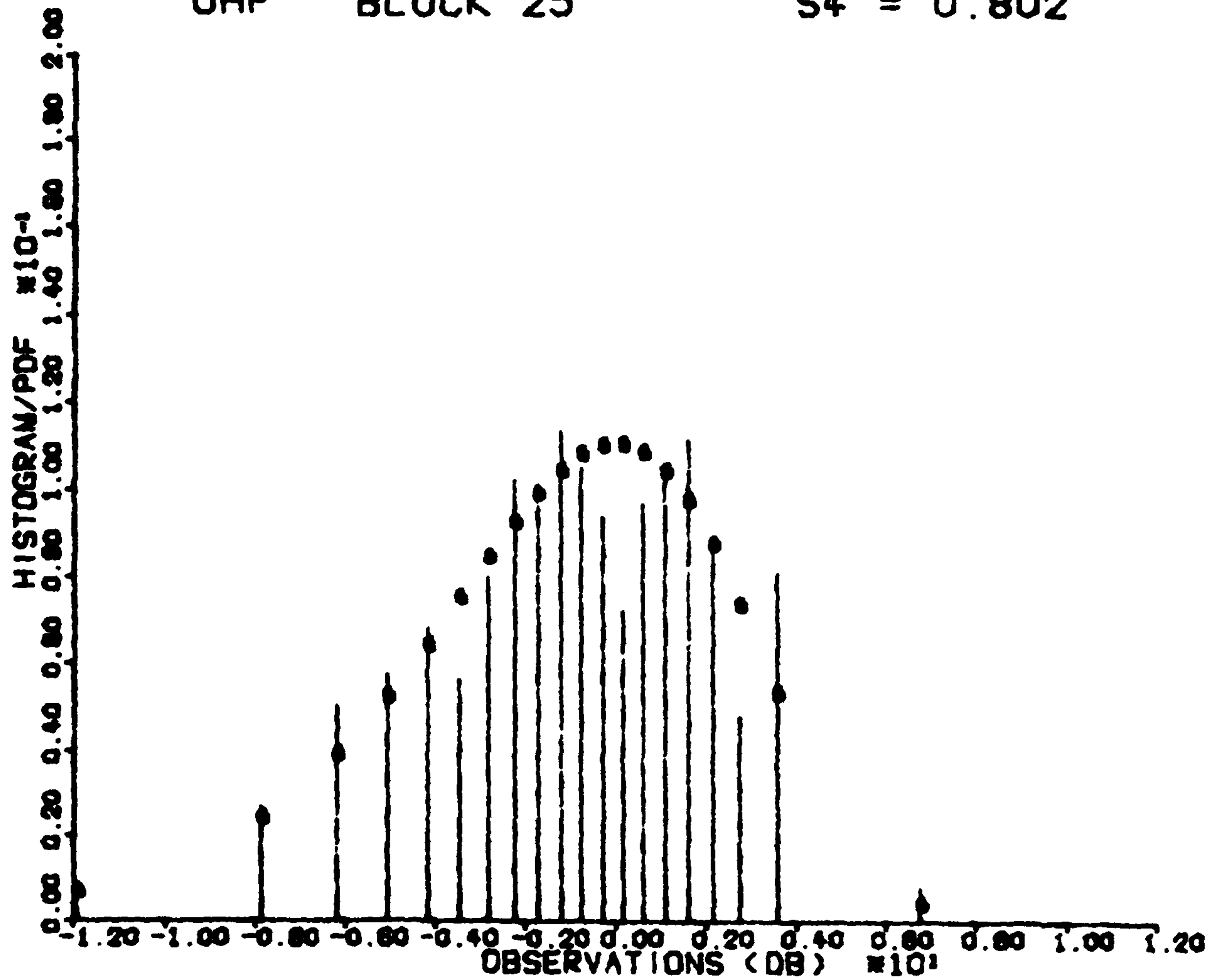


FIGURE 2.10

HISTOGRAM AND NAKAGAMI PDF

UHF BLOCK 55 S4 = 0.859

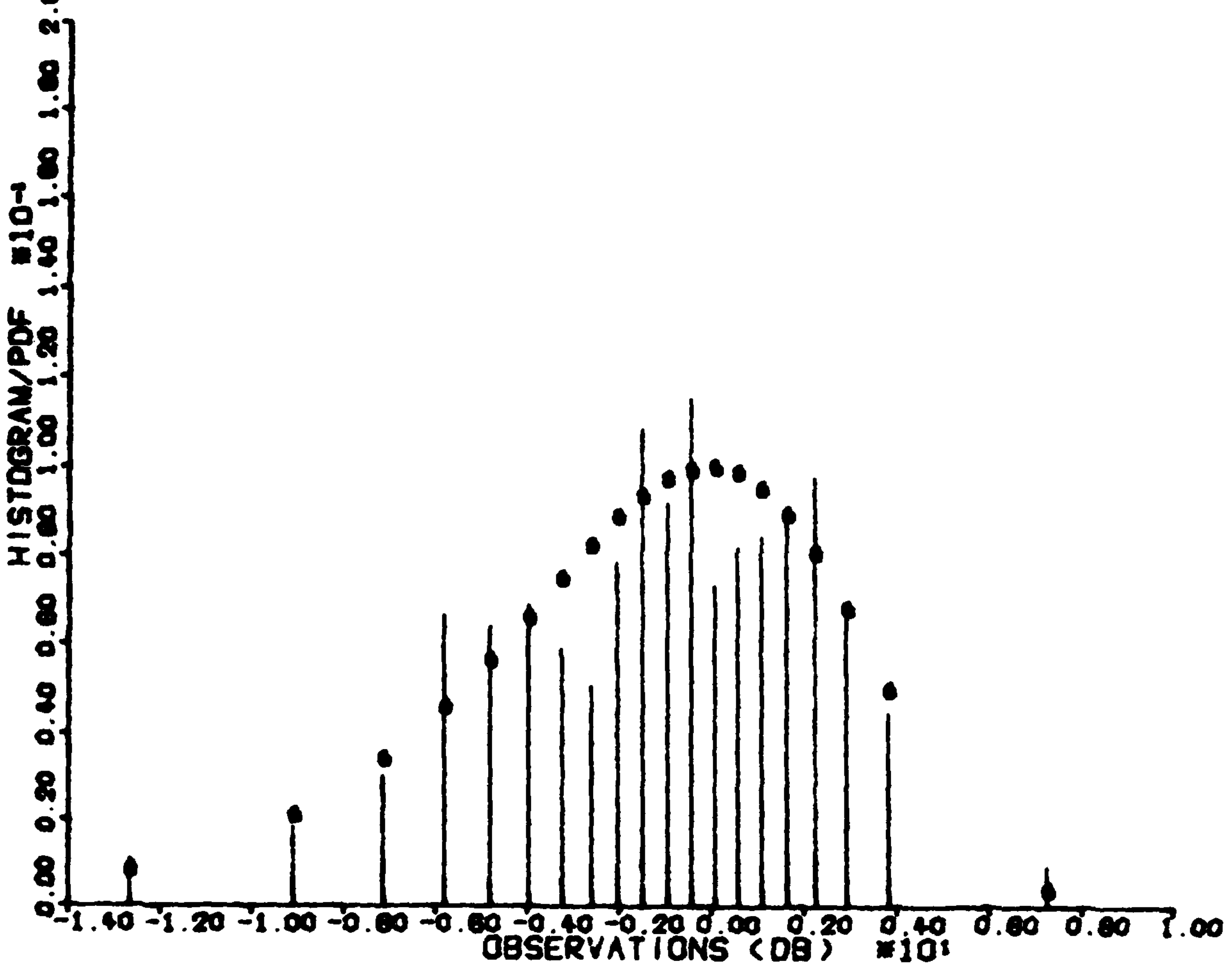


FIGURE 2.11

HISTOGRAM AND NAKAGAMI PDF
UHF BLOCK 85 S4 = 0.966

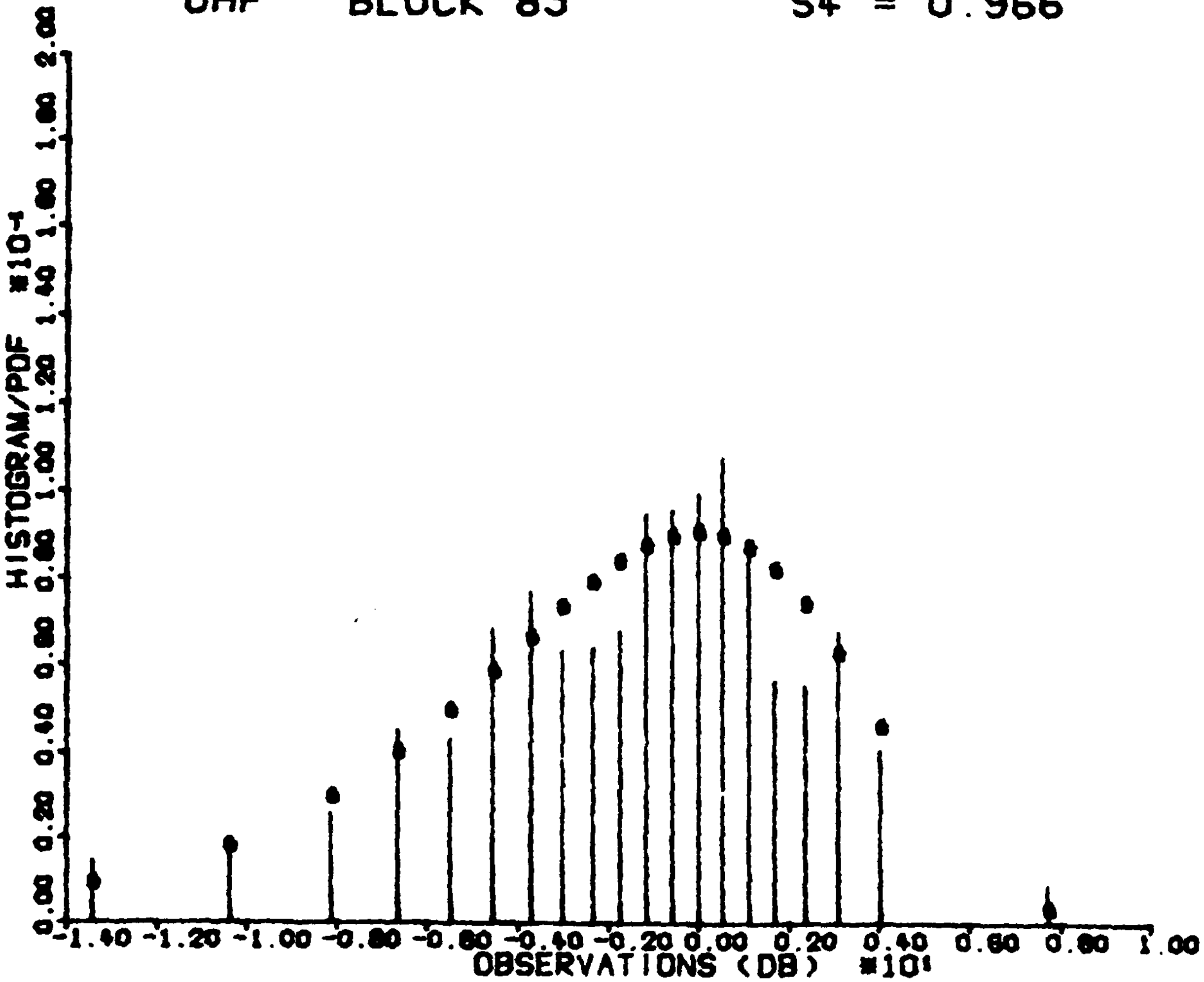


FIGURE 2.12

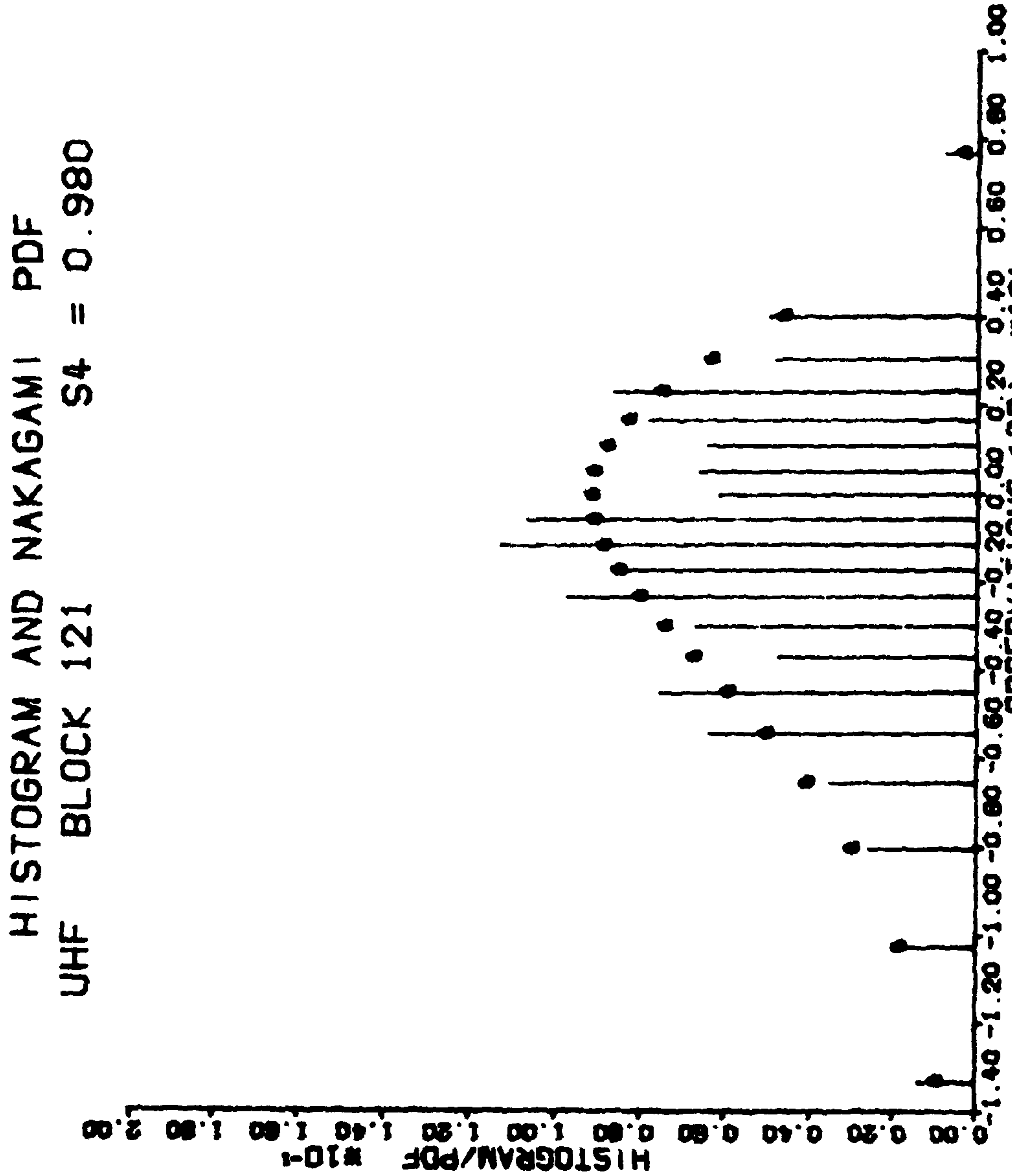

HISTOGRAM AND NAKAGAMI PDF
UHF BLOCK 121 S4 = 0.980
HISTOGRAM/PDF *10-1
0.00 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00
-1.40 -1.20 -1.00 -0.80 -0.60 -0.40 -0.20 0.00 0.20 0.40 0.60 0.80 1.00
OBSERVATIONS (DB) *101

FIGURE 2.13

HISTOGRAM AND NAKAGAMI PDF
UHF BLOCK 145 S4 = 0.916

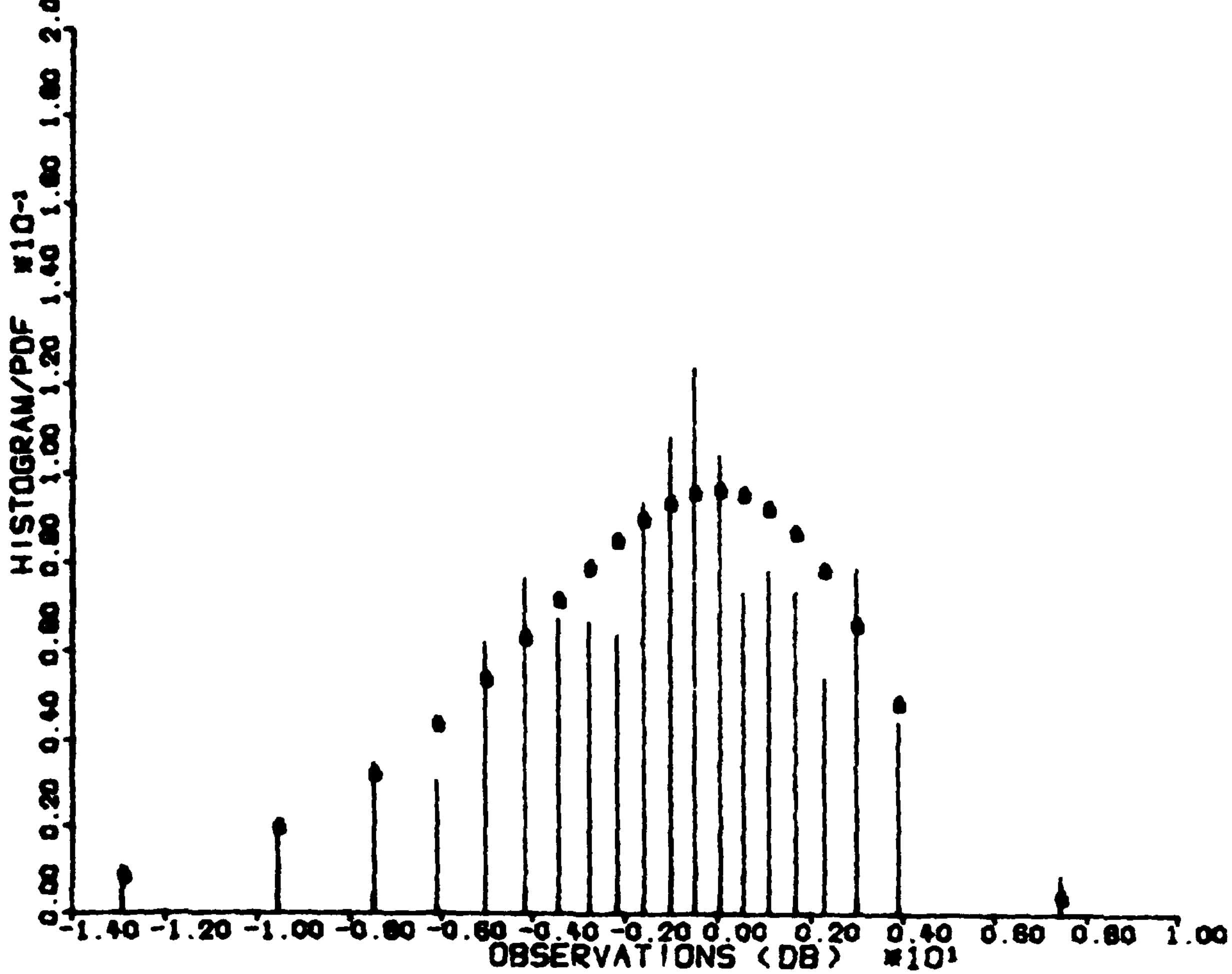


FIGURE 2.14

UHF /NAKAGAMI CDF PLOTS: BLOCK 25

S4 = 0.802 90 % CONF. INTERVALS SHOWN

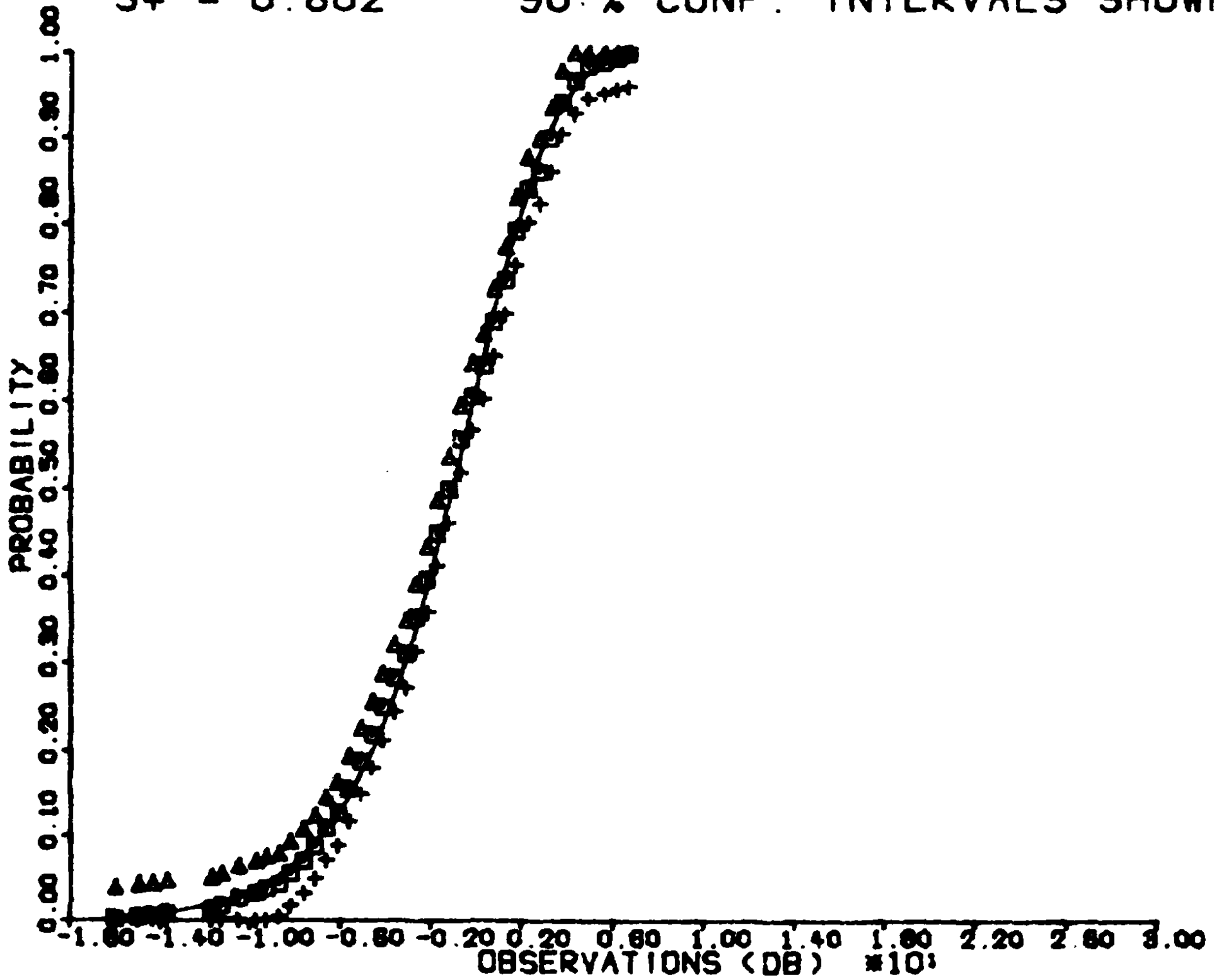


FIGURE 2.15

UHF /NAKAGAMI CDF PLOTS: BLOCK 55

S4 = 0.859 90 % CONF. INTERVALS SHOWN

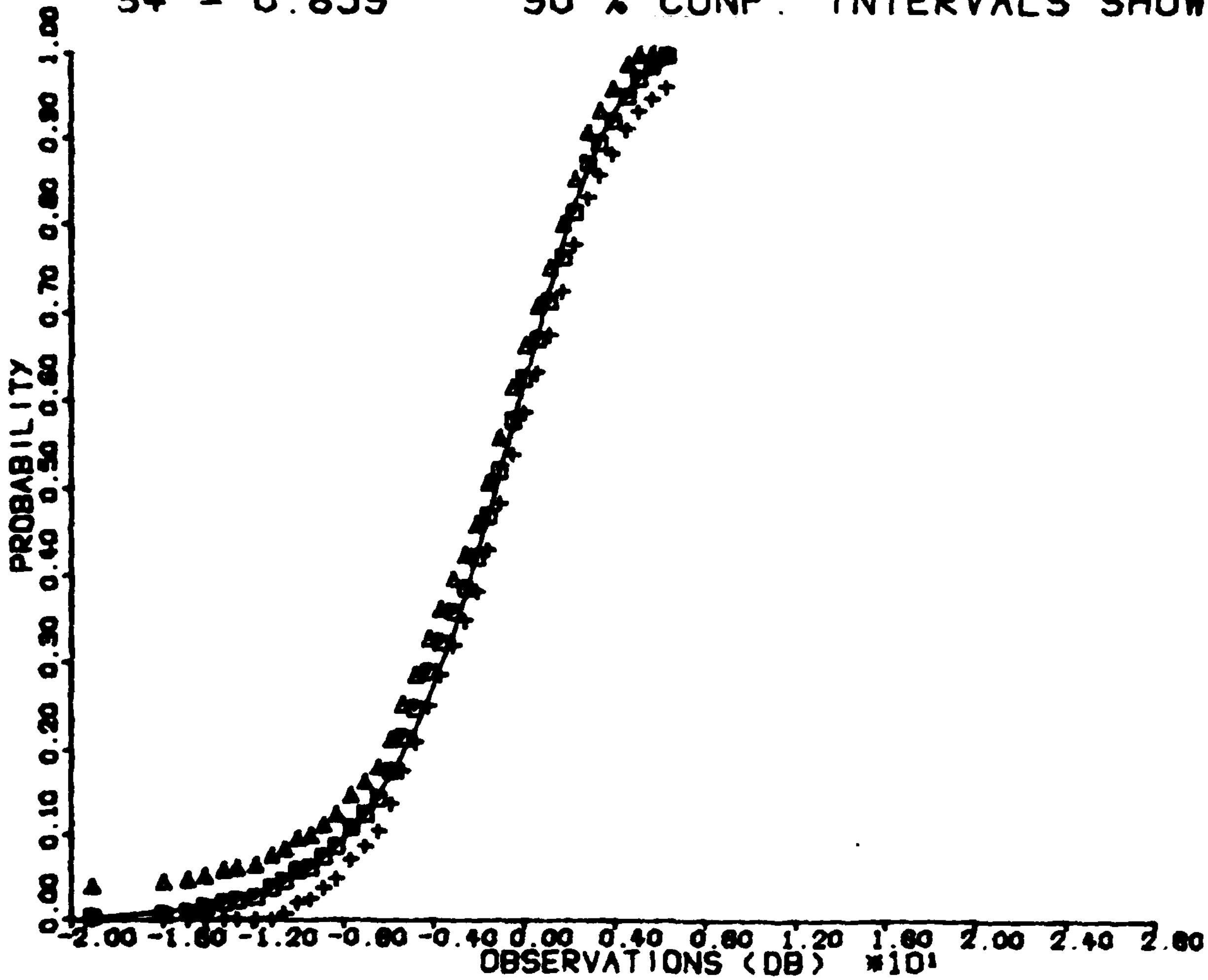
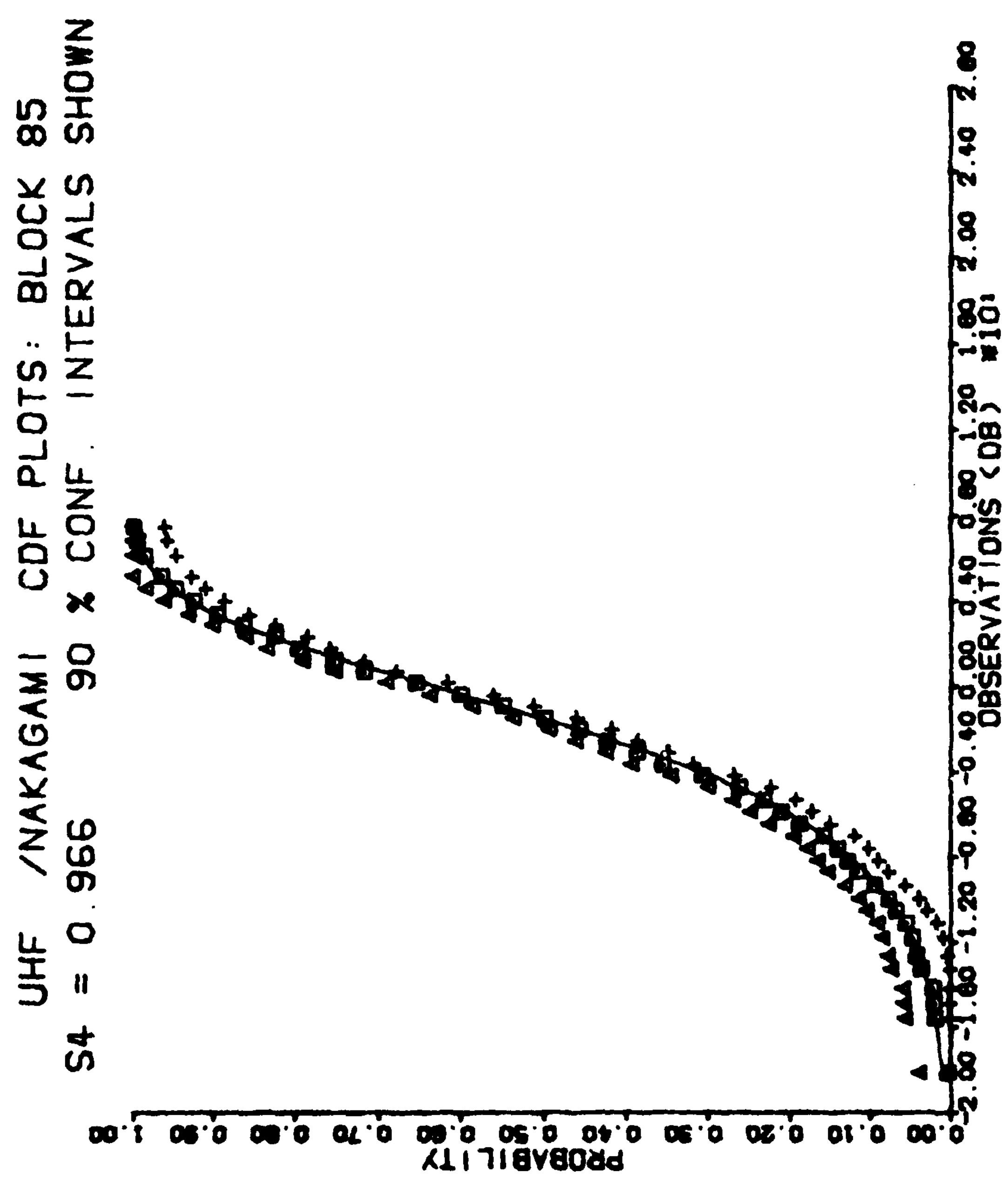


FIGURE 2.16



UHF /NAKAGAMI CDF PLOTS: BLOCK 85
S4 = 0.966 90 % CONF. INTERVALS SHOWN
PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
OBSERVATIONS (DB) *10¹
-2.00 -1.60 -1.20 -0.80 -0.40 0.00 0.40 0.80 1.20 1.60 2.00 2.40 2.80

FIGURE 2.17

UHF /NAKAGAMI CDF PLOTS: BLOCK 121

S4 = 0.980 95 % CONF. INTERVALS SHOWN

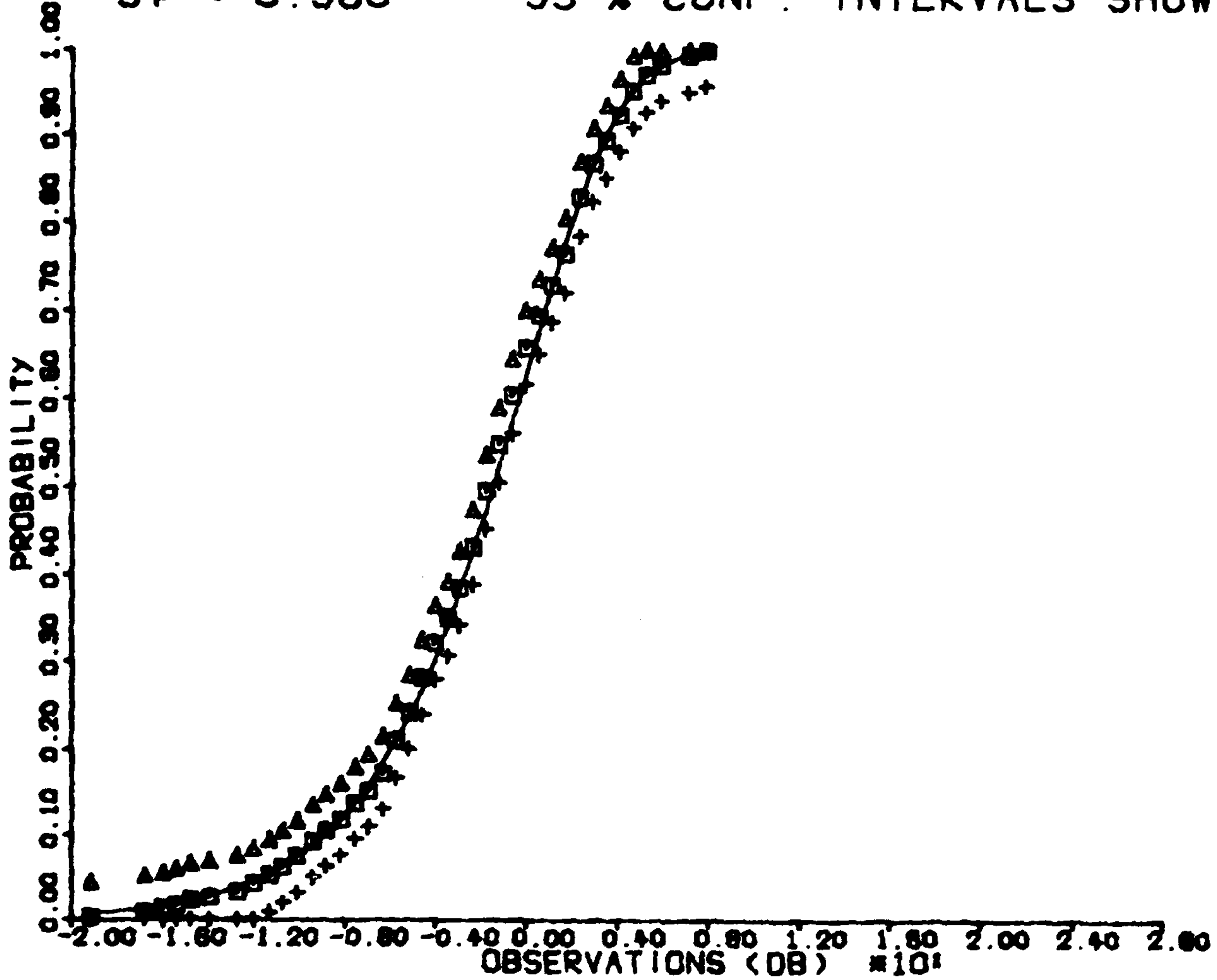


FIGURE 2.18

UHF /NAKAGAMI CDF PLOTS: BLOCK 145

S4 = 0.916 90 % CONF. INTERVALS SHOWN

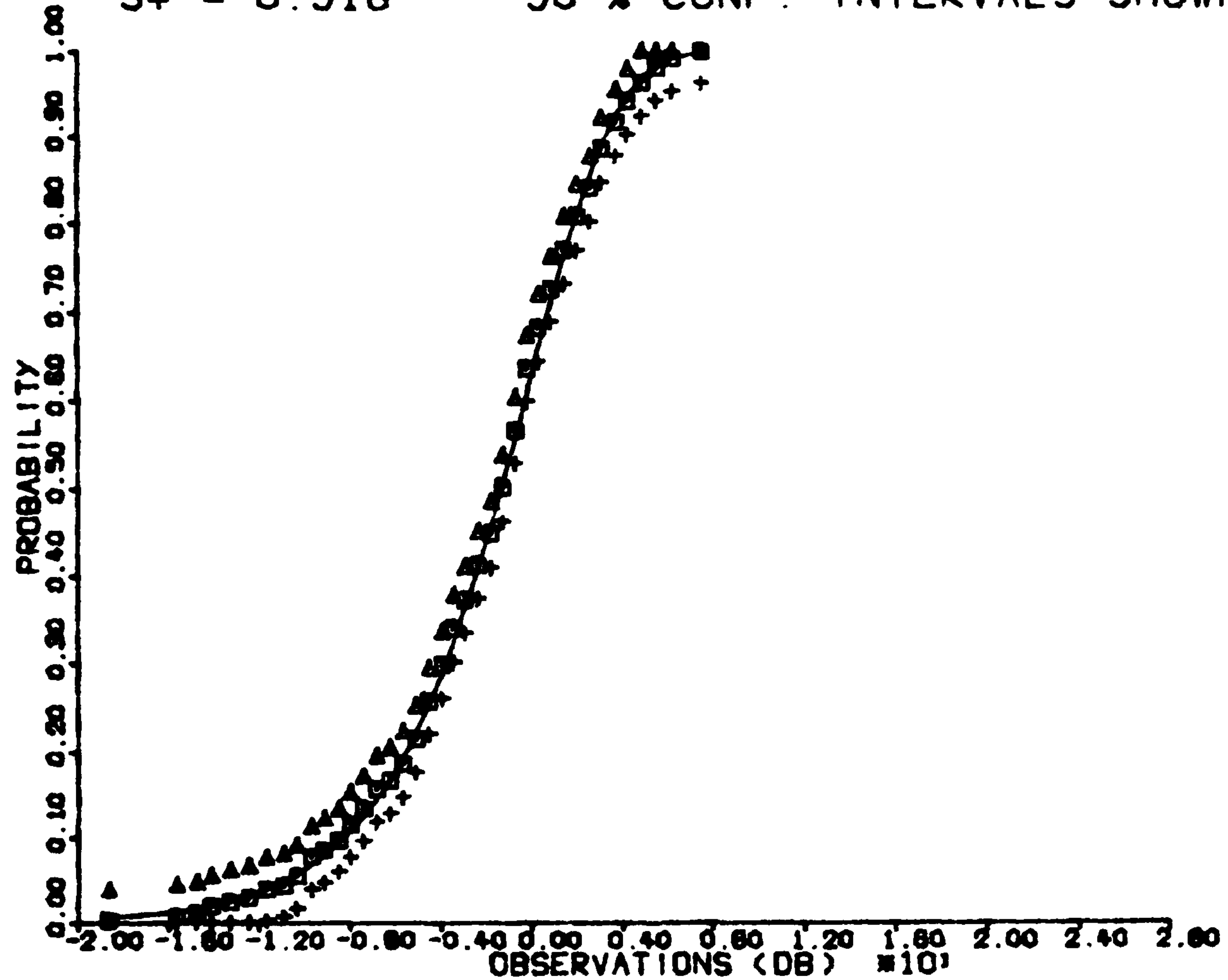


FIGURE 2.19

UHF /NAKAGAMI PROBABILITY PLOTS: BLOCK 25
S4 = 0.802 LEAST SQUARES LINE SHOWN

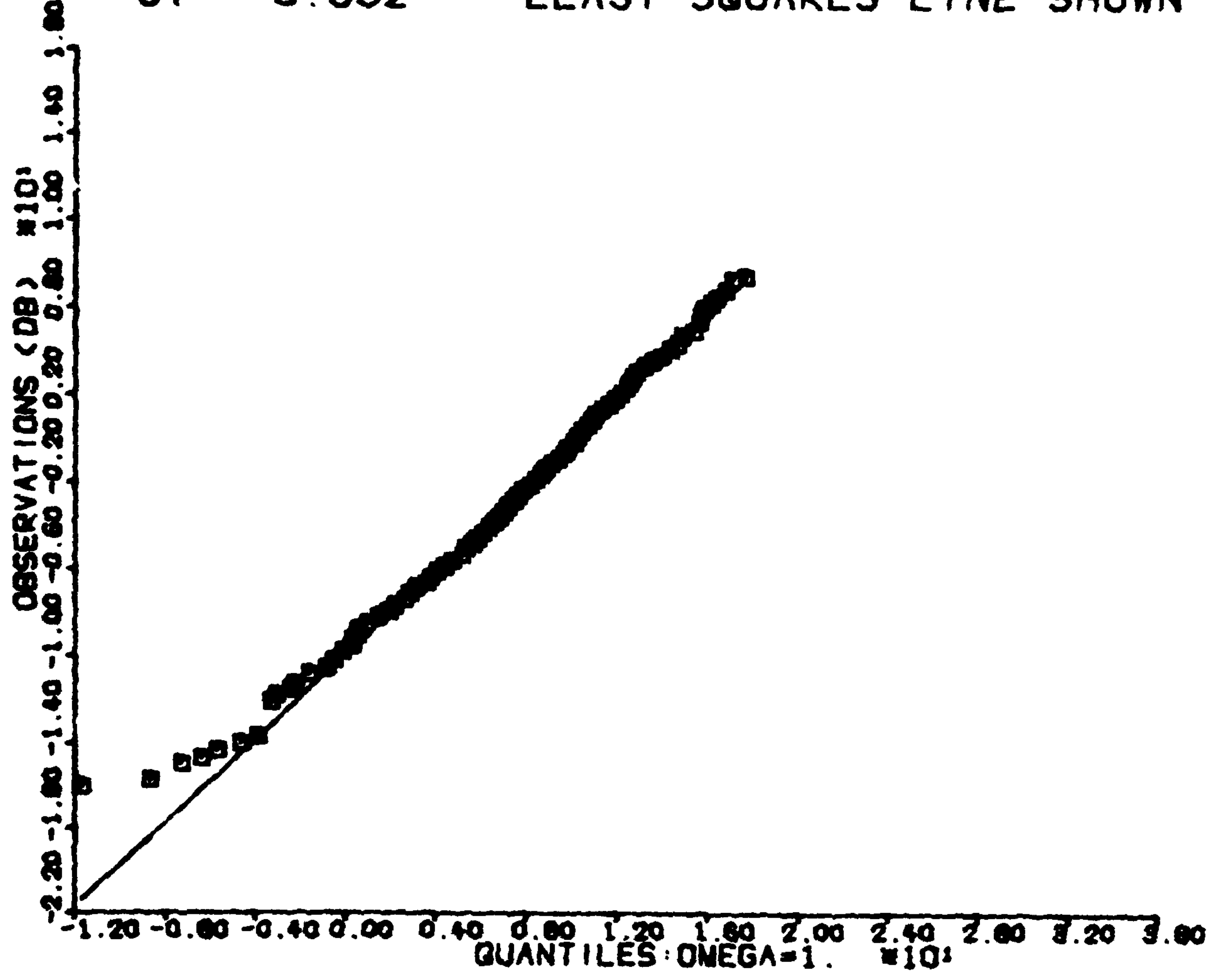


FIGURE 2.20

UHF /NAKAGAMI PROBABILITY PLOTS: BLOCK 55
S4 = 0.859 LEAST SQUARES LINE SHOWN

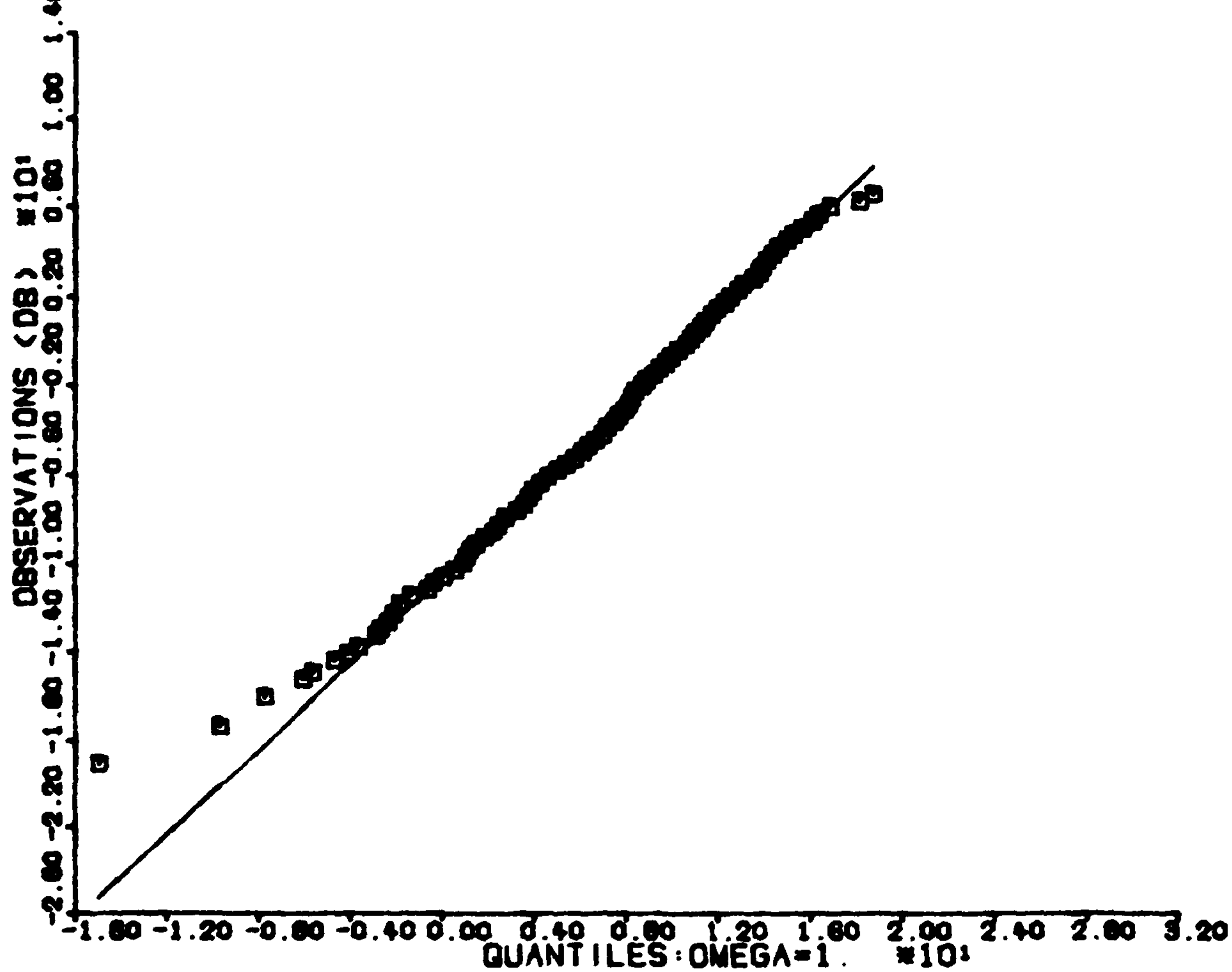
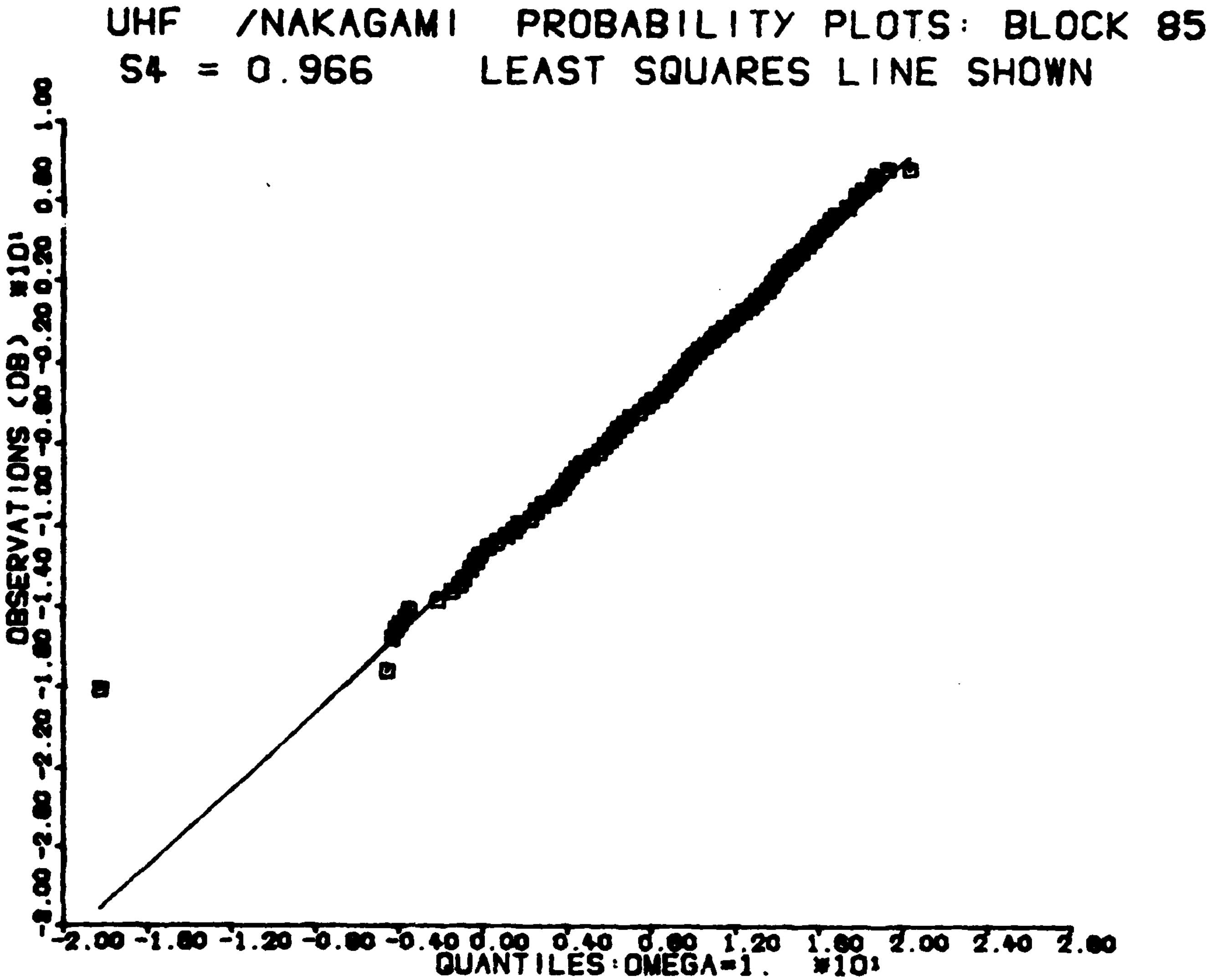


FIGURE 2.21



UHF /NAKAGAMI PROBABILITY PLOTS: BLOCK 85
S4 = 0.966 LEAST SQUARES LINE SHOWN
OBSERVATIONS (DB) *10¹
-3.00 -2.60 -2.20 -1.80 -1.40 -1.00 -0.60 -0.20 0.20 0.60 1.00
-2.00 -1.60 -1.20 -0.80 -0.40 0.00 0.40 0.80 1.20 1.60 2.00 2.40 2.80
QUANTILES:OMEGA=1. *10¹

FIGURE 2.22

UHF /NAKAGAMI PROBABILITY PLOTS: BLOCK 121
S4 = 0.980 LEAST SQUARES LINE SHOWN

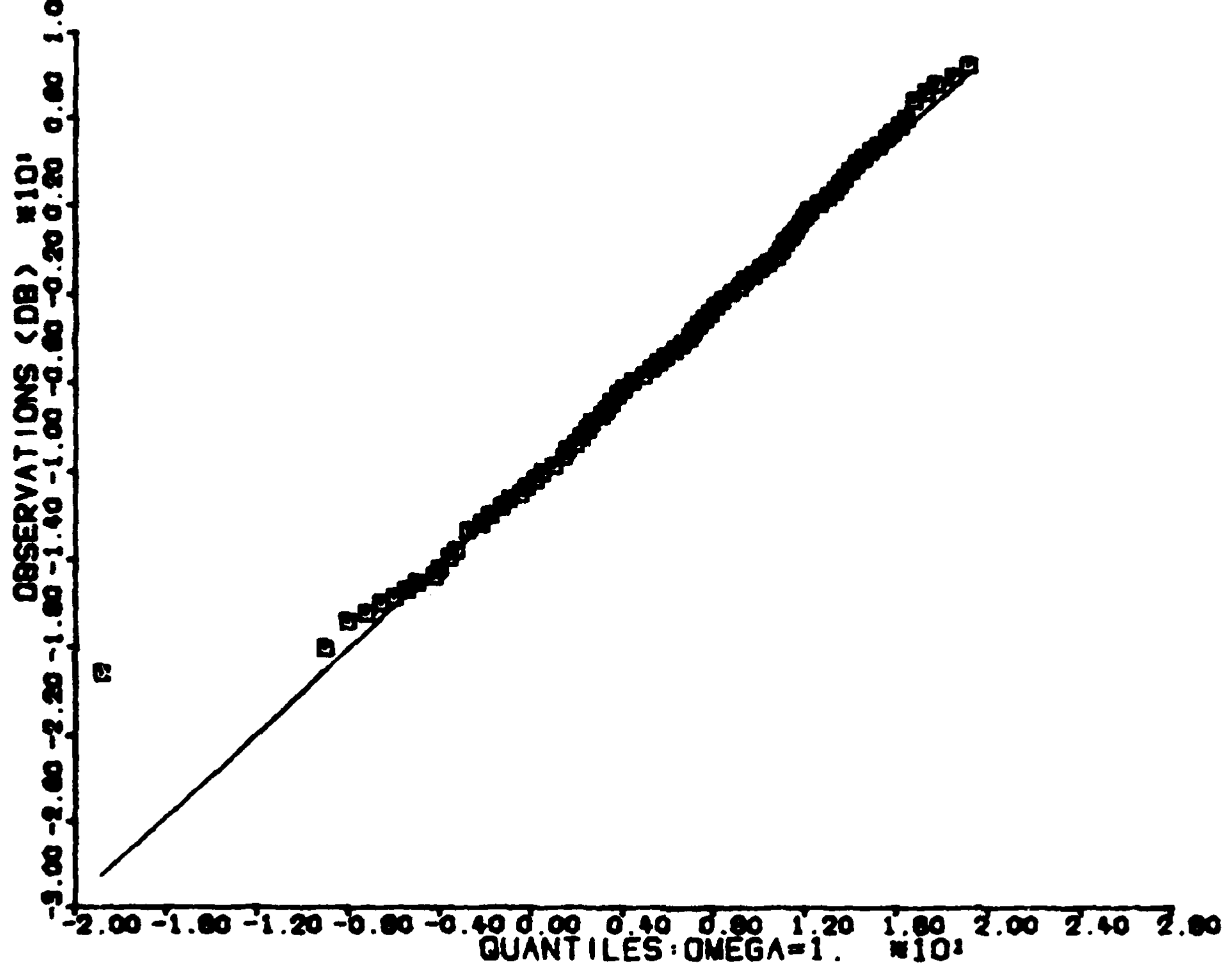


FIGURE 2.23

UHF /NAKAGAMI PROBABILITY PLOTS: BLOCK 145

S4 = 0.916 LEAST SQUARES LINE SHOWN

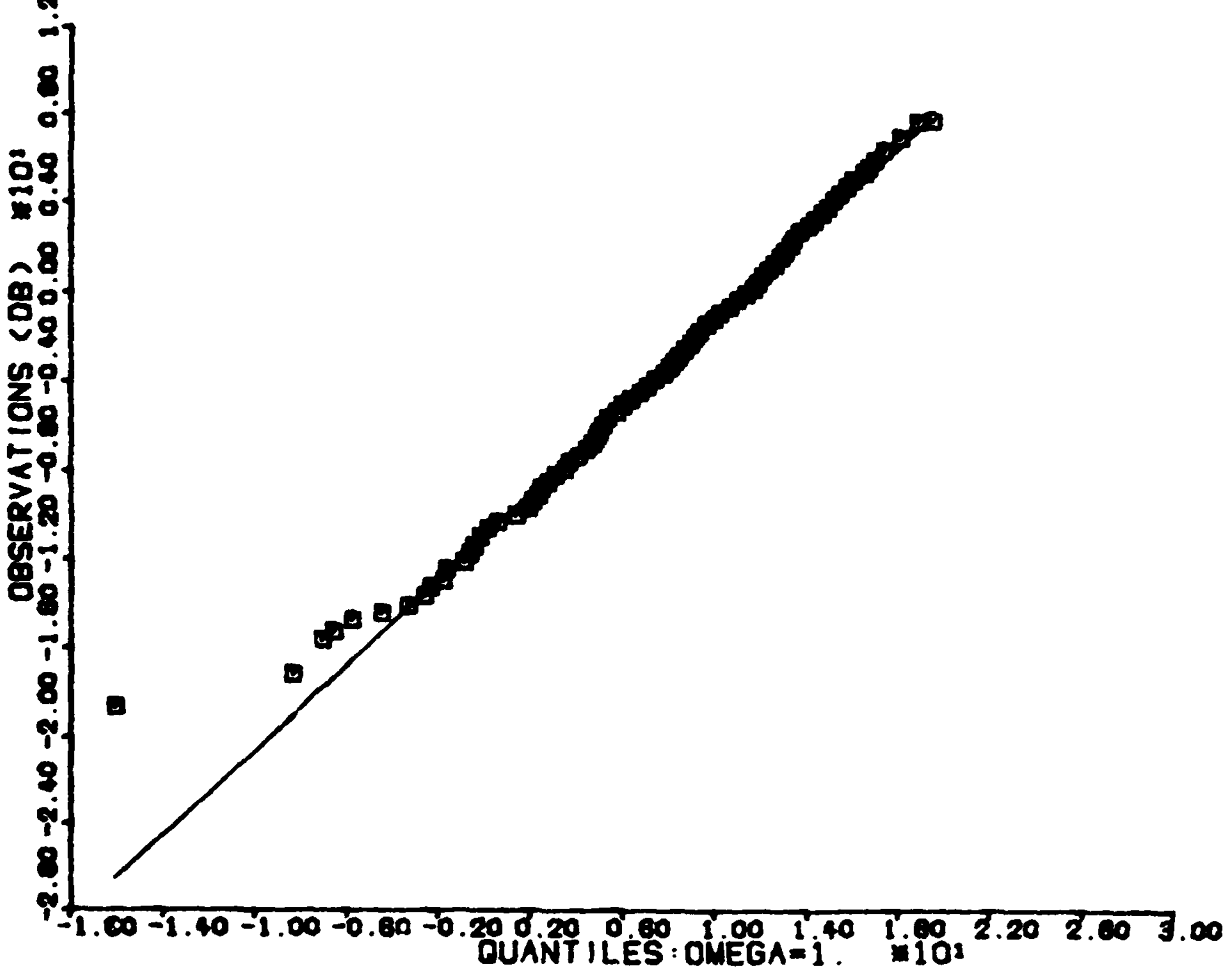


FIGURE 3.1

Power Spectrum of *L-Band Scintillations* at 36 per second: Block 25

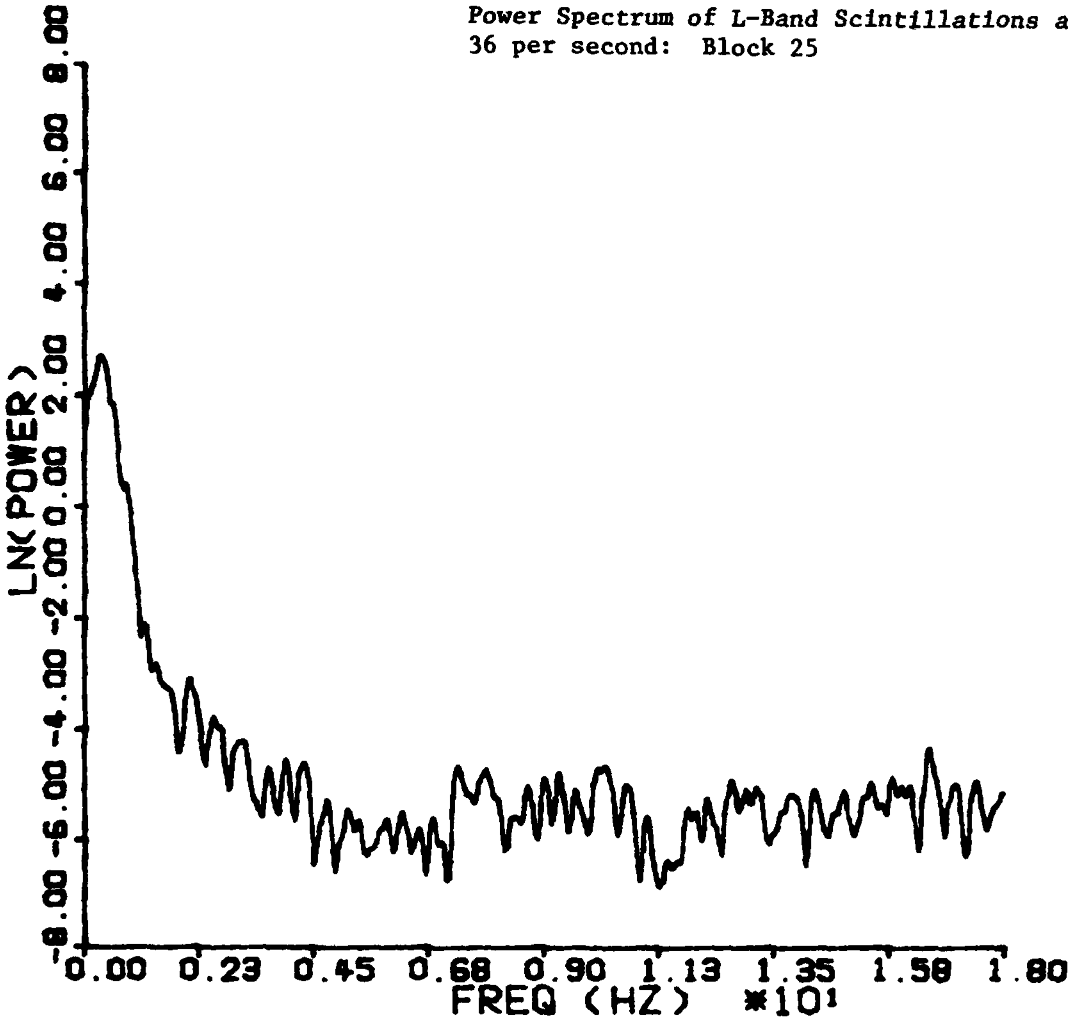


FIGURE 3.2

Power Spectrum of L-Band Scintillations at
36 per second: Block 85

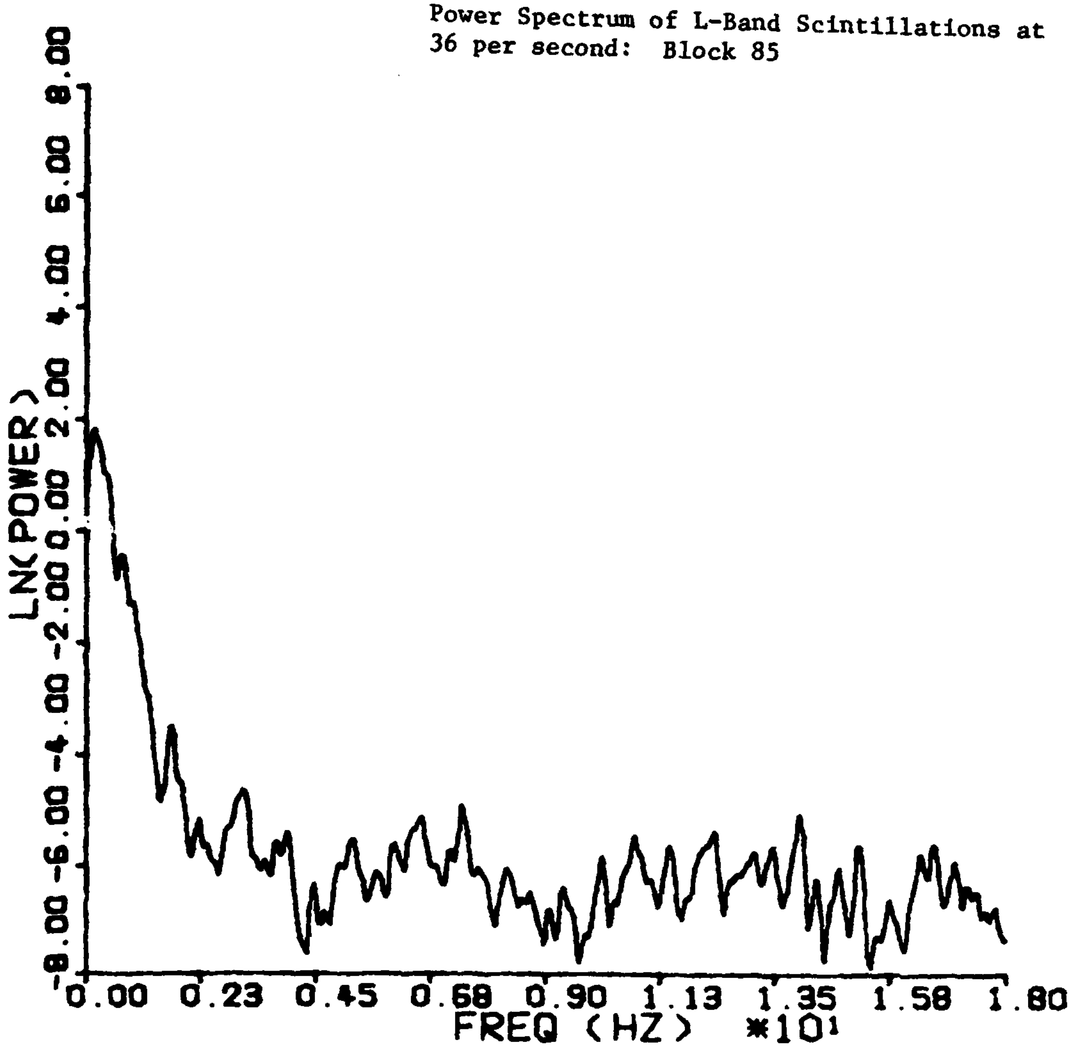


FIGURE 3.3

Power Spectrum of L-Band Scintillations at
6 per second: Block 25

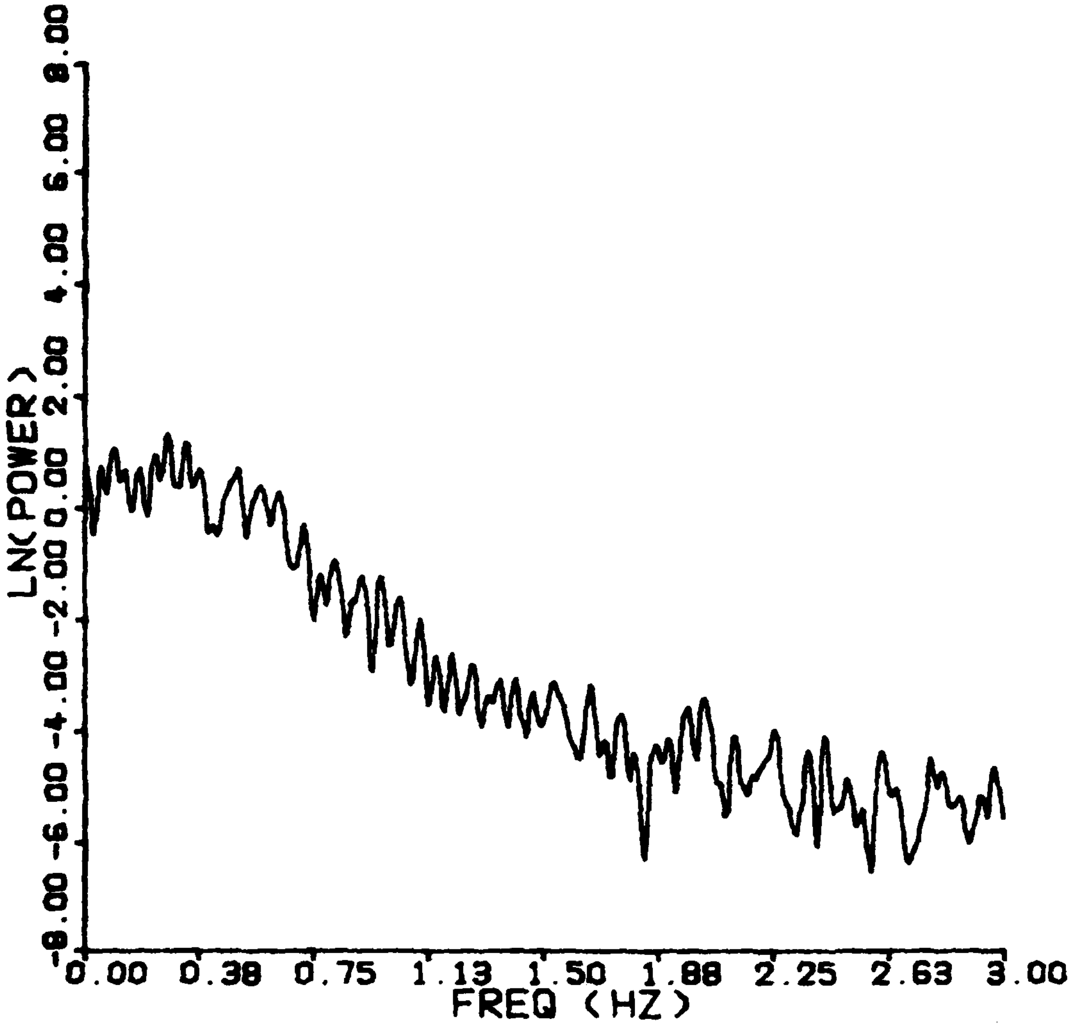


FIGURE 3.4

Power Spectrum of L-Band Scintillations at 6 per second: Block 85

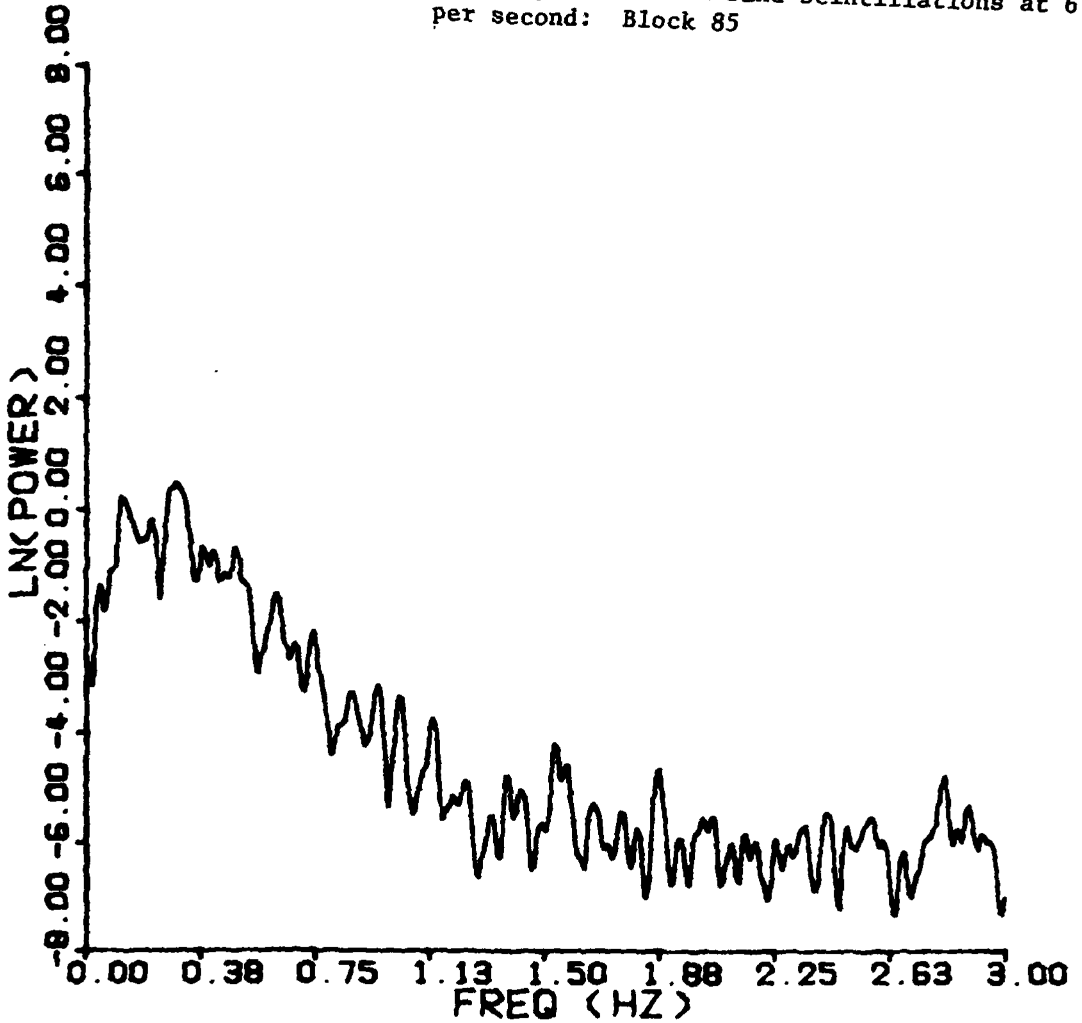
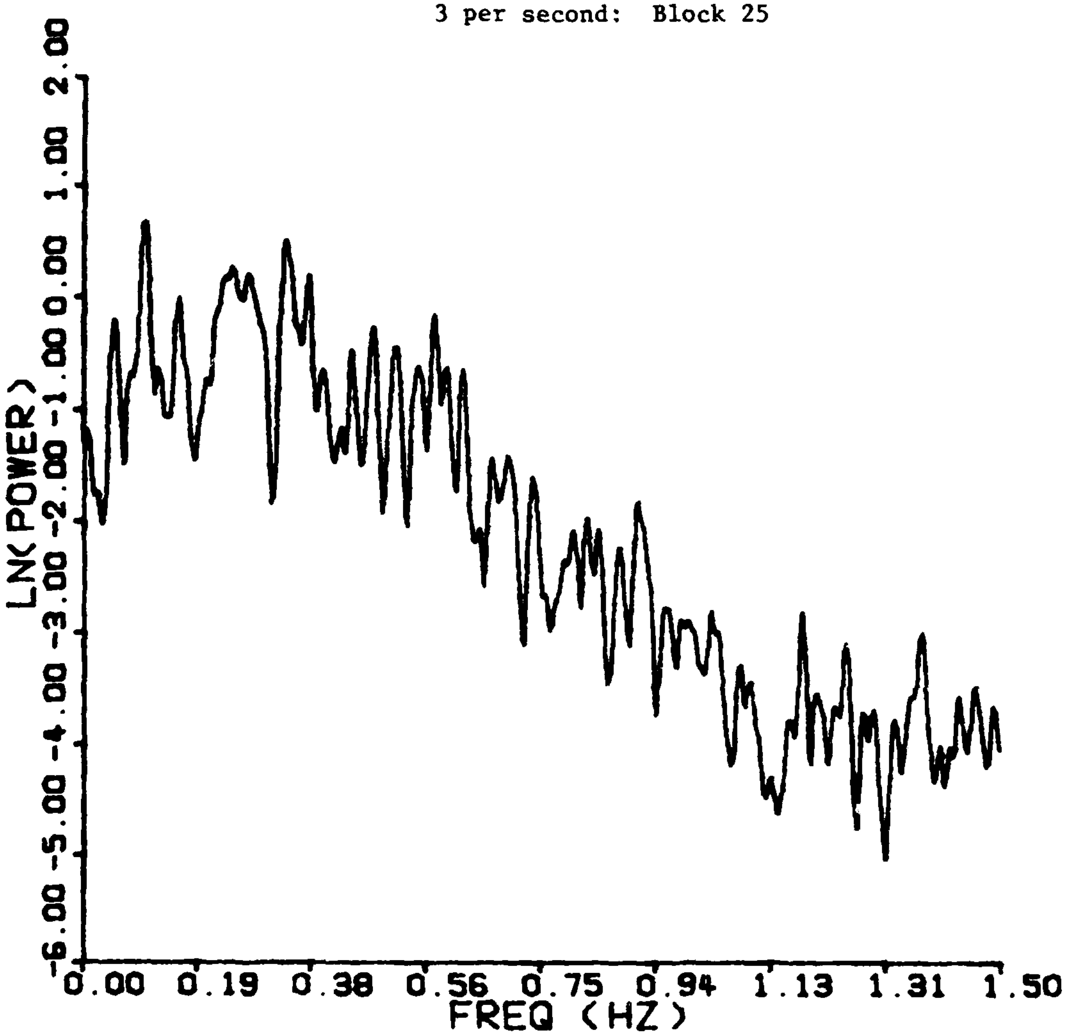


FIGURE 3.5

Power Spectrum of L-Band Scintillations at 3 per second: Block 25



AD-A111 831 BEDFORD RESEARCH ASSOCIATES MA F/G 20/14

STATISTICAL ANALYSIS OF SCINTILLATION DATA,(U)

SEP 81 S CHUA, J P NOONAN, S BASU F19628-80-C-0216

UNCLASSIFIED SCIENTIFIC-1 NL

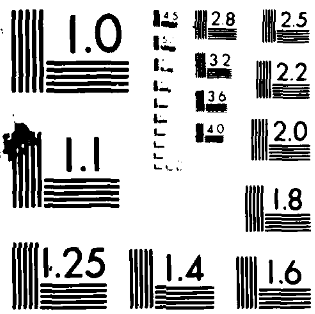
2 - 2

END

DATE FILMED

4 82

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

FIGURE 3.6

Power Spectrum of L-Band Scintillations at 1.5 per second: Block 25

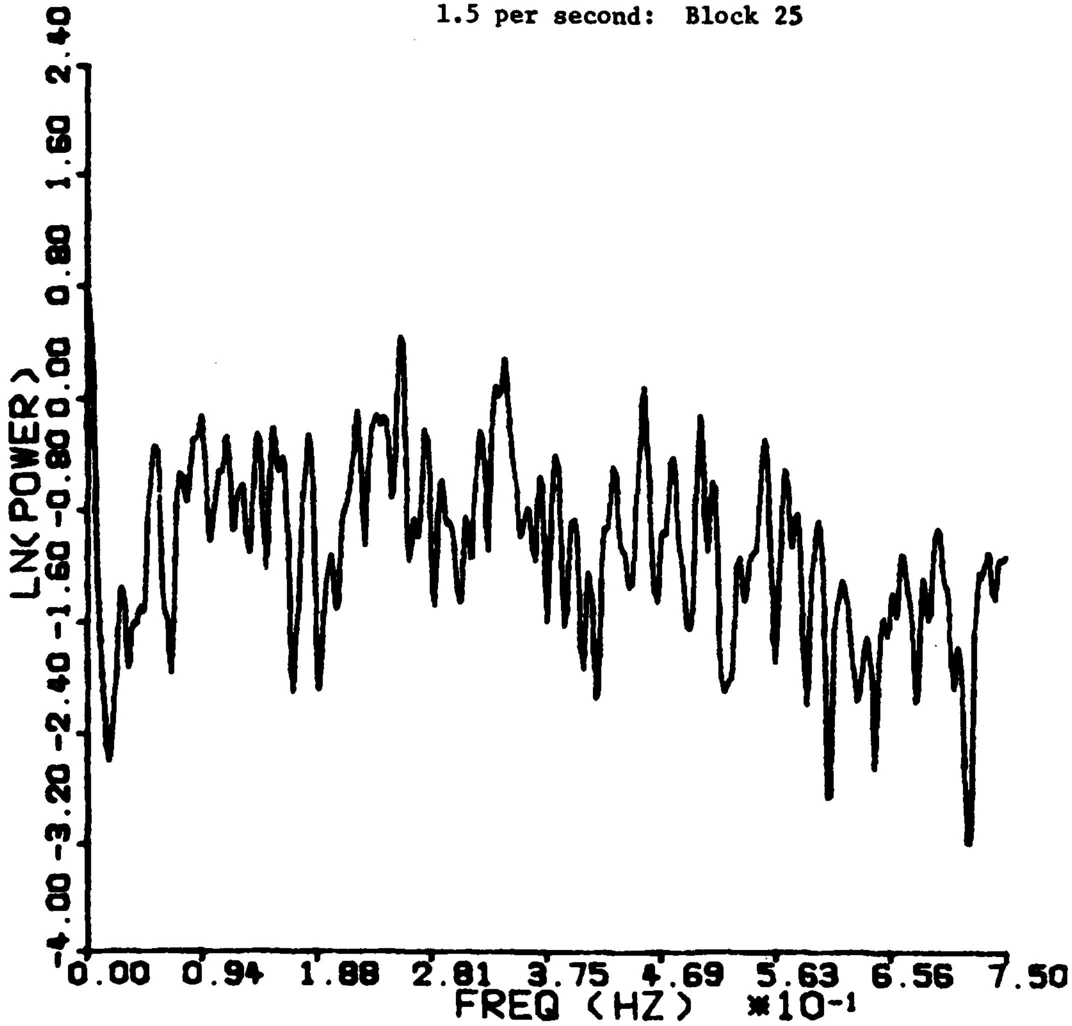


FIGURE 3.7

Power Spectrum of L-Band Scintillations at
1.5 per second: Block 73

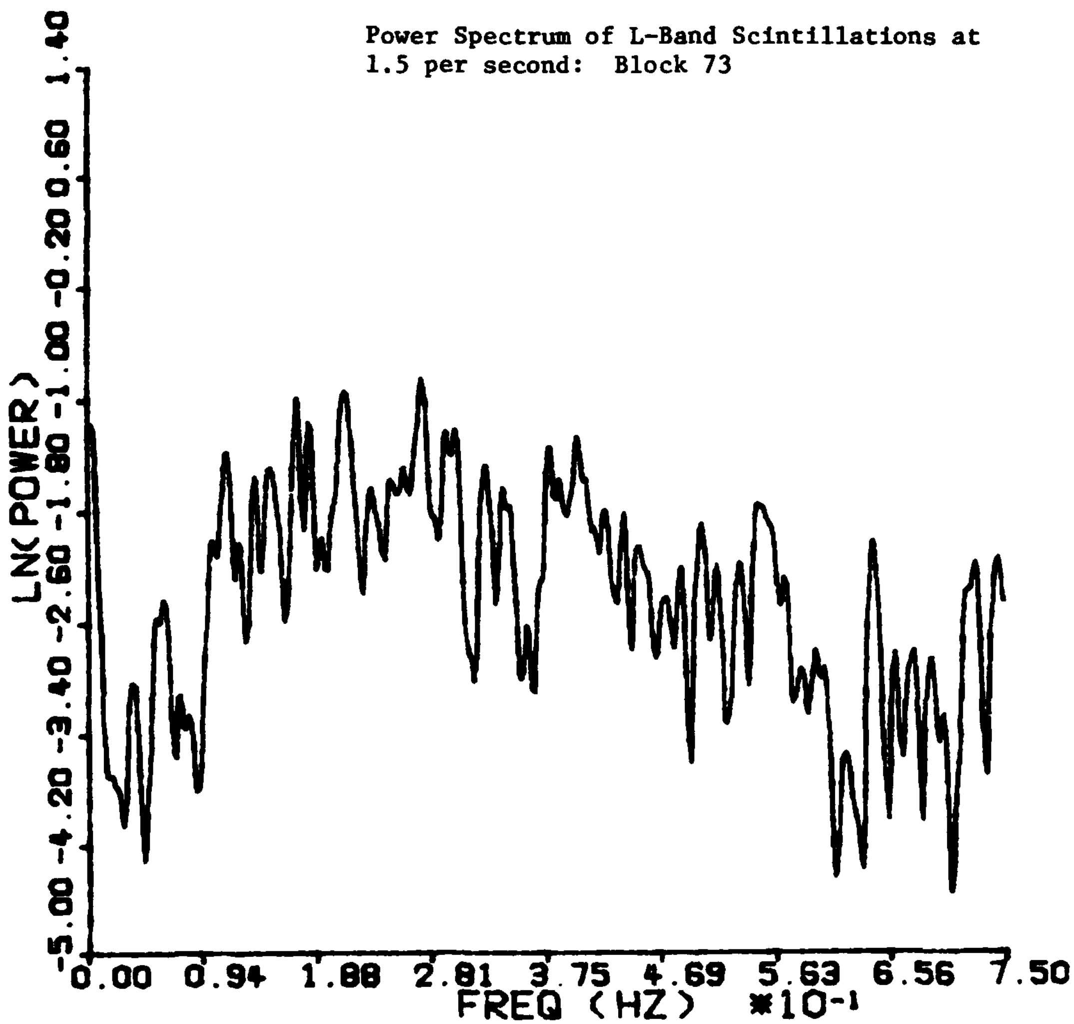


FIGURE 3.8

Autocorrelation of L-Band Scintillations at 36 per second: Block 25

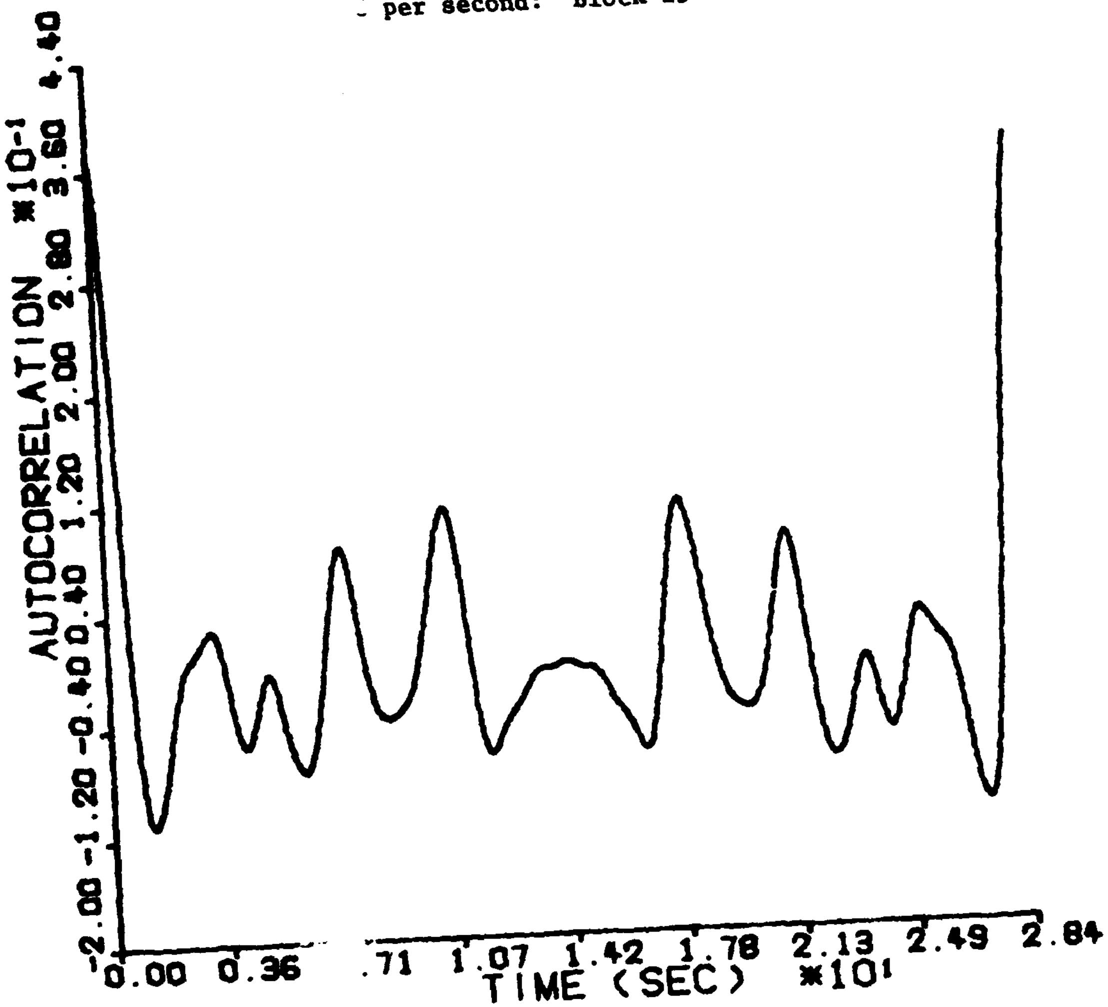


FIGURE 3.9

Autocorrelation of L-Band Scintillations at 6 per second: Block 25

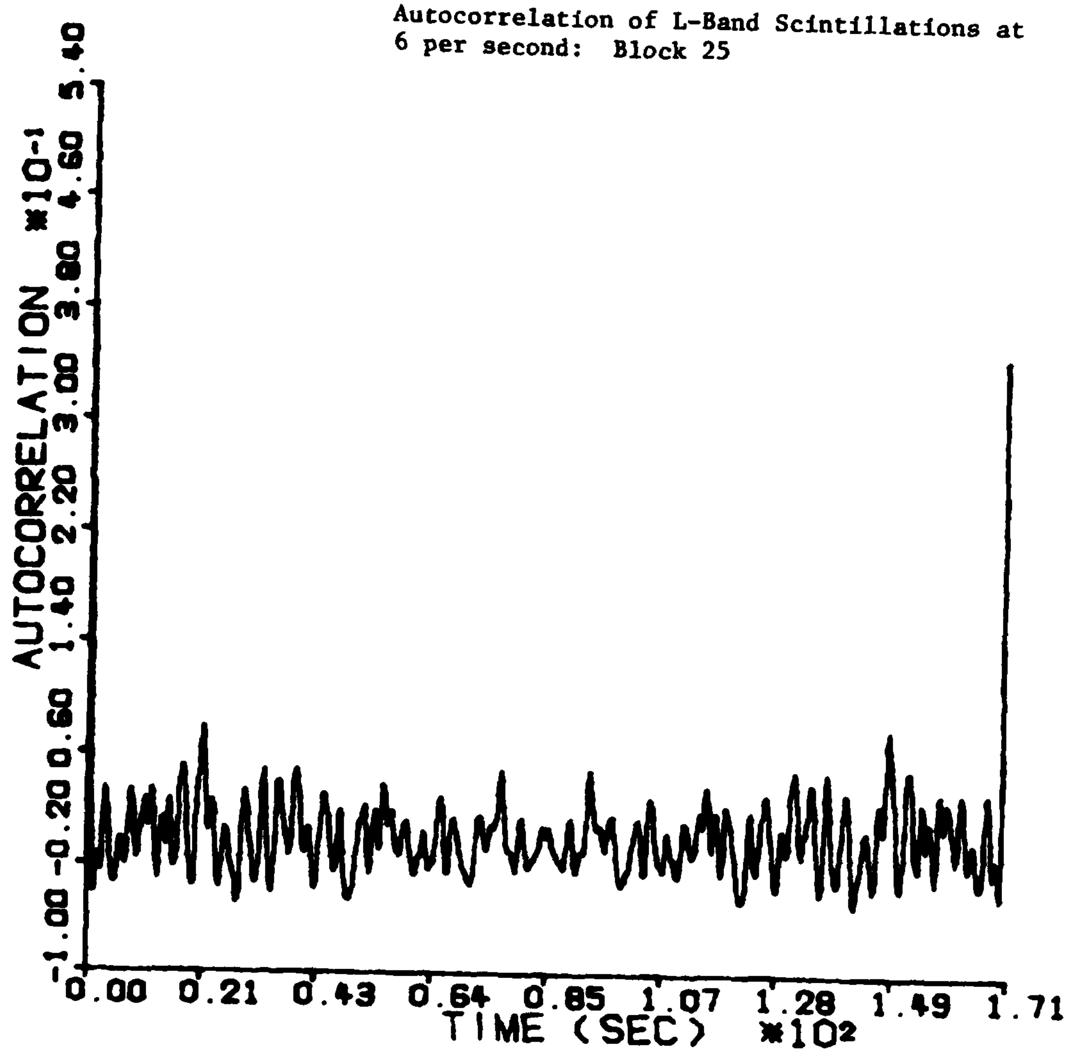


FIGURE 3.10

Autocorrelation of L-Band Scintillations at
3 per second: Block 25

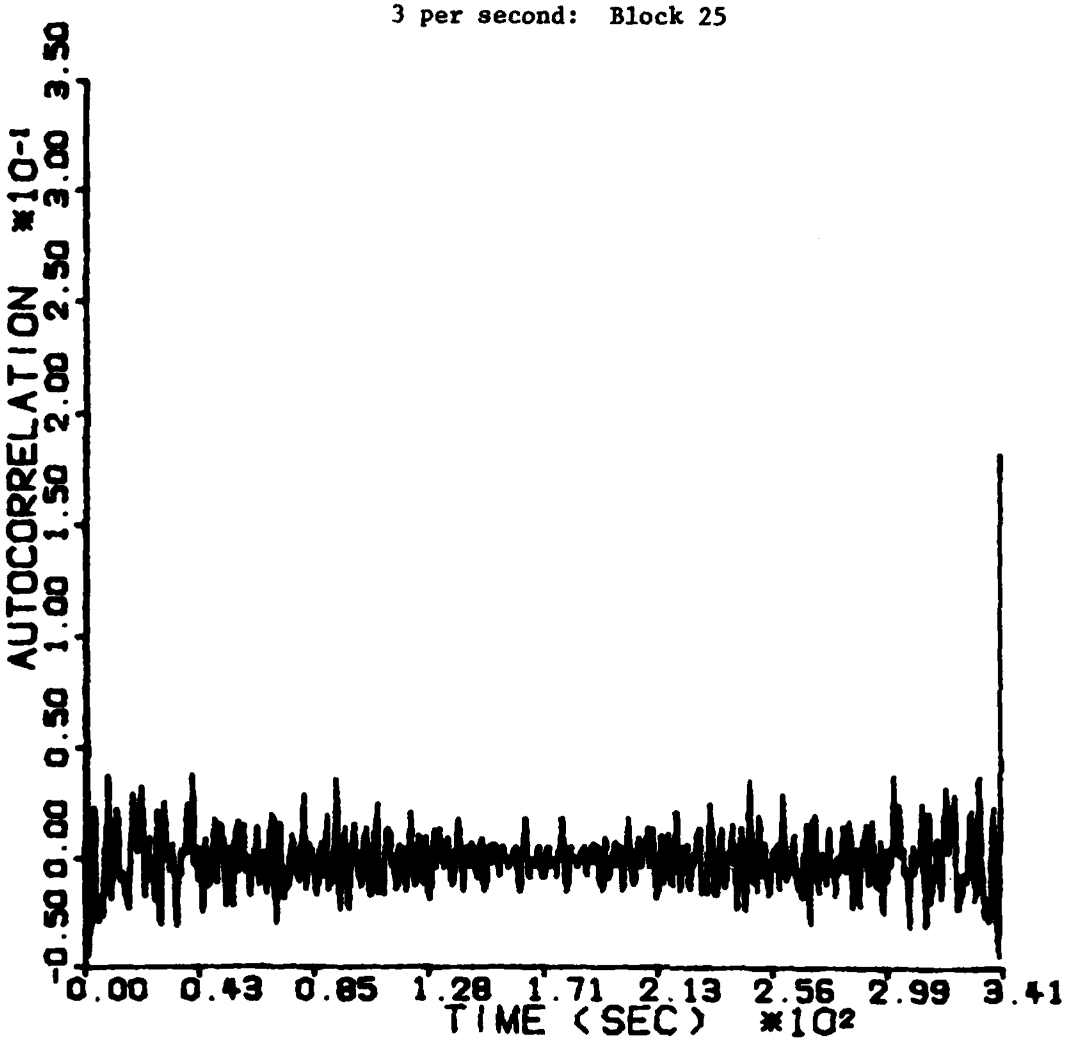


FIGURE 3.11

Autocorrelation of L-Band Scintillations at
1.5 per second: Block 25

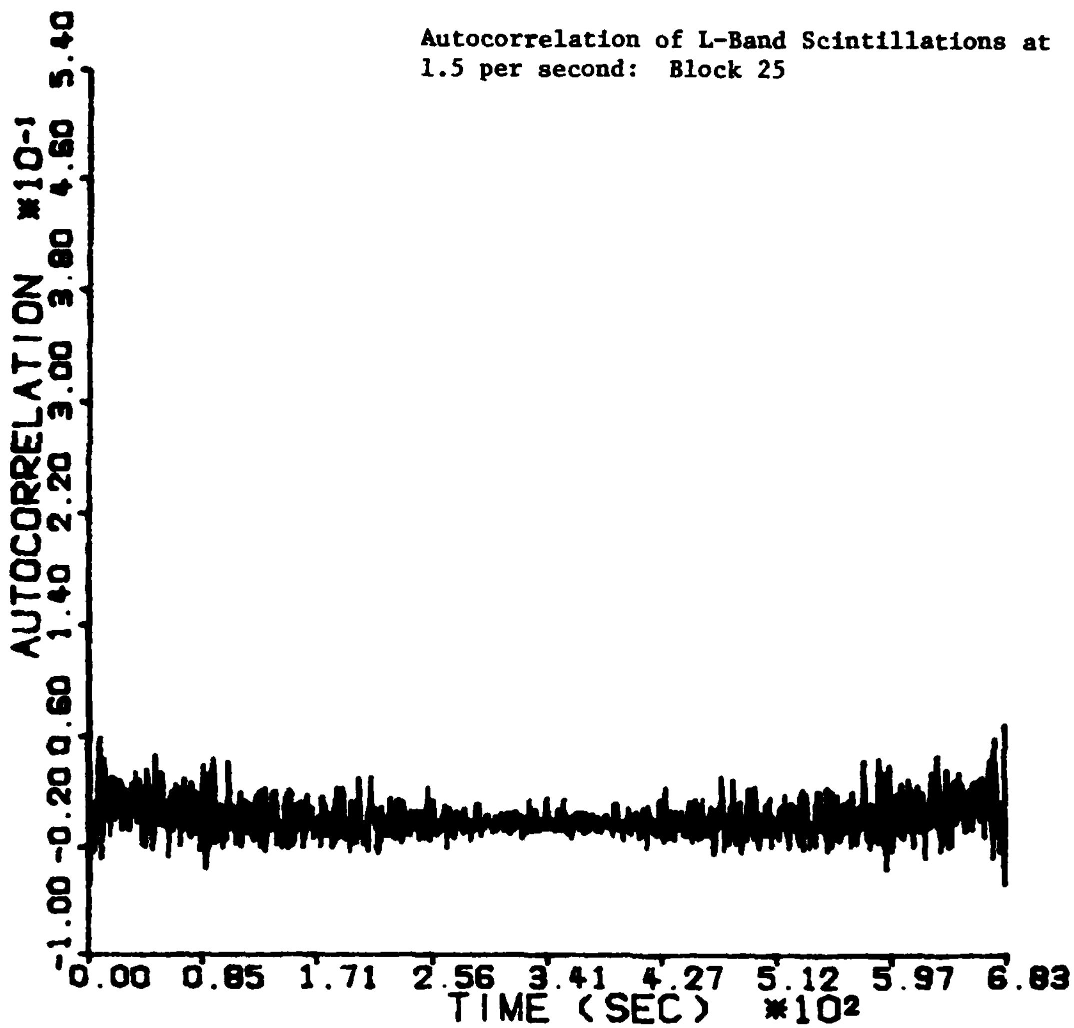


FIGURE 3.12

HISTOGRAM AND NAKAGAMI PDF

L-BAND BLOCK 25 S4 = 0.926

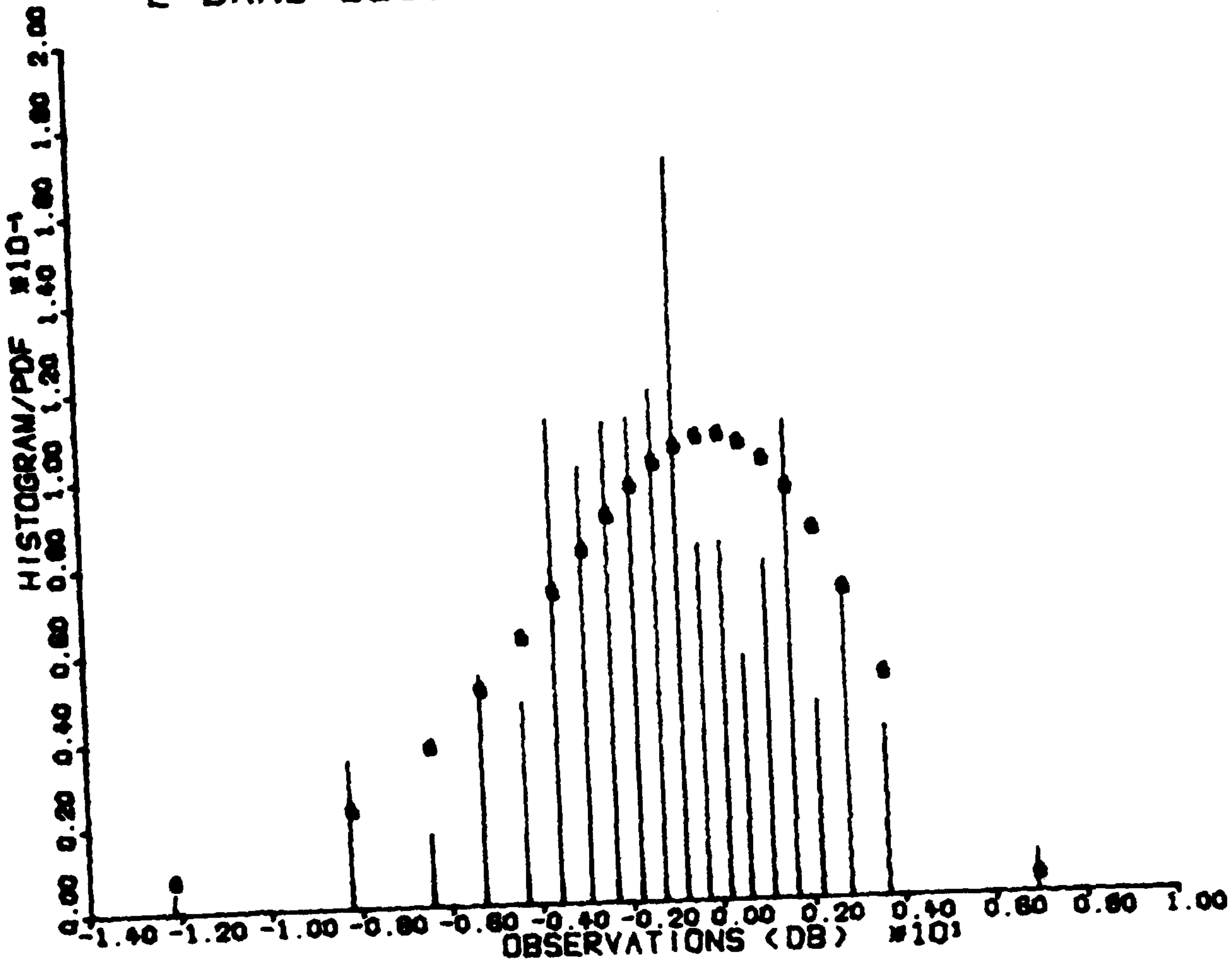


FIGURE 3.13

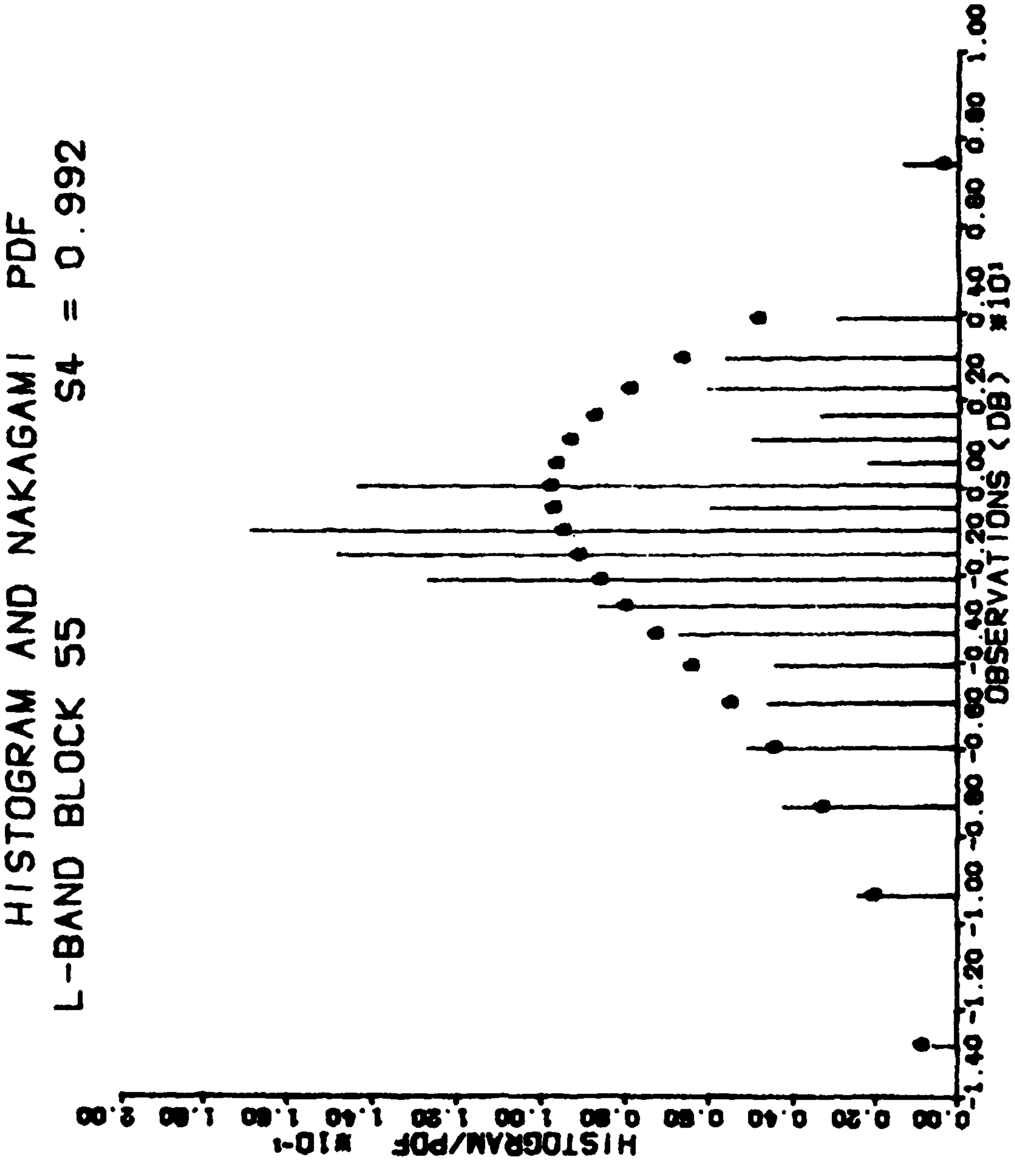

HISTOGRAM AND NAKAGAMI PDF
L-BAND BLOCK 55
S4 = 0.992
OBSERVATIONS (DB) *10¹
HISTOGRAM/PDF *10⁻¹
-1.40 -1.20 -1.00 -0.80 -0.60 -0.40 -0.20 0.00 0.20 0.40 0.60 0.80 1.00
0.00 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00

FIGURE 3.14

HISTOGRAM AND NAKAGAMI PDF

L-BAND BLOCK 85 S4 = 0.578

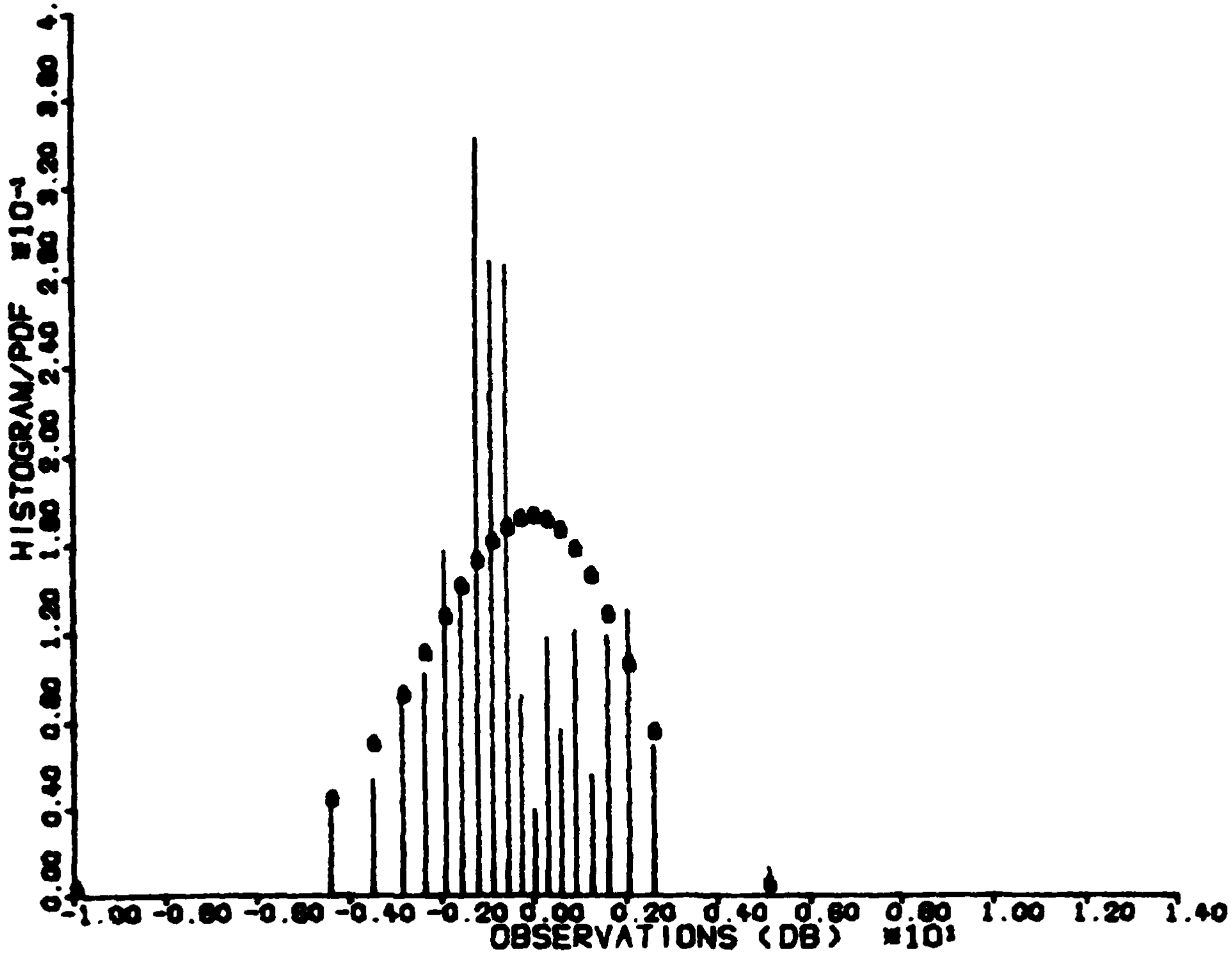


FIGURE 3.15

HISTOGRAM AND NAKAGAMI PDF

L-BAND BLOCK 121 S4 = 0.483

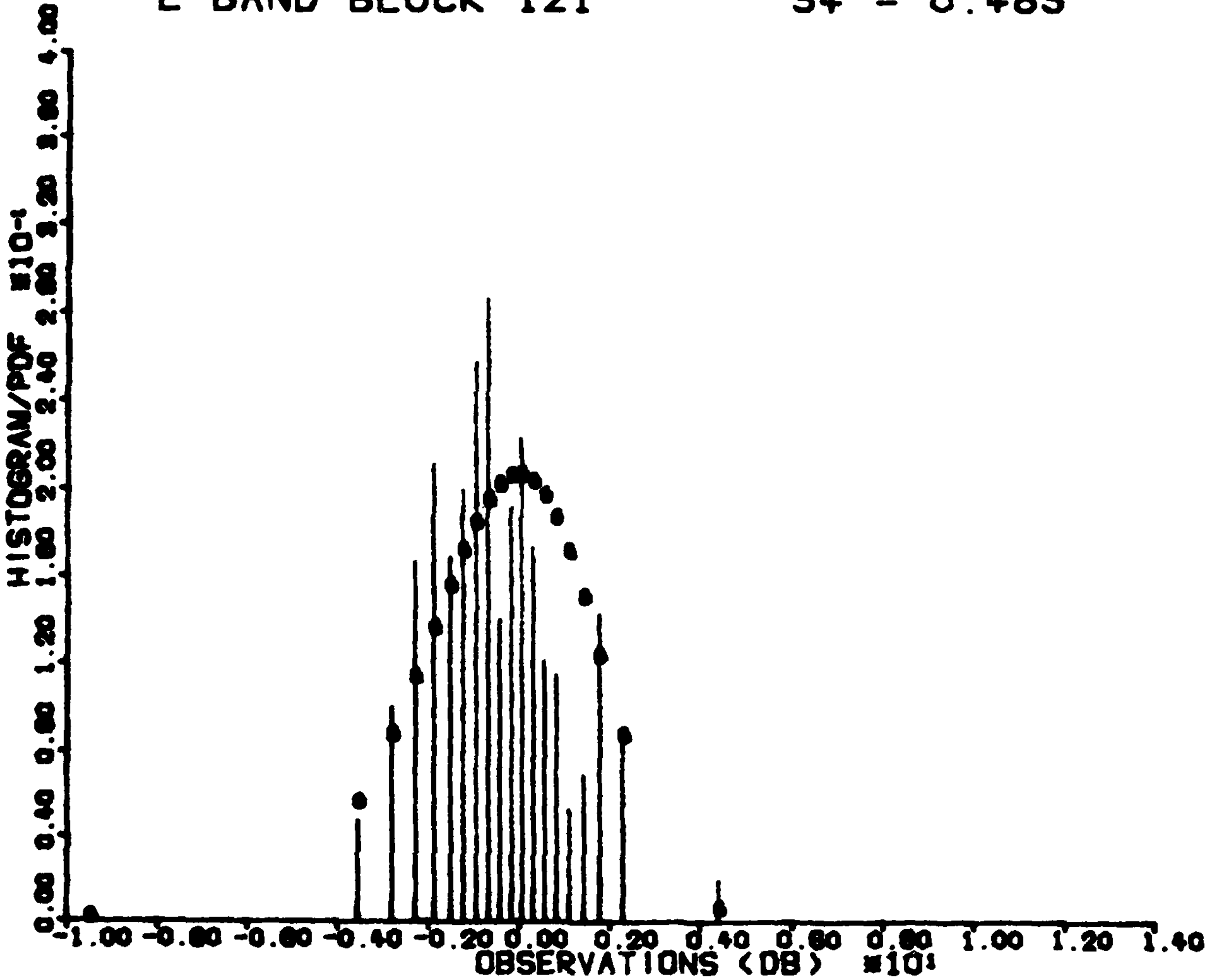


FIGURE 3.16

HISTOGRAM AND NAKAGAMI PDF
L-BAND BLOCK 145 S4 = 0.775

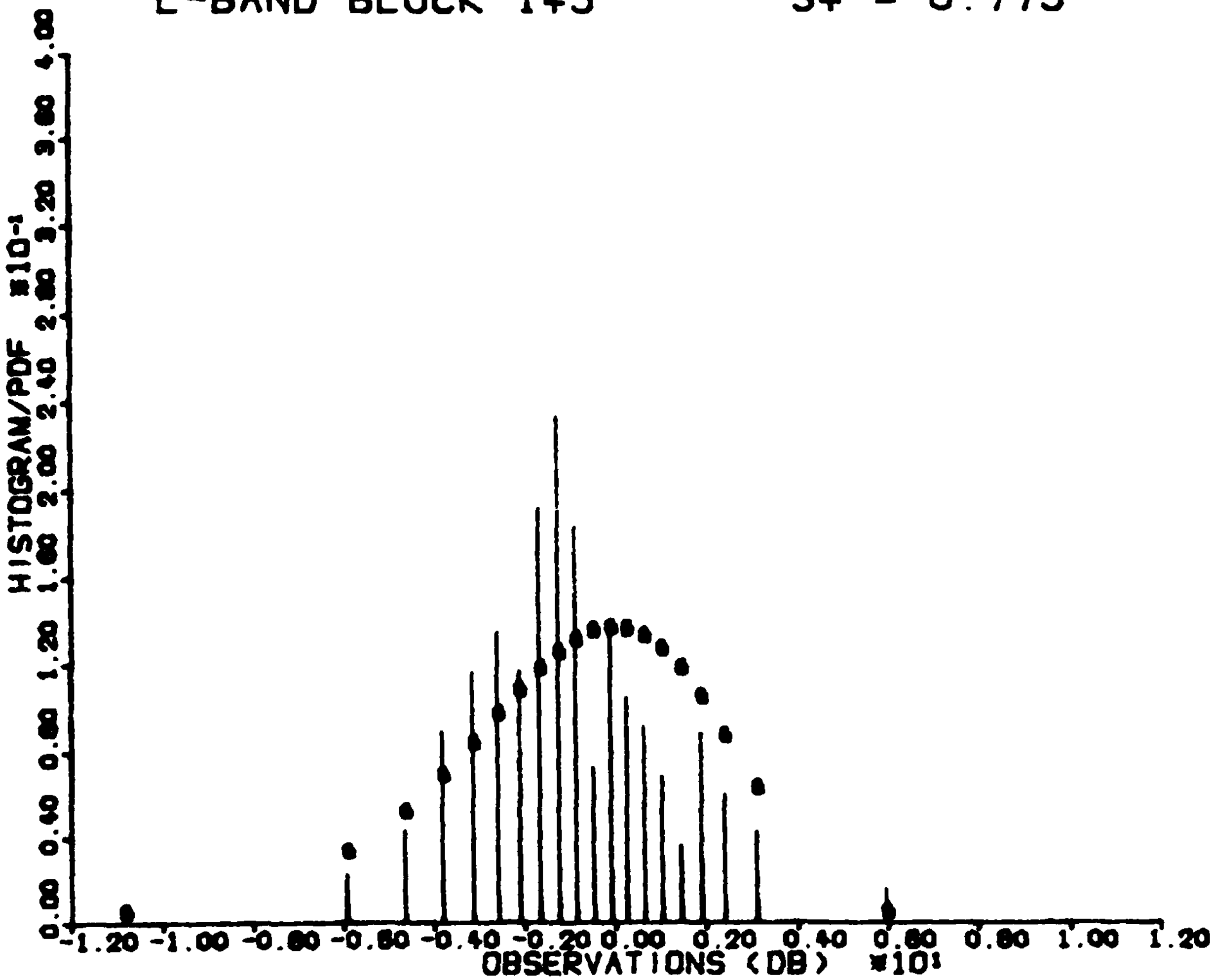


FIGURE 3.17

L-BAND/NAKAGAMI CDF PLOTS: BLOCK 25

S4 = 0.926 95 % CONF. INTERVALS SHOWN

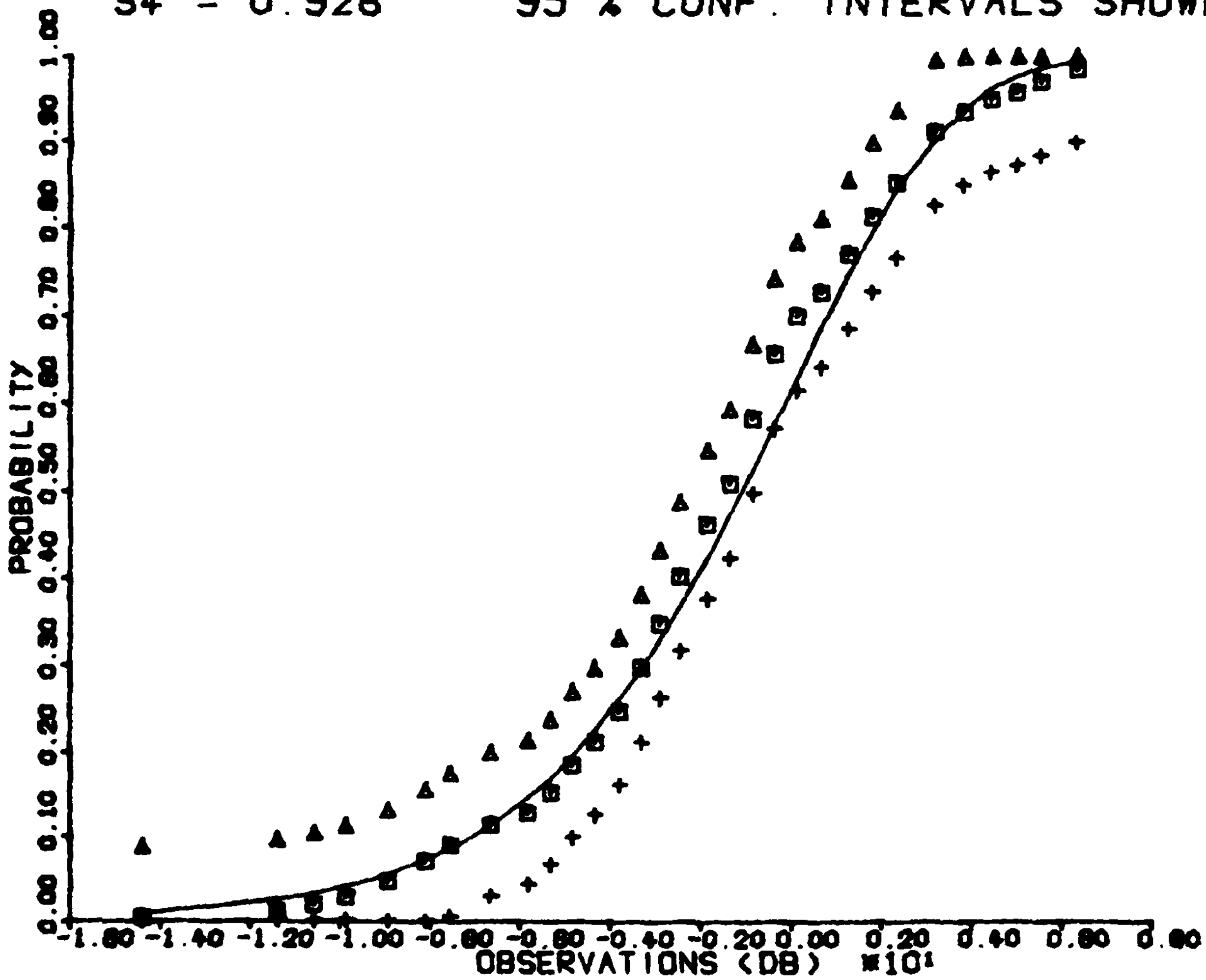


FIGURE 3.18

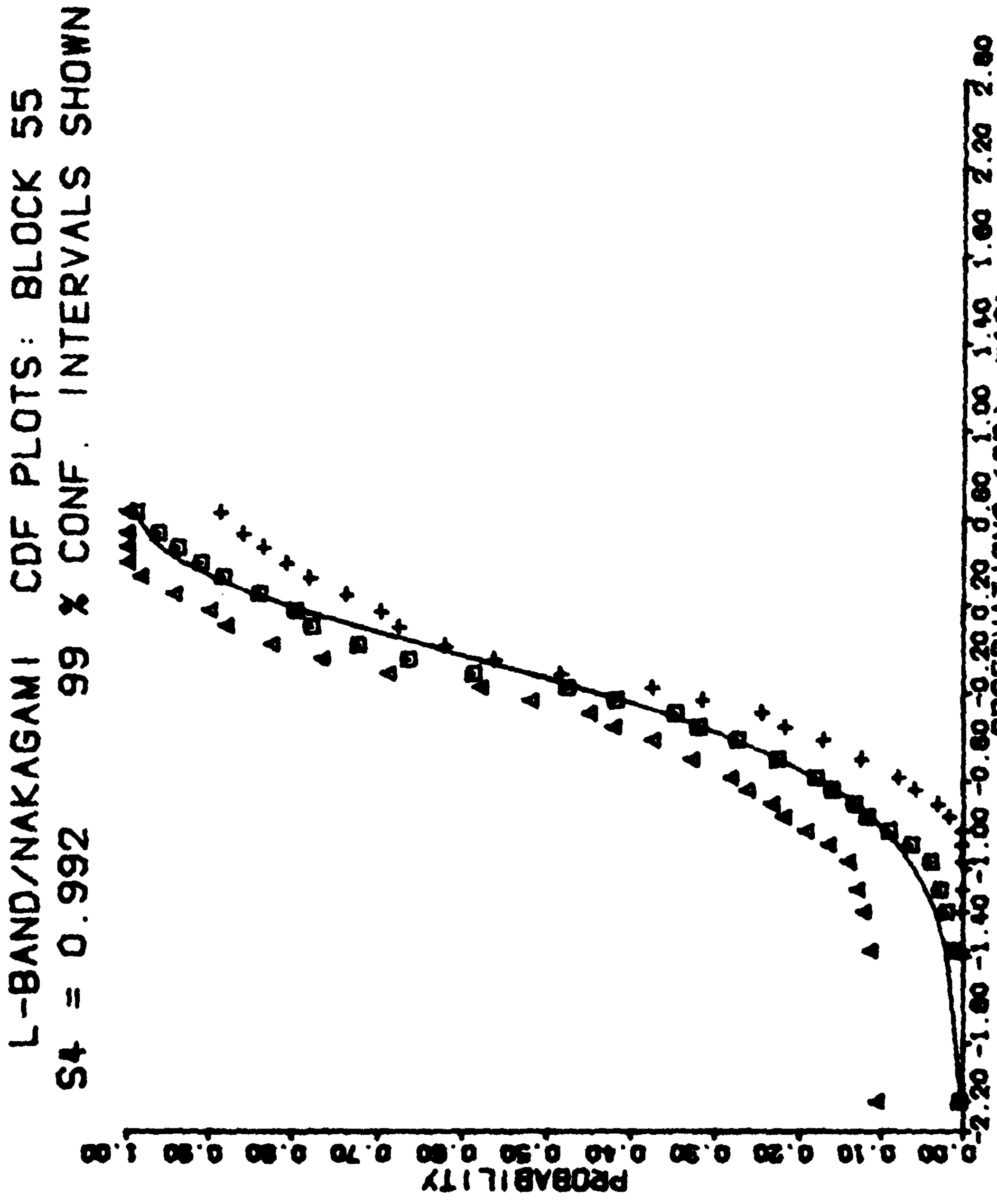
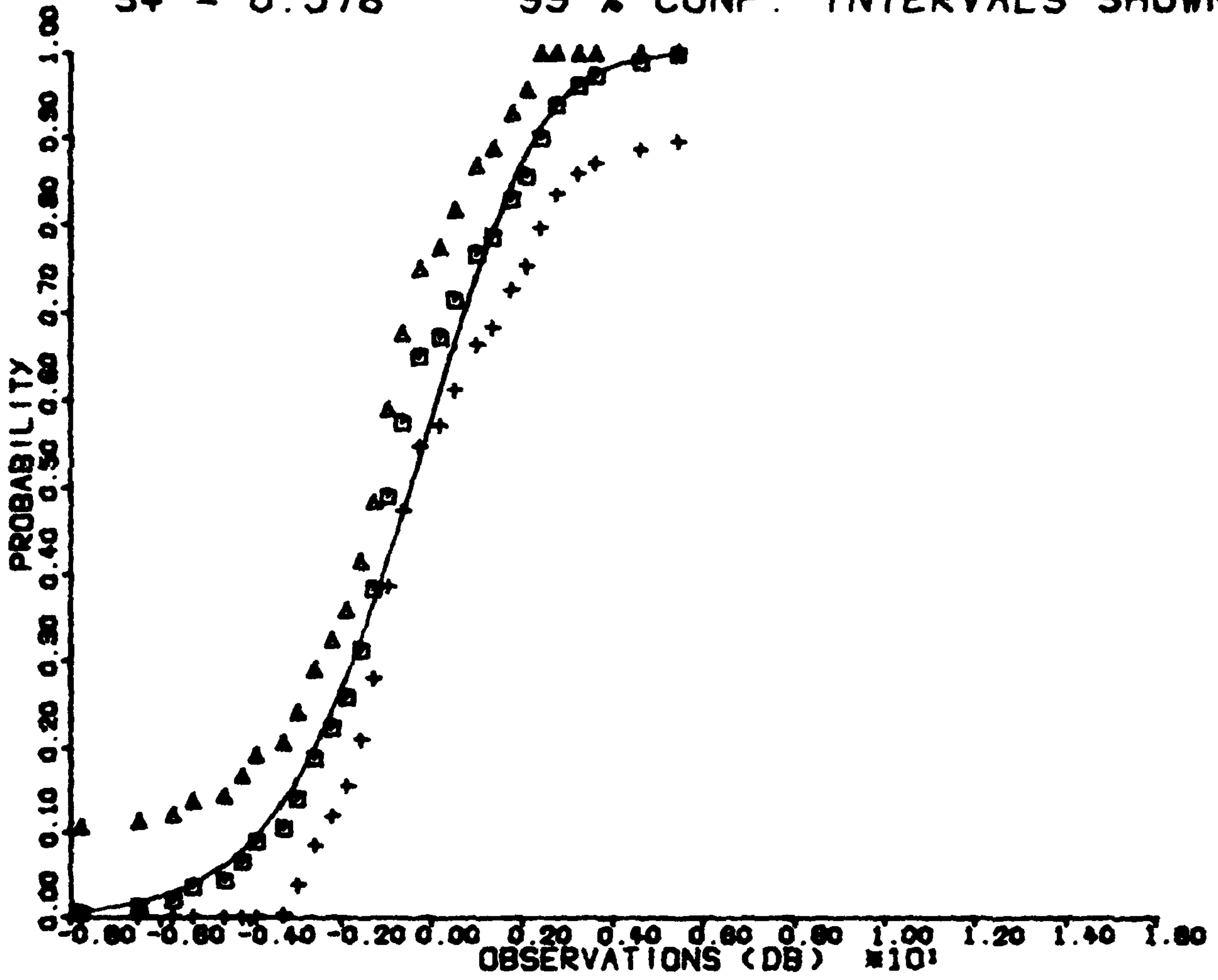

L-BAND/NAKAGAMI CDF PLOTS: BLOCK 55
S4 = 0.992 99 % CONF. INTERVALS SHOWN
PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
-2.20 -1.80 -1.40 -1.00 -0.60 -0.20 0.20 0.60 1.00 1.40 1.80 2.20 2.60
OBSERVATIONS (DB) *10¹

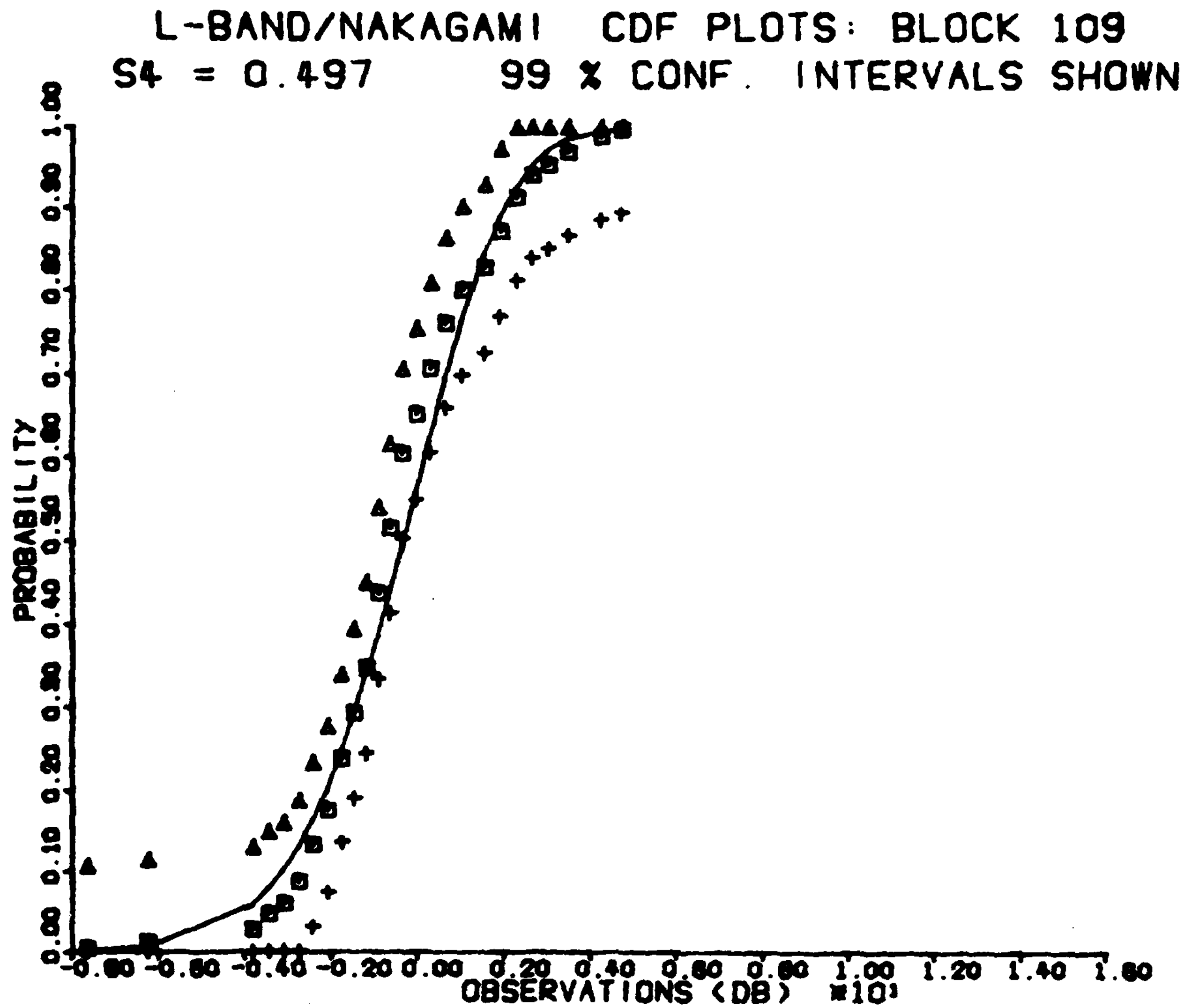
FIGURE 3.19

L-BAND/NAKAGAMI CDF PLOTS: BLOCK 85
S4 = 0.578 99 % CONF. INTERVALS SHOWN



110

FIGURE 3.20



L-BAND/NAKAGAMI CDF PLOTS: BLOCK 109
S4 = 0.497 99 % CONF. INTERVALS SHOWN
PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
-0.80 -0.60 -0.40 -0.20 0.00 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60
OBSERVATIONS (DB) *10¹

FIGURE 3.21

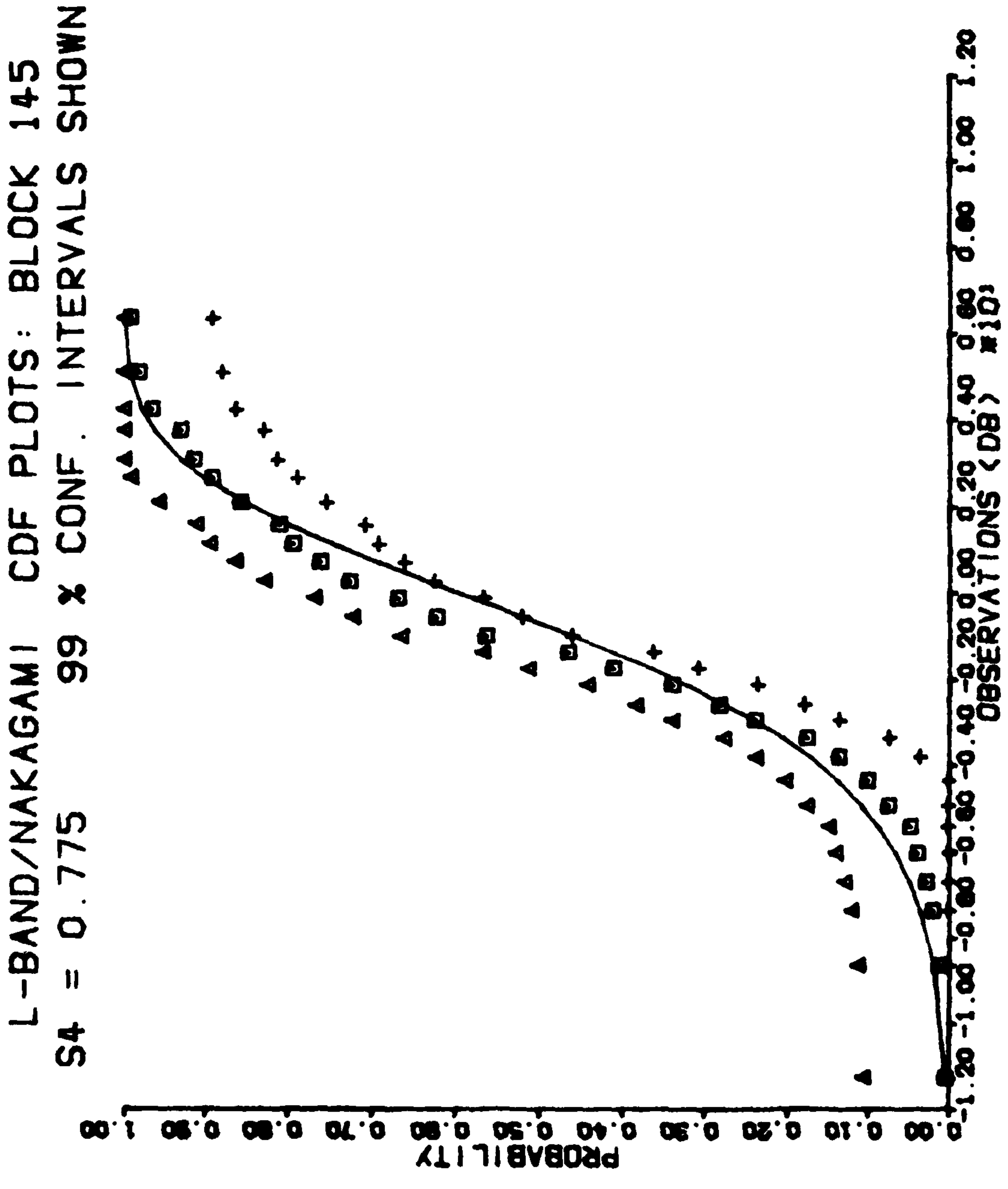

L-BAND/NAKAGAMI CDF PLOTS: BLOCK 145
S4 = 0.775 99 % CONF. INTERVALS SHOWN
PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
-1.20 -1.00 -0.80 -0.60 -0.40 -0.20 0.00 0.20 0.40 0.60 0.80 1.00 1.20
OBSERVATIONS (DB)

FIGURE 3.22

L-BAND/NAKAGAMI PROBABILITY PLOTS: BLOCK 25

S4 = 0.926 LEAST SQUARES LINE SHOWN

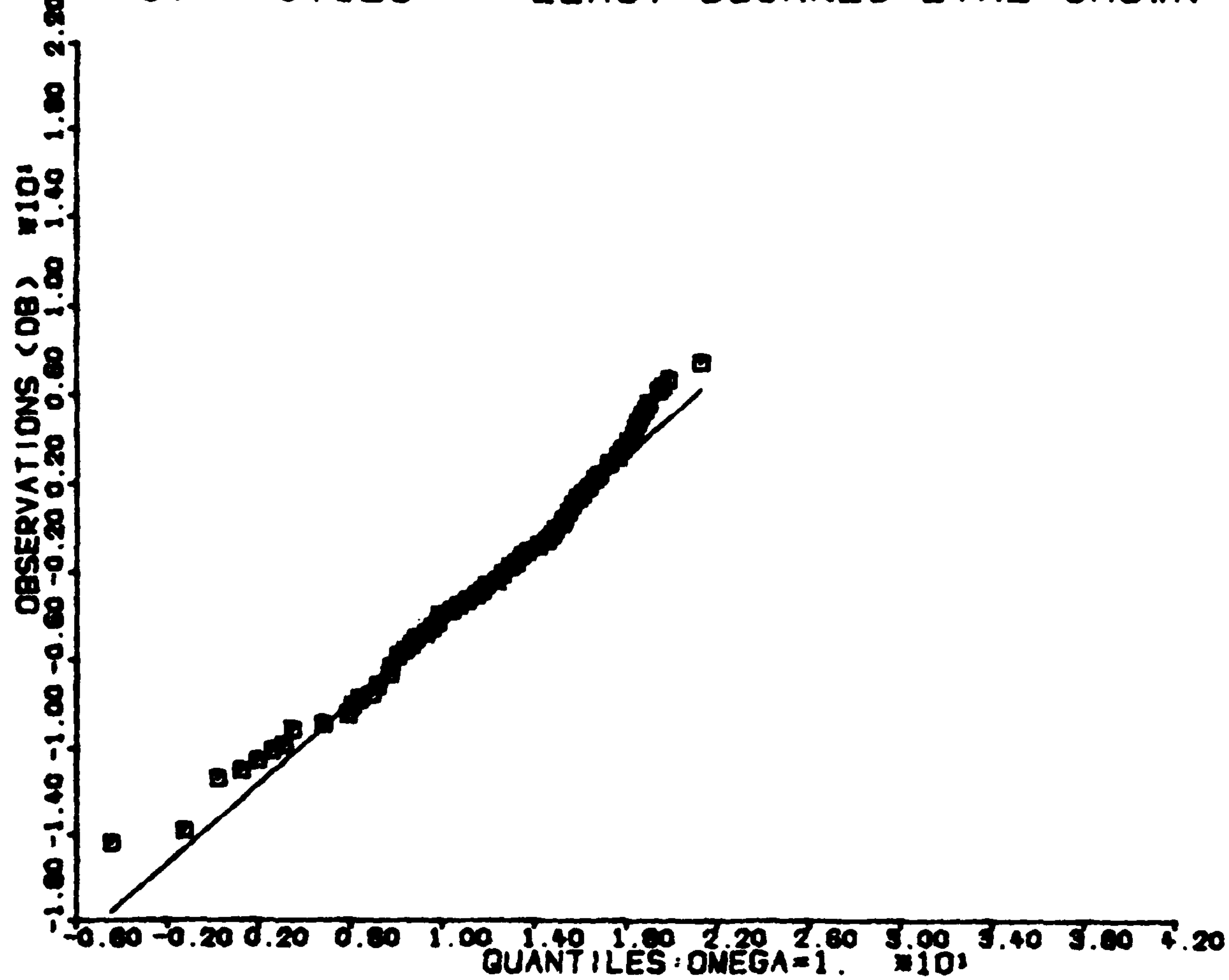


FIGURE 3.23

L-BAND/NAKAGAMI PROBABILITY PLOTS: BLOCK 55
S4 = 0.992 LEAST SQUARES LINE SHOWN

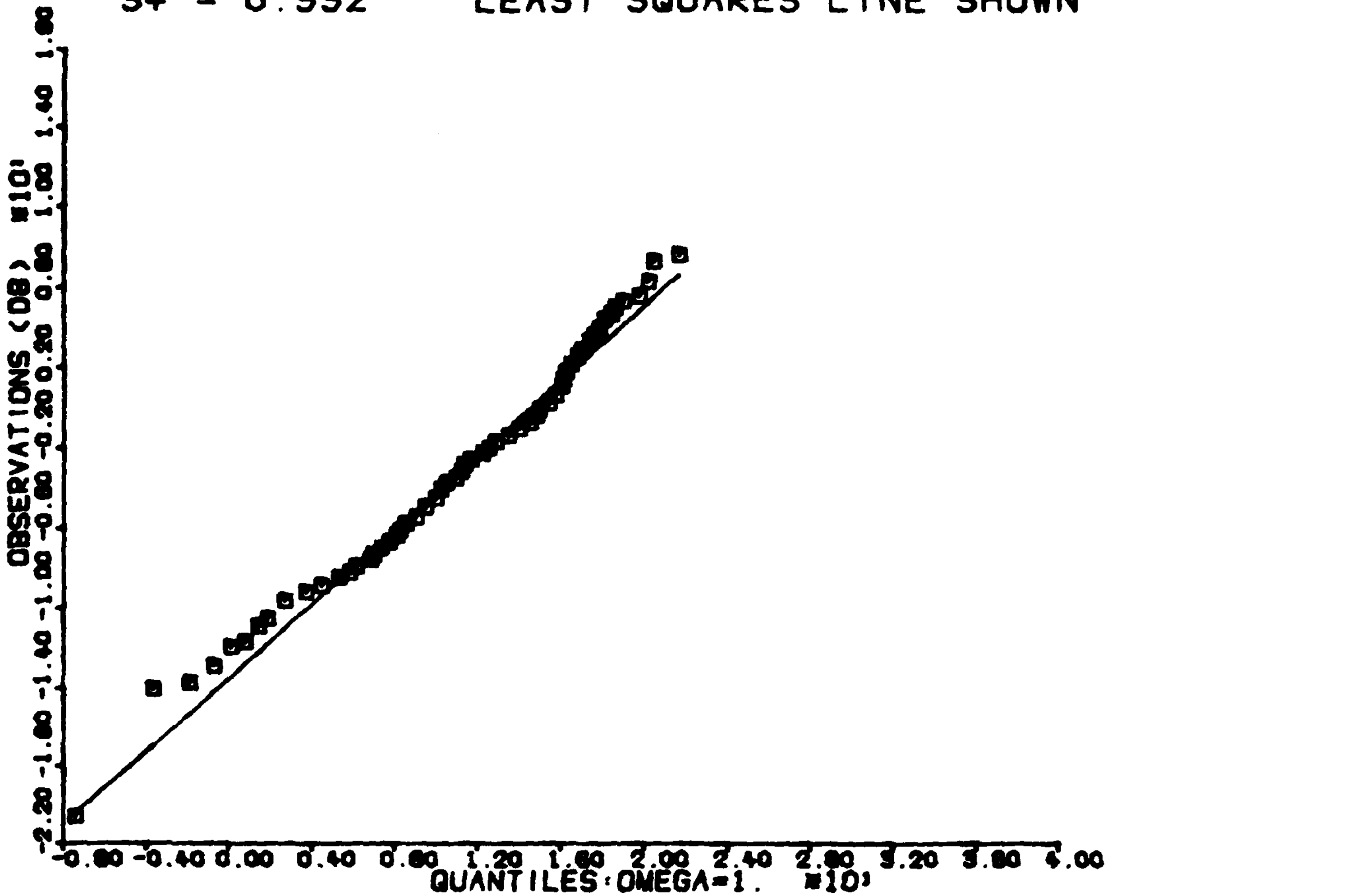


FIGURE 3.24

L-BAND/NAKAGAMI PROBABILITY PLOTS: BLOCK 85
S4 = 0.578 LEAST SQUARES LINE SHOWN

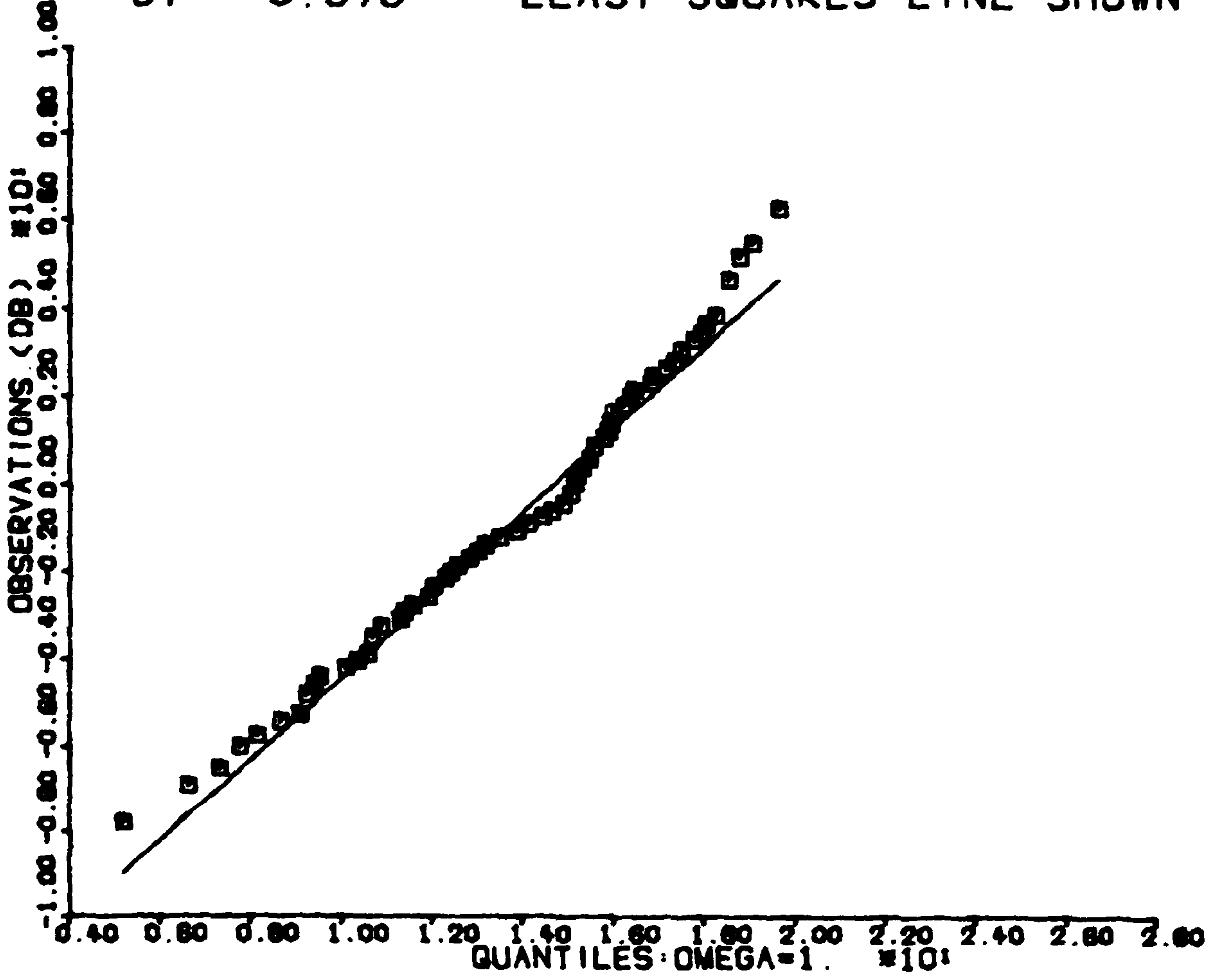


FIGURE 3.25

L-BAND/NAKAGAMI PROBABILITY PLOTS: BLOCK 109
S4 = 0.497 LEAST SQUARES LINE SHOWN

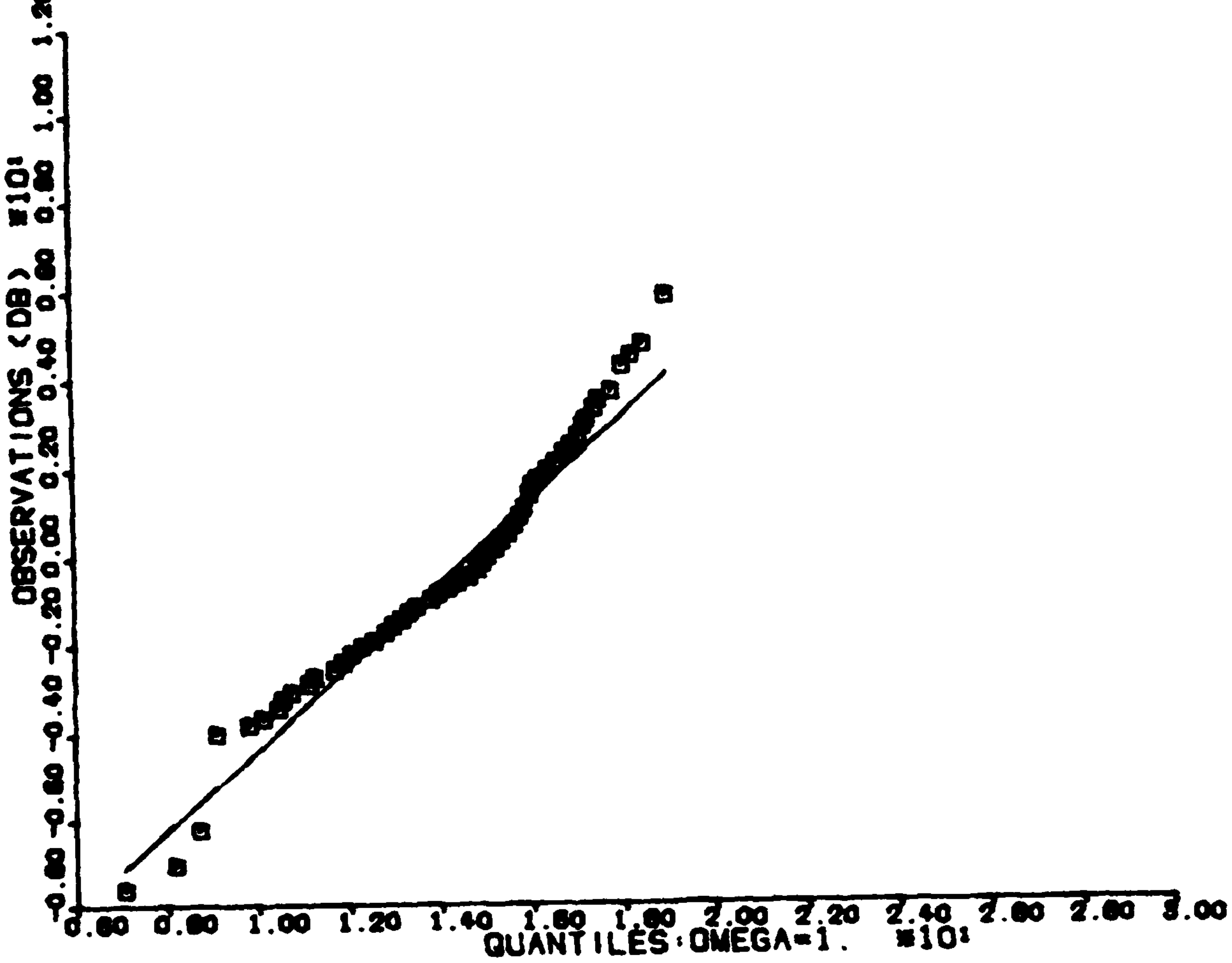


FIGURE 3.26

L-BAND/NAKAGAMI PROBABILITY PLOTS: BLOCK 145

S4 = 0.775 LEAST SQUARES LINE SHOWN

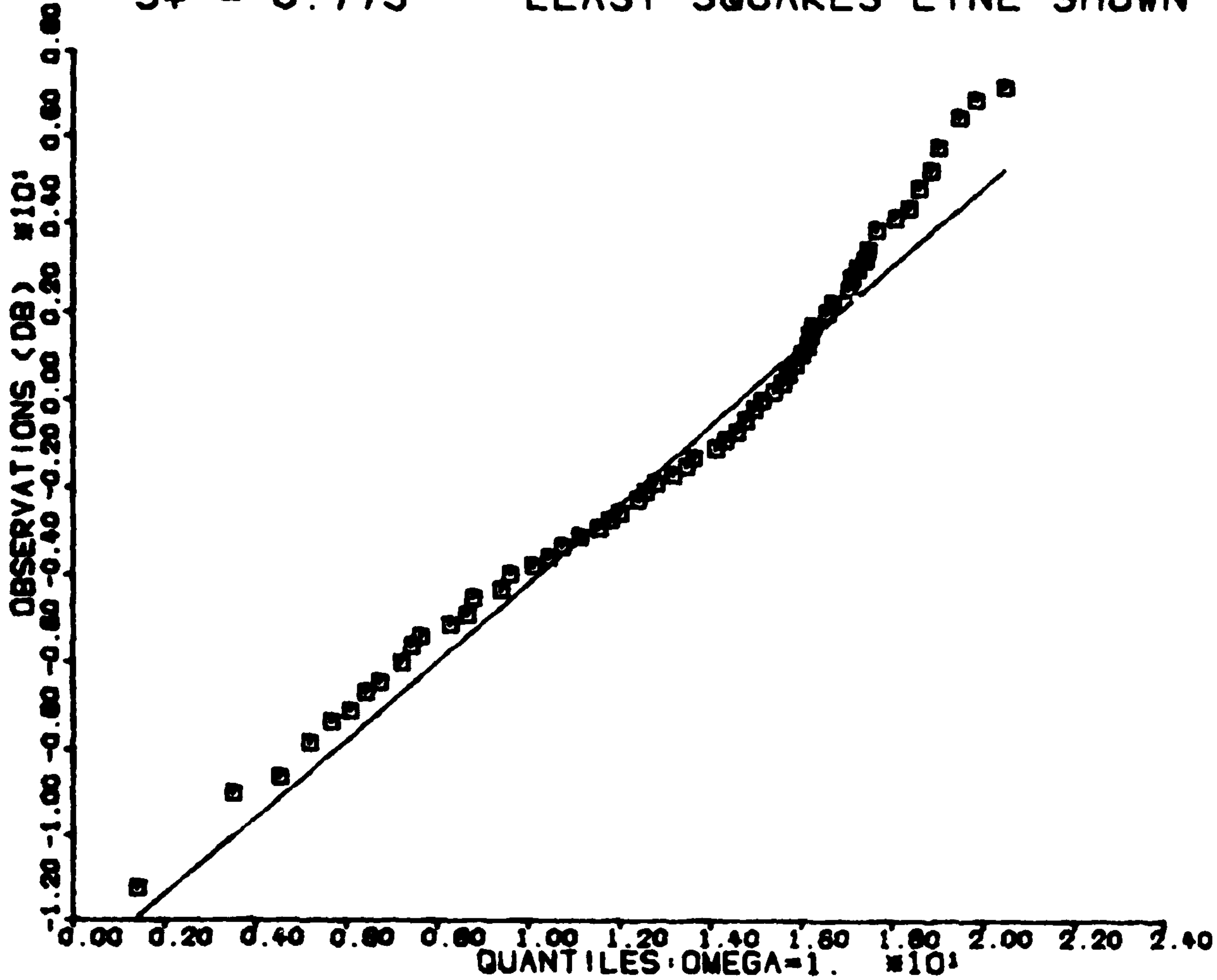


FIGURE 4.1

HISTOGRAM AND LOGNORMAL PDF

L-BAND BLOCK 25 S4 = 0.926

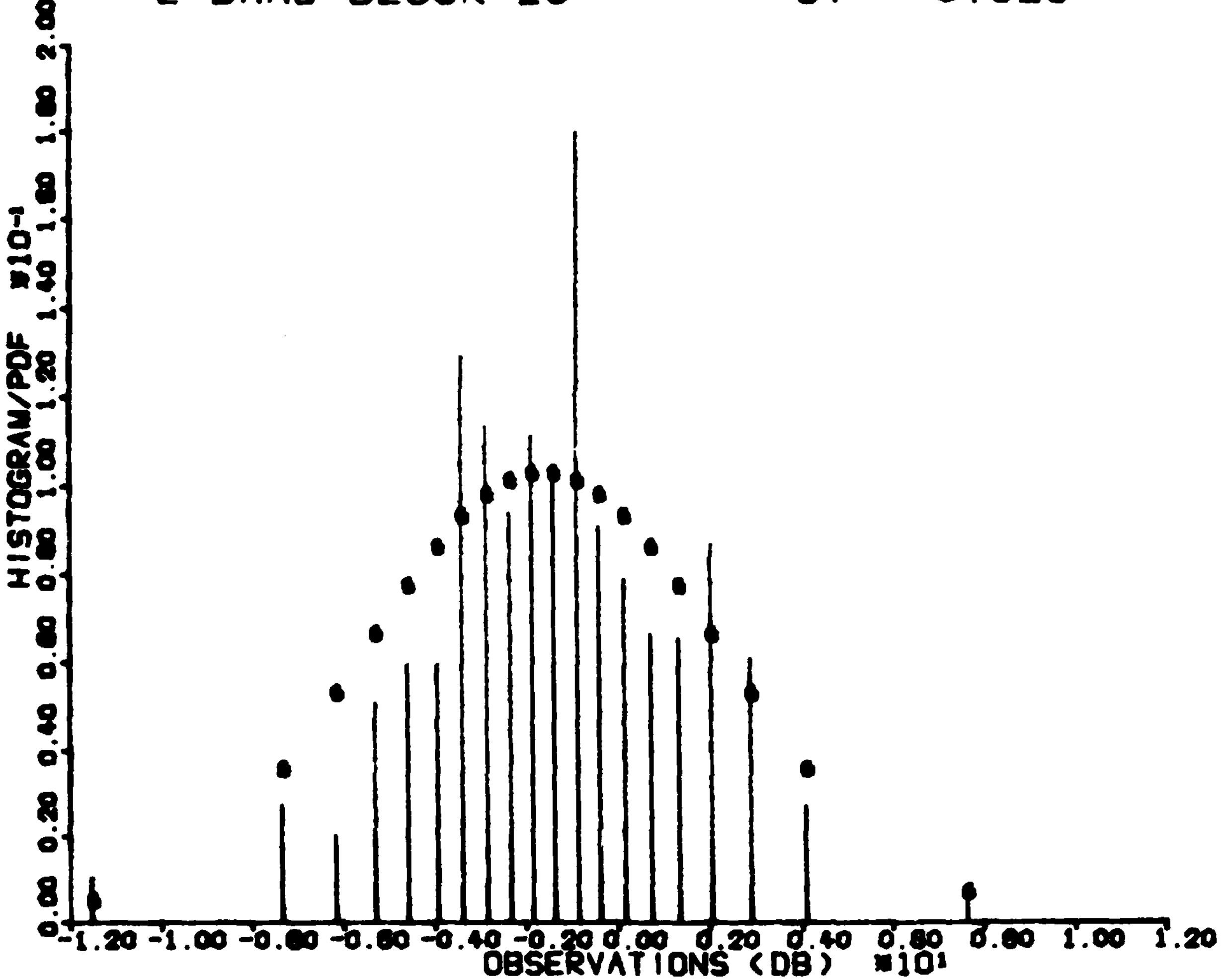


FIGURE 4.2

HISTOGRAM AND LOGNORMAL PDF
L-BAND BLOCK 55 S4 = 0.992

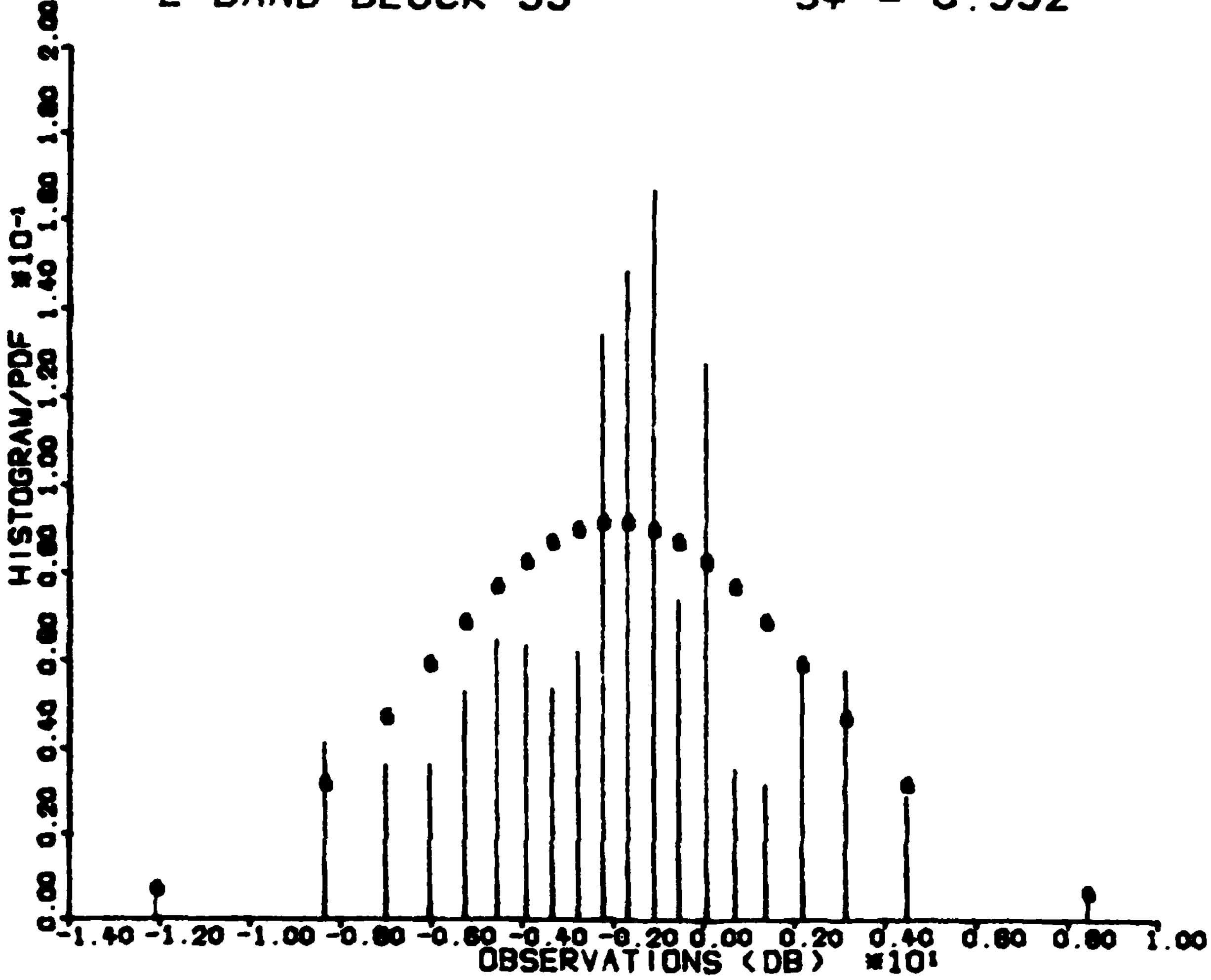


FIGURE 4.3

HISTOGRAM AND LOGNORMAL PDF

L-BAND BLOCK 85 S4 = 0.578

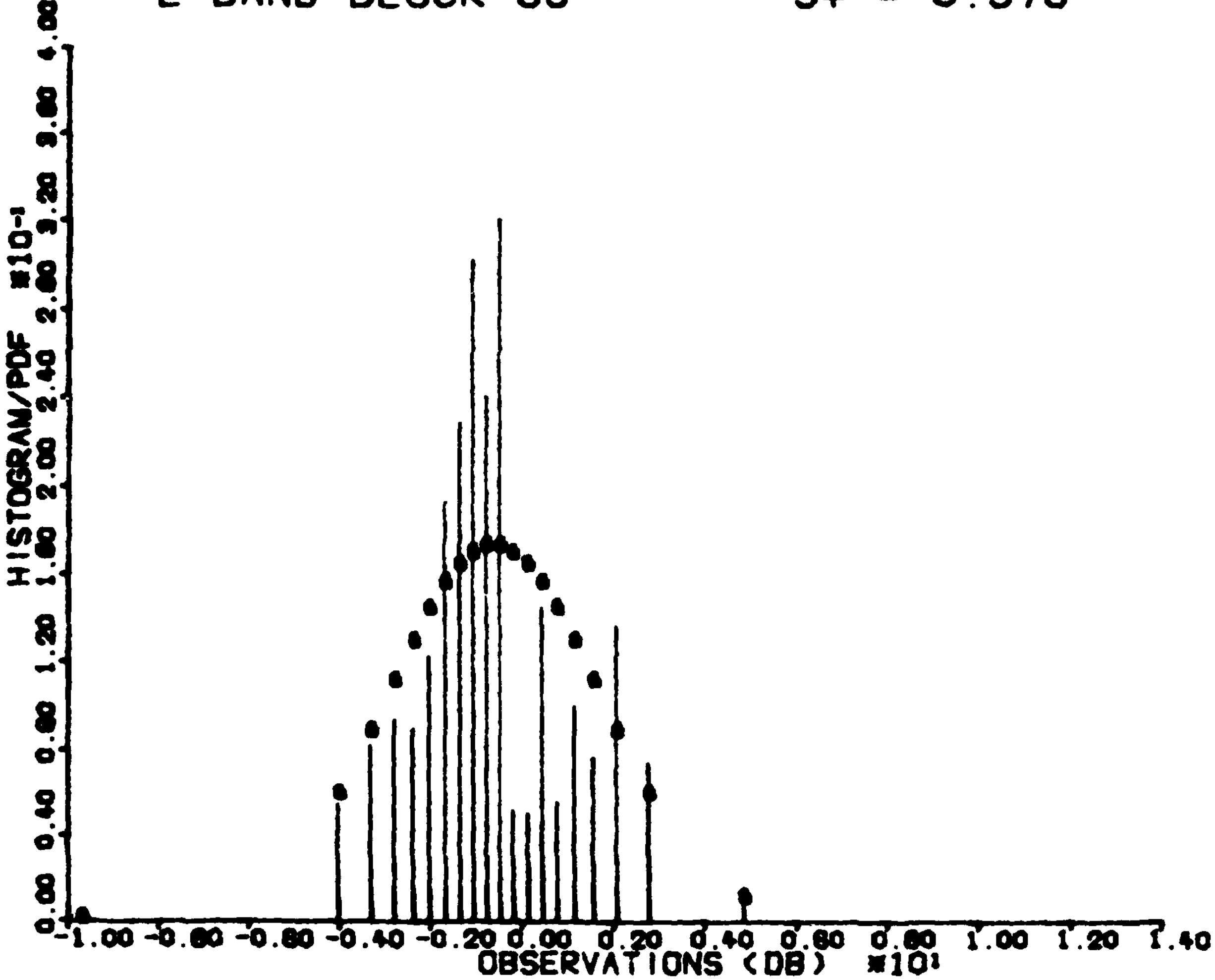


FIGURE 4.4

HISTOGRAM AND LOGNORMAL PDF

L-BAND BLOCK 121   S4 = 0.483

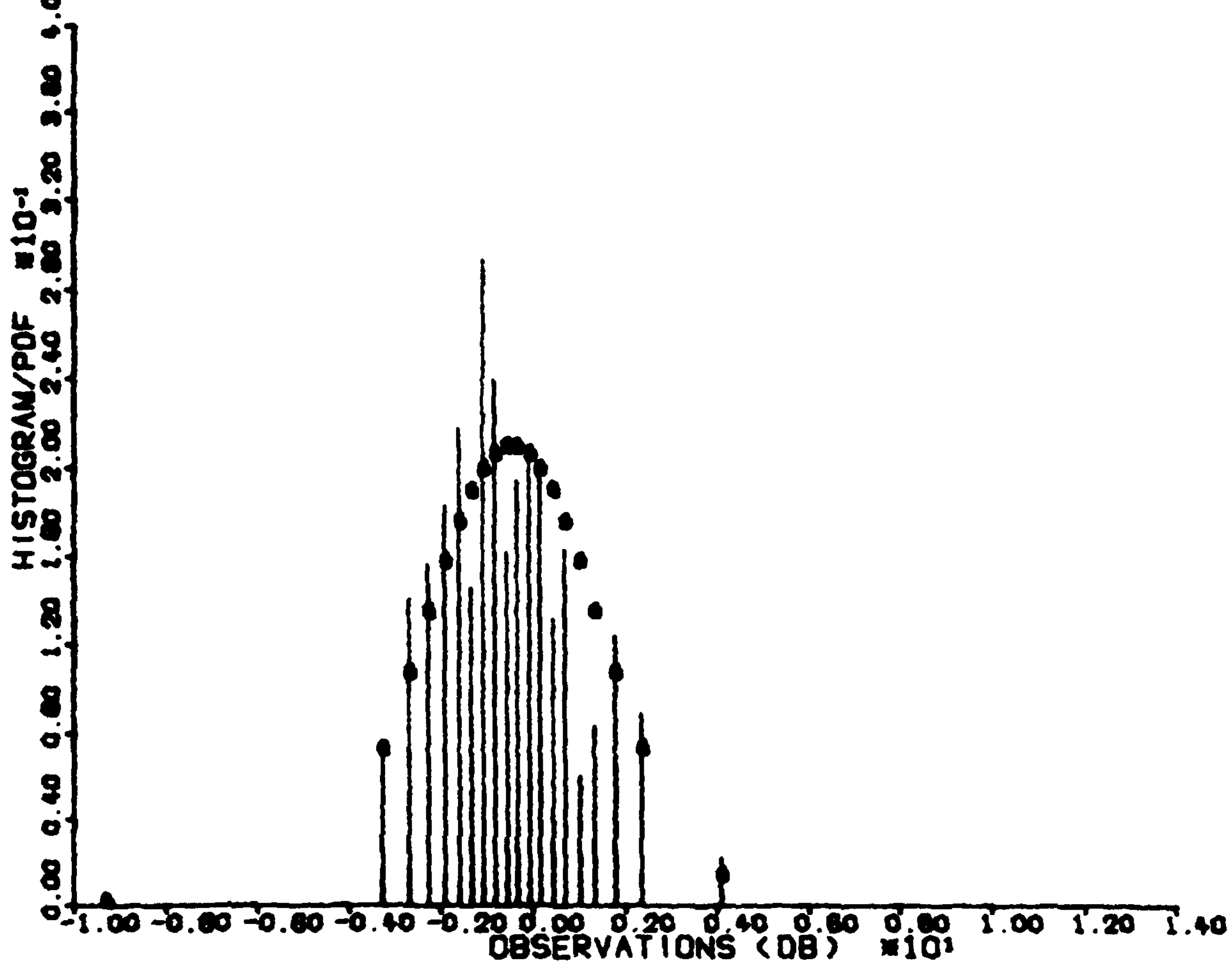


FIGURE 4.5

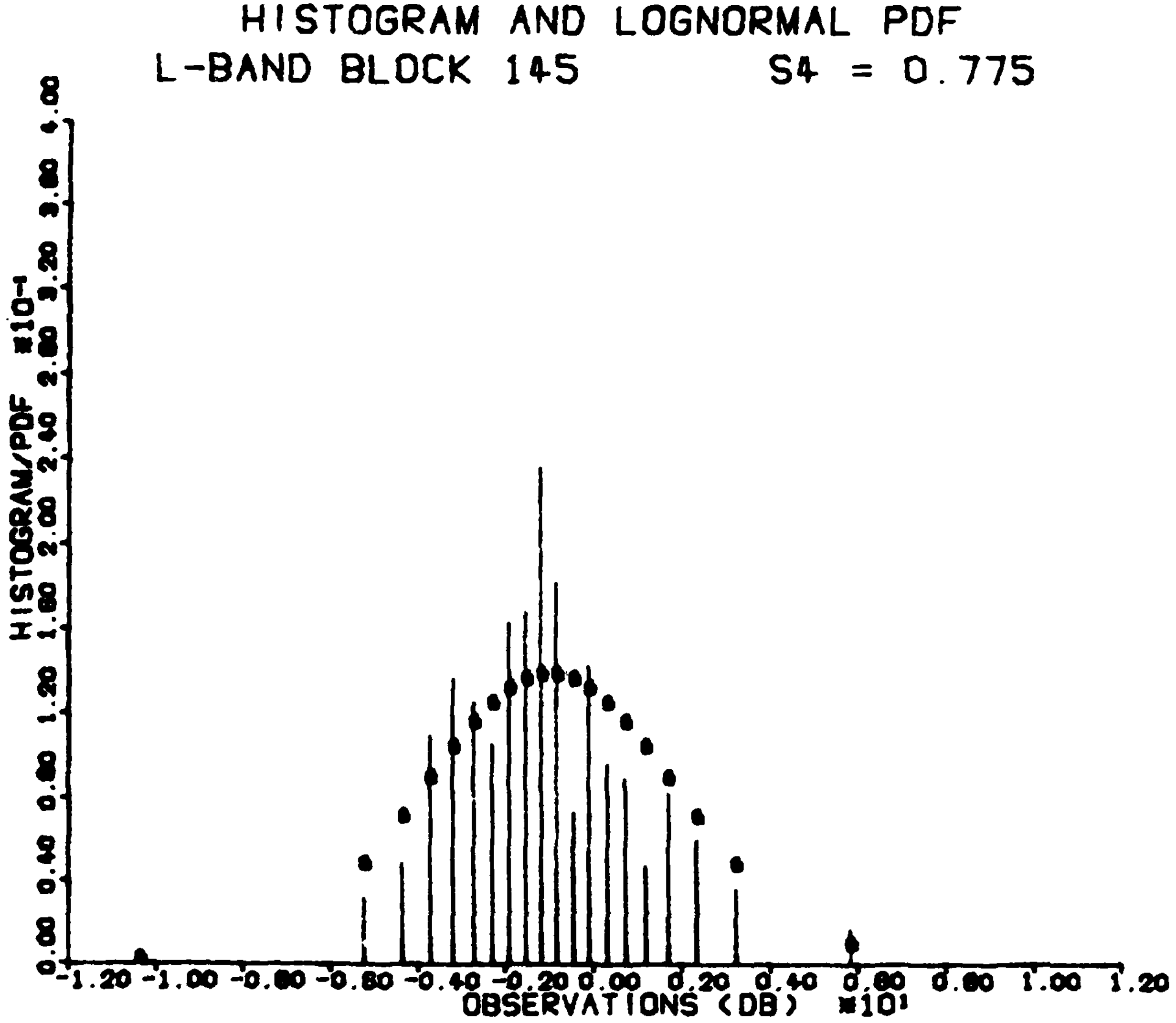

HISTOGRAM AND LOGNORMAL PDF
L-BAND BLOCK 145 S4 = 0.775
HISTOGRAM/PDF *10⁻¹
0.00 0.40 0.80 1.20 1.60 2.00 2.40 2.80 3.20 3.60 4.00
-1.20 -1.00 -0.80 -0.60 -0.40 -0.20 0.00 0.20 0.40 0.60 0.80 1.00 1.20
OBSERVATIONS (DB) *10¹

FIGURE 4.6

L-BAND/LOGNORMAL CDF PLOTS: BLOCK 25

S4 = 0.926   90 % CONF. INTERVALS SHOWN

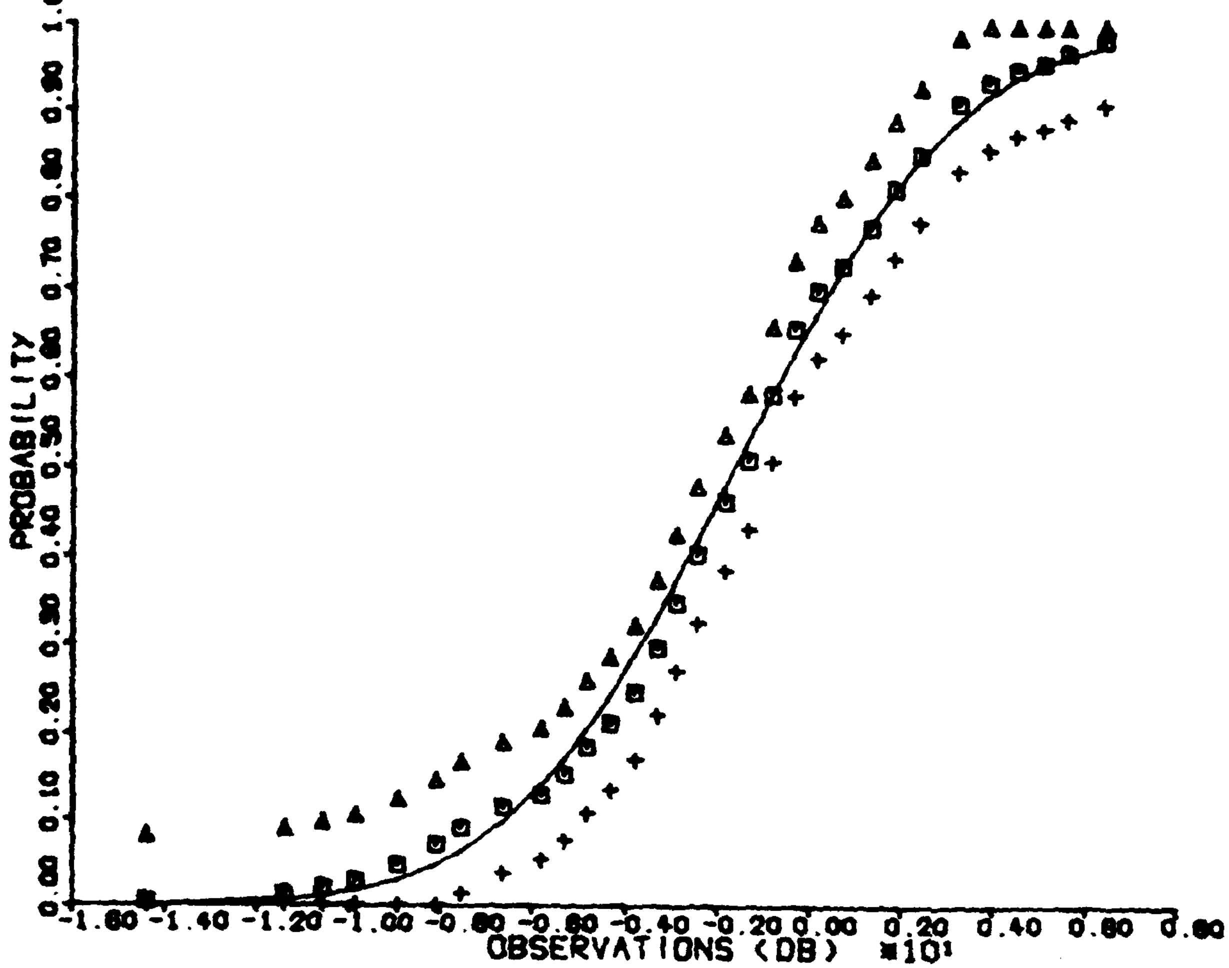
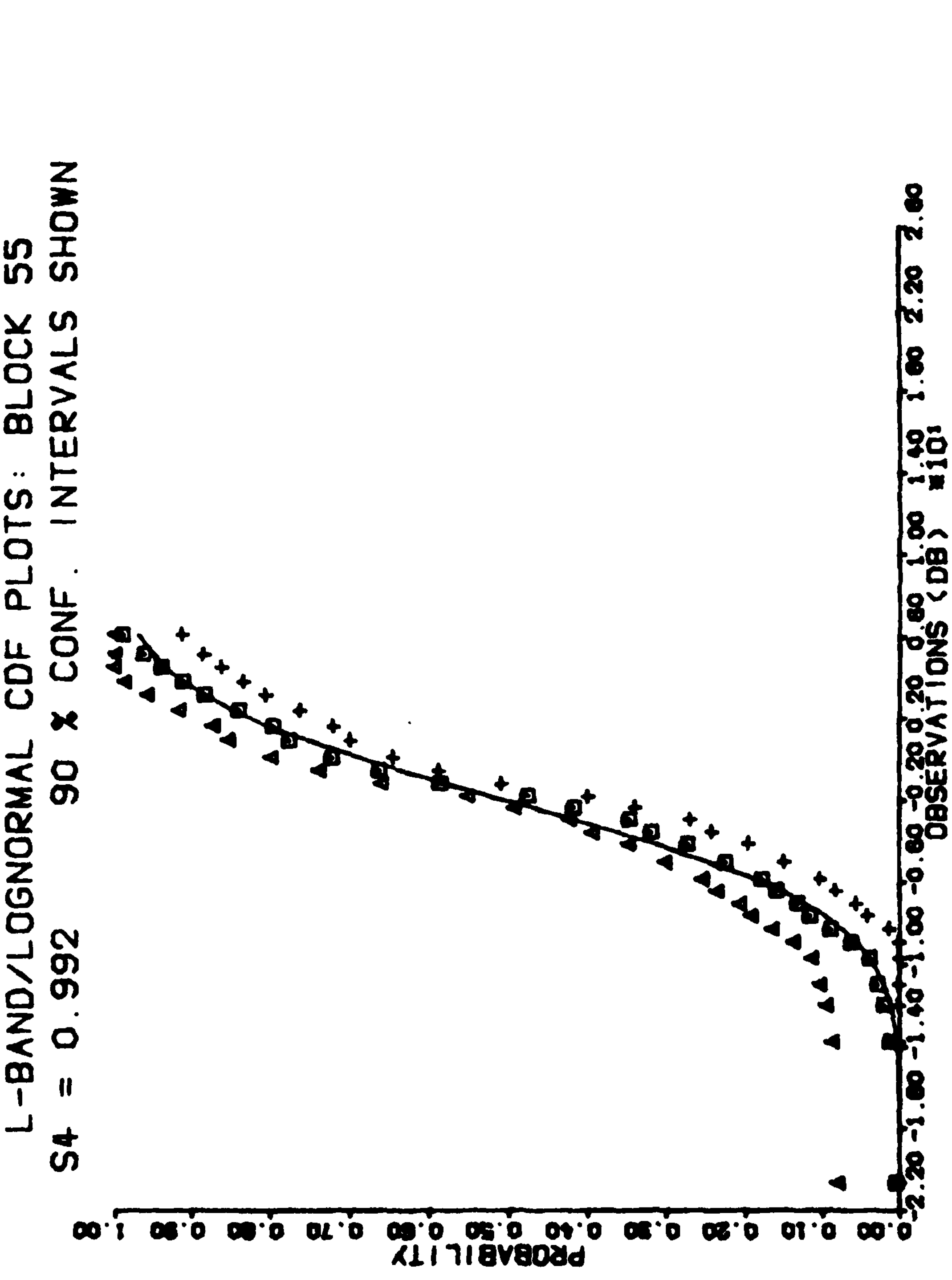


FIGURE 4.7



L-BAND/LOGNORMAL CDF PLOTS: BLOCK 55
S4 = 0.992 90 % CONF. INTERVALS SHOWN
PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
OBSERVATIONS (DB) *10¹
-2.20 -1.80 -1.40 -1.00 -0.60 -0.20 0.20 0.60 1.00 1.40 1.80 2.20 2.60

FIGURE 4.8

L-BAND/LOGNORMAL CDF PLOTS: BLOCK 85

S4 = 0.578   99 % CONF. INTERVALS SHOWN

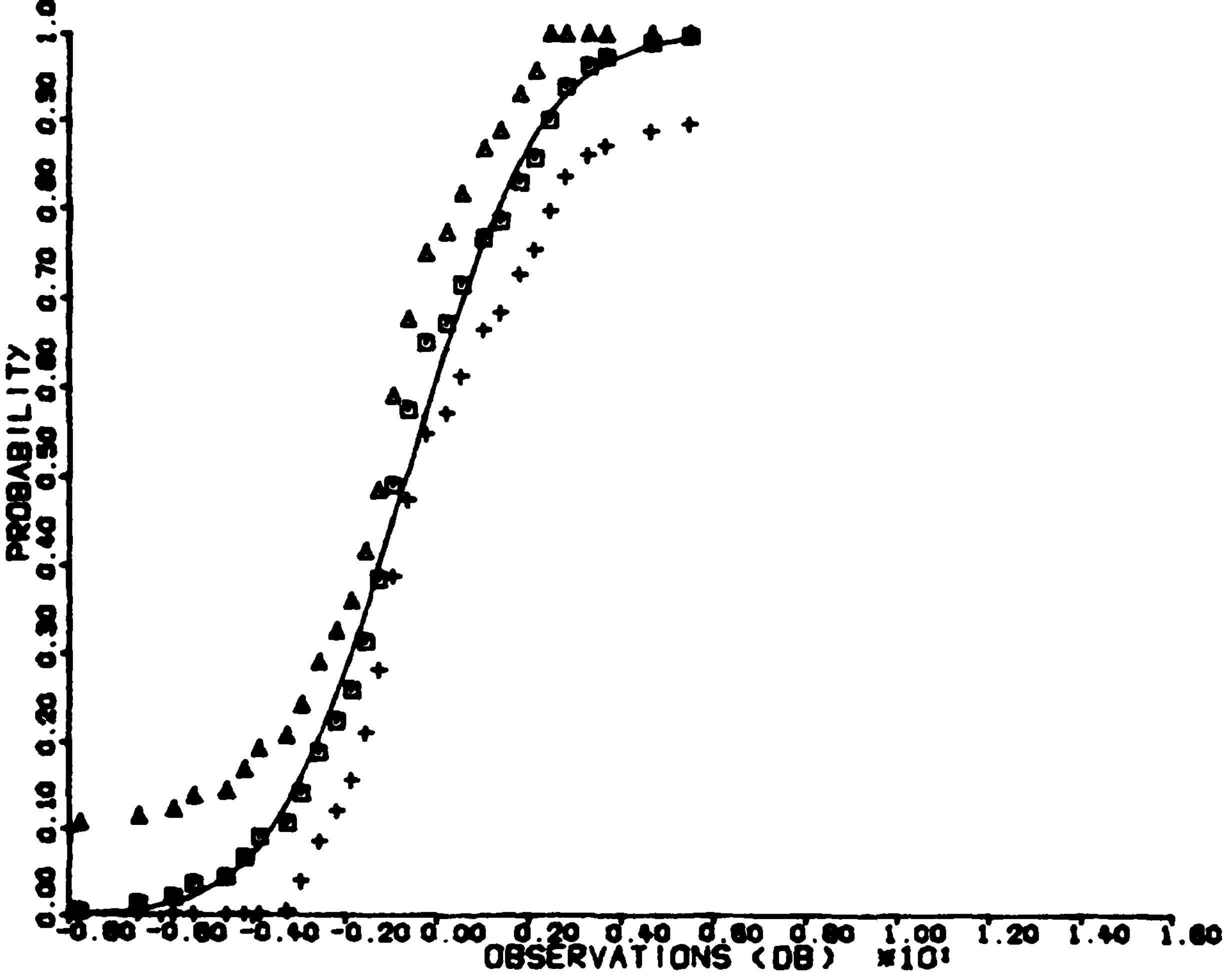


FIGURE 4.9

L-BAND/LOGNORMAL CDF PLOTS: BLOCK 109

S4 = 0.497   95 % CONF. INTERVALS SHOWN

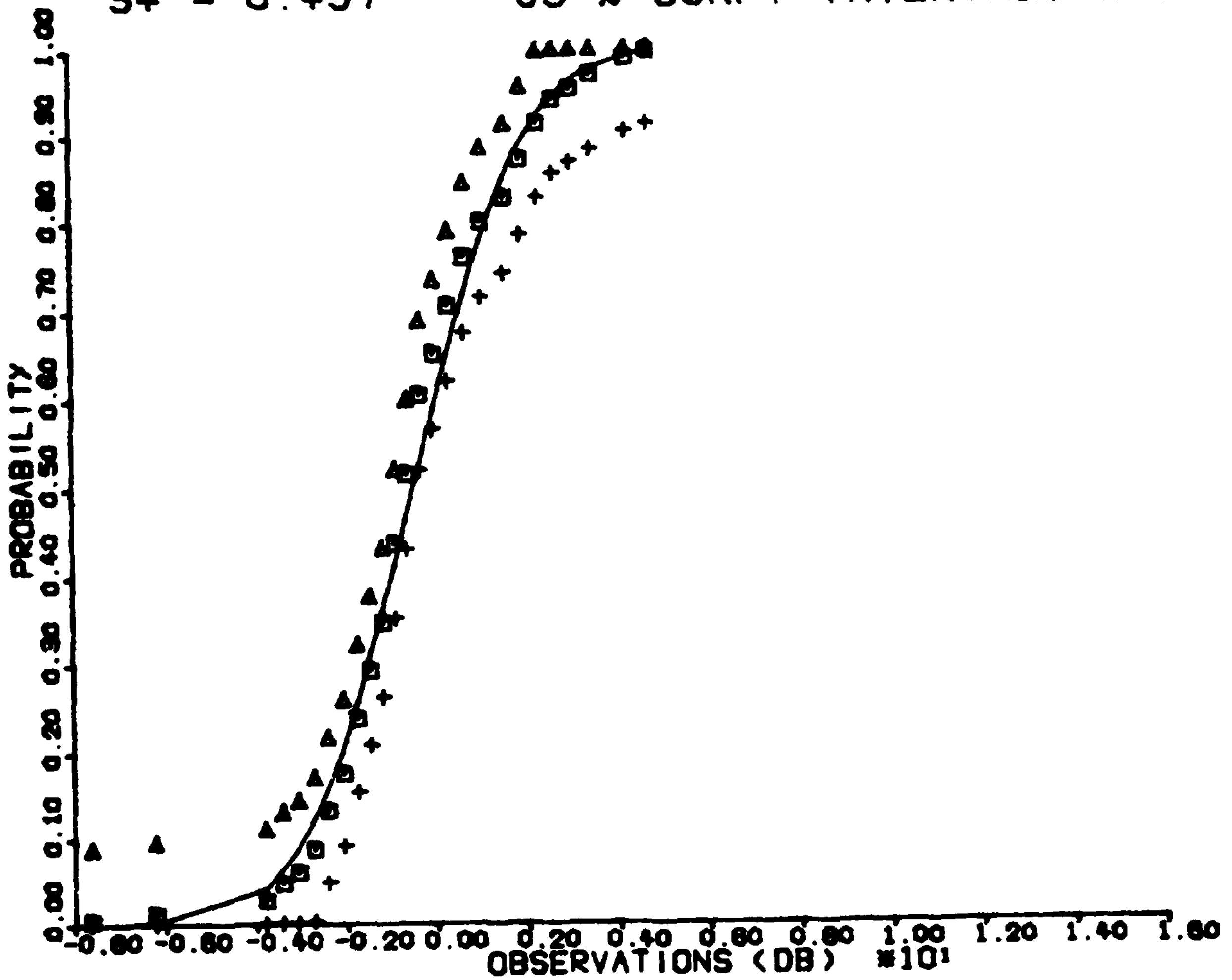


FIGURE 4.10

L-BAND/LOGNORMAL CDF PLOTS: BLOCK 145

S4 = 0.775   90 % CONF. INTERVALS SHOWN

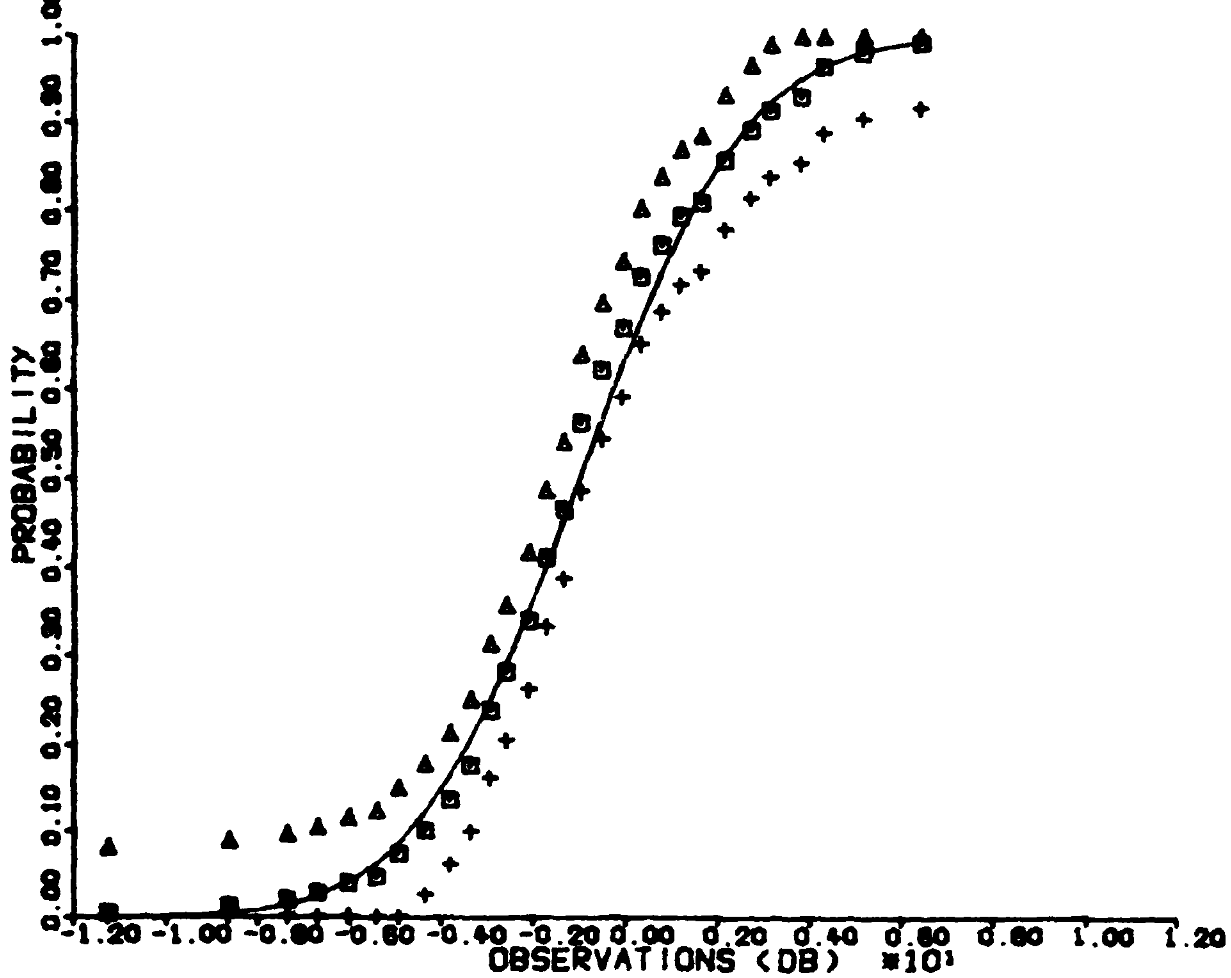


FIGURE 4.11

L-BAND/LOGNORMAL PROBABILITY PLOTS: BLOCK 25

S4 = 0.926 LEAST SQUARES LINE SHOWN

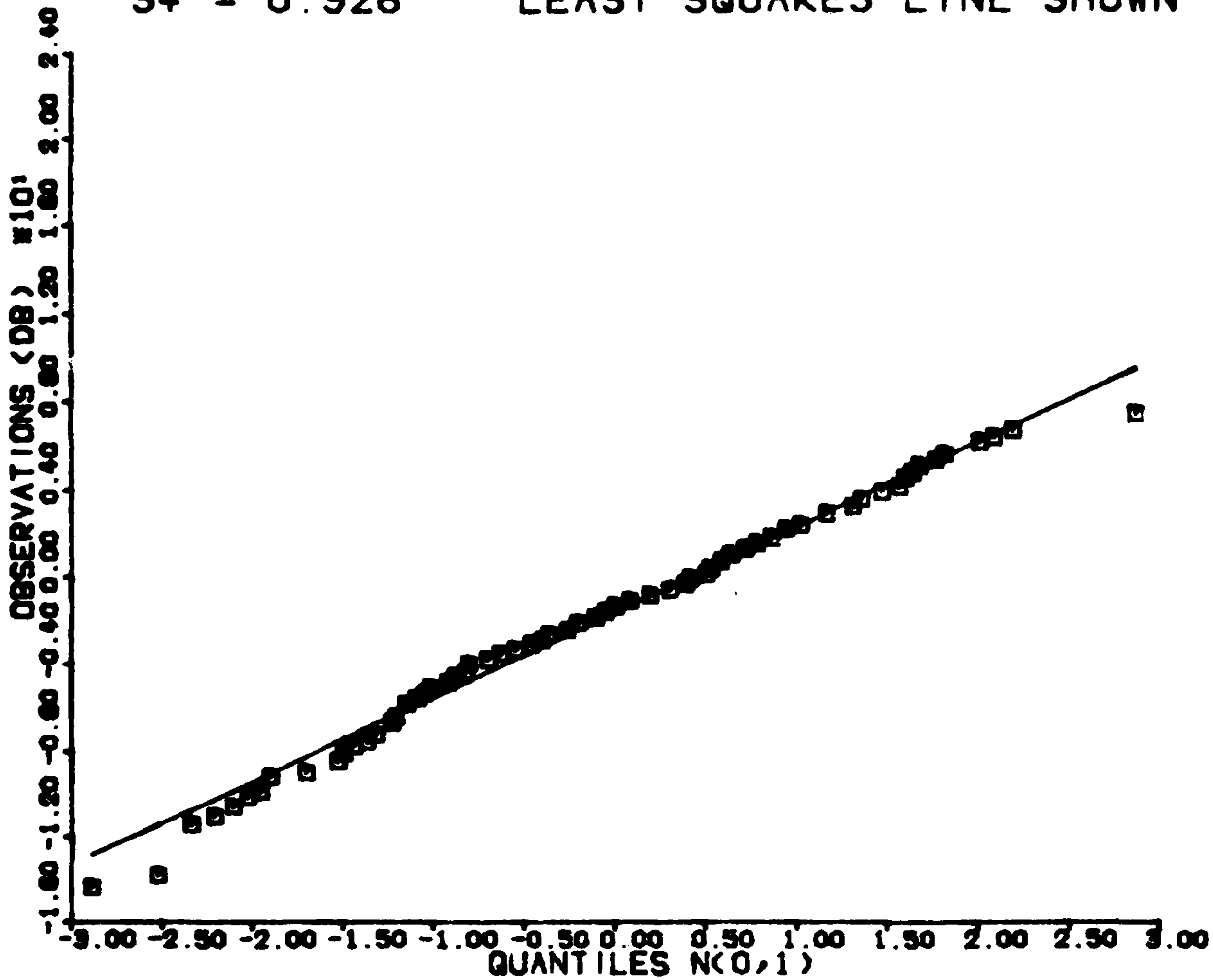


FIGURE 4.12

L-BAND/LOGNORMAL PROBABILITY PLOTS: BLOCK 55
S4 = 0.992 LEAST SQUARES LINE SHOWN

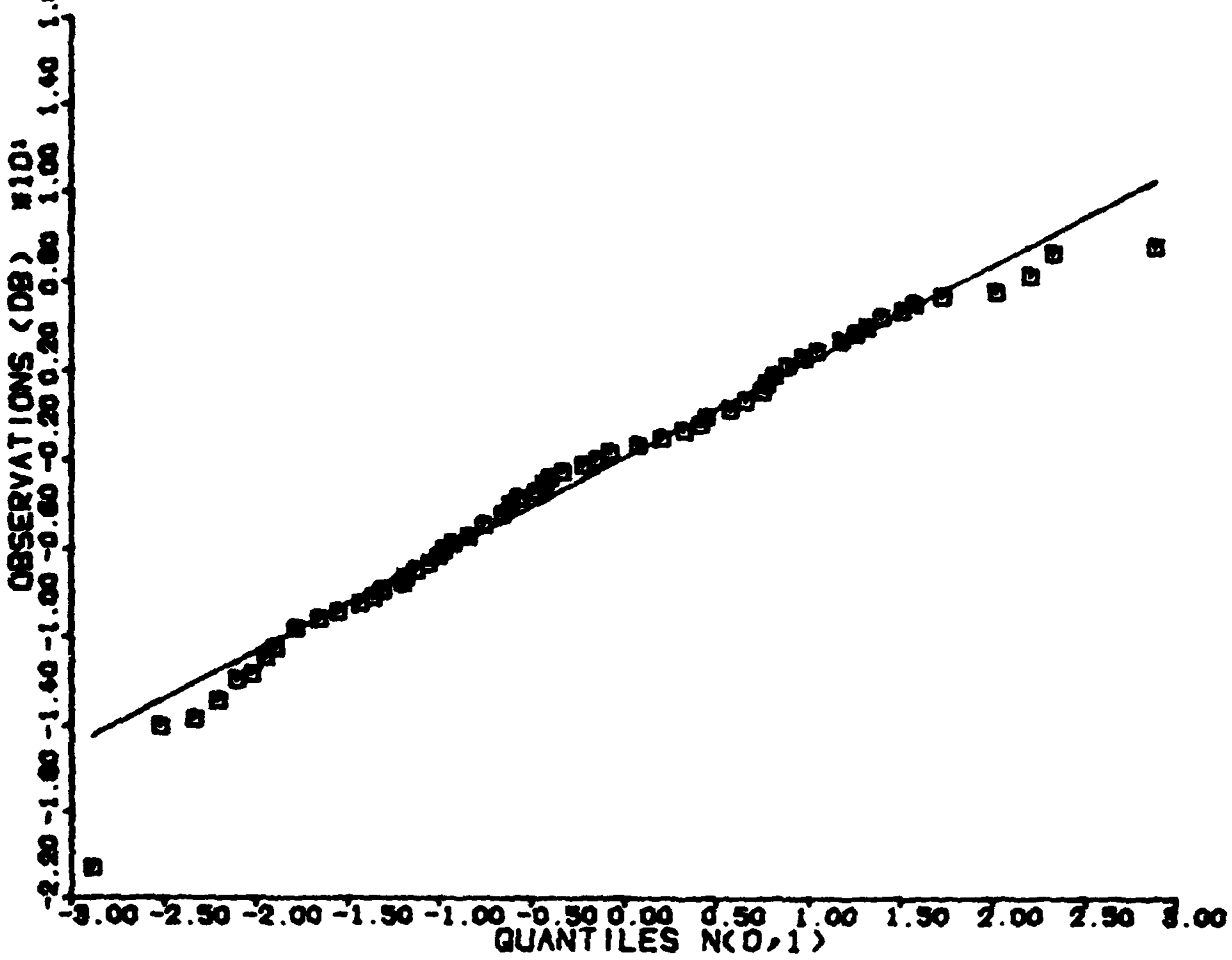


FIGURE 4.13

L-BAND/LOGNORMAL PROBABILITY PLOTS: BLOCK 85
S4 = 0.578   LEAST SQUARES LINE SHOWN

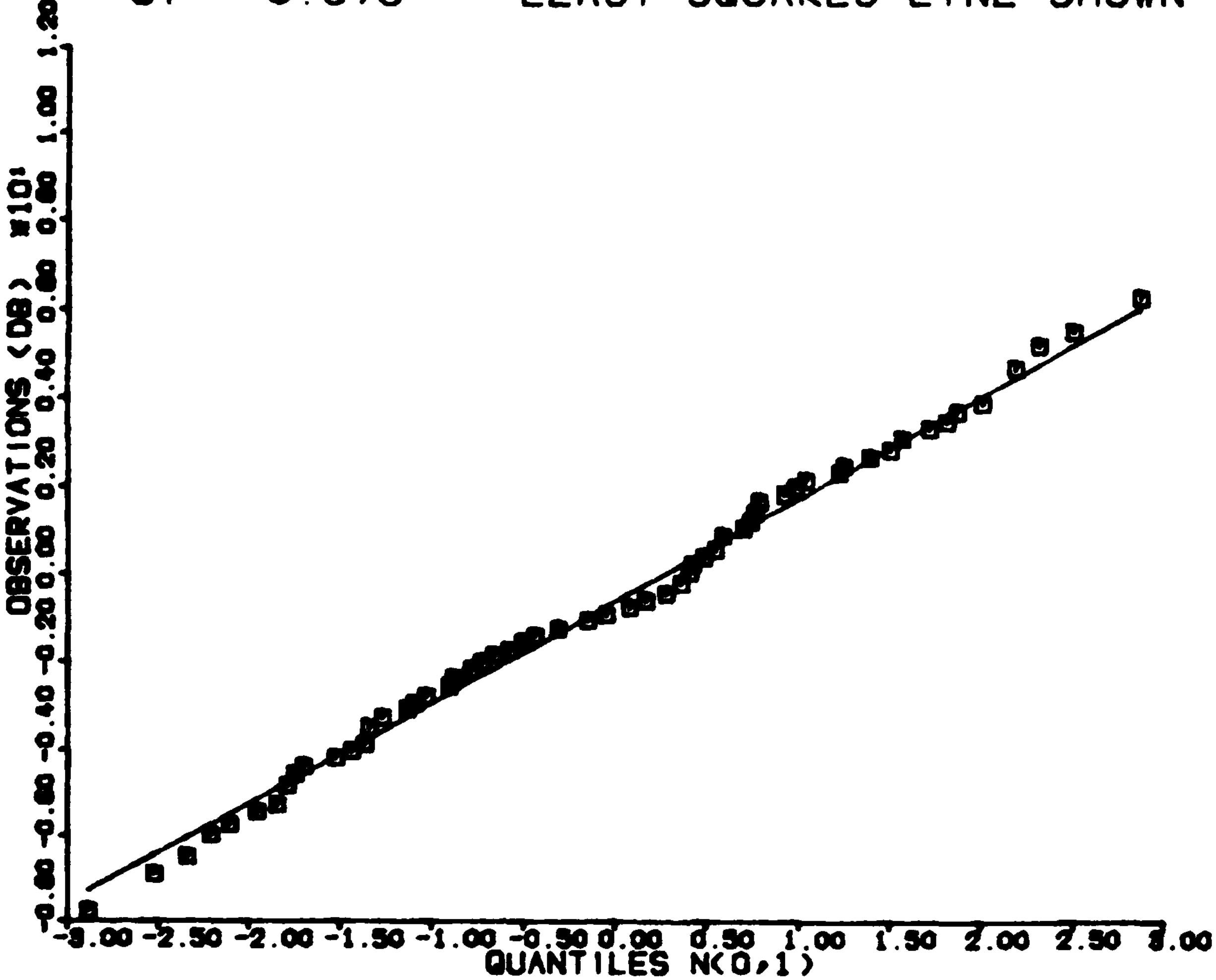


FIGURE 4.14

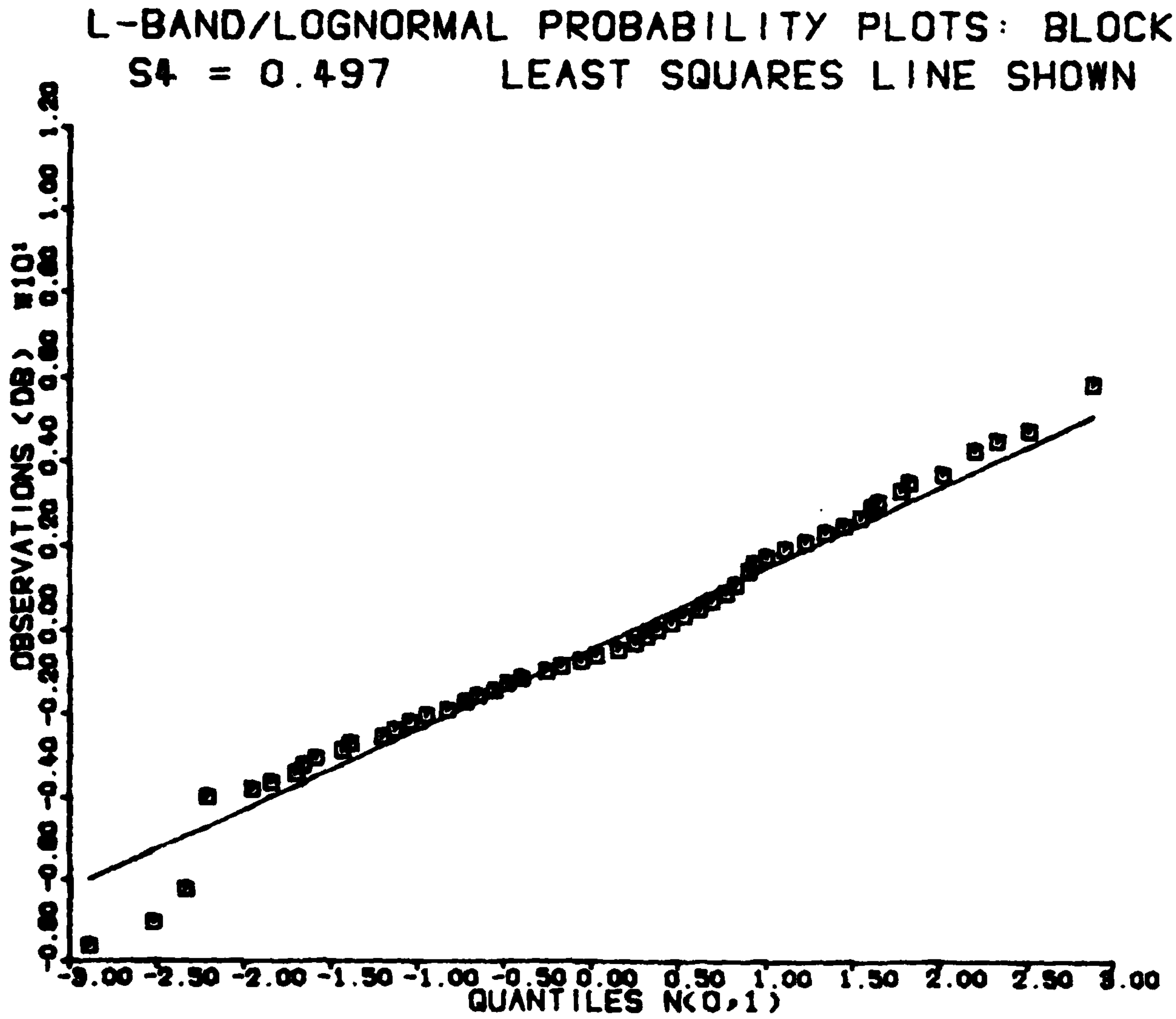

L-BAND/LOGNORMAL PROBABILITY PLOTS: BLOCK 109
S4 = 0.497   LEAST SQUARES LINE SHOWN
OBSERVATIONS (DB) *10¹
QUANTILES N(0,1)
-3.00 -2.50 -2.00 -1.50 -1.00 -0.50 0.00 0.50 1.00 1.50 2.00 2.50 3.00

FIGURE 4.15

L-BAND/LOGNORMAL PROBABILITY PLOTS: BLOCK 145

S4 = 0.775   LEAST SQUARES LINE SHOWN

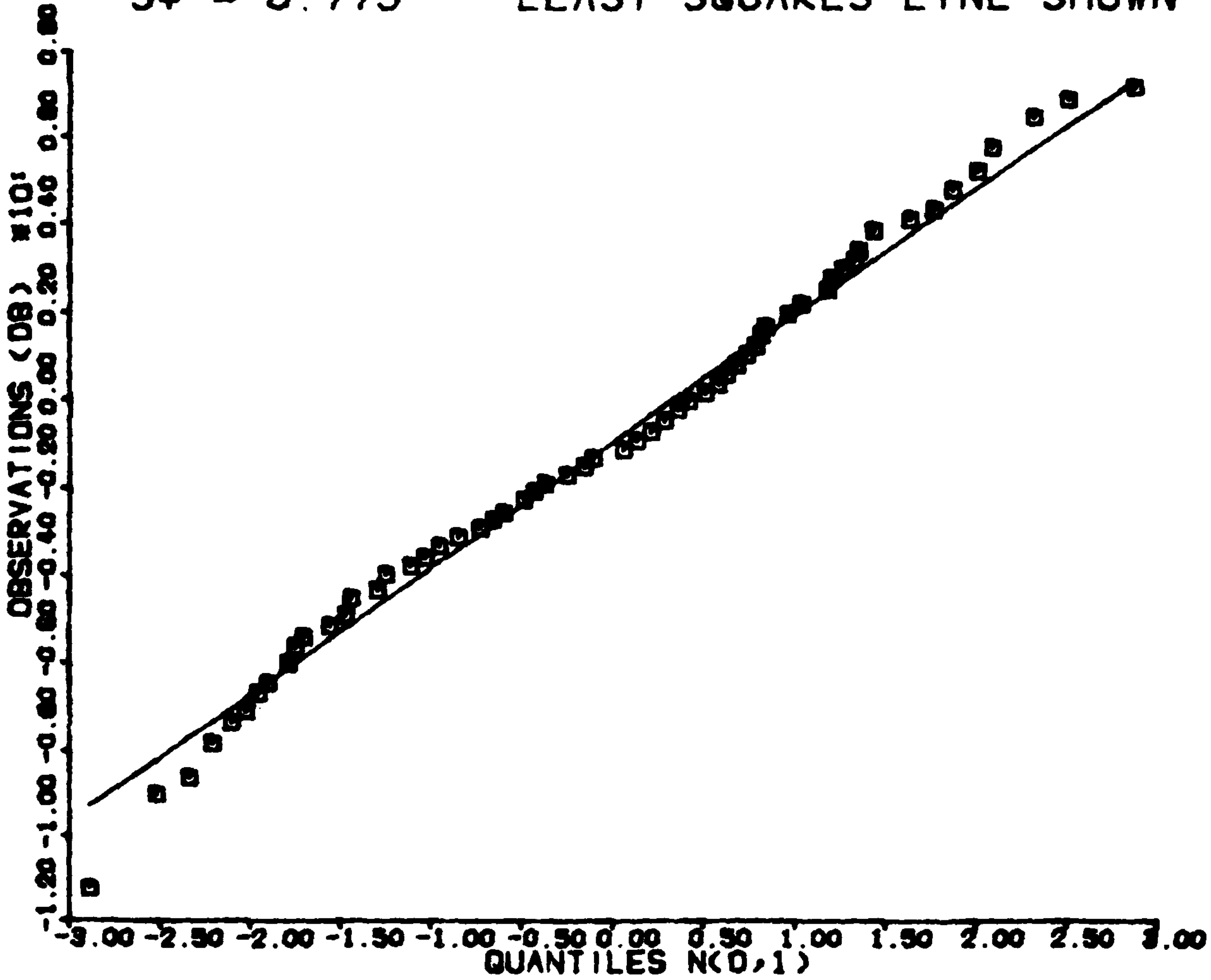


FIGURE A.1

UHF /LOGNORMAL CDF PLOTS: BLOCK 25

S4 = 0.802 99 % CONF. INTERVALS SHOWN

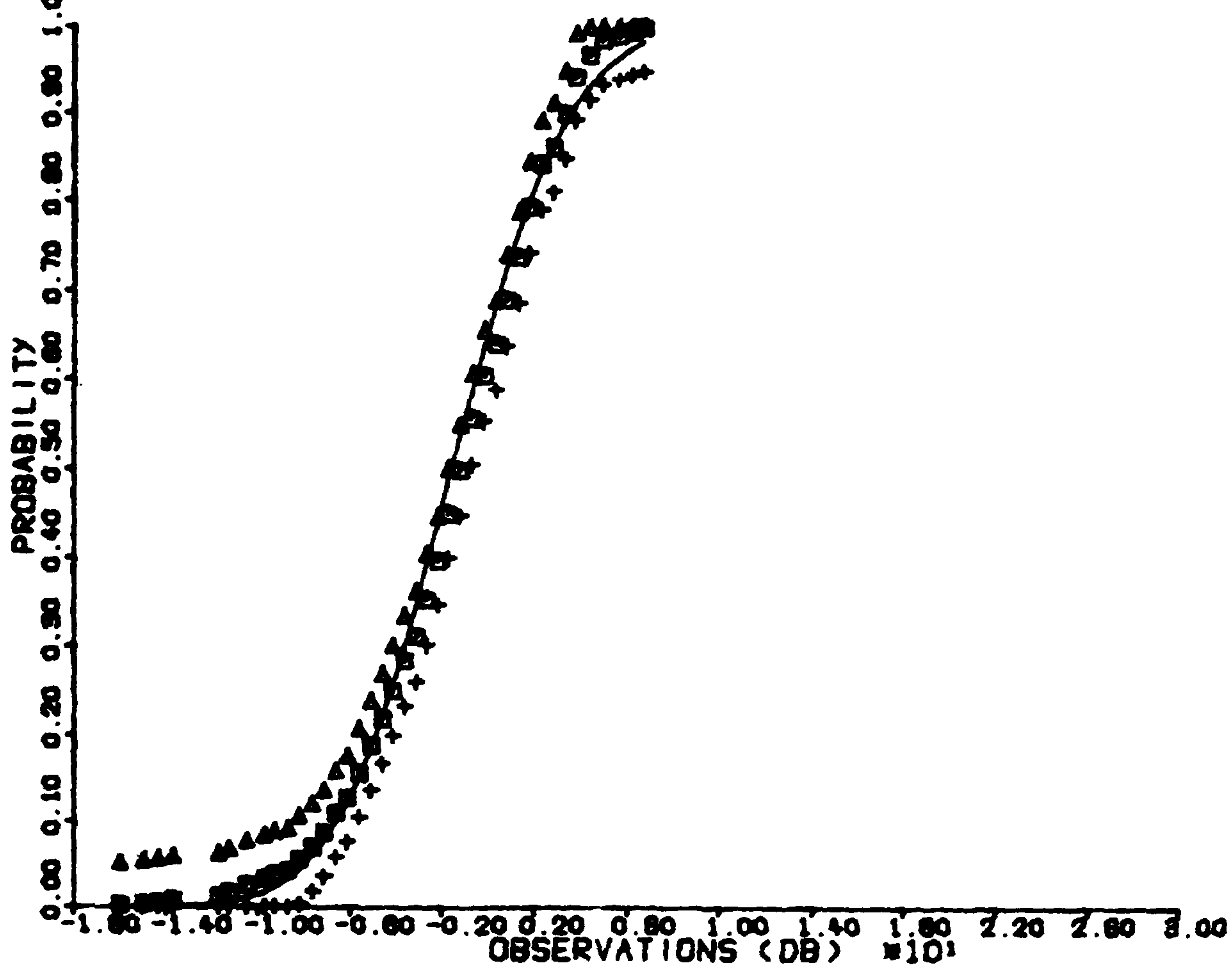


FIGURE A.2

UHF /LOGNORMAL CDF PLOTS: BLOCK 85

S4 = 0.966 99 % CONF. INTERVALS SHOWN

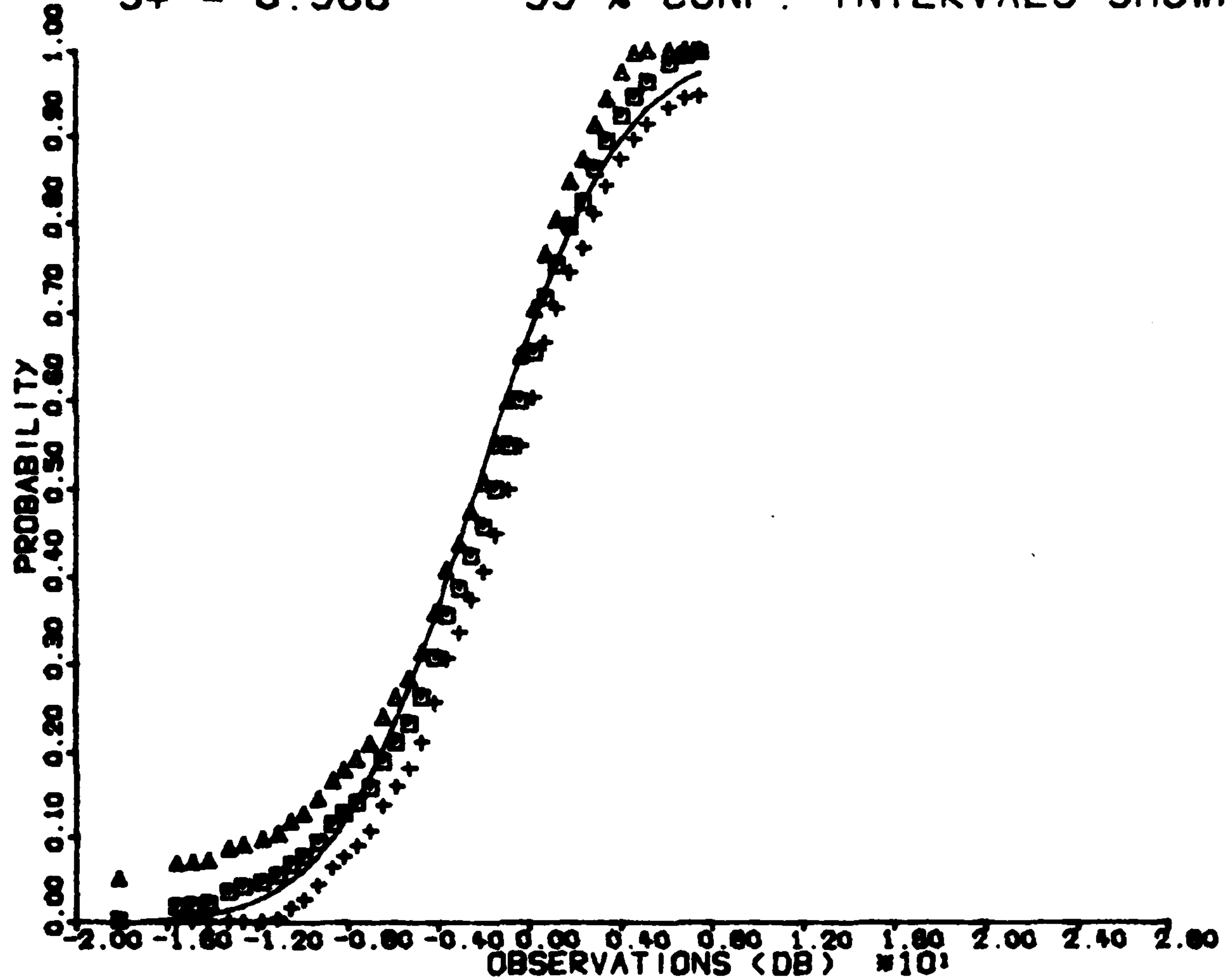


FIGURE A.3

UHF /LOGNORMAL PROBABILITY PLOTS: BLOCK 25

S4 = 0.802 LEAST SQUARES LINE SHOWN

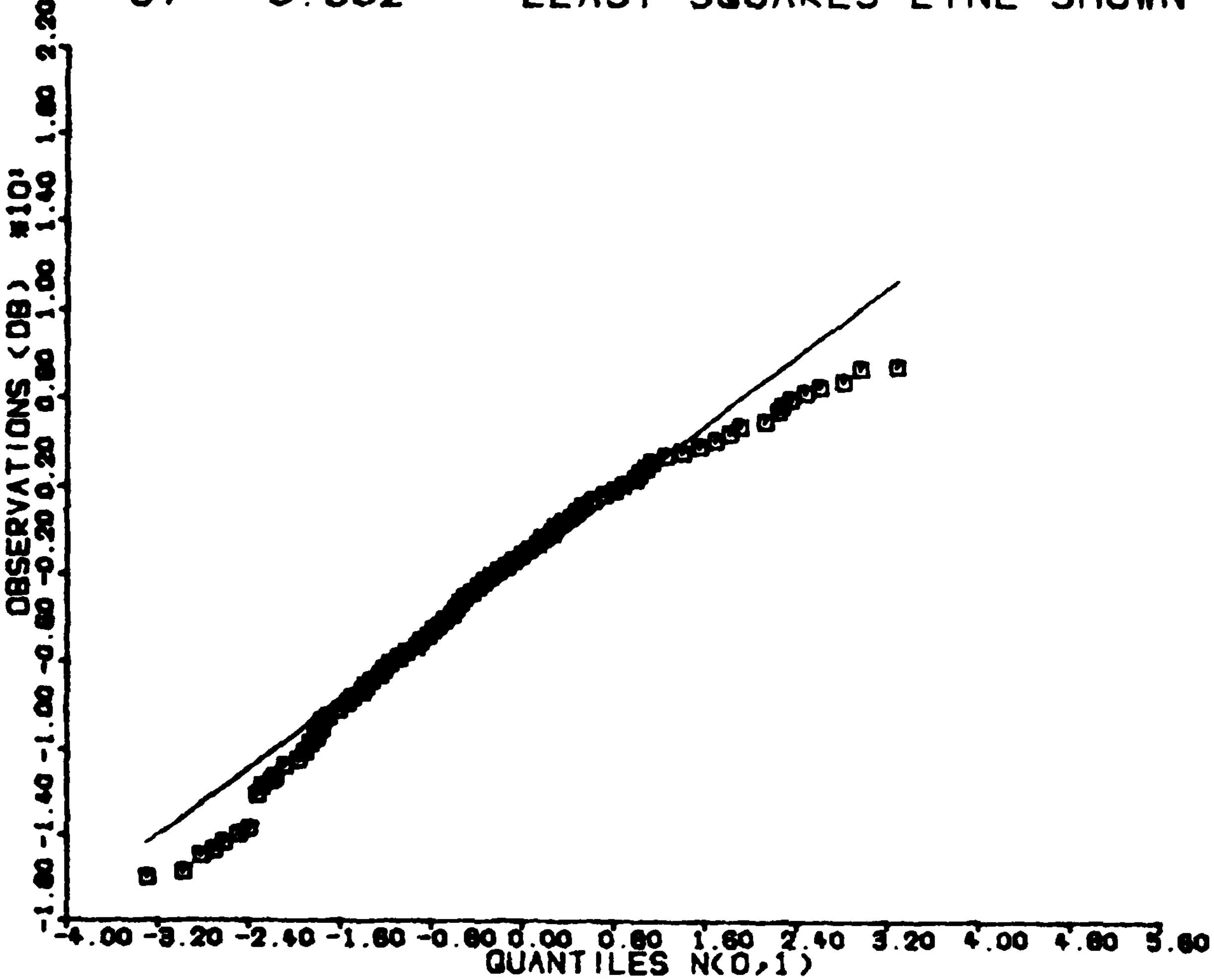
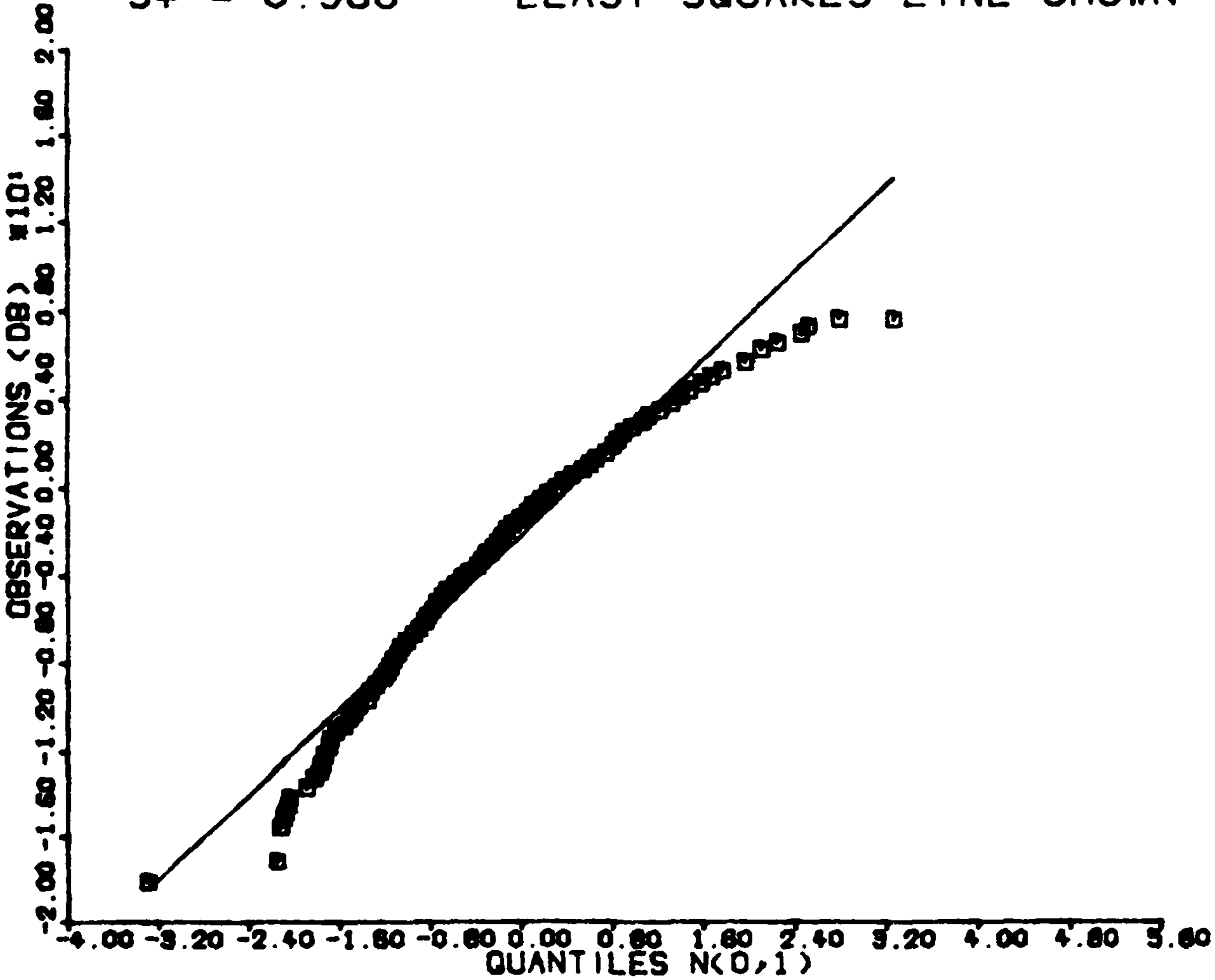


FIGURE A.4

UHF /LOGNORMAL PROBABILITY PLOTS: BLOCK 85
S4 = 0.966 LEAST SQUARES LINE SHOWN



DA
FILM