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**SIGNAL FADING  
CHARACTERISTICS, ECHO II**

*Prepared by*  
**COLLINS RADIO COMPANY**  
Cedar Rapids, Iowa  
*for Goddard Space Flight Center*



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JULY 1966



## SIGNAL FADING CHARACTERISTICS, ECHO II

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Prepared under Contract No. NAS 5-9648 by  
COLLINS RADIO COMPANY  
Cedar Rapids, Iowa

for

Goddard Space Flight Center  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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## ABSTRACT

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This report contains an analysis of the fading of the Echo II satellite radio cross section. The analysis is based on Collins Radio Company-Naval Research Laboratory bistatic data taken during the 1964 Echo II Program. Fade duration and fade period probability distribution and density functions were obtained at various cross-section levels. The results of the analysis indicate that the fading characteristics of Echo II did not change noticeably over the first year from launch. The fading of Echo II is similar to that observed on other communication links.

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## SECTION 1

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### INTRODUCTION

The objective of this program, performed under NASA Contract NAS5 - 9648, is to determine the fading characteristics of radio signals reflected by the Echo II passive Satellite from data collected during the 1964 Echo II Experimental Program (contract NAS5 - 3640). The Echo II Satellite is a 135-foot diameter spherical satellite in a 750-mile earth orbit. The satellite was illuminated with a 2380-mc CW signal from the Collins Radio Company facility at Dallas, Texas; the energy reflected by the satellite was received at the Naval Research Laboratory facility at Stumpneck, Maryland. Monostatic measurements were made simultaneously at 2190 mc by Collins Radio Company at Dallas.

During the 1964 Echo II Program the received signal-power data from the Naval Research Laboratory and Collins Radio Company was reduced to determine the behavior of the satellite radio cross section. For the program reported herein, data was selected for satellite cross-section fade analysis from the data reduced during the 1964 program.

Collins Radio Company-Naval Research Laboratory bistatic data was reduced for seven Echo II passes and two Echo I passes, and Collins monostatic data was reduced for two Echo II passes. The data ranged in time from Echo II pass no. 25 (27 January 1964) to Echo II pass no. 4505 (30 December 1964). The fade analysis consisted of the determination of the first-order statistics of the durations of fades and the periods of fades at cross-section levels distributed over the range of instantaneous cross-section excursion.

## SECTION 2

### FADE ANALYSIS

For an amplitude versus time waveform such as shown in figure 1, a fade is defined as an amplitude excursion below a given amplitude level. The waveform has a negative slope at the beginning of a fade and a positive slope at the end of a fade. One method of characterizing the fading structure of a waveform

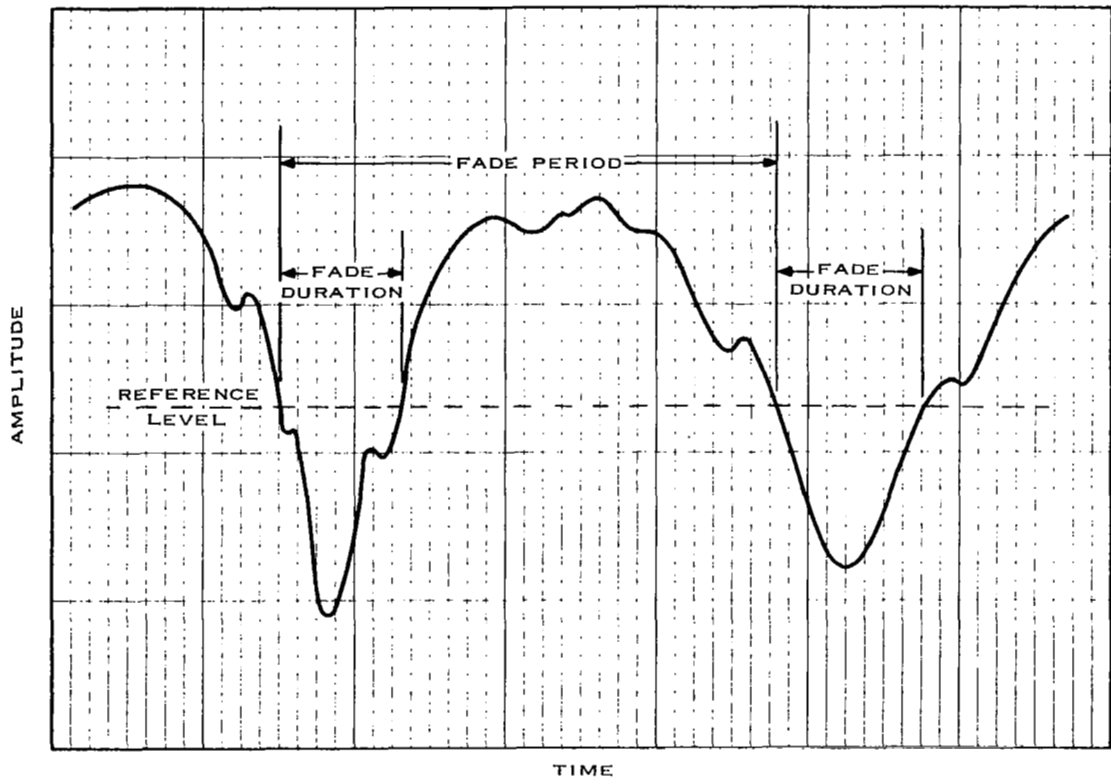


Figure 1. Amplitude Vs Time Waveform with Duration and Fade Period Indicated

is by a statistical description of the time durations of the fades and of the time periods between the beginnings of adjacent fades. These quantities are referred to as fade duration and fade period, and are indicated on the waveform in figure 1. A reference level is required to define a fade, and the fade duration and period will be a function of the chosen level. For a complete characterization of fading structure, the duration and period statistics must be known at all amplitude levels. However, for experimental analysis, a selection of discrete levels over the amplitude range must be made.

## 2.1 FADE DURATION ANALYSIS.

A first-order statistical analysis of fade durations consists of the determination of the probability distributions and densities of durations at a set of amplitude levels. The probability distribution is a plot of duration values versus the probability that these values are exceeded. The probability density is the negative derivative of the distribution. Examples of a fade duration probability distribution and a fade duration probability density are shown in figures 2 and 3. The distribution and density will generally be different at each amplitude level.

## 2.2 FADE PERIOD ANALYSIS.

The statistical analysis of fade periods consists of determination of the probability distributions and probability densities of the time intervals between the beginnings of adjacent fades. These statistics will be a function of the amplitude reference level used to define the fades.

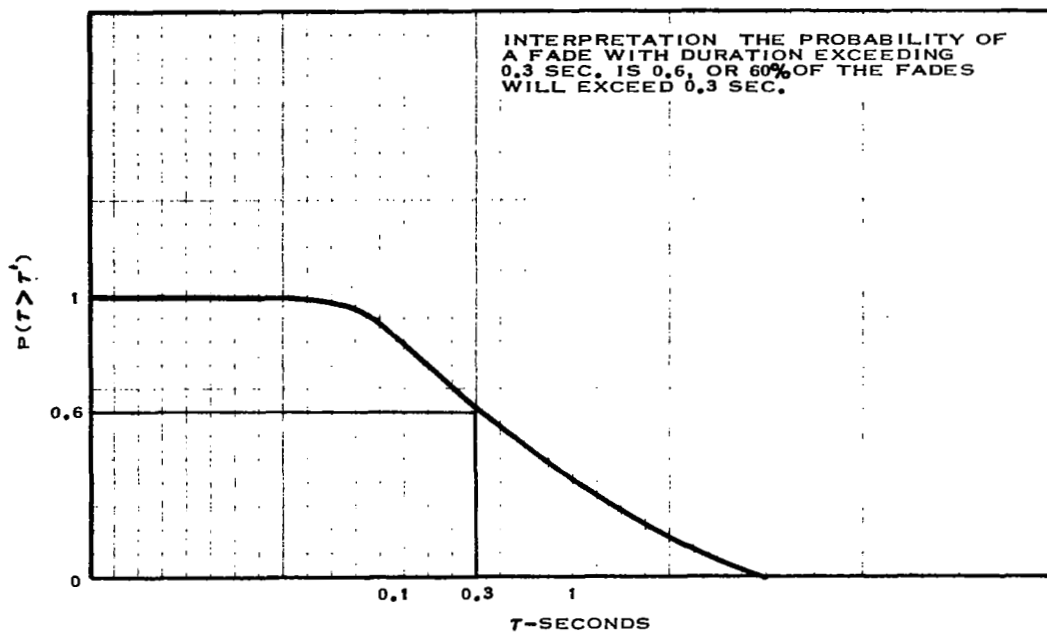


Figure 2. An Example of a Fade Duration Probability Distribution with Interpretation

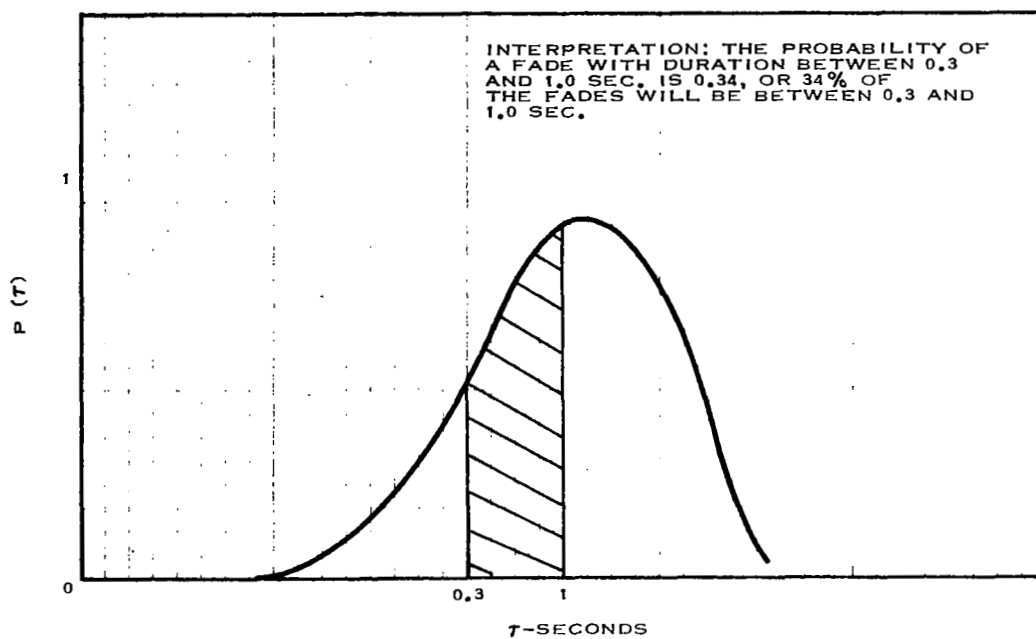


Figure 3. An Example of a Fade Duration Probability Density with Interpretation

## SECTION 3

---

### SELECTION OF DATA

The data on which the fade analysis was performed was selected from the data taken during the 1964 Echo II Program and reduced for satellite cross section during that program. The criteria used in the selection of data consisted of:

- (1) Quality of the data as determined by strip charts and tracking reports from the stations involved.
- (2) Distribution of the data over the first year after launch.

#### 3.1 DATA SELECTED.

The data available for selection consisted of the following:

- 25 Echo II passes from Collins-NRL bistatic operation.
- 6 Echo II passes from Collins monostatic operation.
- 4 Echo I passes from Collins-NRL bistatic operation.

From this data, seven Echo II bistatic passes, two Echo II monostatic passes, and two Echo I bistatic passes were selected for fade analysis. From each pass, a segment of continuous data was selected for reduction.

The passes selected with their times of occurrence and amount of data reduced are given in table 1.

TABLE 1. DATA SELECTED FOR FADE ANALYSIS

| PASS NO. | TIME (GMT)                | LENGTH OF DATA ANALYZED<br>(sec) |
|----------|---------------------------|----------------------------------|
|          | <u>Echo II Bistatic</u>   |                                  |
| 25       | 640127.11                 | 240                              |
| 1197     | 640425.02                 | 150                              |
| 1414     | 640511.11                 | 240                              |
| 1717     | 640603.18                 | 300                              |
| 2653     | 640813.01                 | 290                              |
| 3977     | 641121.00                 | 120                              |
| 4505     | 641230.19                 | 160                              |
|          | <u>Echo II Monostatic</u> |                                  |
| 1717     | 640603.18                 | 300                              |
| 2653     | 640813.01                 | 300                              |
|          | <u>Echo I Bistatic</u>    |                                  |
| 16983    | 640511.09                 | 170                              |
| 17965    | 640728.06                 | 240                              |

## DATA REDUCTION

The received signal level data was recorded on 1/2-inch magnetic tape at 15 inches per second using IRIG telemetry band C. The data reduction process involved the following steps:

(1) Linearization of Data in Dbm.

The effects of receiver nonlinearities were removed by the use of receiver calibration levels recorded for each satellite pass.

(2) Removal of Range Effects from Data.

The satellite range functions were derived from the NASA-furnished range data.

(3) Determination of Fade Duration and Fade Period Probability Distributions.

The probability distributions were obtained from the analog data by a specially constructed fade analyzer.

(4) Determination of Fade Duration and Fade Period Probability Densities.

The probability densities were obtained by differentiations of the distributions on a Digital computer.

#### 4.1 REMOVAL OF RANGE EFFECTS.

The received power data contains the effects of the changing range between the satellite and the tracking stations. In order to determine the fading characteristics of the satellite, these effects were removed. The received power is given by

$$P_R = \frac{P_T G_T G_R \lambda^2 \sigma}{(4\pi)^3 (d_1 d_2)^2} \quad (1)$$

where

$P_R$  = Received Power

$P_T$  = Transmitted Power

$G_T$  = Transmitting Antenna Gain

$G_R$  = Receiving Antenna Gain

$\lambda$  = wavelength

$\sigma$  = Satellite effective cross section

$d_1$  = Transmitter - Satellite Range

$d_2$  = Receiver - Satellite Range

For each satellite pass, the values of  $P_T$ ,  $G_T$ ,  $G_R$ , and  $\lambda$  are known. Values of  $d_1$  and  $d_2$  at 1-minute intervals were furnished by NASA Goddard Space Flight Center. By digital linear interpolation on the 1-minute data, range values at 15-second intervals were obtained and values of  $20 \log (d_1 d_2)$  were computed. A plot of  $20 \log (d_1 d_2)$  versus time for Echo II pass 1717 is shown in figure 4. The received power data was linearized in terms of dbm. By subtracting the  $20 \log (d_1 d_2)$  and inserting the appropriate values of the other parameters in equation (1), analog data of satellite cross section ( $\sigma$ ) in terms of db relative to one square meter were obtained. The fade analysis was conducted on this data. An example of the cross-section waveform for Echo II pass 1717 is shown in figure 5.

#### 4.2 FADE ANALYSIS INSTRUMENTATION.

The fade duration and period analysis of the instantaneous satellite cross-section data was done on specially built fade analysis instrumentation. A count is obtained of the number of fades below a specified amplitude level whose duration exceeds a threshold duration. By varying the amplitude level and threshold duration over the data range, the fade duration probability distribution is obtained. The fade period probability distribution is similarly obtained.

by comparing the period between the start of adjacent fades with a period threshold. A block diagram of the fade duration and fade period analysis system is shown in figure 6. The system operation for duration analysis is illustrated in figure 7. For fade period analysis, only the leading edges of the level detector output are used for control.

#### 4.3 DIGITAL COMPUTATION.

The fade duration and fade period probability density functions were obtained by numerically differentiating the probability distribution functions. The derivative was obtained by curve fitting sets of three successive experimentally derived points of the distribution function with second order polynomials and differentiating the polynomials in the regions of fit. The mean values of fade duration and fade period were computed from the density functions.

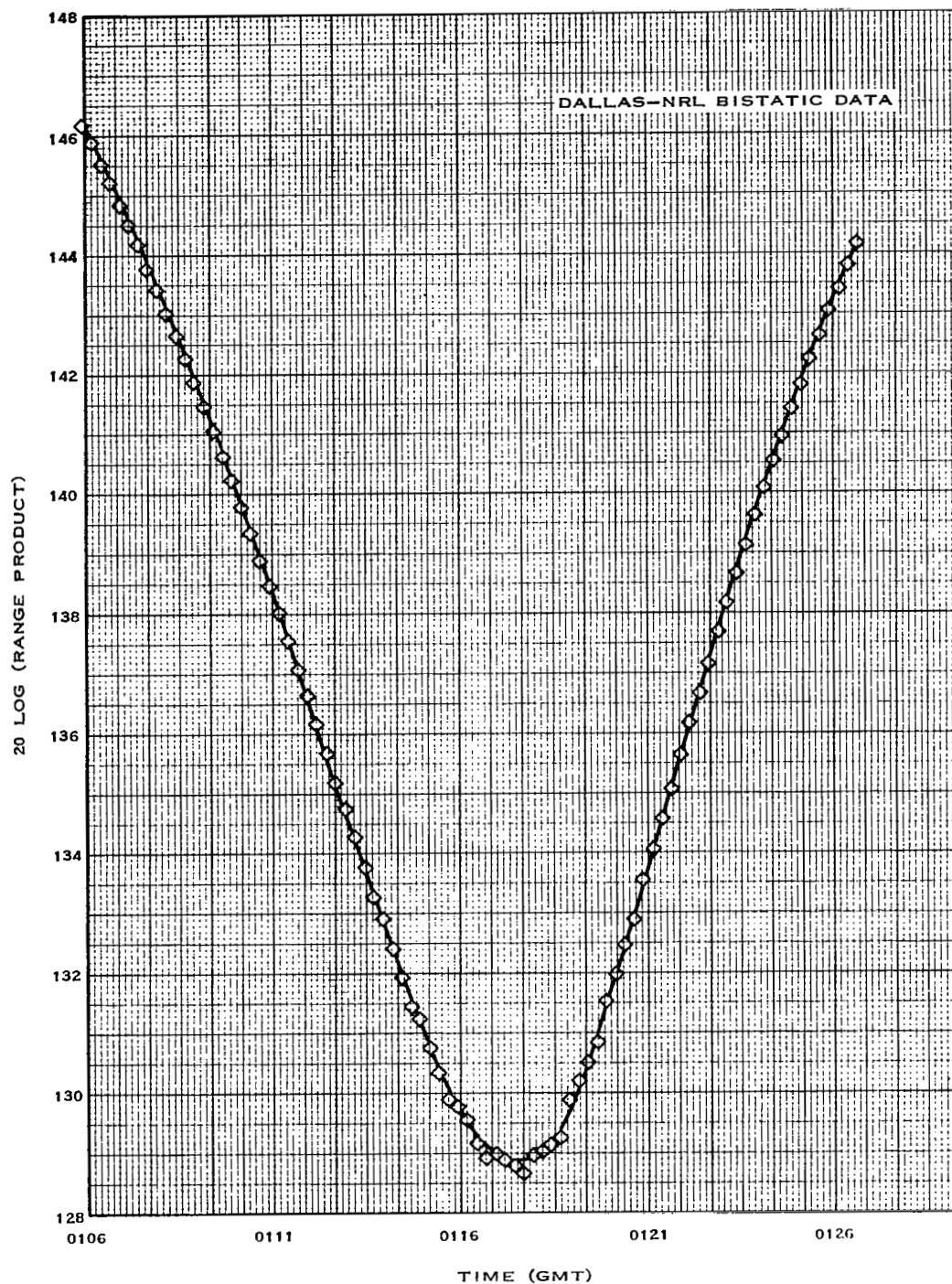


Figure 4. 20 Log (Range Product) Vs Time, Echo II 1717

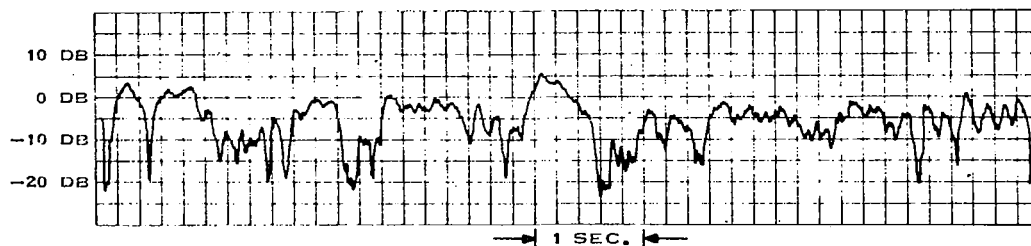


Figure 5. Echo II Pass No. 1717 Cross-Section Waveform

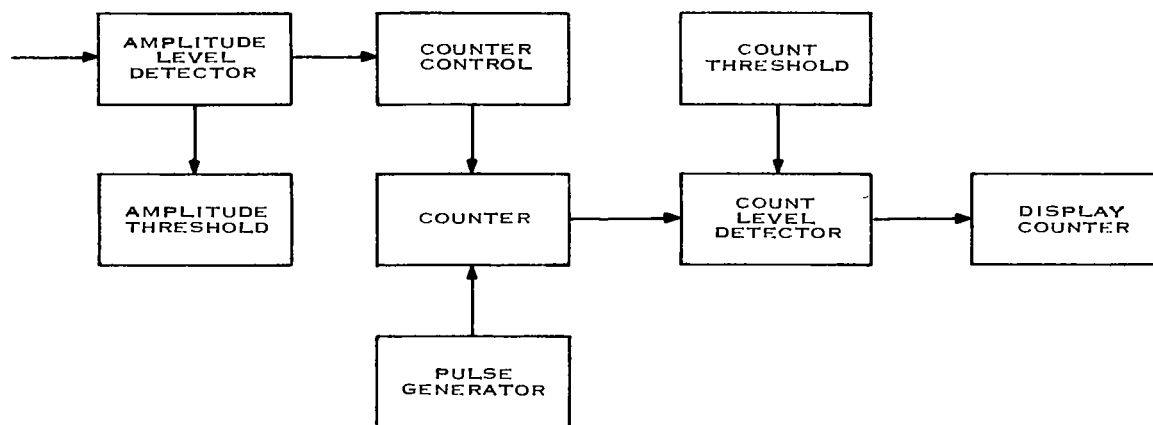


Figure 6. Fade Duration and Fade Period Analysis System

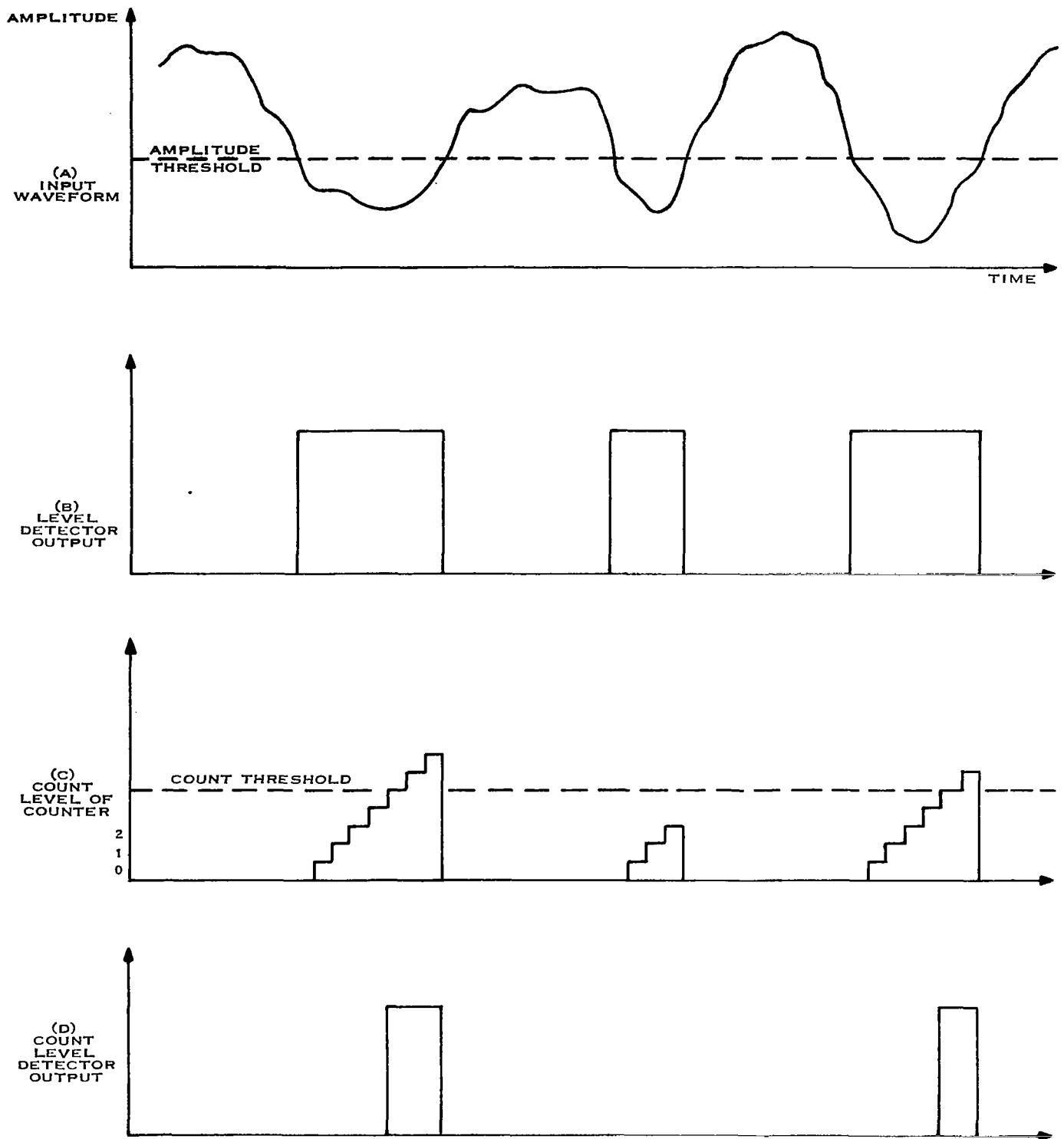


Figure 7. System Operation for Fade Duration Analysis

## REDUCED DATA

The reduced data is presented by grouping together the Echo II bistatic data, Echo II monostatic data, and Echo I bistatic data. For each pass, the curves presented are as follows:

- (1) Probability distribution of fade duration.
- (2) Probability density of fade duration.
- (3) Probability distribution of fade period.
- (4) Probability density of fade period.
- (5) Mean fade duration versus cross-section level.
- (6) Mean fade period versus cross-section level.

The probability distribution and density functions are taken at approximately eight cross-section levels distributed over the range of amplitude excursion. The cross-section levels are expressed in db relative to the mean cross section taken over the pass.

#### 5.1 ECHO II BISTATIC DATA.

This section contains the results of the fade analysis of the Collins-NRL bistatic data. The passes reduced are 25, 1197, 1414, 1717, 2653, 3977, and 4505. The fade analysis results are shown in figures 8 through 56.

#### 5.2 ECHO II MONOSTATIC DATA.

This section contains the results of the fade analysis of Collins monostatic data. Since a limited amount of data was available for selection, only two passes (1717, 2653) were reduced for comparison with the Collins-NRL bistatic data. The fade analysis results are shown in figures 57 through 70.

### 5.3 ECHO I BISTATIC DATA.

Two Echo I bistatic passes (16983, 17965) were selected for reduction from the Collins-NRL bistatic data. These passes will provide a limited comparison between Echo I and Echo II. The results for the two Echo I passes are shown in figures 71 through 84.

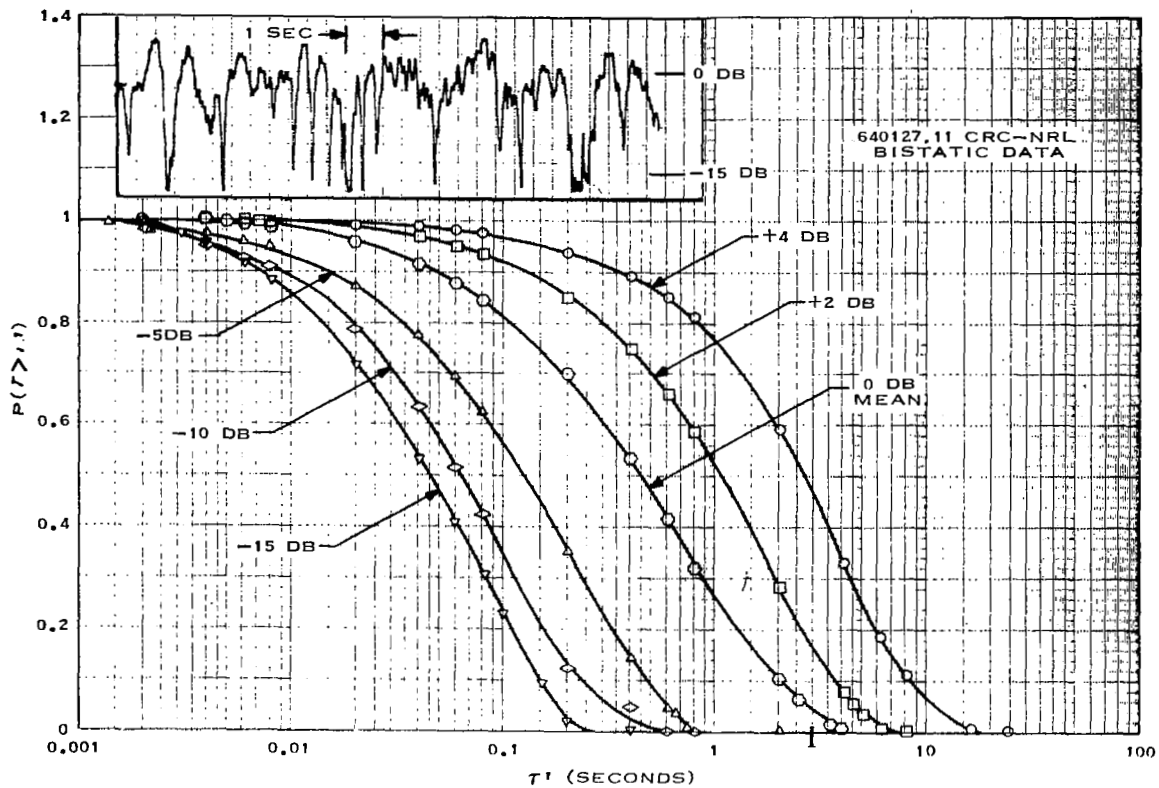


Figure 8. Probability Distribution of Fade Duration, Pass No. 25,  
 $P(\tau > \tau')$  Vs  $\tau'$  -5, -10, -15 Db, +4, +2, 0 Db

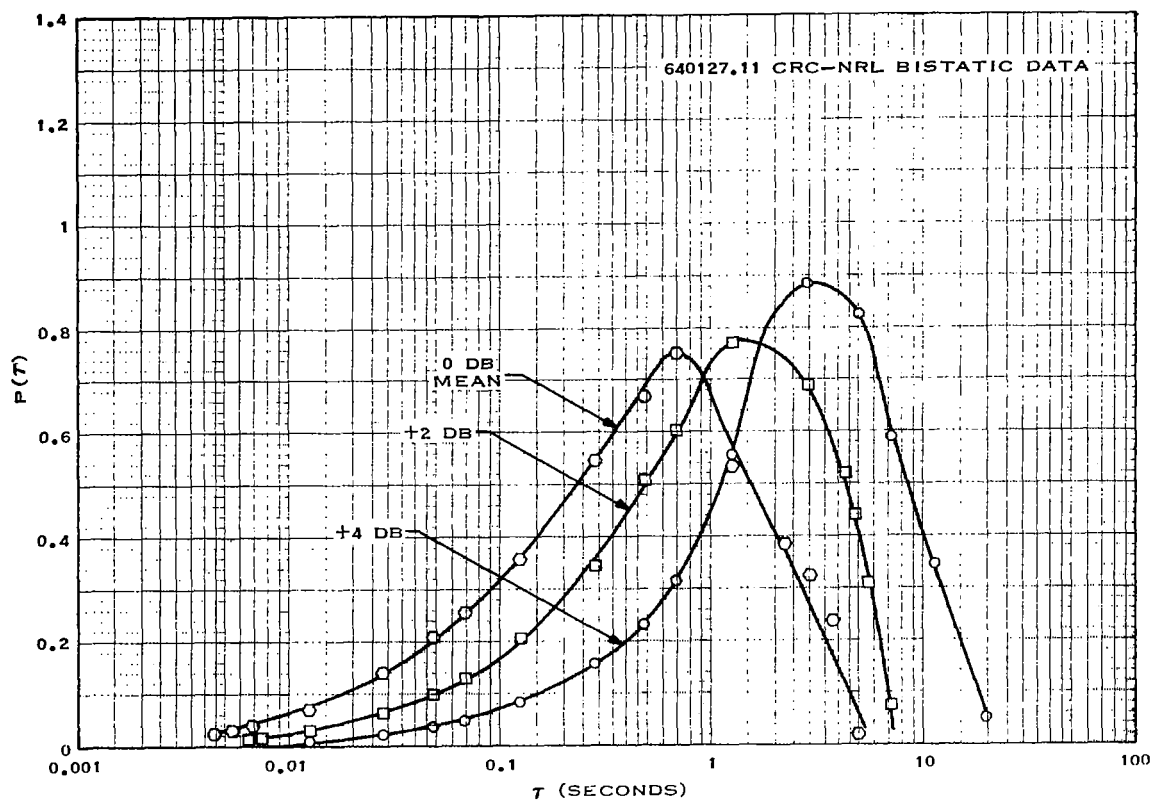


Figure 9. Probability Density of Fade Duration, Pass No. 25,  
 $P(\tau)$  Vs  $\tau$ , 0, +2, +4 Db

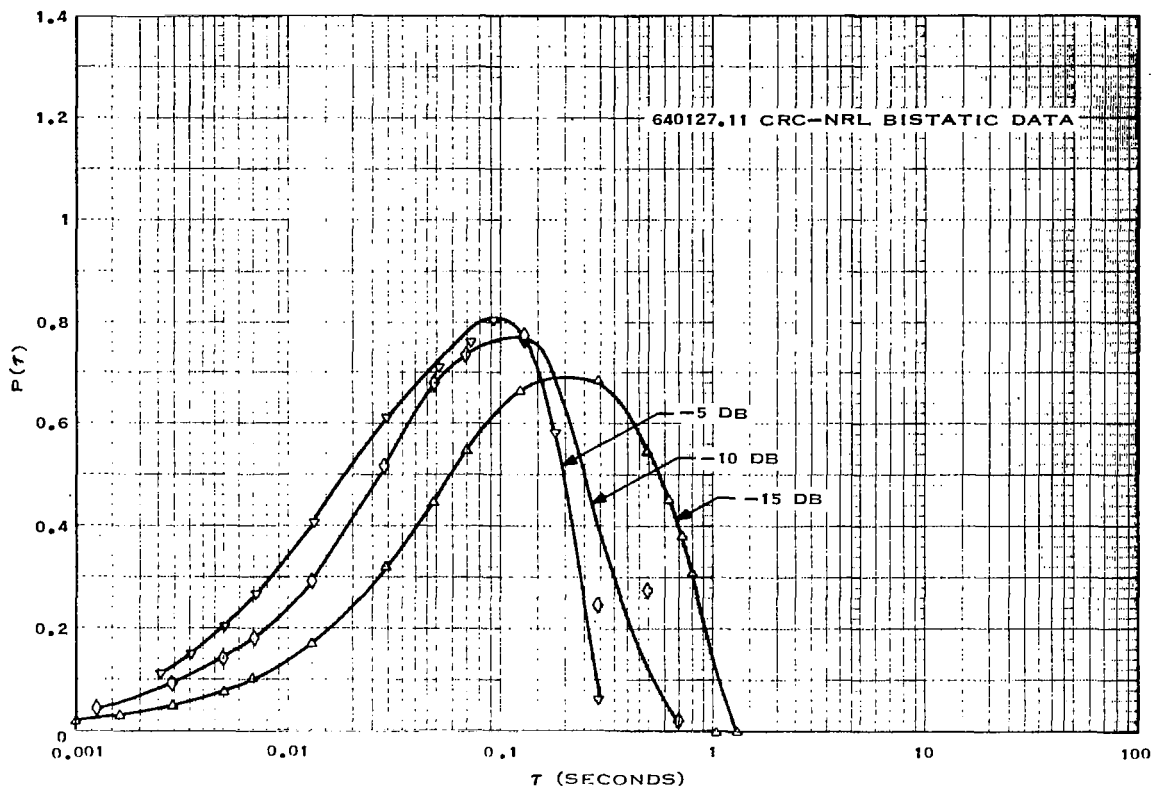


Figure 10. Probability Density Fade Duration, Pass No. 25,  
 $P(\tau)$  Vs  $\tau$ , -5, -10, -15 Db

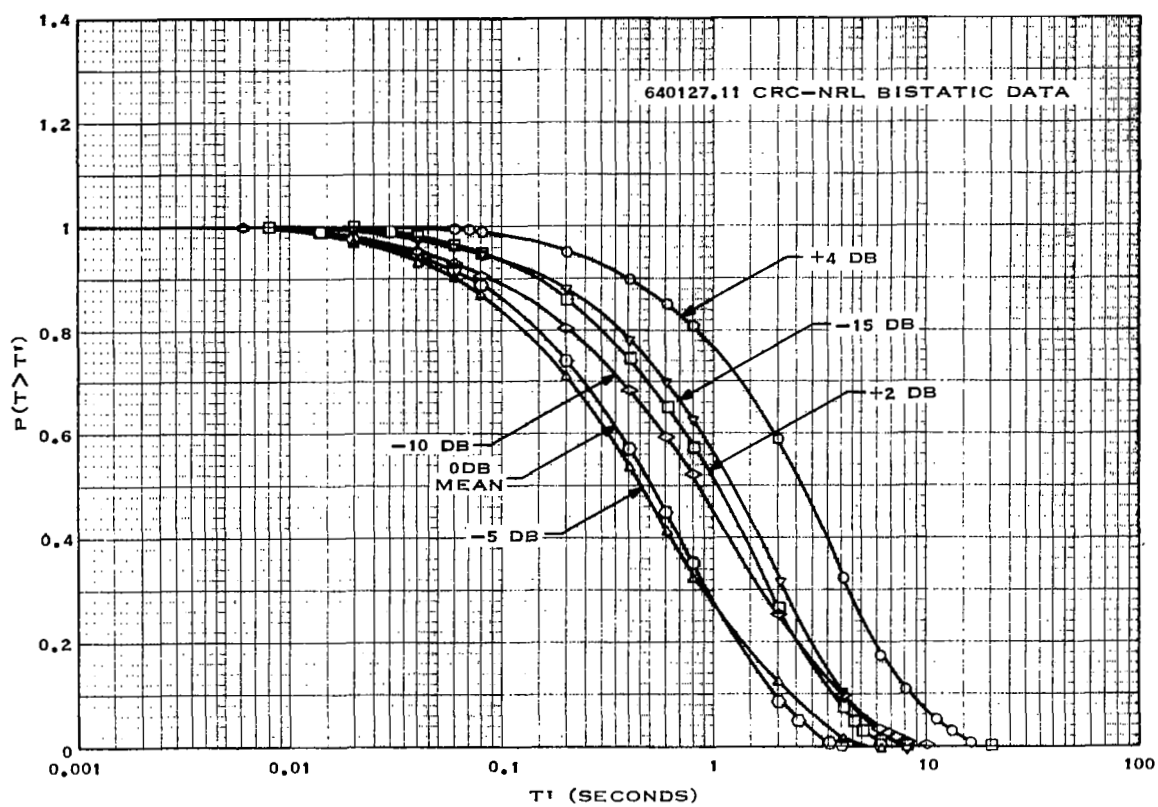


Figure 11. Probability Distribution of Fade Period, Pass No. 25,  
 $P(T > T')$  Vs  $T'$ , -10, 0, -5 Db, +4, -15, +2 Db

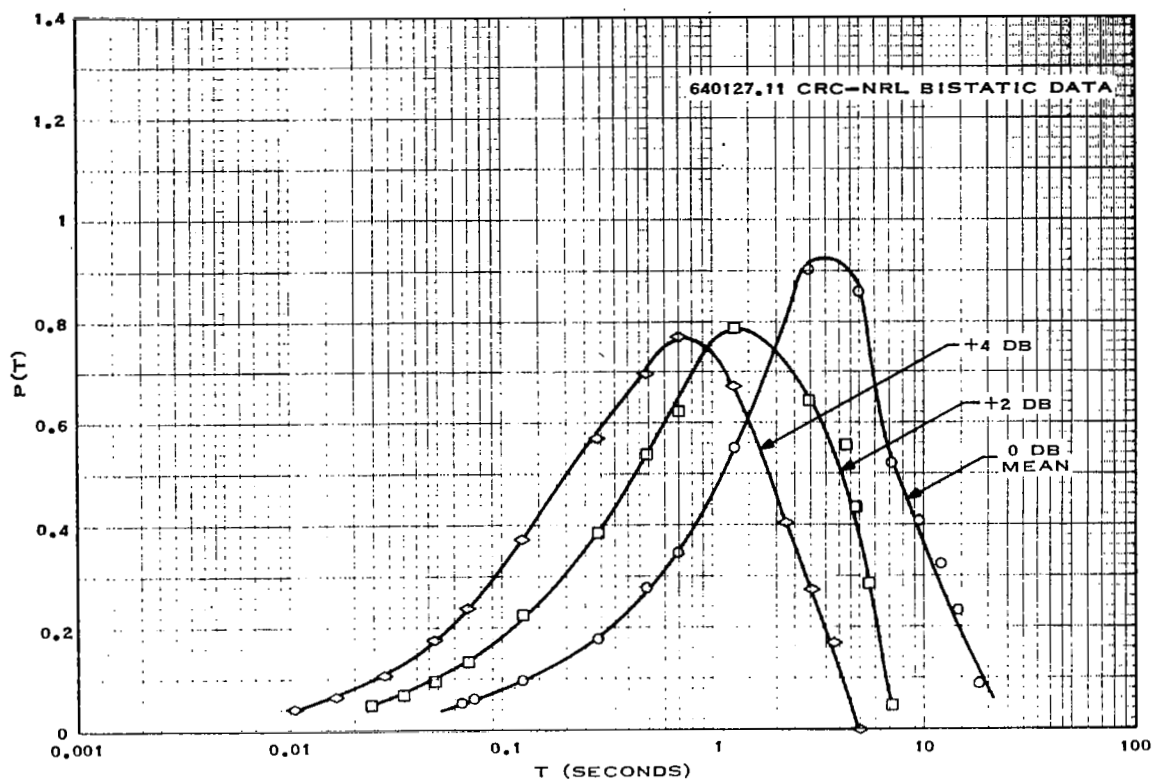


Figure 12. Probability Density of Fade Period, Pass No. 25,  
 $P(T)$  Vs  $T$ , 0, +2, +4 Db

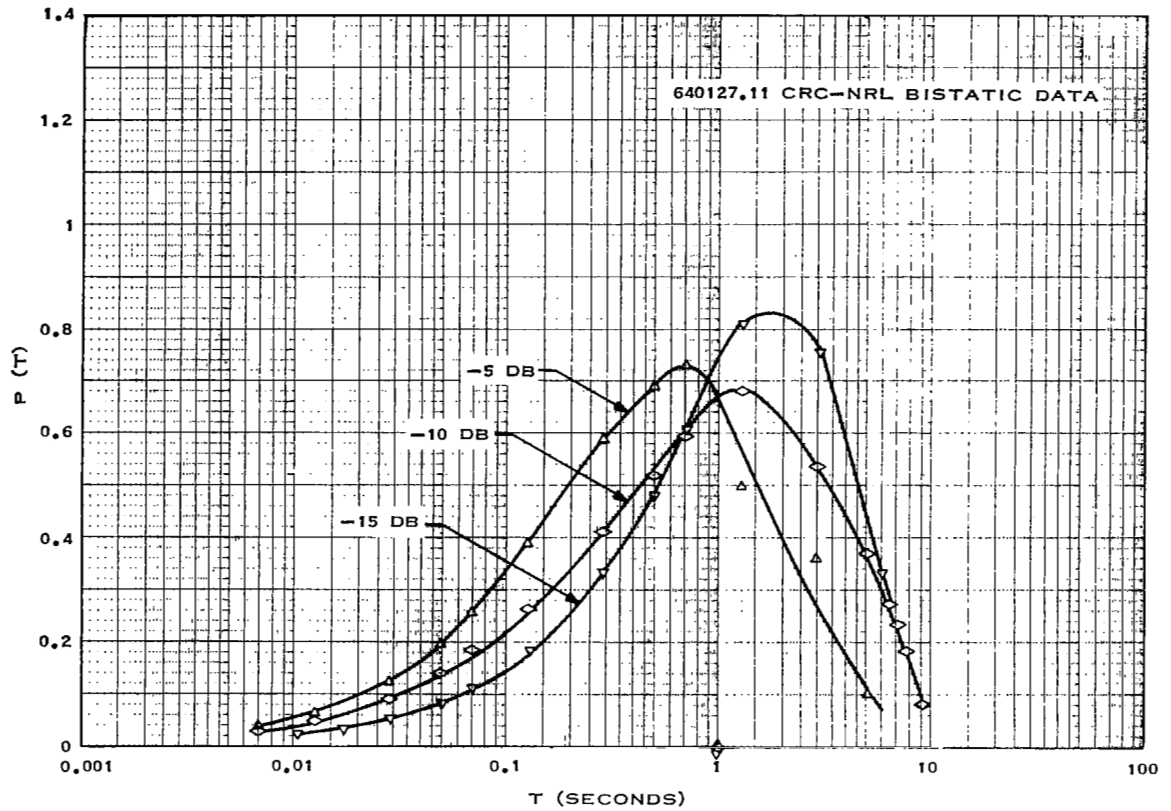


Figure 13. Probability Density of Fade Period, Pass No. 25,  
 $P(T)$  Vs  $T$ , -5, -10, -15 Db

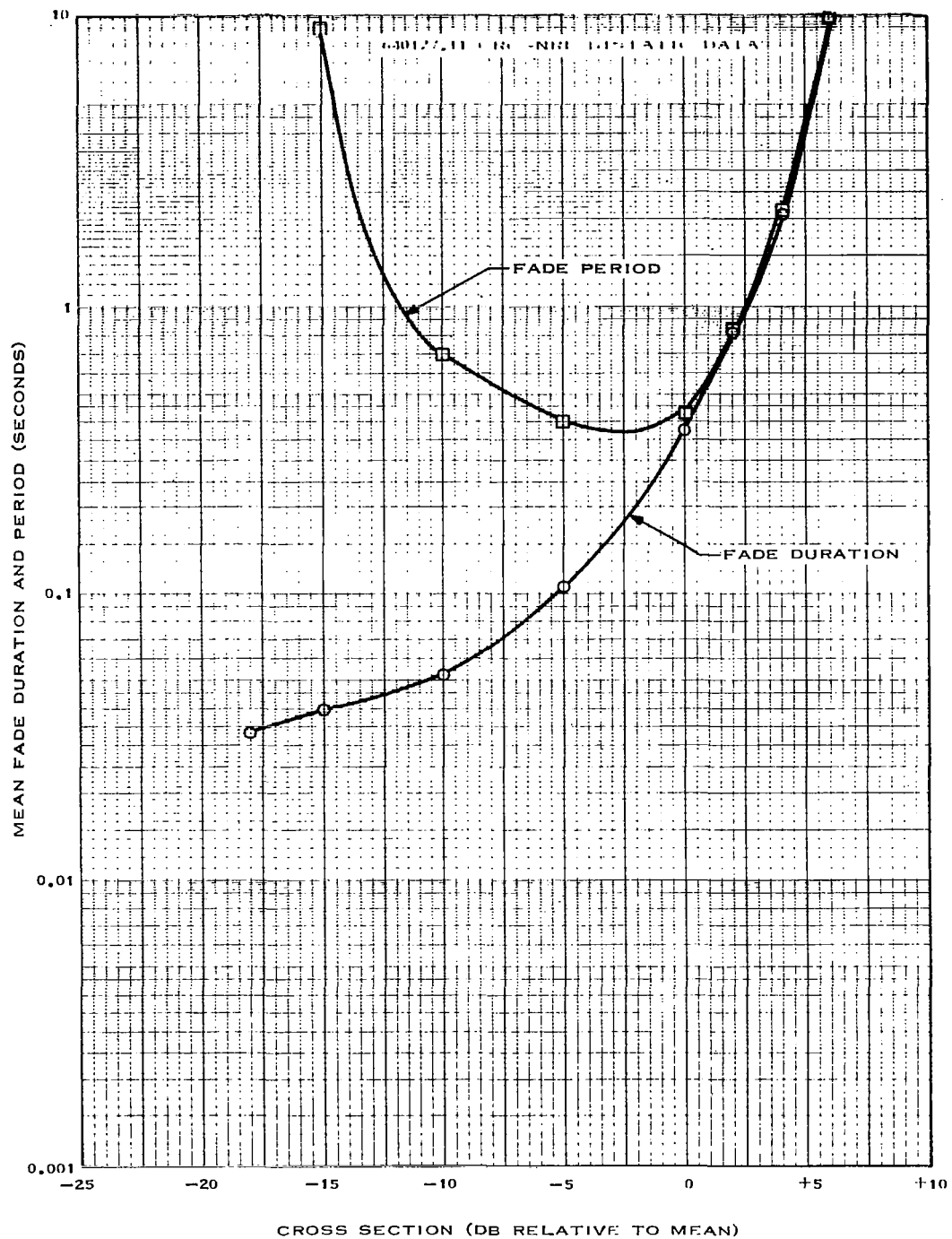


Figure 14. Mean Fade Period and Fade Period Vs Cross-Section Level, Pass No. 25

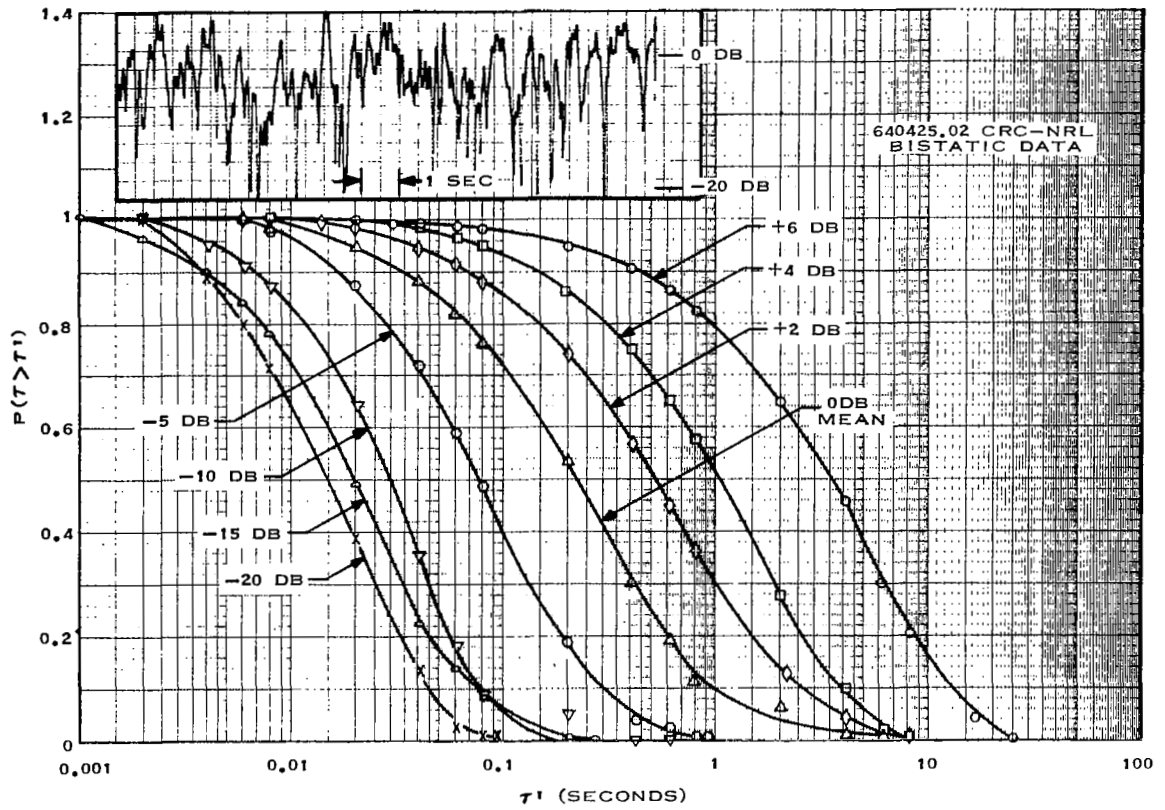


Figure 15. Probability Distribution of Fade Duration, Pass No. 1197,  
 $P(\tau > \tau')$  Vs  $\tau'$ , -5, -10, -15, -20 Db, +6, +4, +2, 0 Db

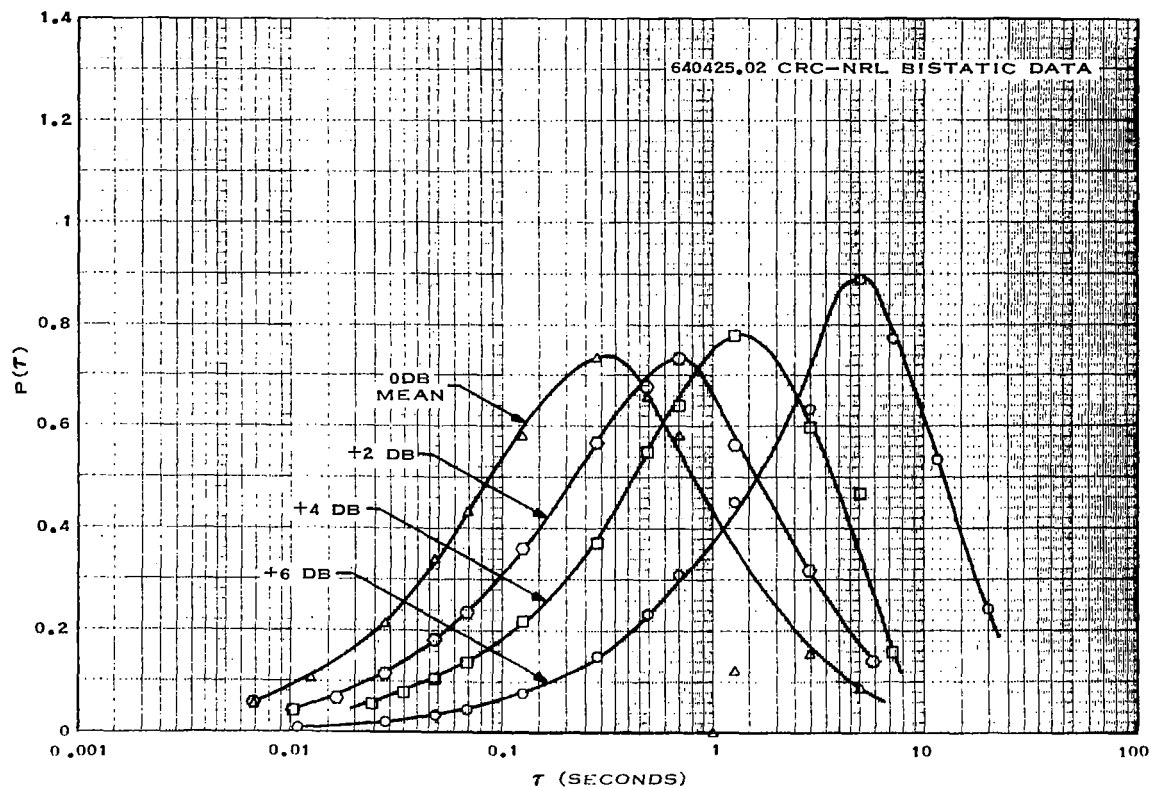


Figure 16. Probability Density of Fade Duration, Pass No. 1197,  
 $P(\tau)$  Vs  $\tau$ , 0, +2, +4, +6 Db

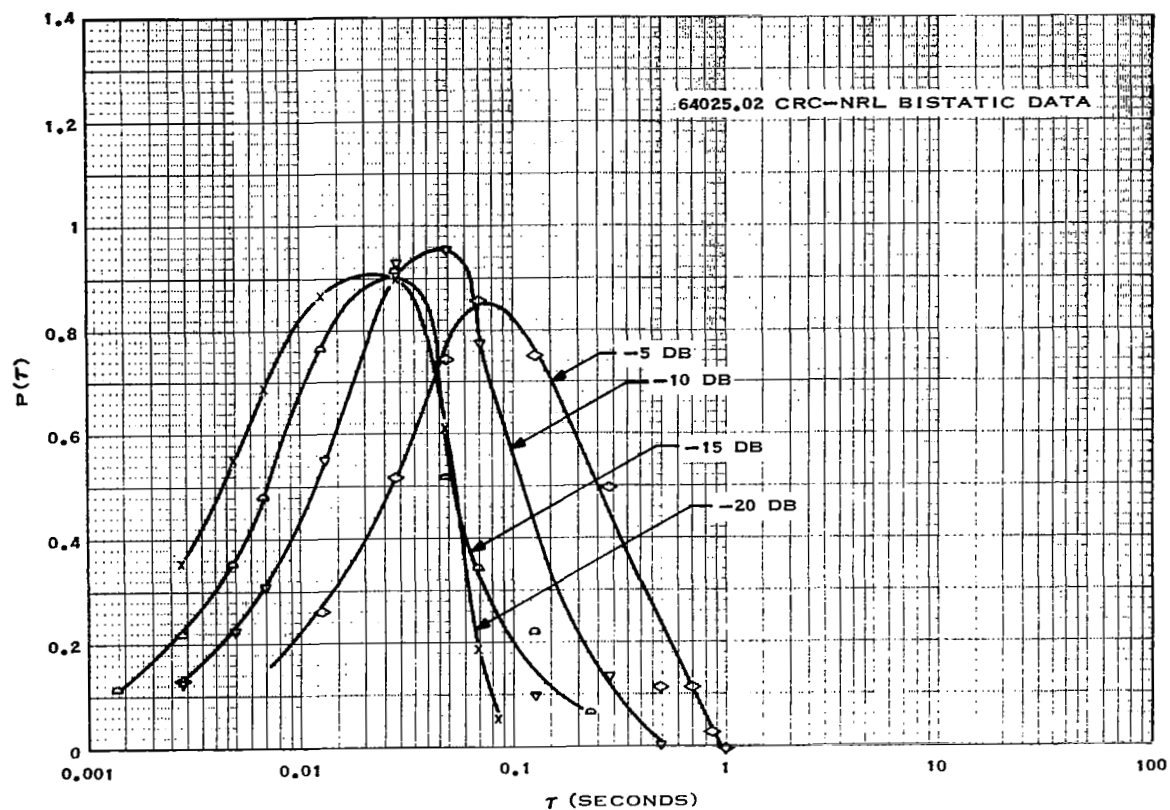


Figure 17. Probability Density of Fade Duration, Pass No. 1197,  
 $P(\tau)$  Vs  $\tau$ , -5, -10, -15, -20 Db

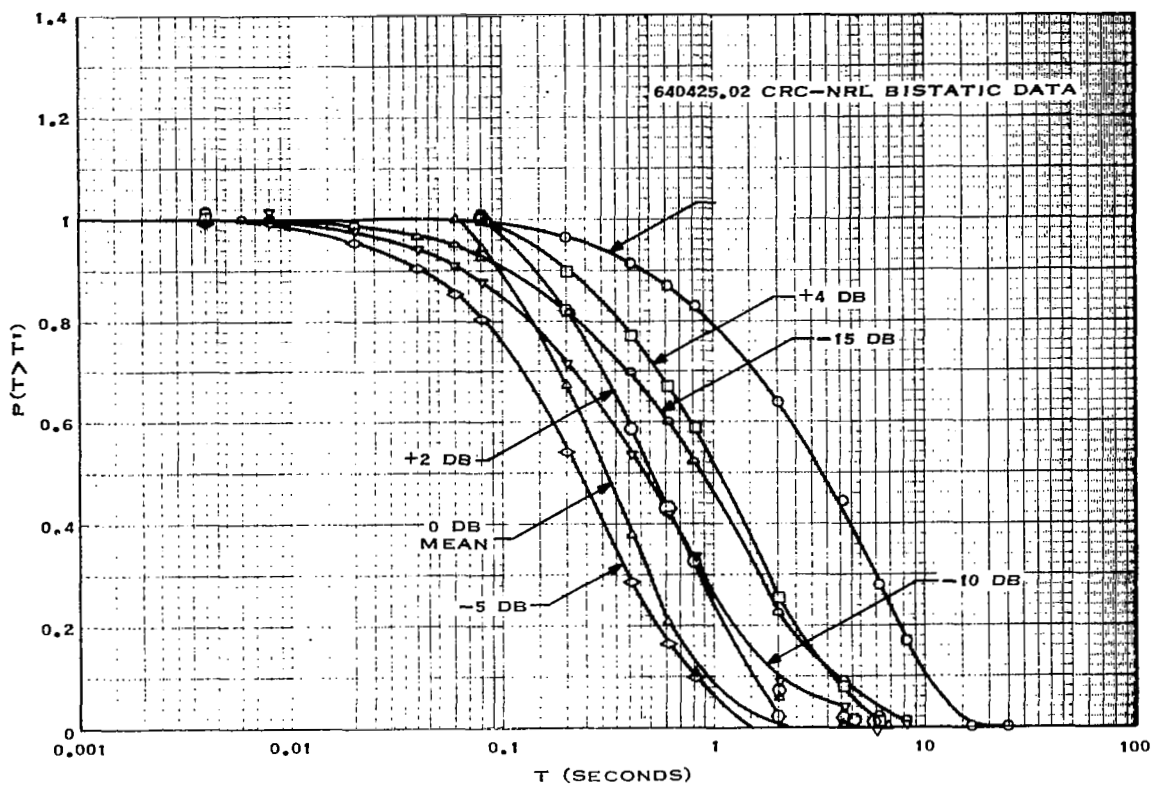


Figure 18. Probability Distribution of Fade Period, Pass No. 1197,  
 $P(T > T')$  Vs T, +2, 0, -5 Db, +6, +4, -15, -10 Db

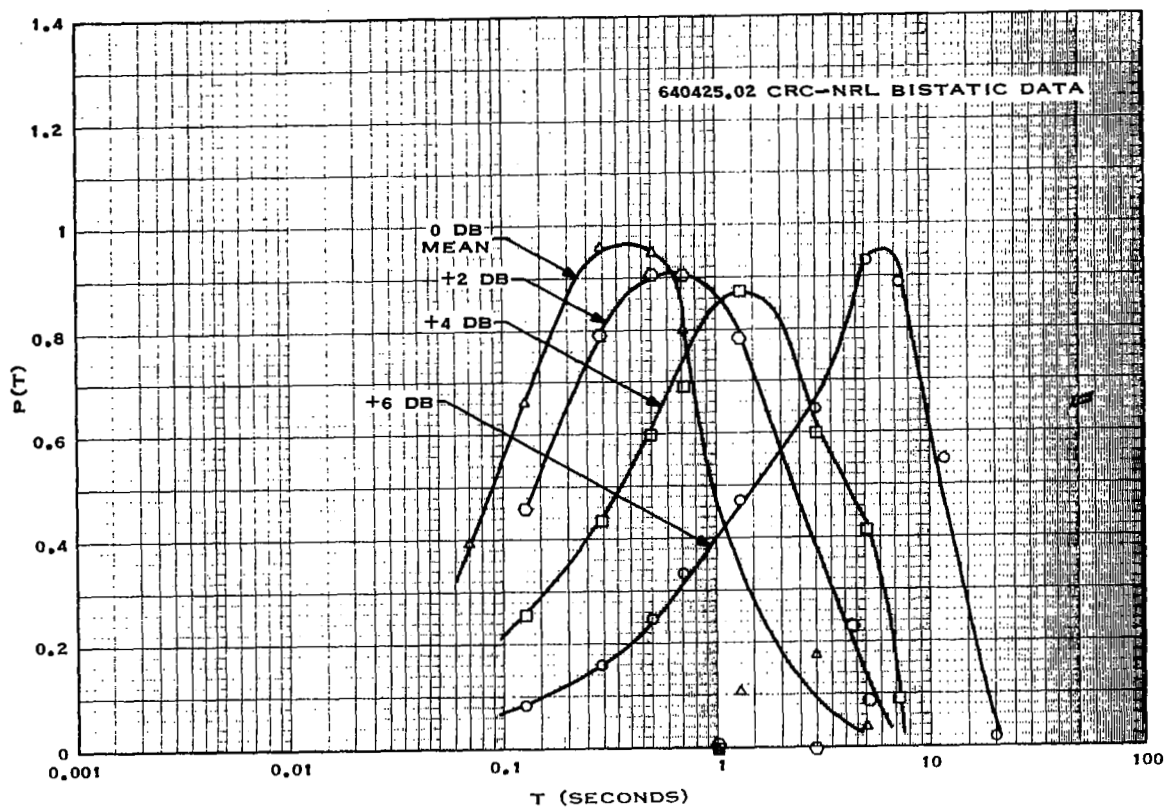


Figure 19. Probability Density of Fade Period, Pass No. 1197,  
 $P(T)$  Vs T, 0, +2, +4, +6 Db

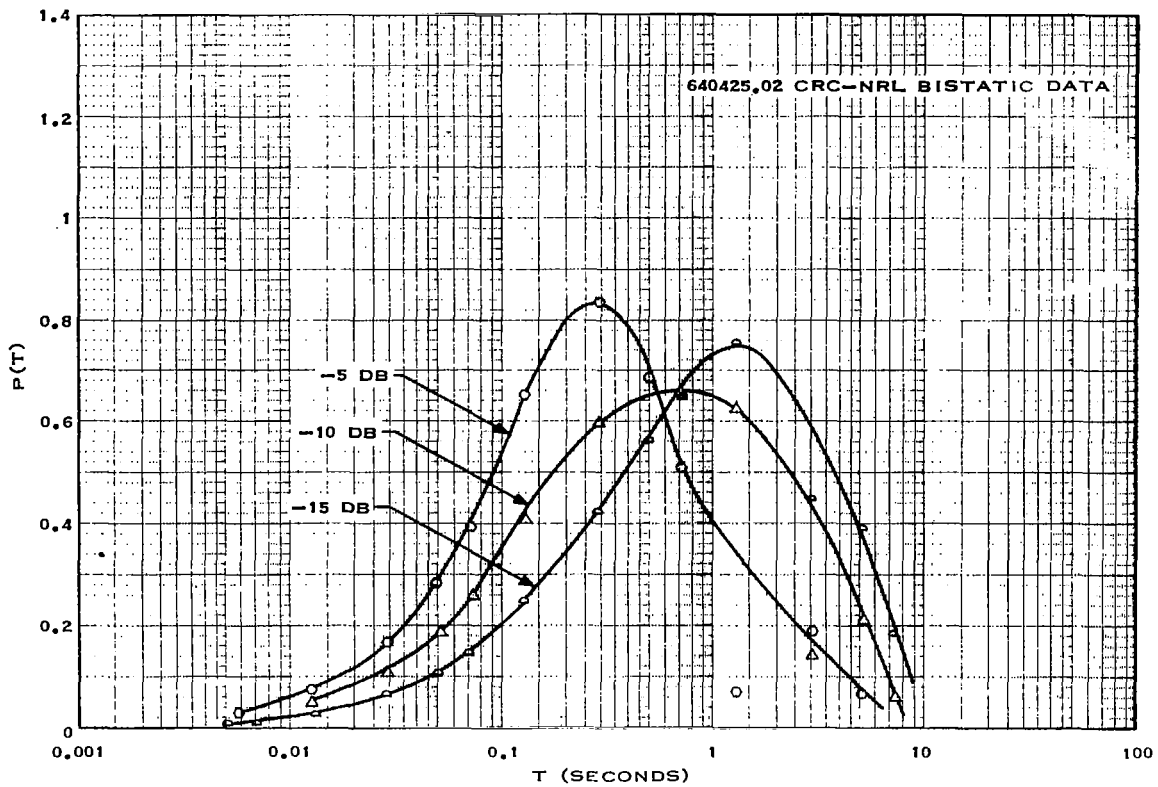


Figure 20. Probability Density of Fade Period, Pass No. 1197,  
 $P(T)$  Vs  $T$ , -5, -10, -15 Db

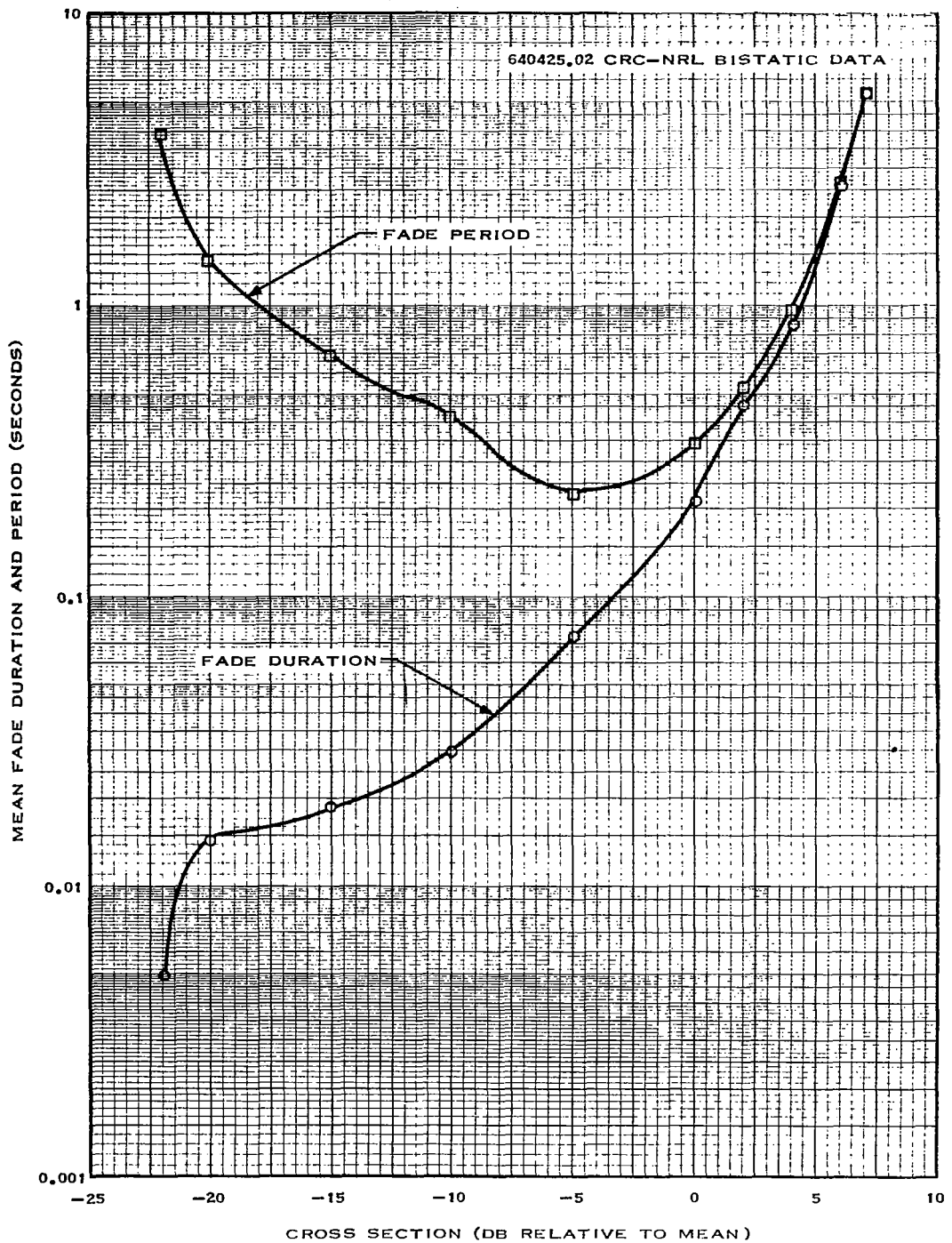


Figure 21. Mean Fade Duration and Fade Period Vs Cross-Section Level, Pass No. 1197

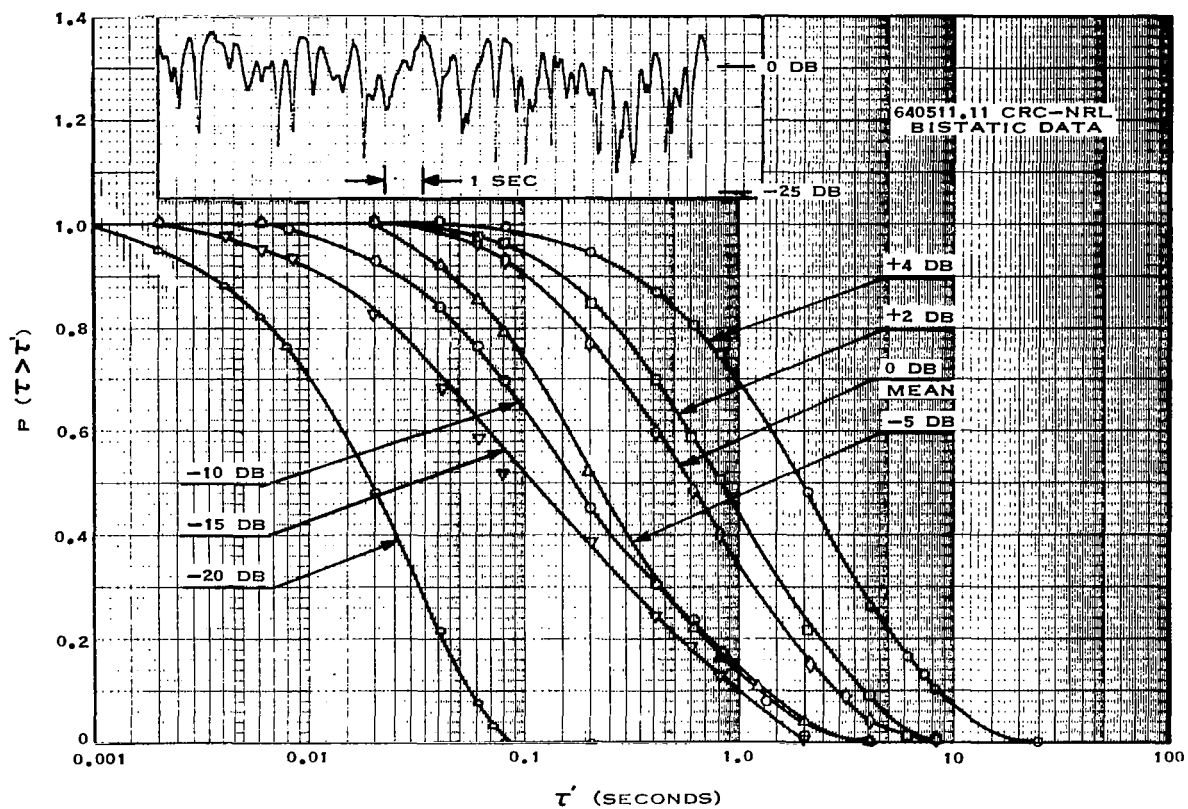


Figure 22. Probability Distribution of Fade Duration, Pass No. 1414,  
 $P(\tau > \tau')$  Vs  $\tau'$ , -10, -15, -20 Db, +4, +2, 0, -5 Db

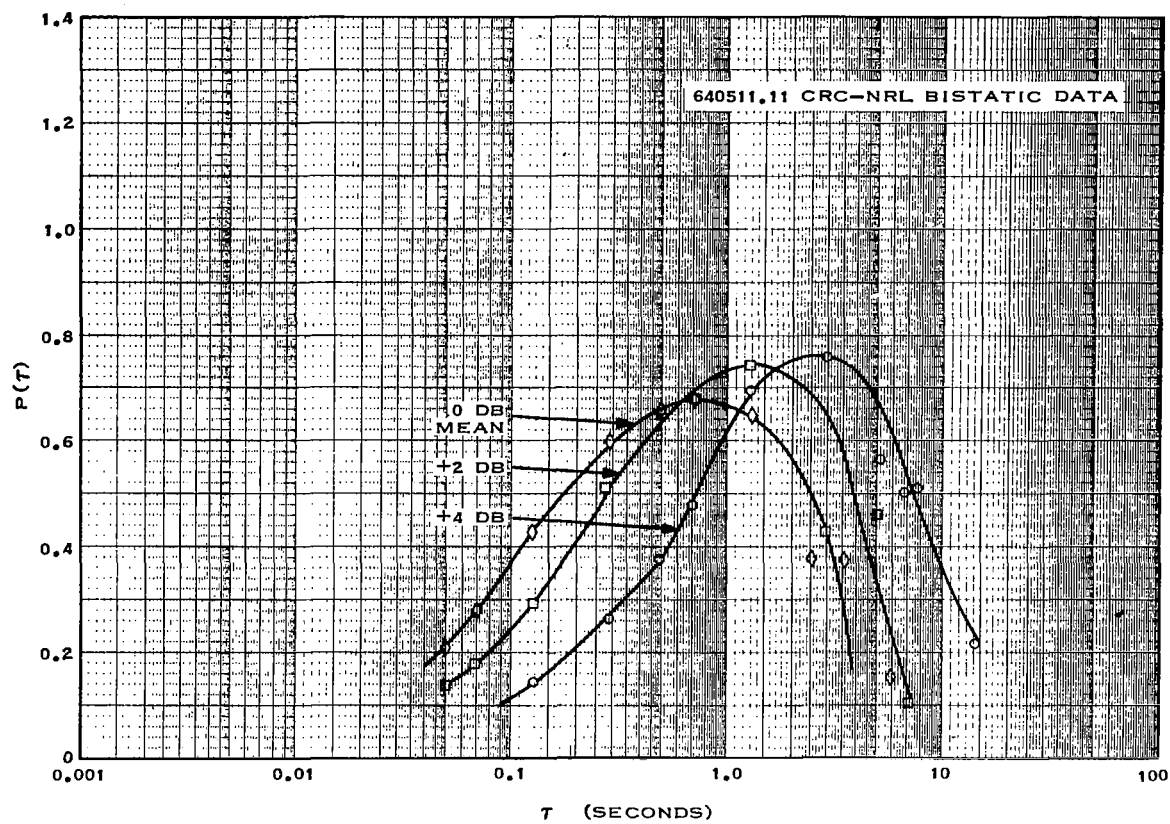


Figure 23. Probability Density of Fade Duration, Pass No. 1414,  
 $P(\tau)$  Vs  $\tau$ , 0, +2, +4 Db

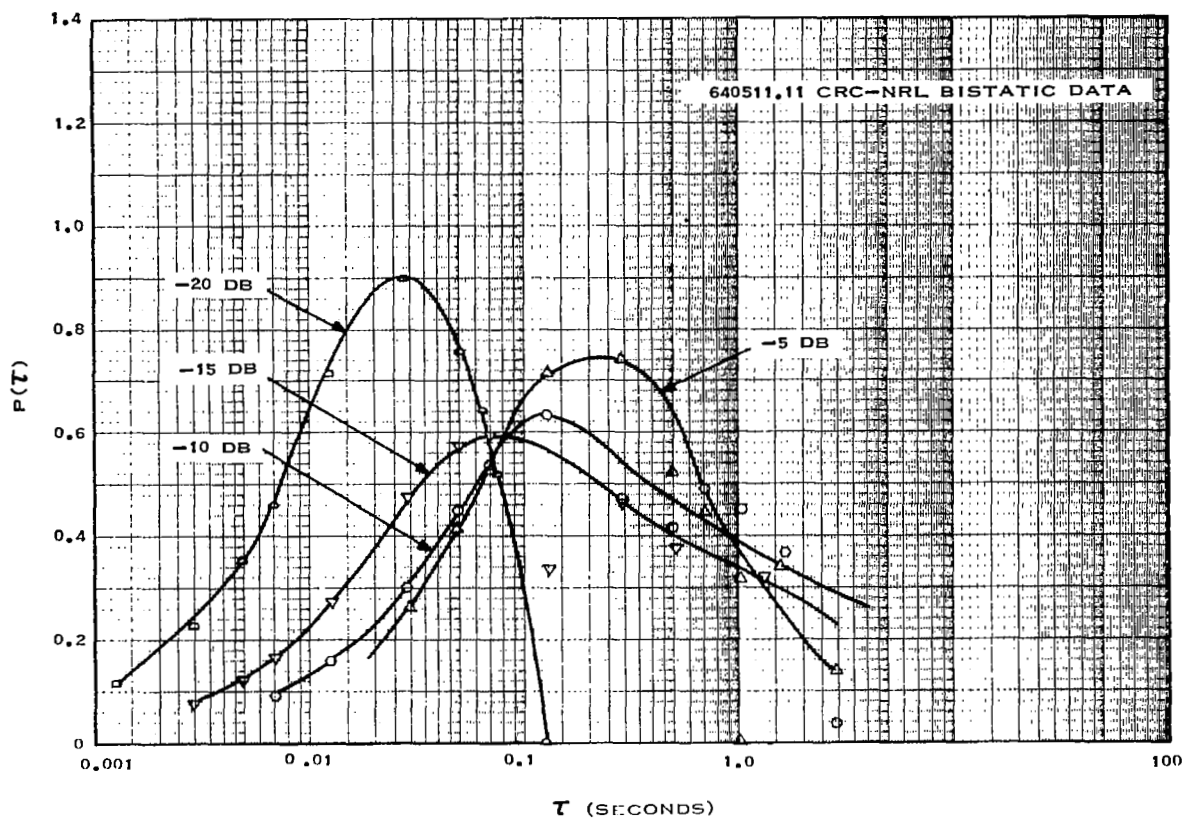


Figure 24. Probability Density of Fade Duration, Pass No. 1414,  
 $P(\tau)$  Vs  $\tau$ , -20, -15, -10 Db, -5 Db

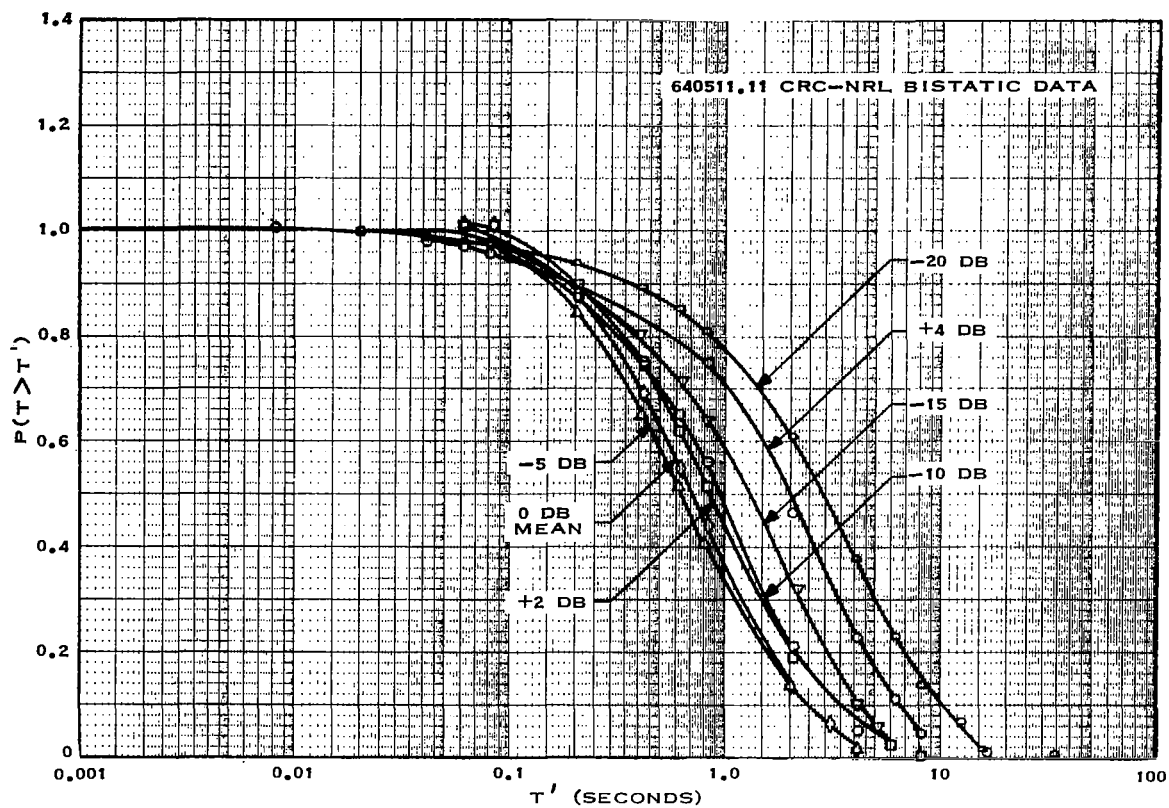


Figure 25. Probability Distribution of Fade Period, Pass No. 1414,  
 $P(T > T')$  Vs  $T'$ , -5, 0, +2 Db, -20, +4, -15, -10 Db

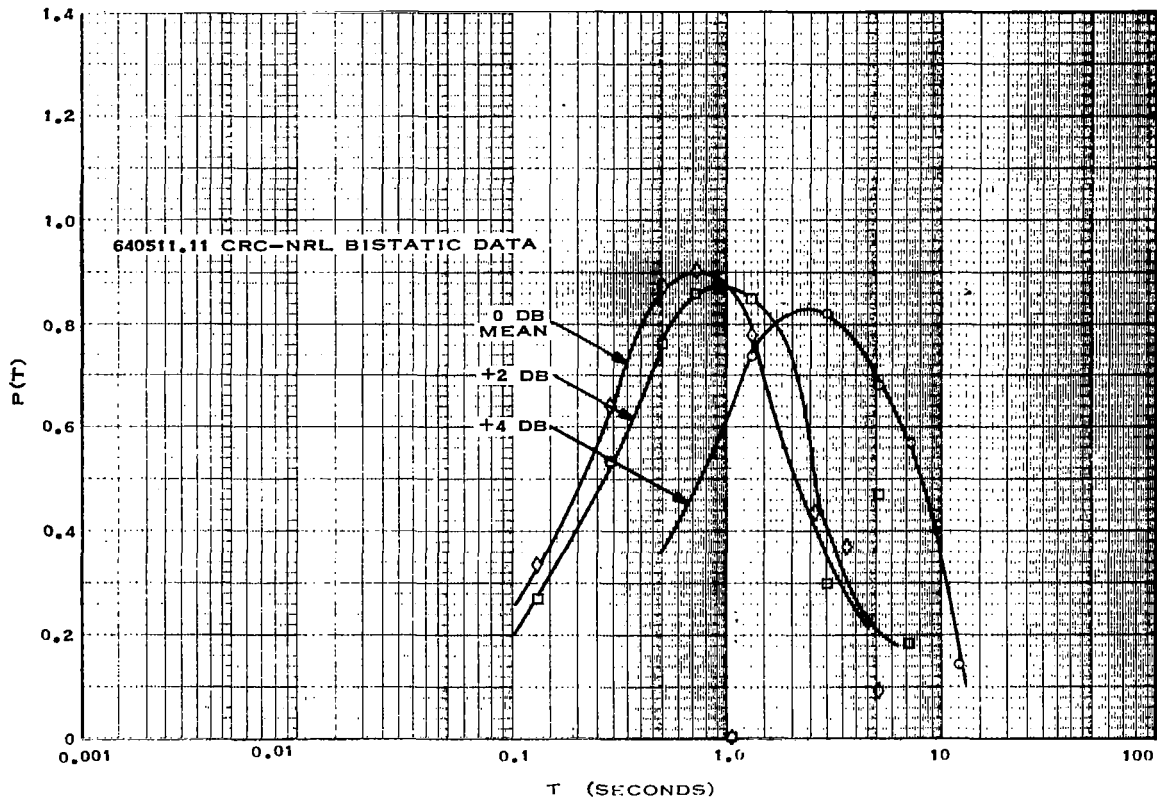


Figure 26. Probability Density of Fade Period, Pass No. 1414,  
 $P(T)$  Vs  $T$ , 0, +2, +4 Db

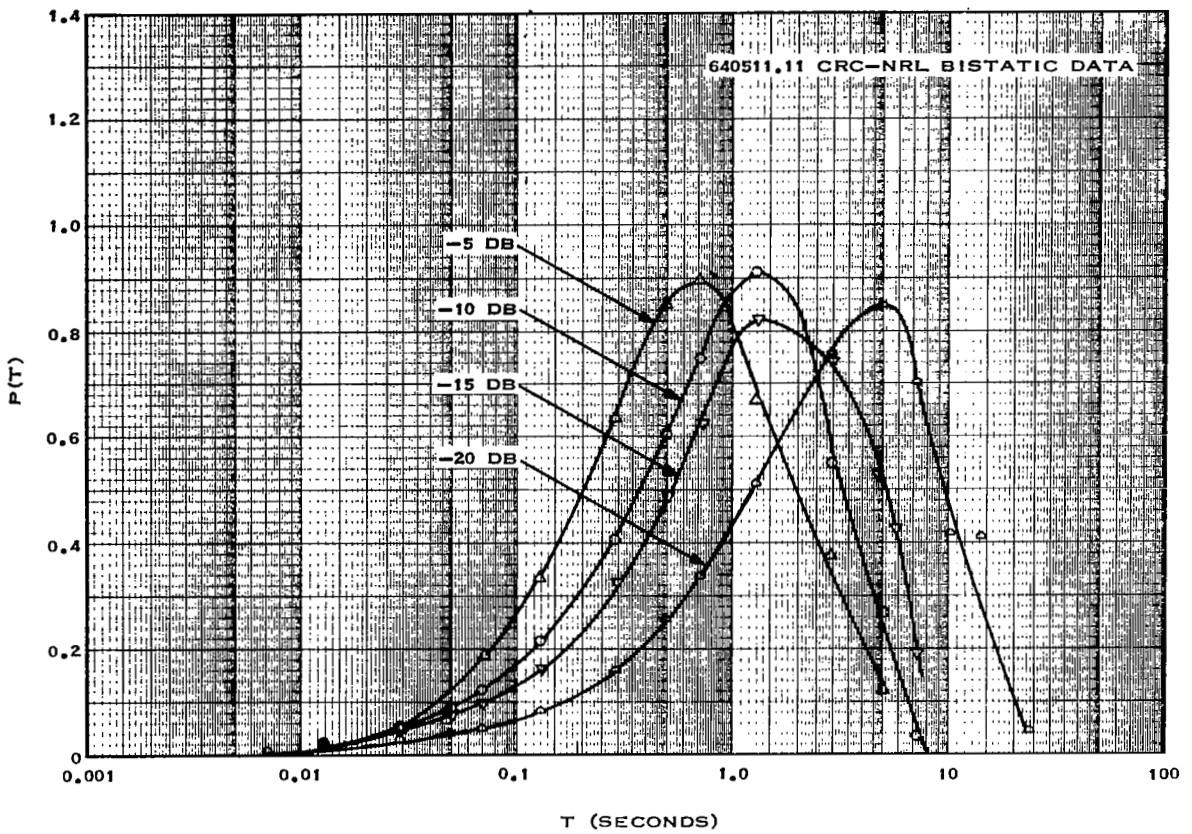


Figure 27. Probability Density of Fade Period, Pass No. 1414,  
 $P(T)$  Vs  $T$ , -5, -10, -15, -20 Db

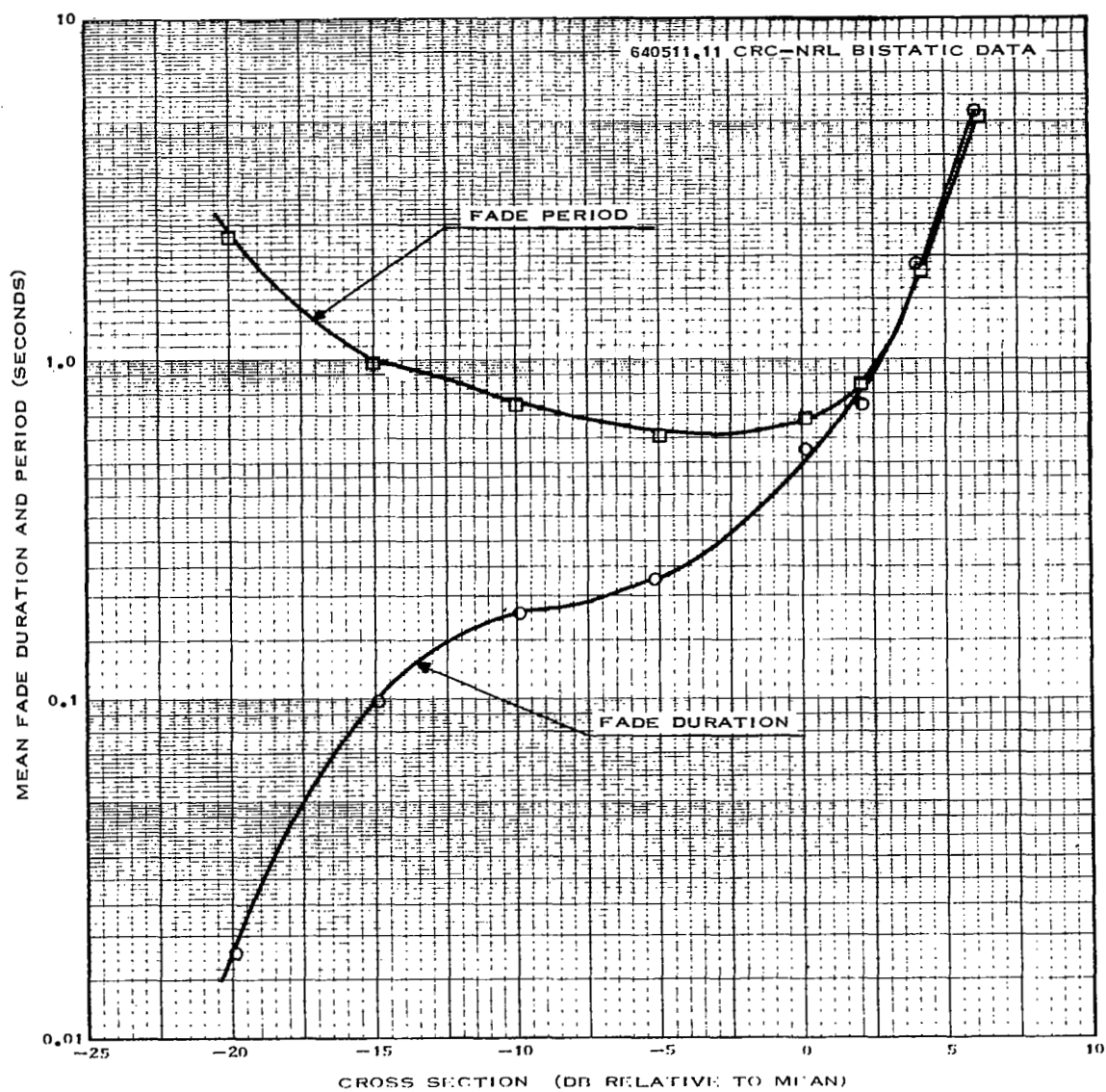


Figure 28. Mean Fade Duration and Fade Period Vs  
Cross-Section Level, Pass No. 1414

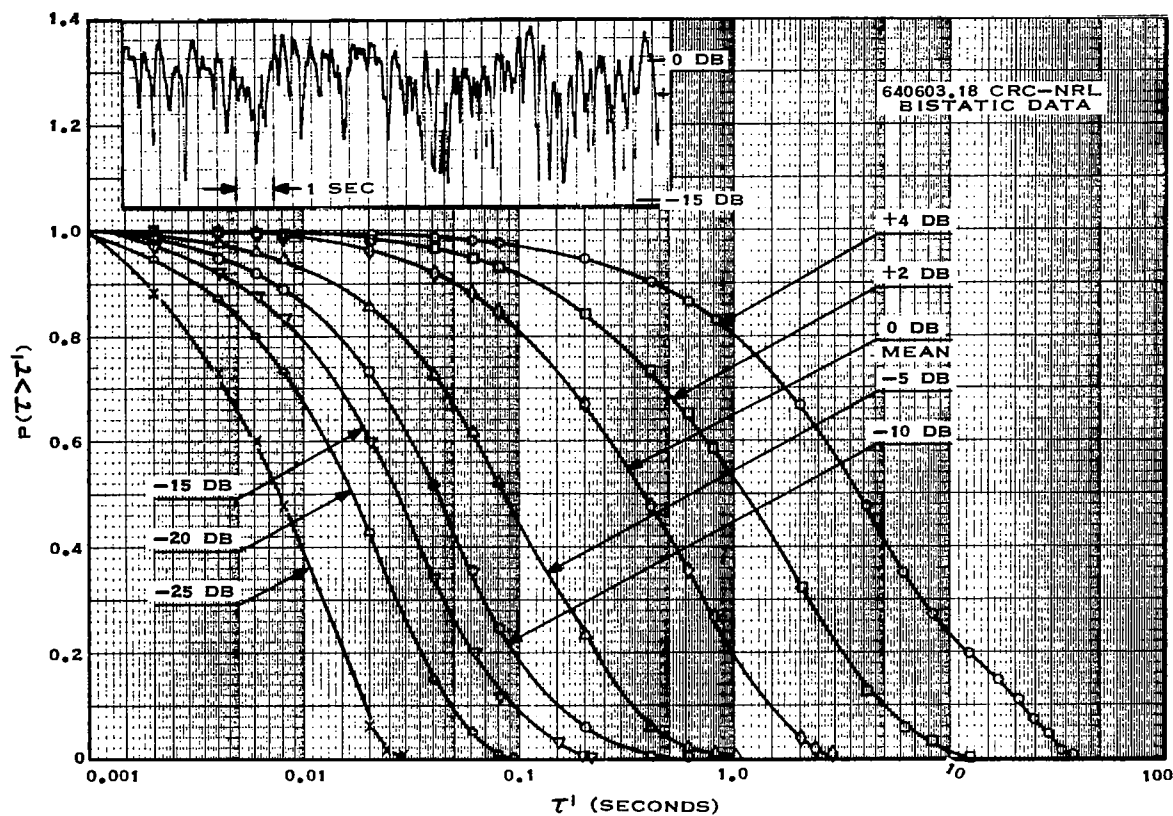


Figure 29. Probability Distribution of Fade Duration, Pass No. 1717,  
 $P(\tau > \tau')$  Vs  $\tau'$ , -15, -20, -25 Db, +4, +2, 0, -5, -10 Db

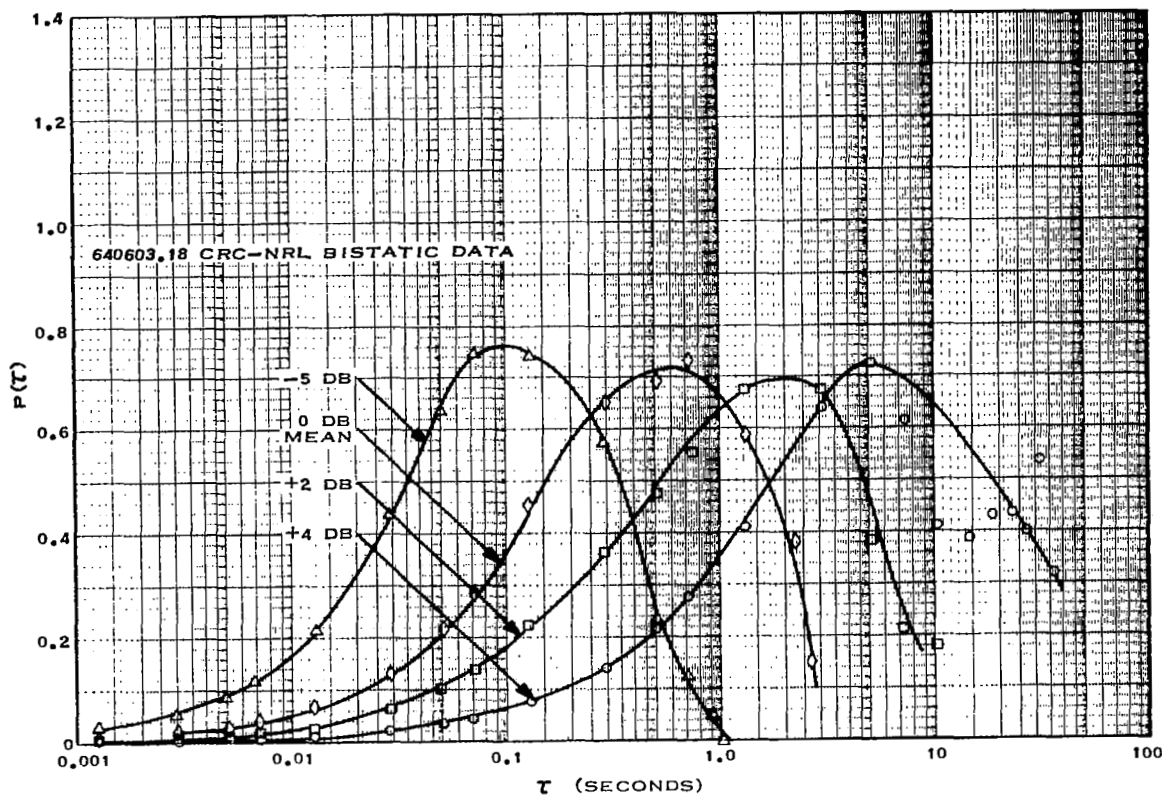


Figure 30. Probability Density of Fade Duration, Pass No. 1717,  
 $P(\tau)$  Vs  $\tau$ , -5, 0, +2, +4 Db

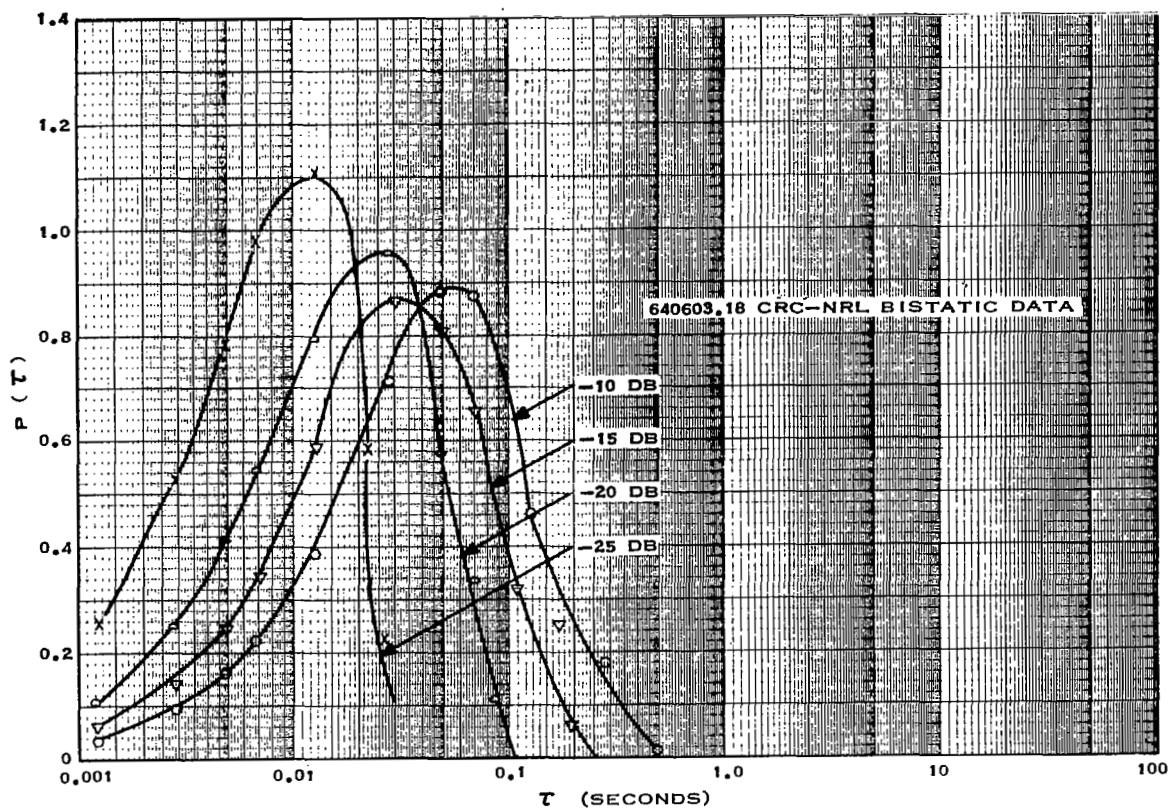


Figure 31. Probability Density of Fade Duration, Pass No. 1717,  
 $P(\tau)$  Vs  $\tau$ , -10, -15, -20, -25 Db

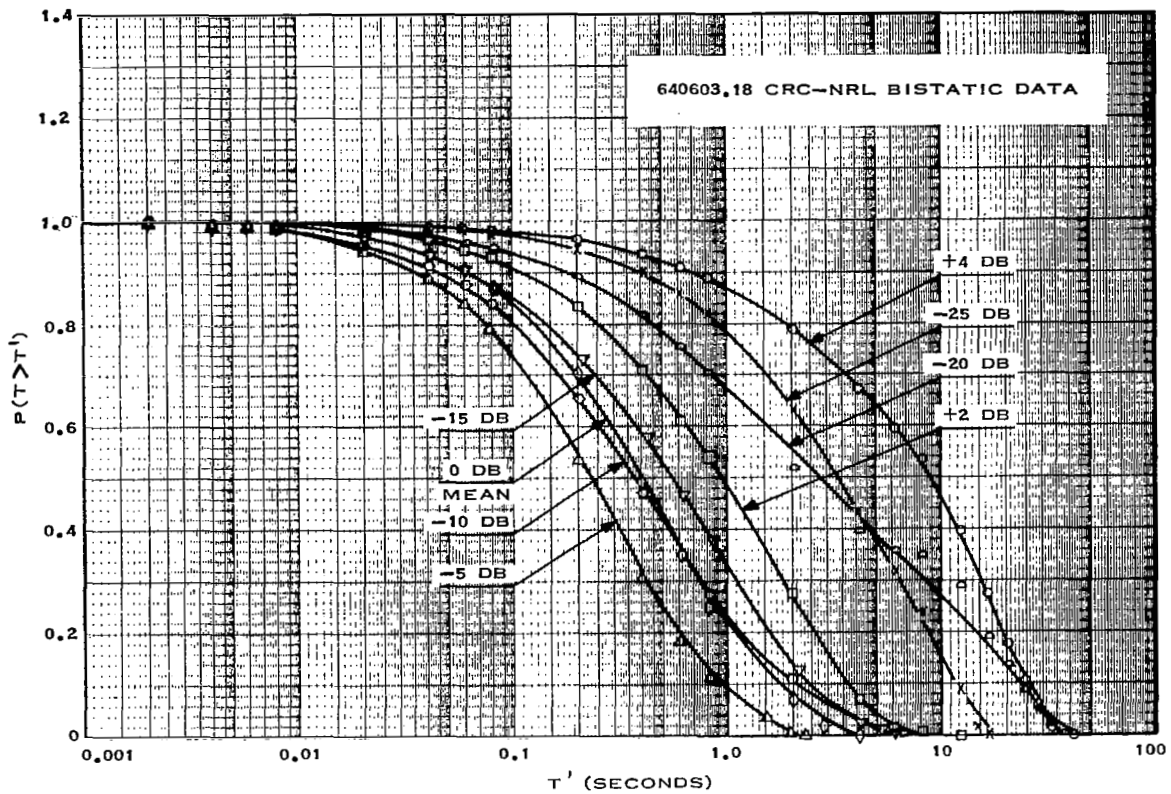


Figure 32. Probability Distribution of Fade Period, Pass No. 1717,  
 $P(T > T')$  Vs  $T'$ , -15, 0, -10, -5 Db, +4, -25, -20, +2 Db

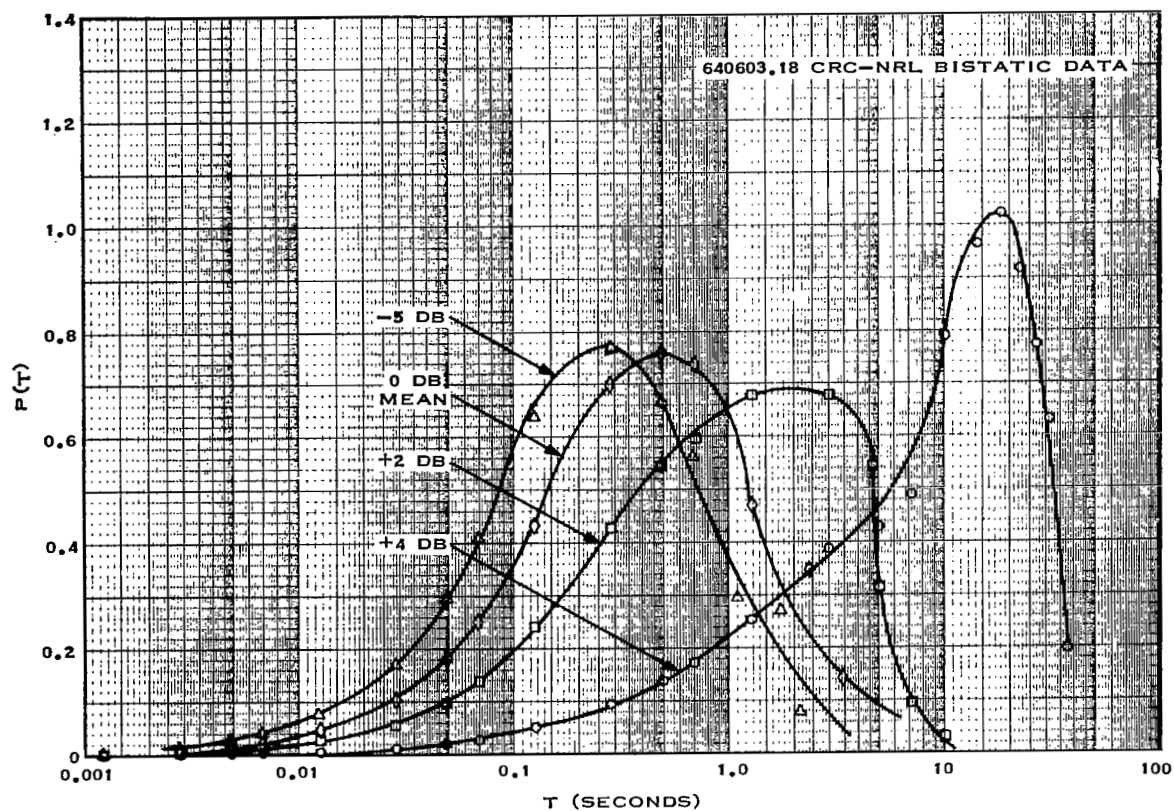


Figure 33. Probability Density of Fade Period, Pass No. 1717,  
 $P(T)$  Vs  $T$ , -5, 0, +2, +4 Db

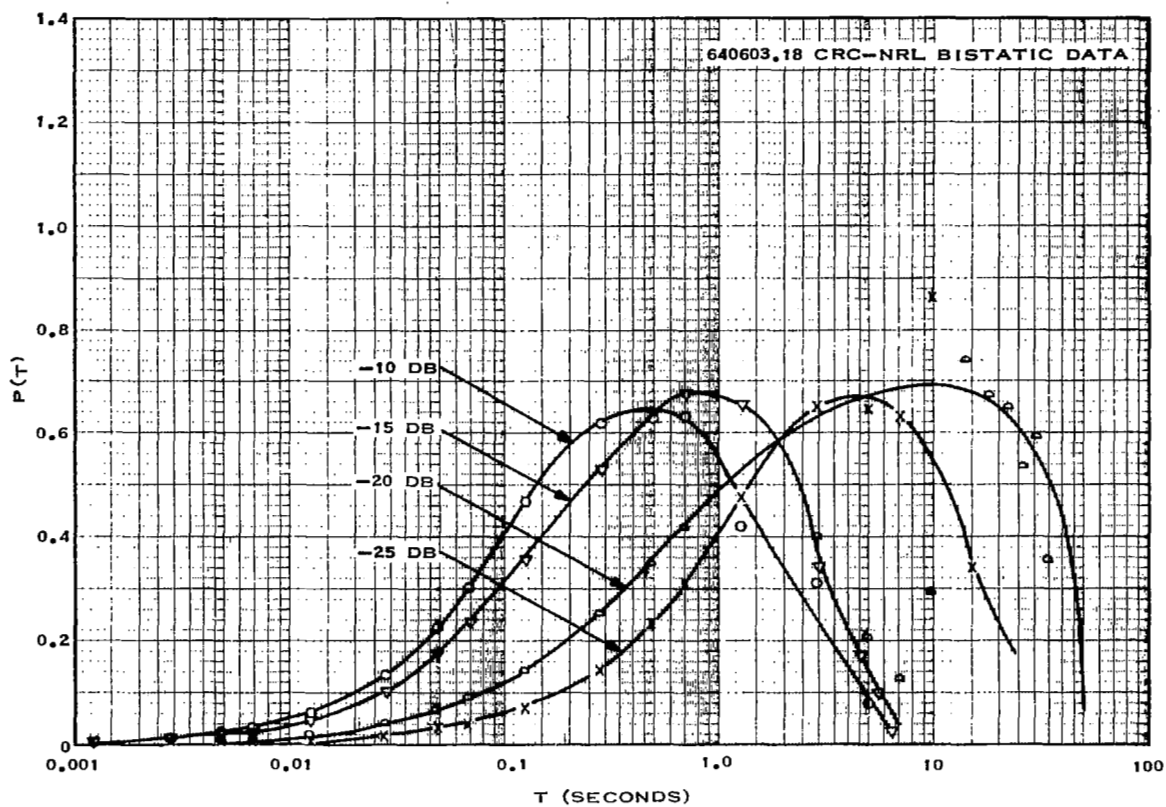


Figure 34. Probability Density of Fade Period, Pass No. 1717,  
 $P(T)$  Vs  $T$ , -10, -15, -20, -25 Db

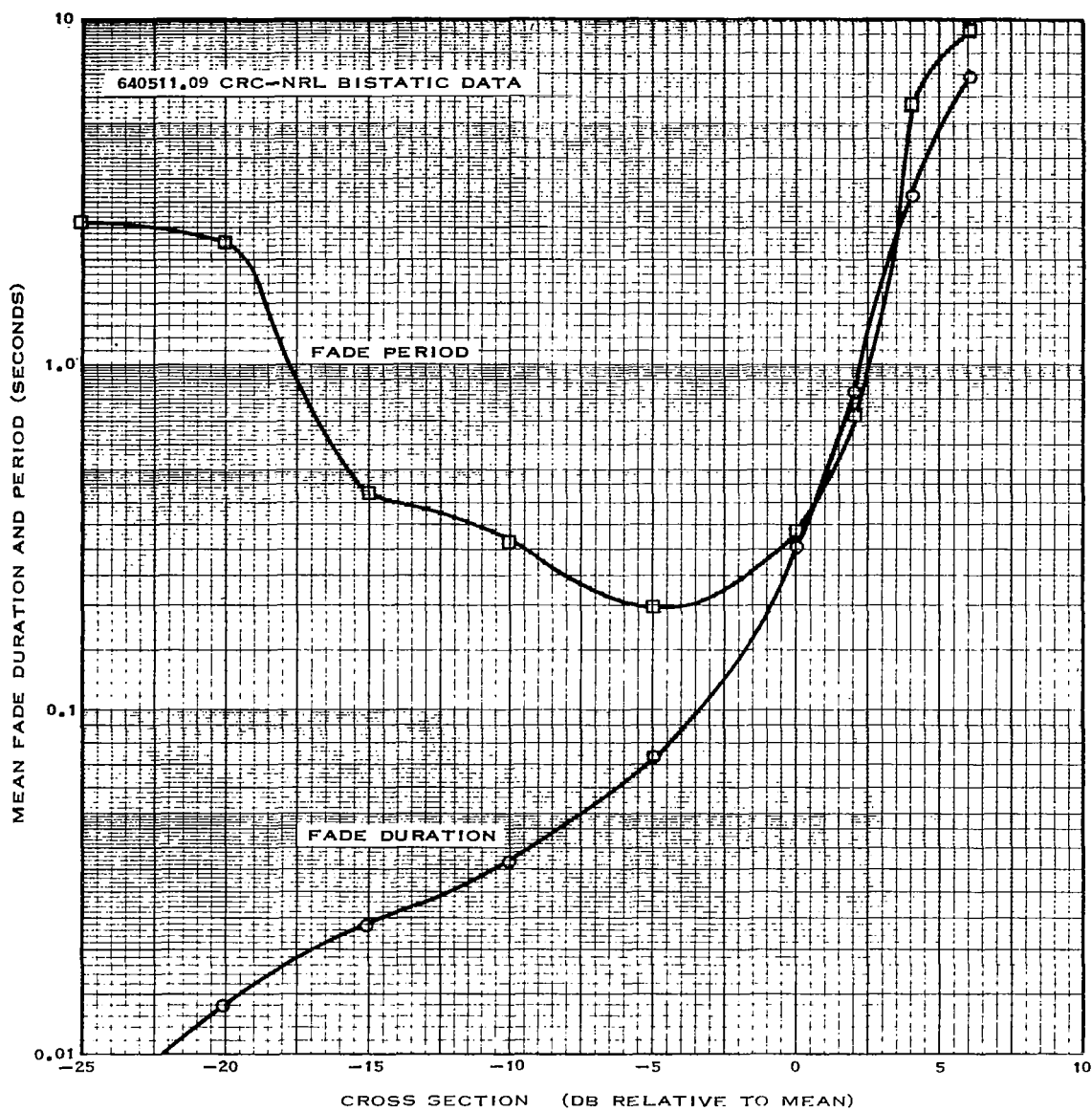


Figure 35. Mean Fade Duration and Fade Period Vs Cross-Section Level, Pass No. 1717

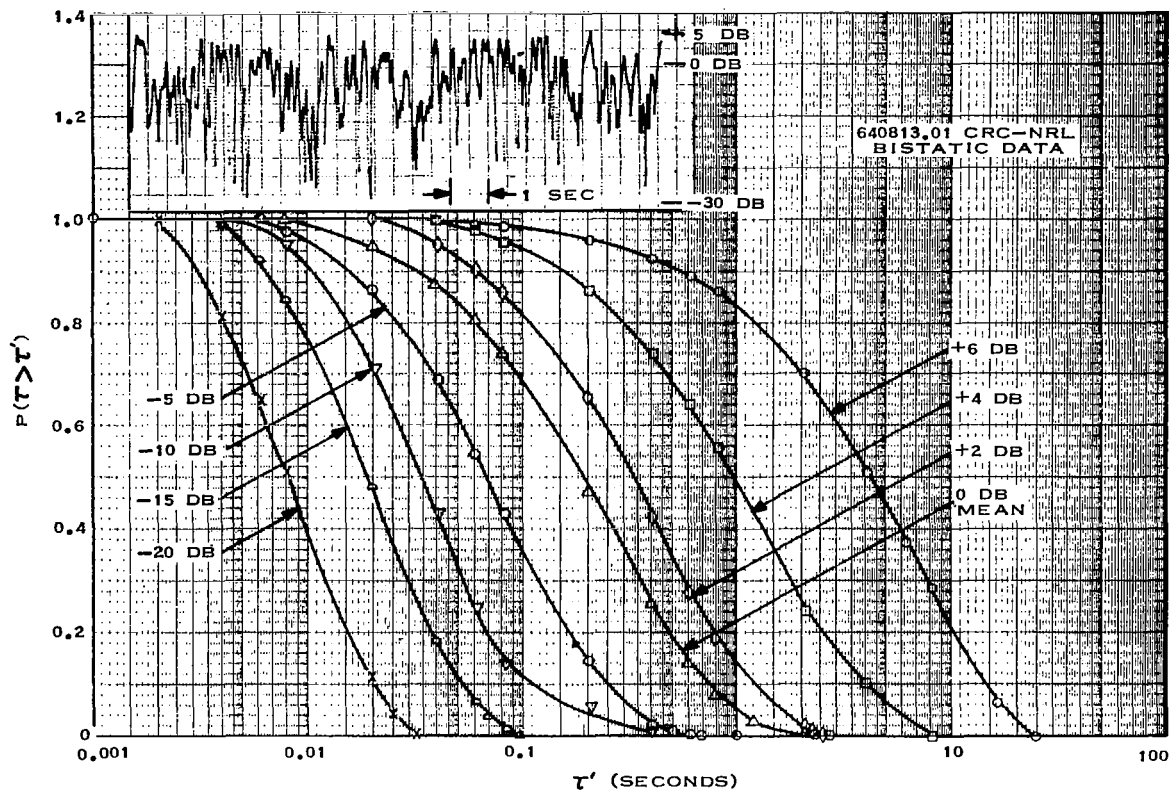


Figure 36. Probability Distribution of Fade Duration, Pass No. 2653,  
 $P(\tau > \tau')$  Vs  $\tau'$ , -5, -10, -15, -20 Db, +6, +4, +2, 0 Db

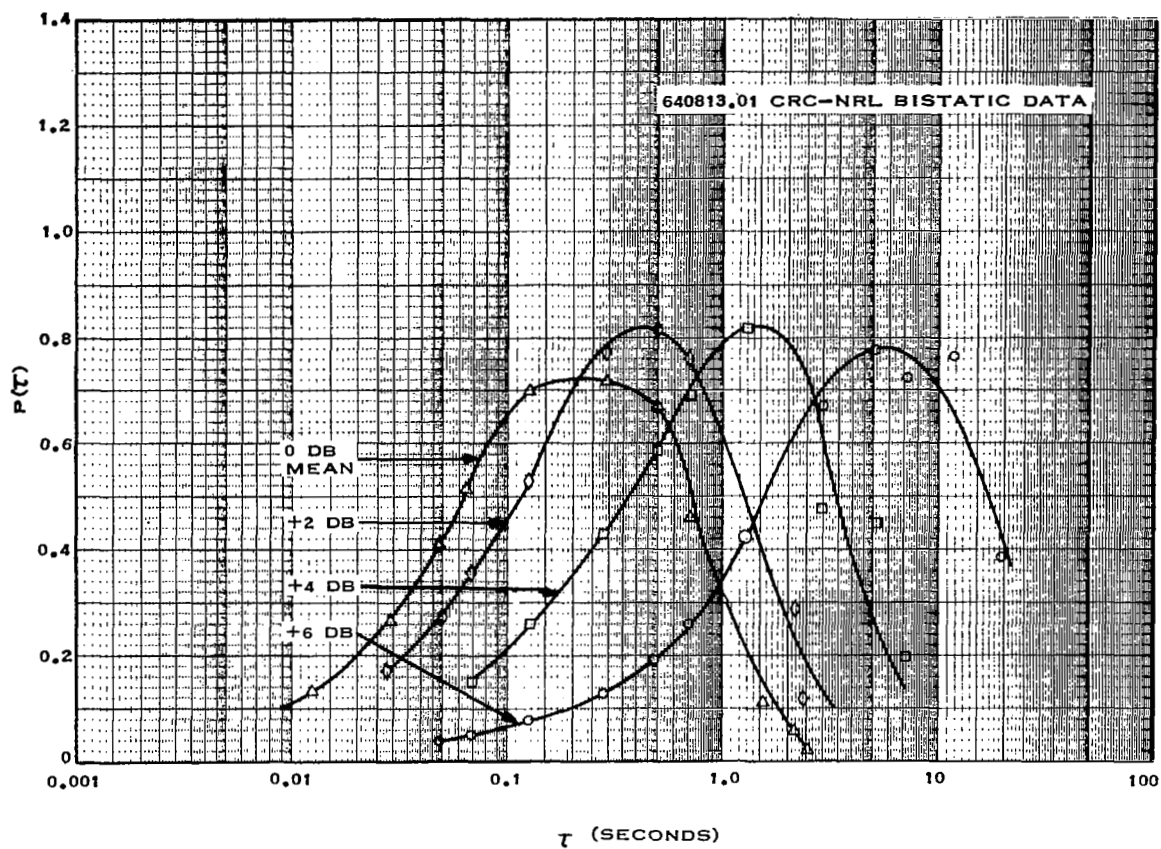


Figure 37. Probability Density of Fade Duration, Pass No. 2653,  
 $P(\tau)$  Vs  $\tau$ , 0, +2, +4, +6 Db

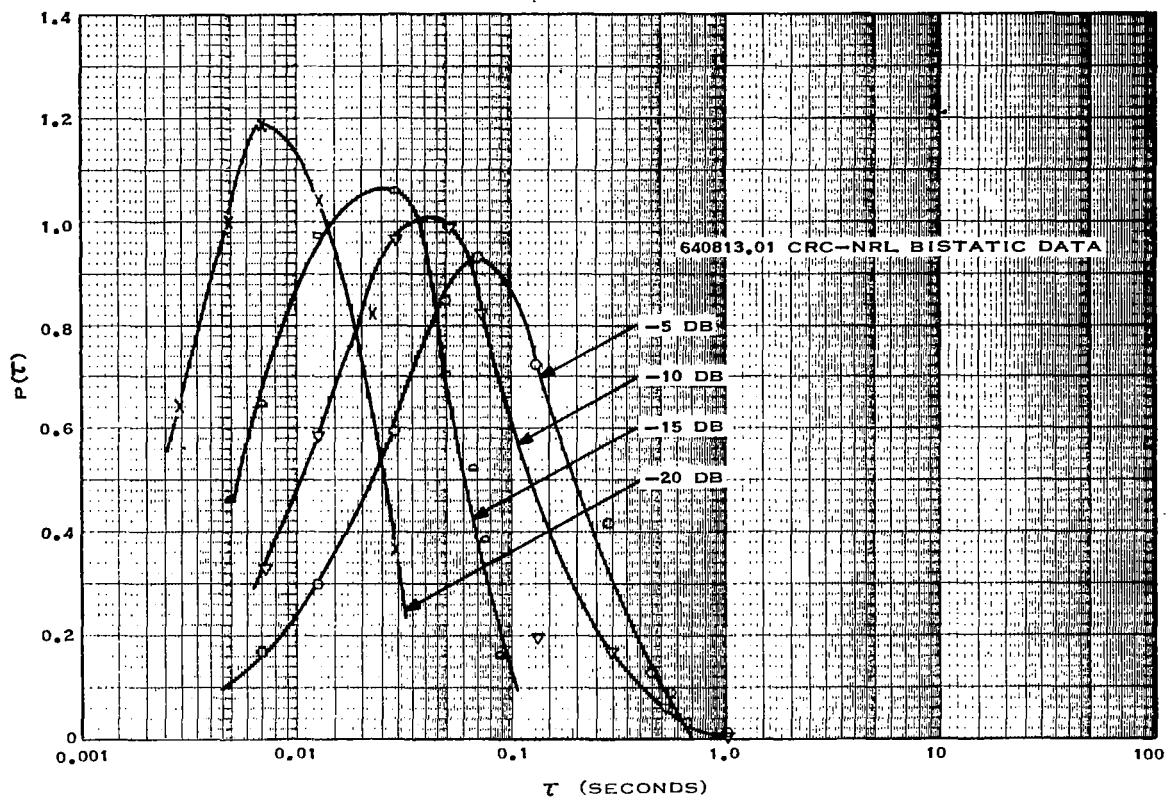


Figure 38. Probability Density of Fade Duration, Pass No. 2653,  
 $P(\tau)$  Vs  $\tau$ , -5, -10, -15, -20 Db

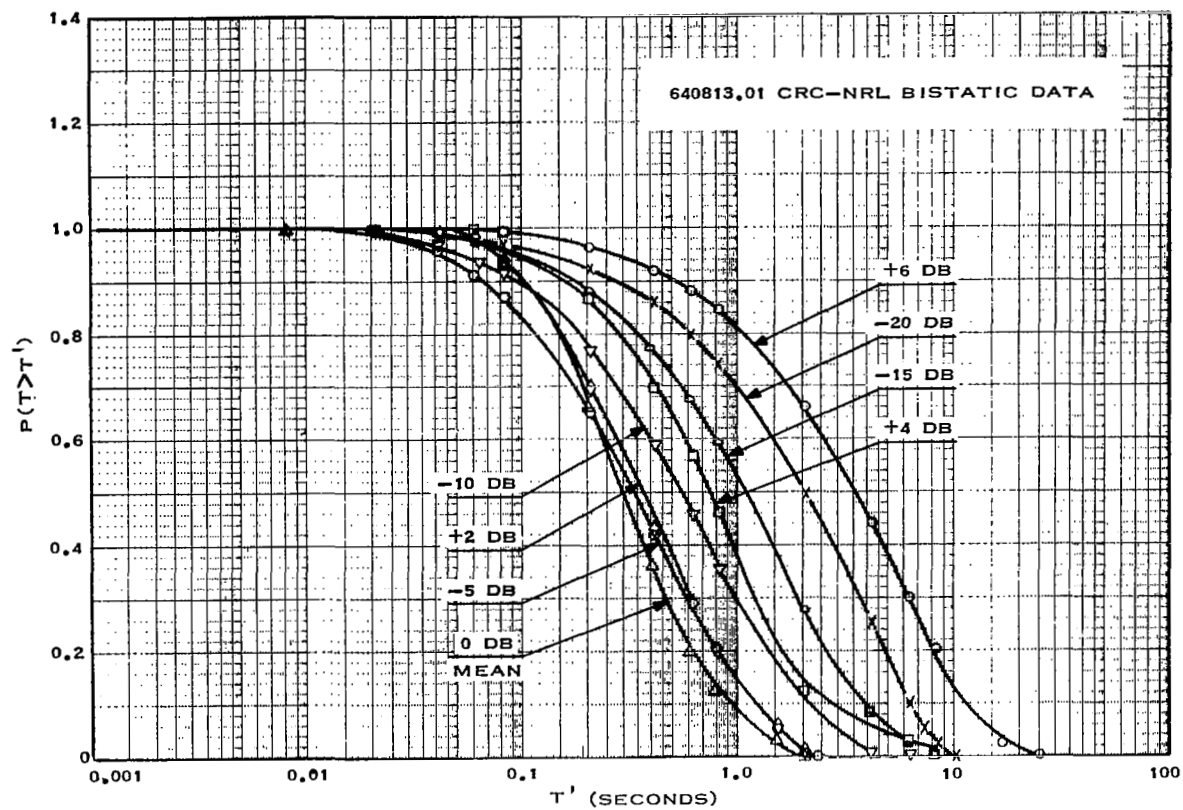


Figure 39. Probability Distribution of Fade Period, Pass No. 2653,  
 $P(T > T')$  Vs  $T'$ , -10, +2, -5, 0 Db, +6, -20, -15, +4 Db

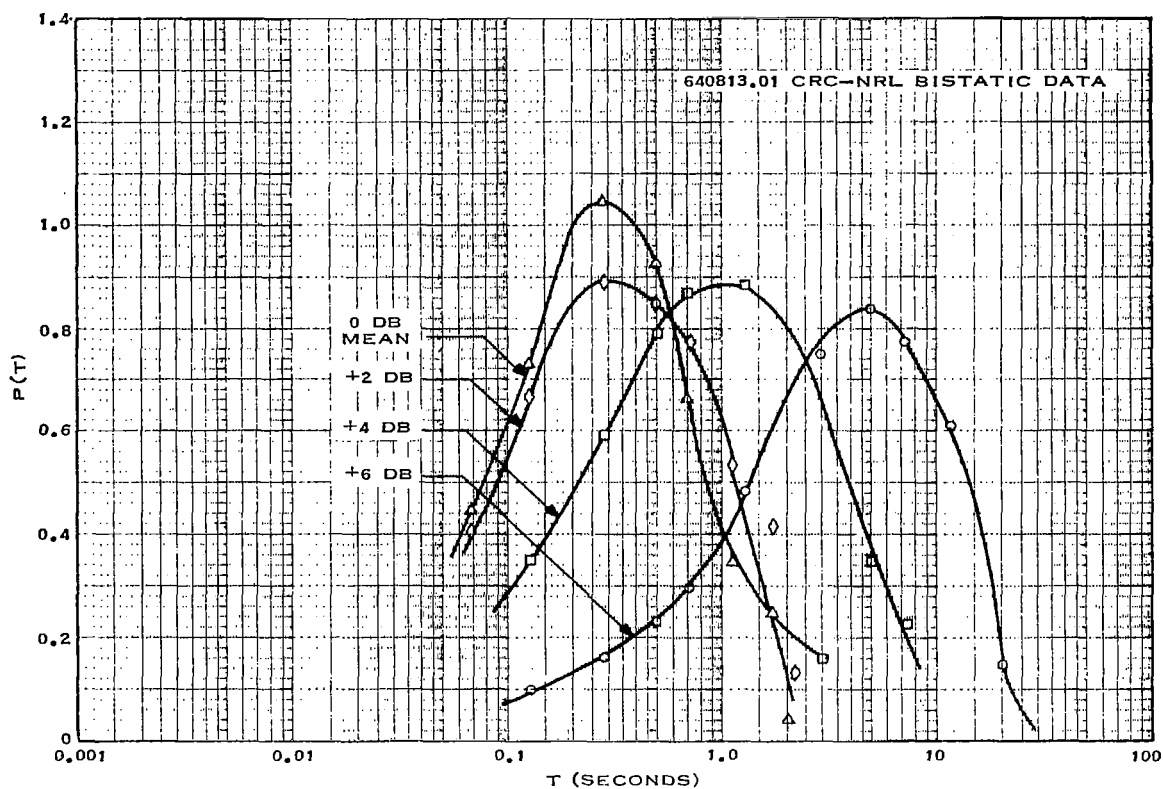


Figure 40. Probability Density of Fade Period, Pass No. 2653,  
 $P(T)$  Vs T, 0, +2, +4, +6 Db

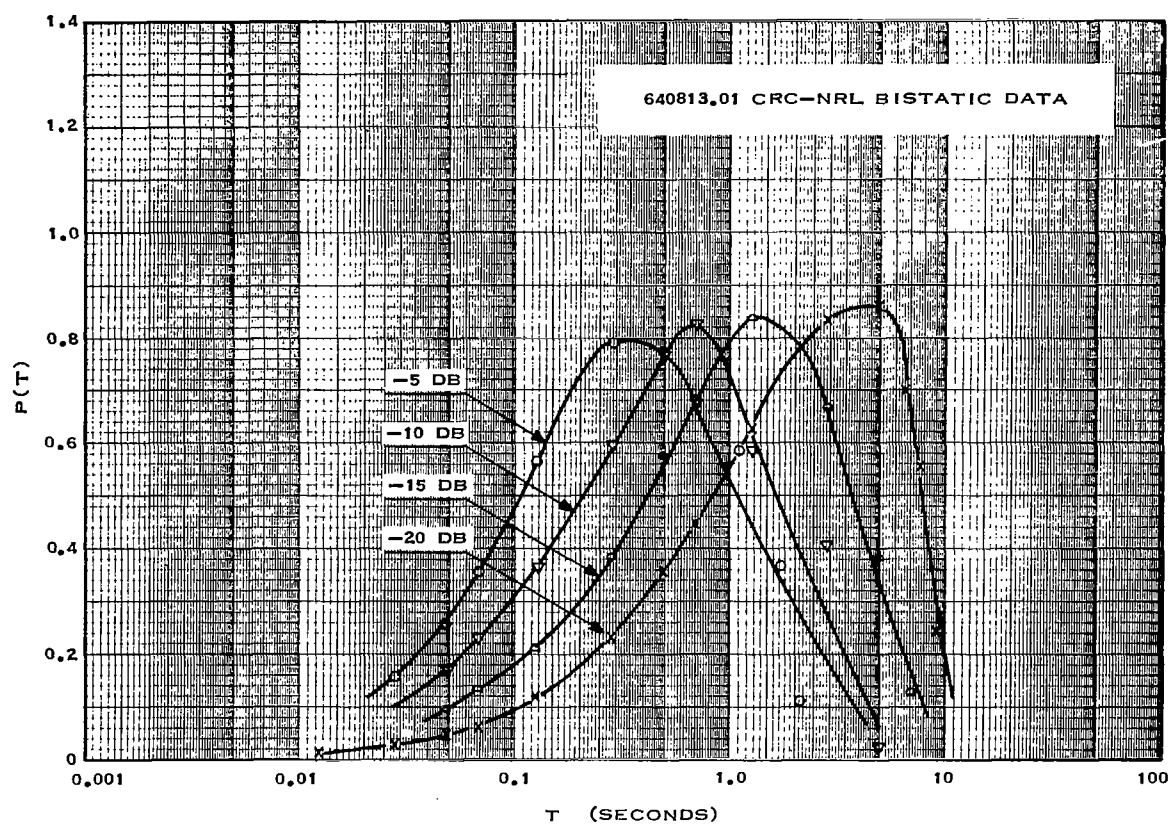


Figure 41. Probability Density of Fade Period, Pass No. 2653,  
 $P(T)$  Vs  $T$ , -5, -10, -15, -20 Db

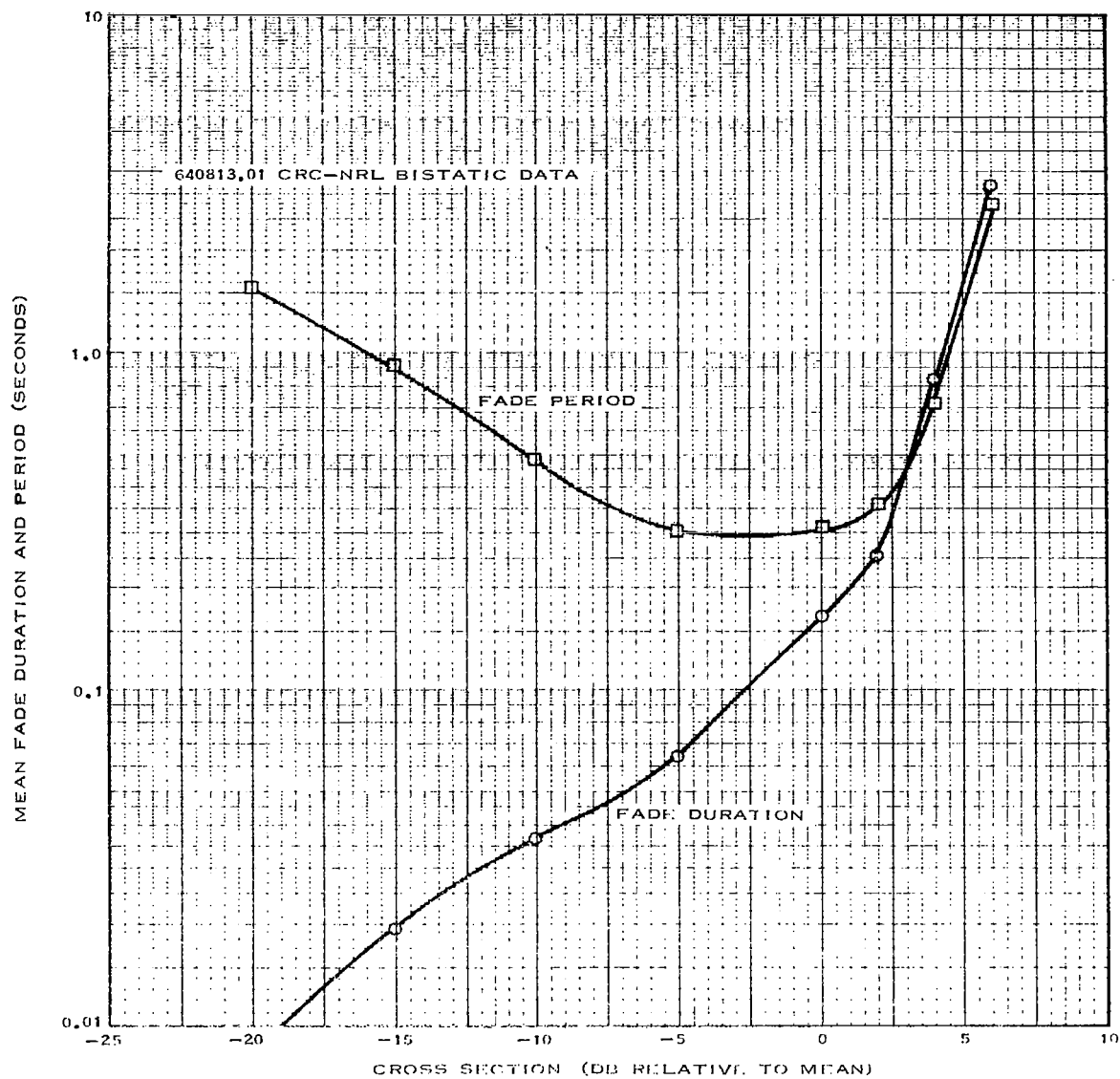


Figure 42. Mean Fade Duration and Fade Period Vs Cross-Section Level, Pass No. 2653

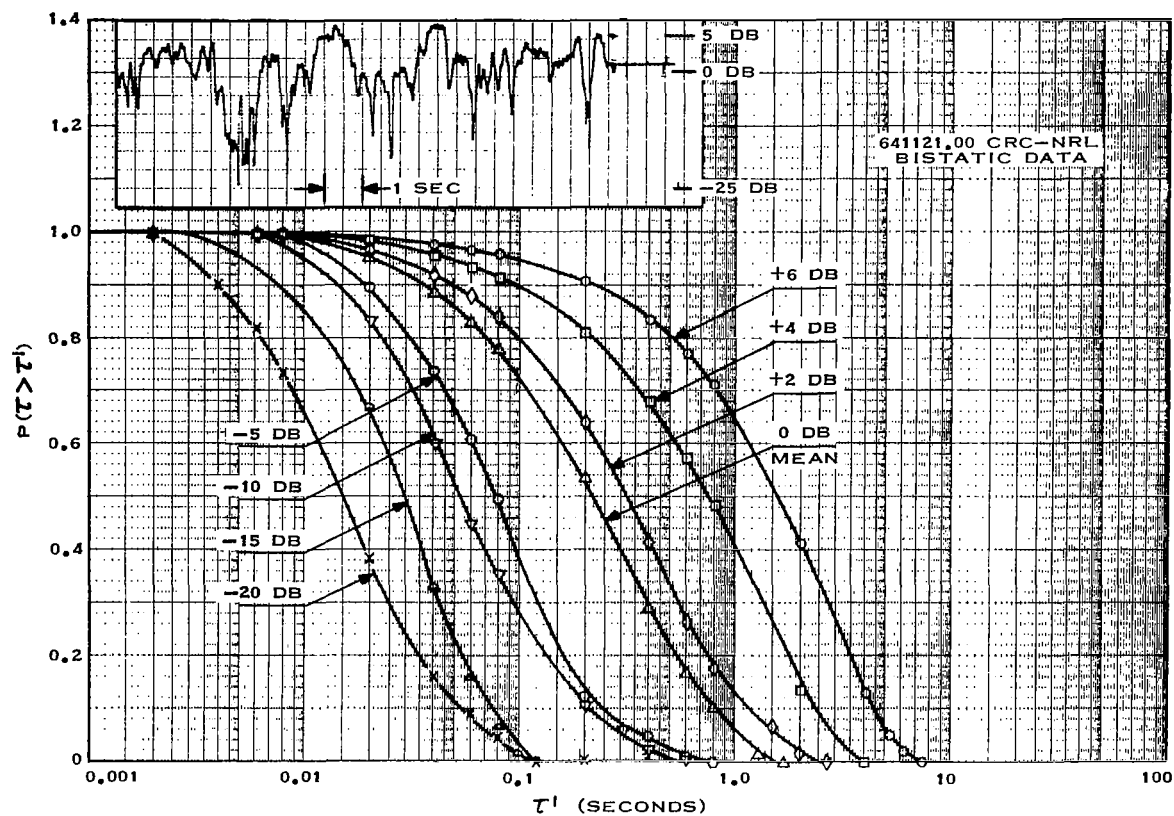


Figure 43. Probability Distribution of Fade Duration, Pass No. 3977,  
 $P(\tau > \tau')$  Vs  $\tau'$ , -5, -10, -15, -20 Db, +6, +4, +2, 0 Db

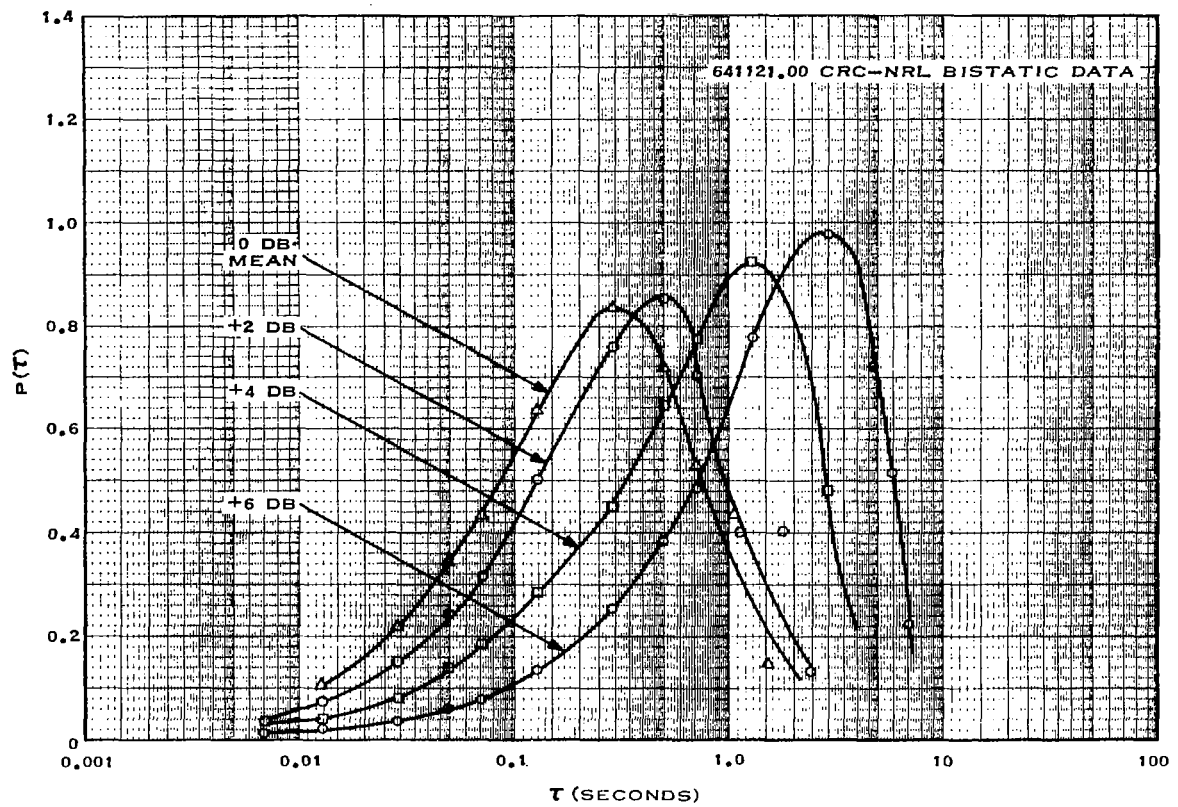


Figure 44. Probability Density of Fade Duration, Pass No. 3977,  
 $P(\tau)$  Vs  $\tau$ , 0, +2, +4, +6 Db

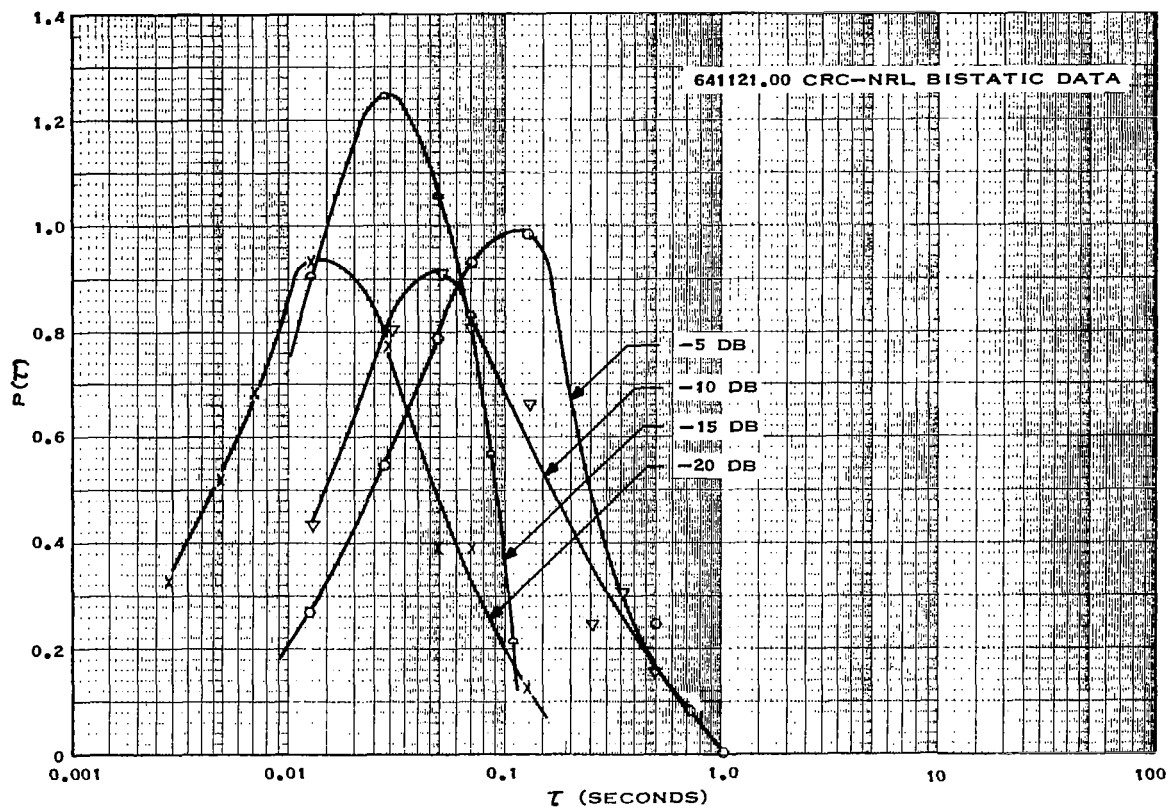


Figure 45. Probability Density of Fade Duration, Pass No. 3977,  
 $P(\tau)$  Vs  $\tau$ , -5, -10, -15, -20 Db

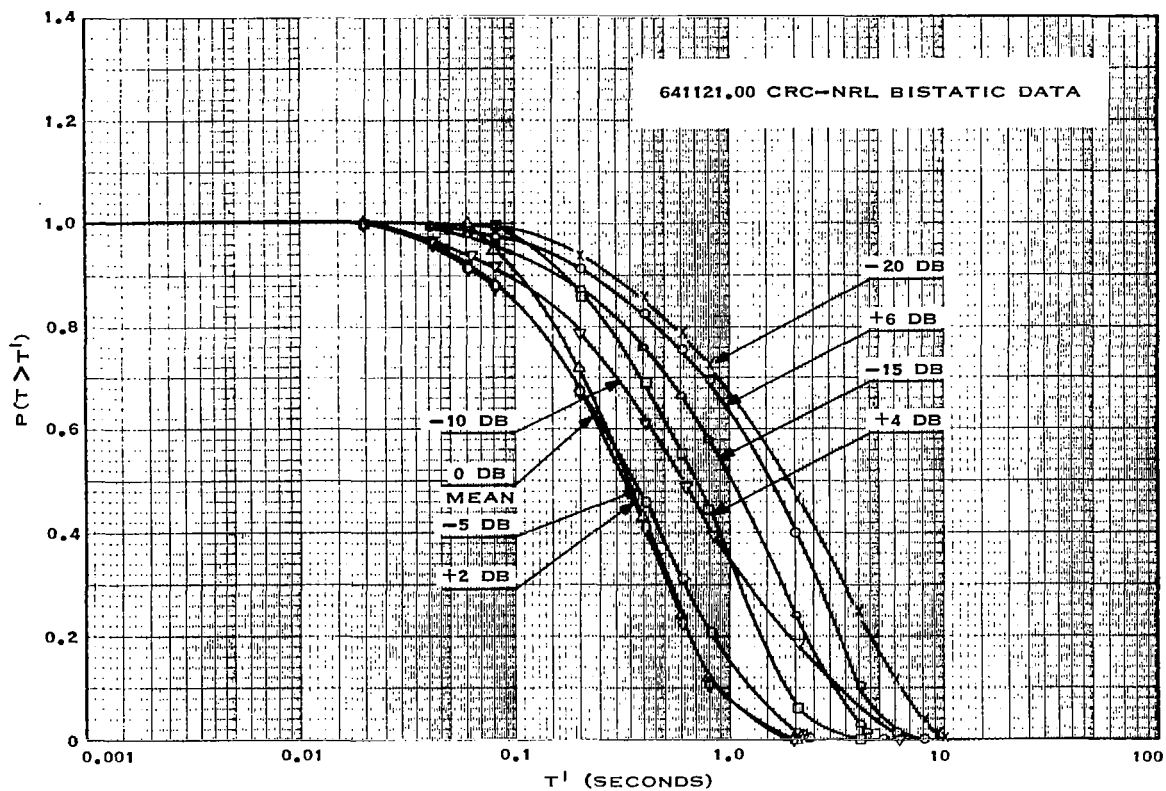


Figure 46. Probability Distribution of Fade Period, Pass No. 3977,  
 $P(T > T')$  Vs  $T'$ , -10, 0, -5, +2 Db, -20, +6, -15, +4 Db

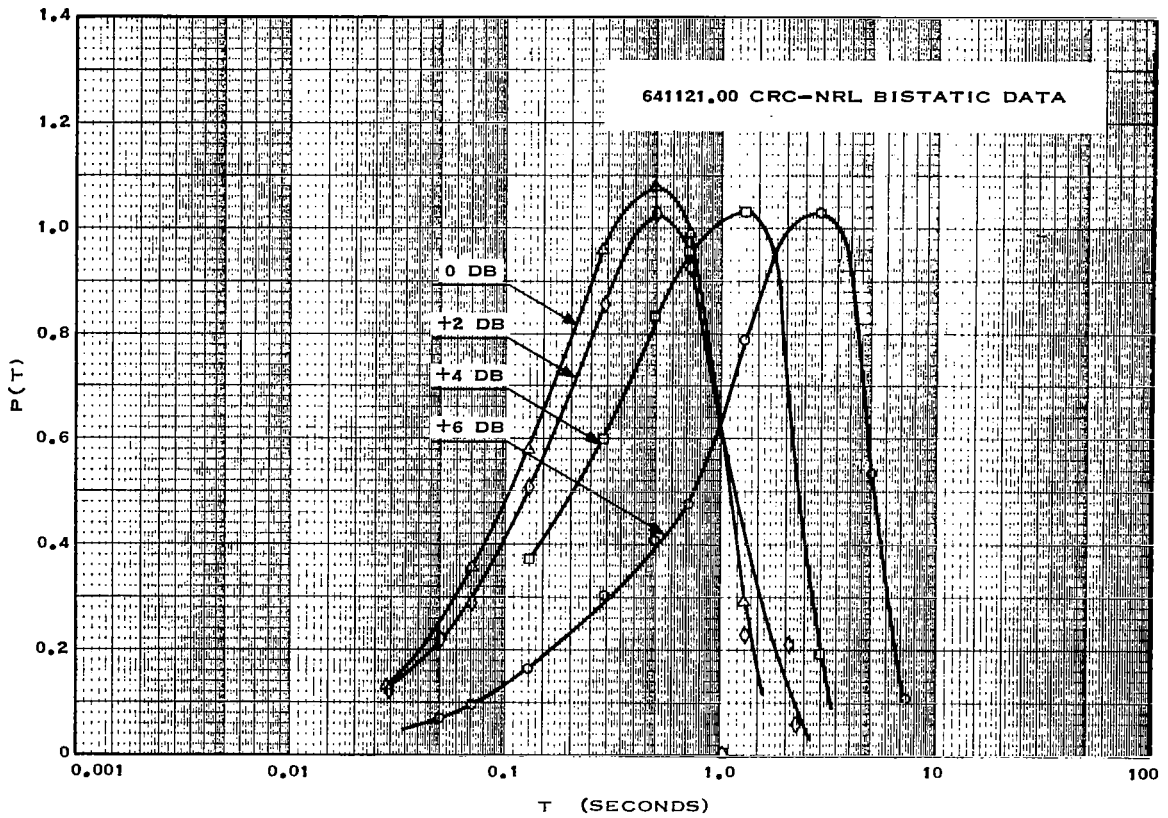


Figure 47. Probability Density of Fade Period, Pass No. 3977,  
P(T) Vs T, 0, +2, +4, +6 Db

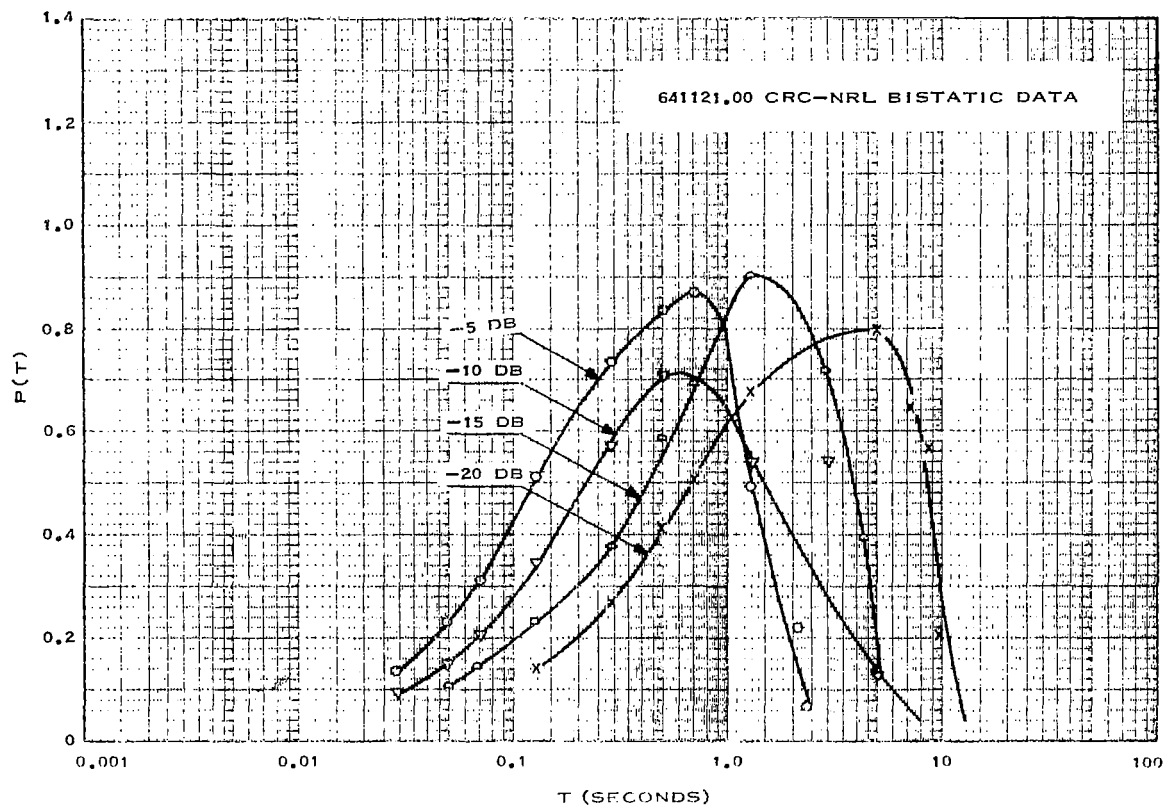


Figure 48. Probability Density of Fade Period, Pass No. 3977,  
 $P(T)$  Vs  $T$ , -5, -10, -15, -20 Db

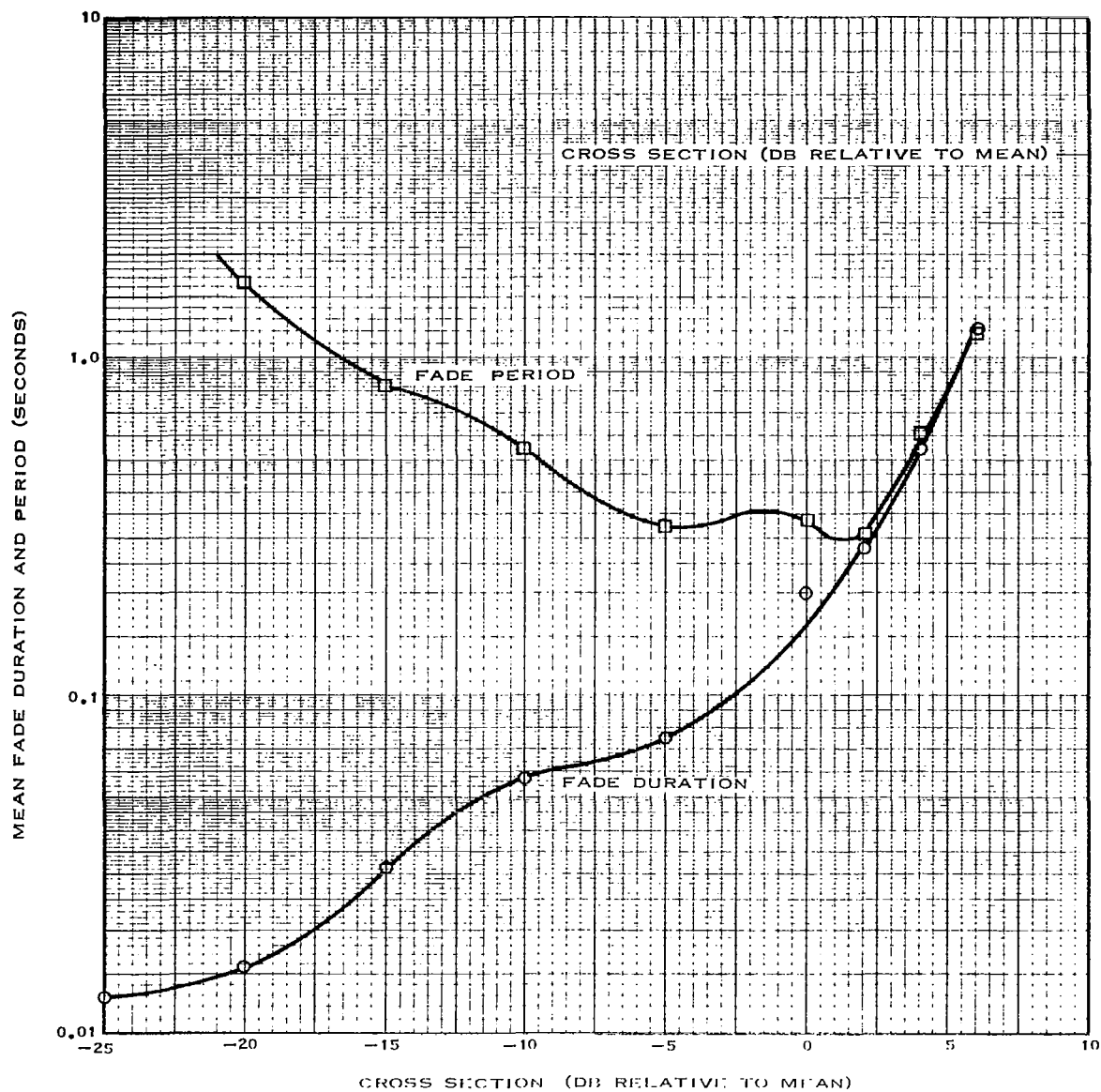


Figure 49. Mean Fade Duration and Fade Period Vs Cross-Section Level, Pass No. 3977

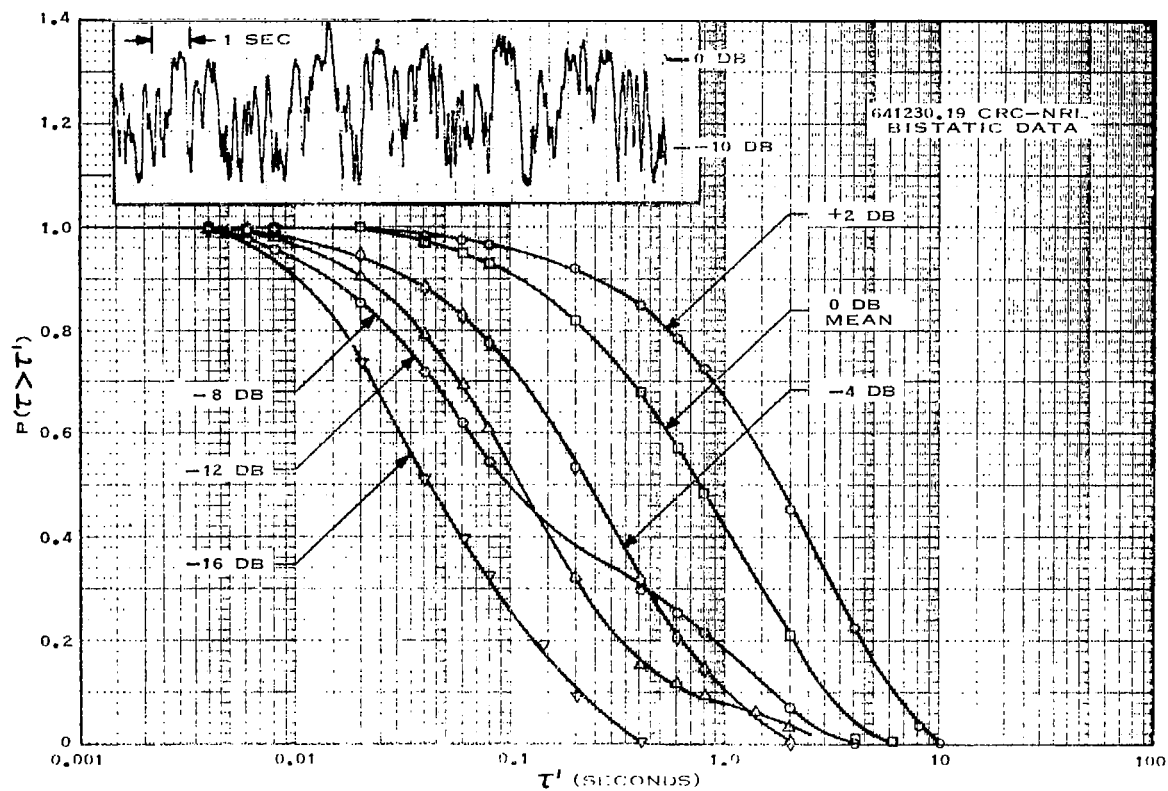


Figure 50. Probability Distribution of Fade Duration, Pass No. 4505,  
 $P(\tau > \tau')$  Vs  $\tau'$ , -8, -12, -16 Db, +2, 0, -4 Db

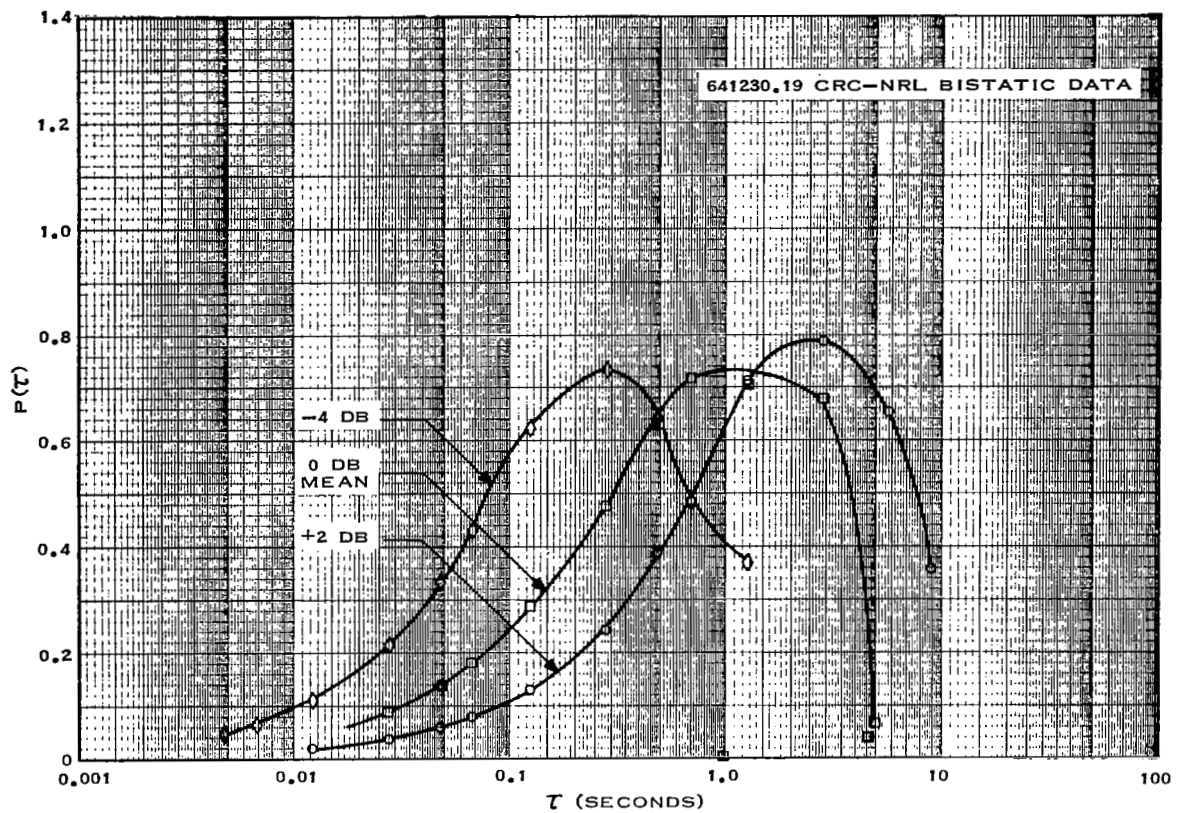


Figure 51. Probability Density of Fade Duration, Pass No. 4505,  
 $P(\tau)$  Vs  $\tau$ , -4, 0, +2 Db

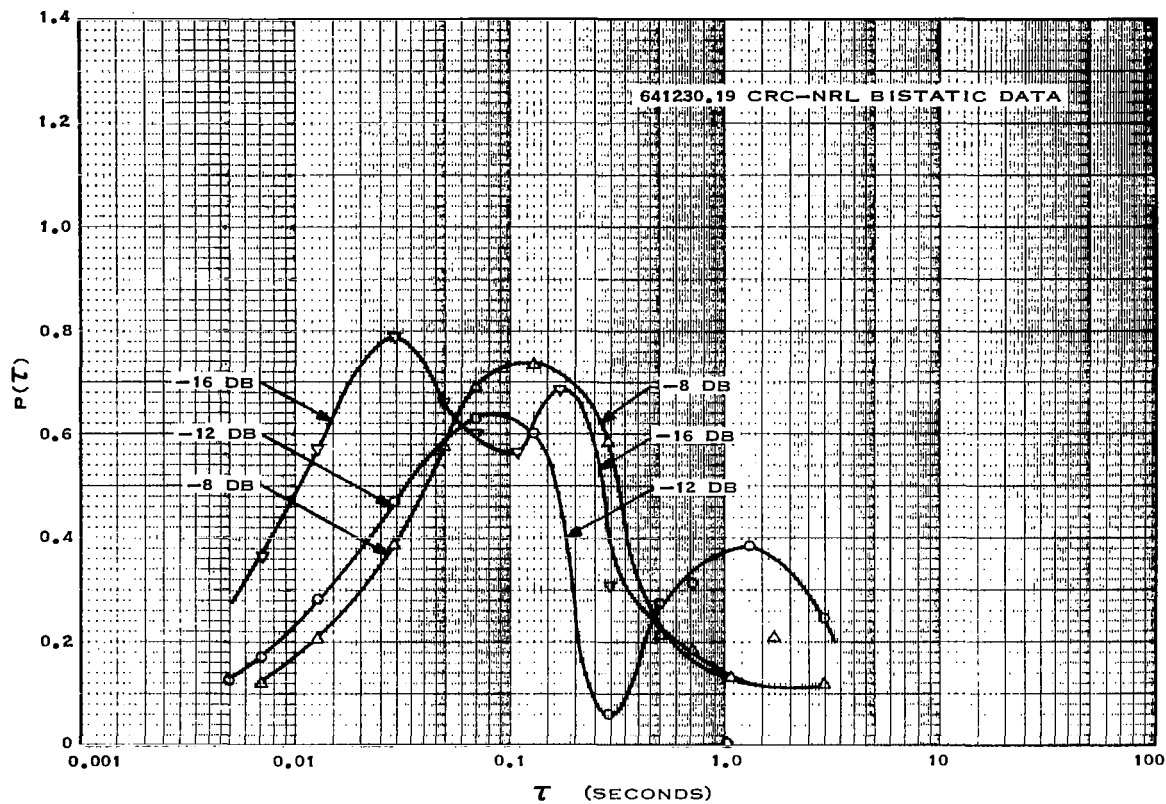


Figure 52. Probability Density of Fade Duration, Pass No. 4505,  
 $P(\tau)$  Vs  $\tau$ , -16, -12, -8 Db, -8, -16, -12 Db

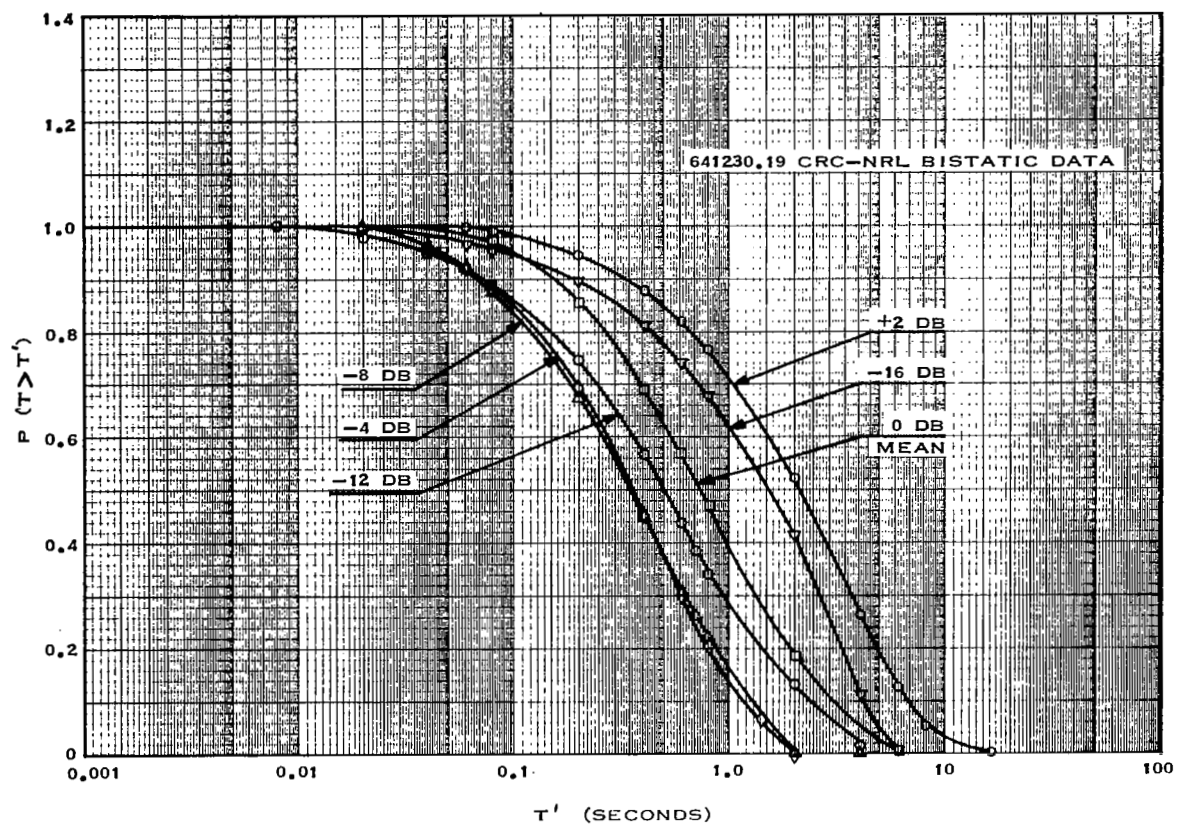


Figure 53. Probability Distribution of Fade Period, Pass No. 4505,  
 $P(T > T')$  Vs  $T'$ , -8, -4, -12 Db, +2, -16, 0 Db

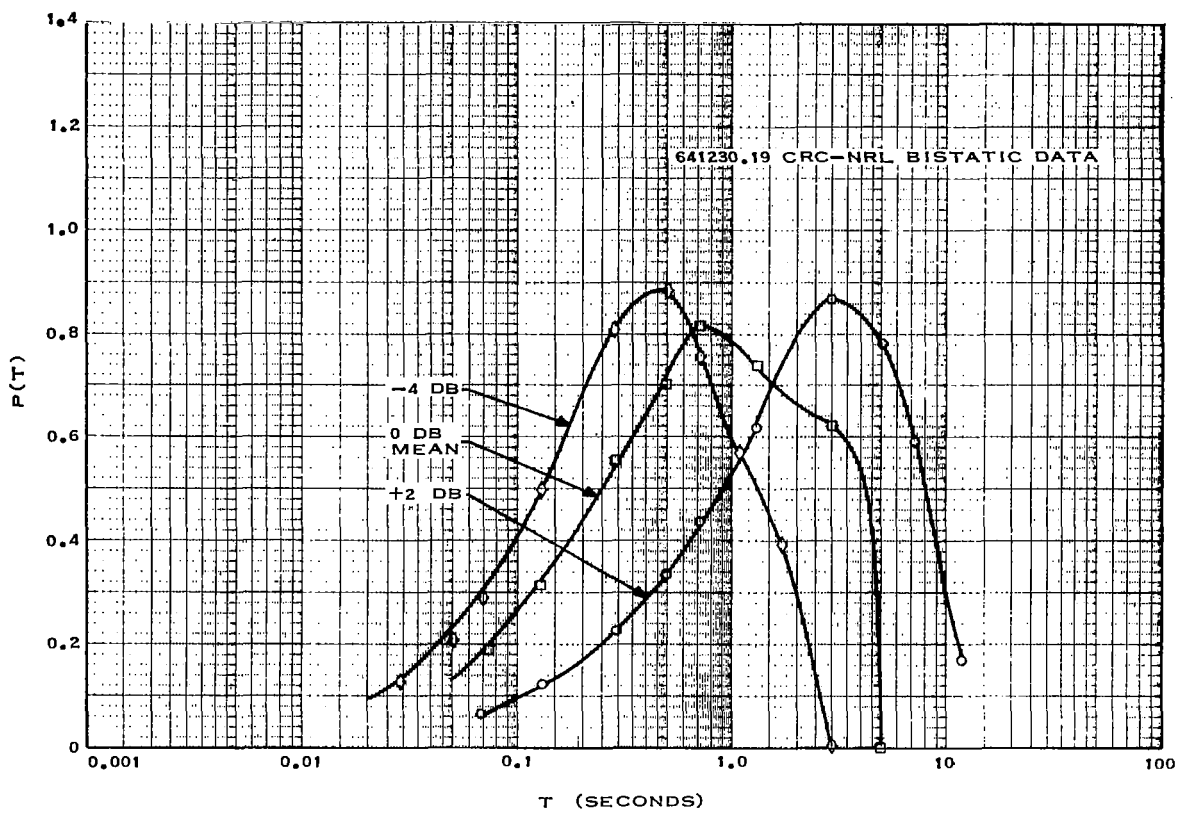


Figure 54. Probability Density of Fade Period, Pass No. 4505,  
 $P(T)$  Vs  $T$ , -4, 0, +2 Db

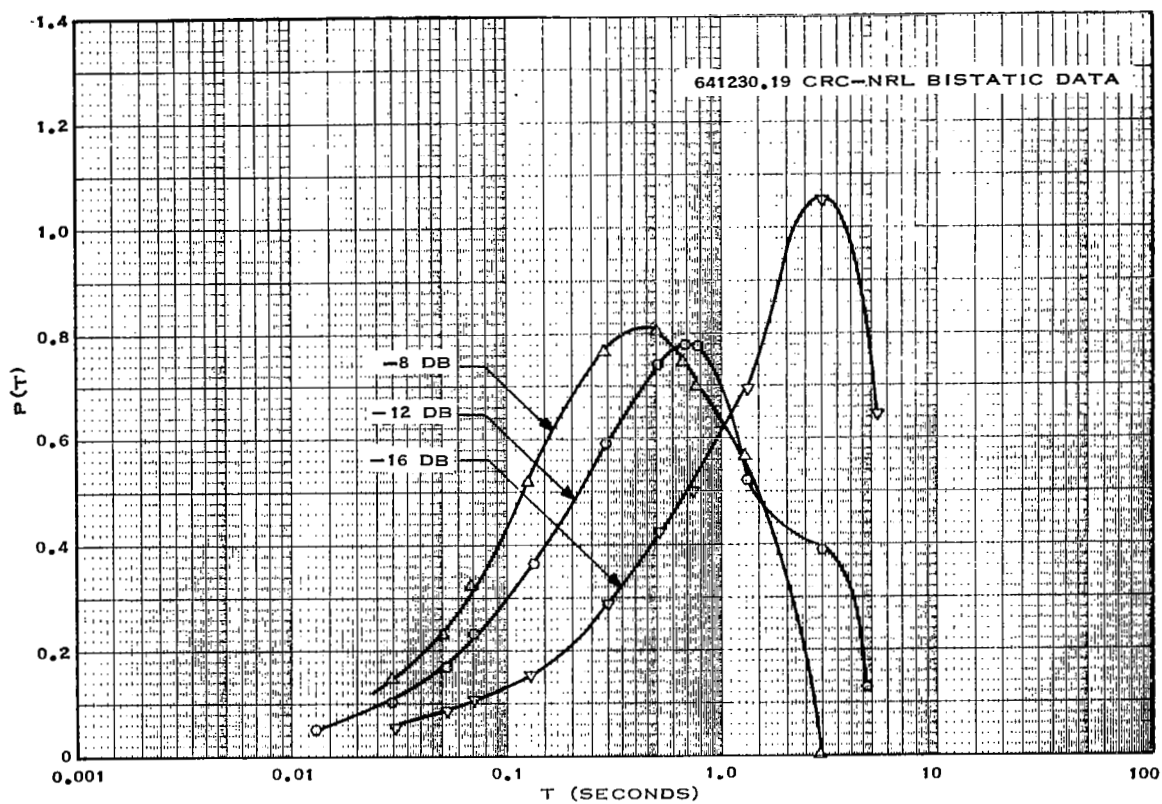


Figure 55. Probability Density of Fade Period, Pass No. 4505,  
 $P(T)$  Vs  $T$ , -8, -12, -16 Db

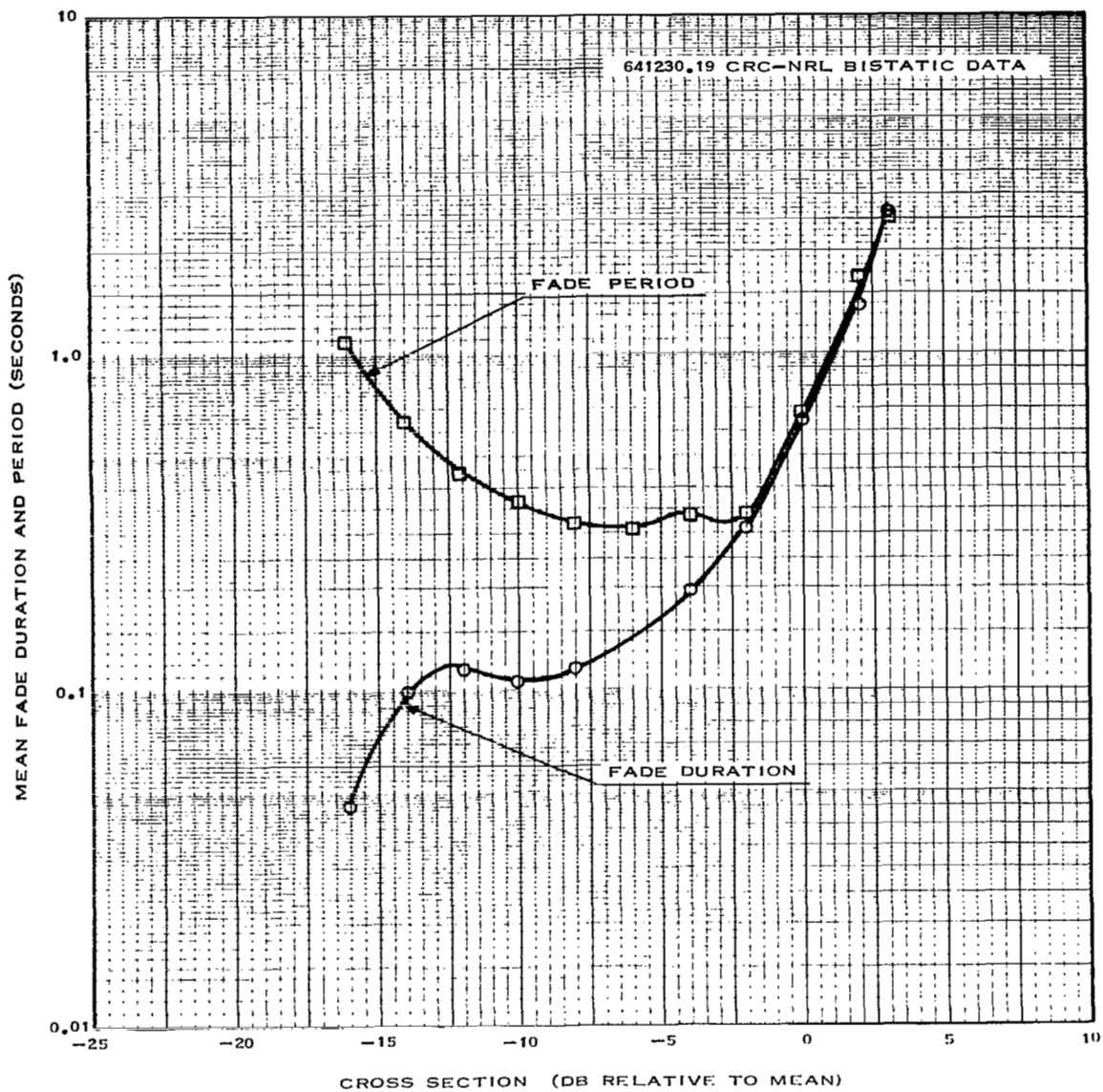


Figure 56. Mean Fade Duration and Fade Period Vs  
Cross-Section Level, Pass No. 4505

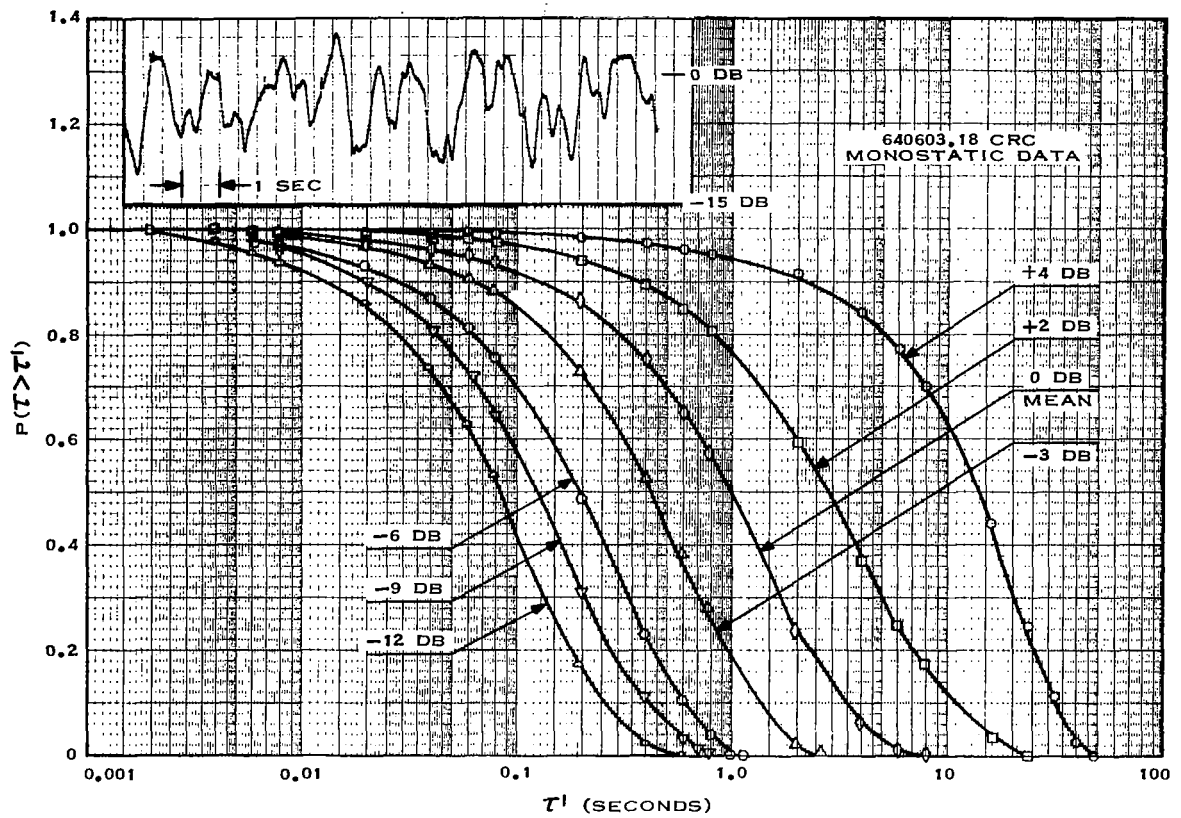


Figure 57. Probability Distribution of Fade Duration, Pass No. 1717,  
 $P(\tau > \tau')$  Vs  $\tau'$ , -6, -9, -12 Db, +4, +2, 0, -3 Db

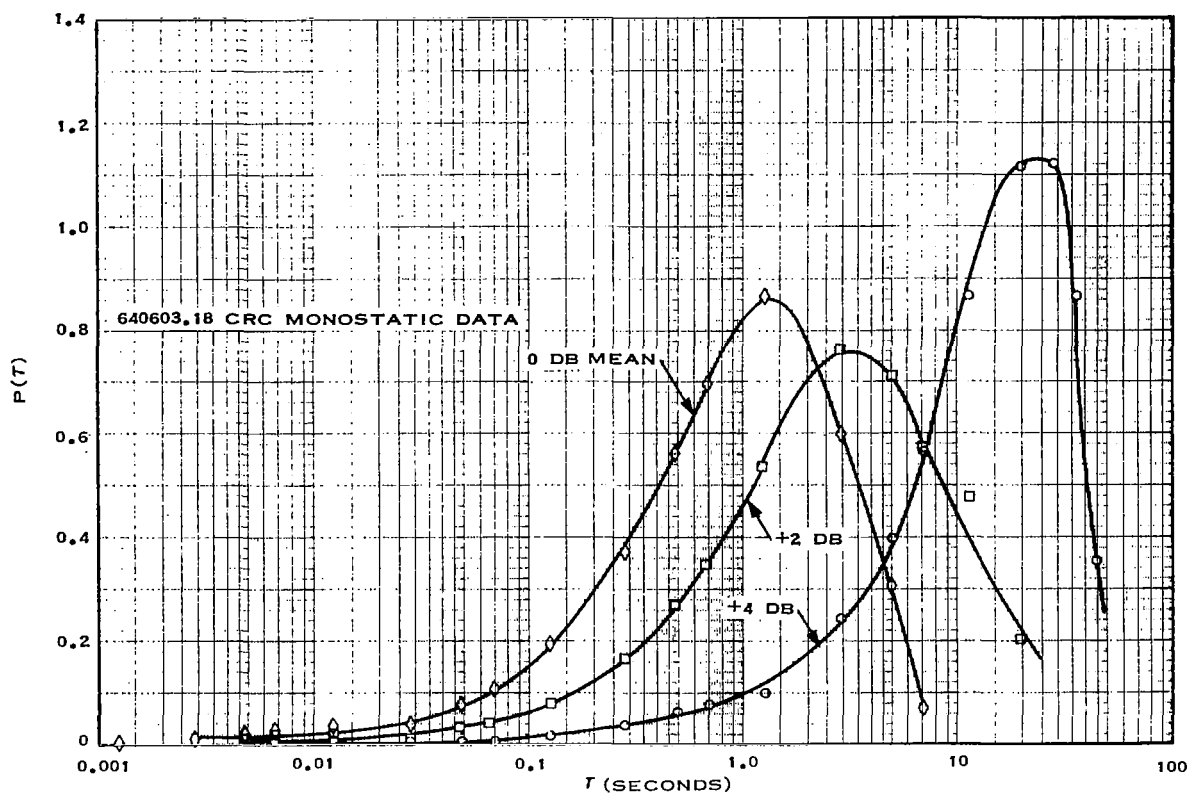


Figure 58. Probability Density of Fade Duration, Pass No. 1717,  
 $P(\tau)$  Vs  $\tau$ , 0, +2, +4 Db

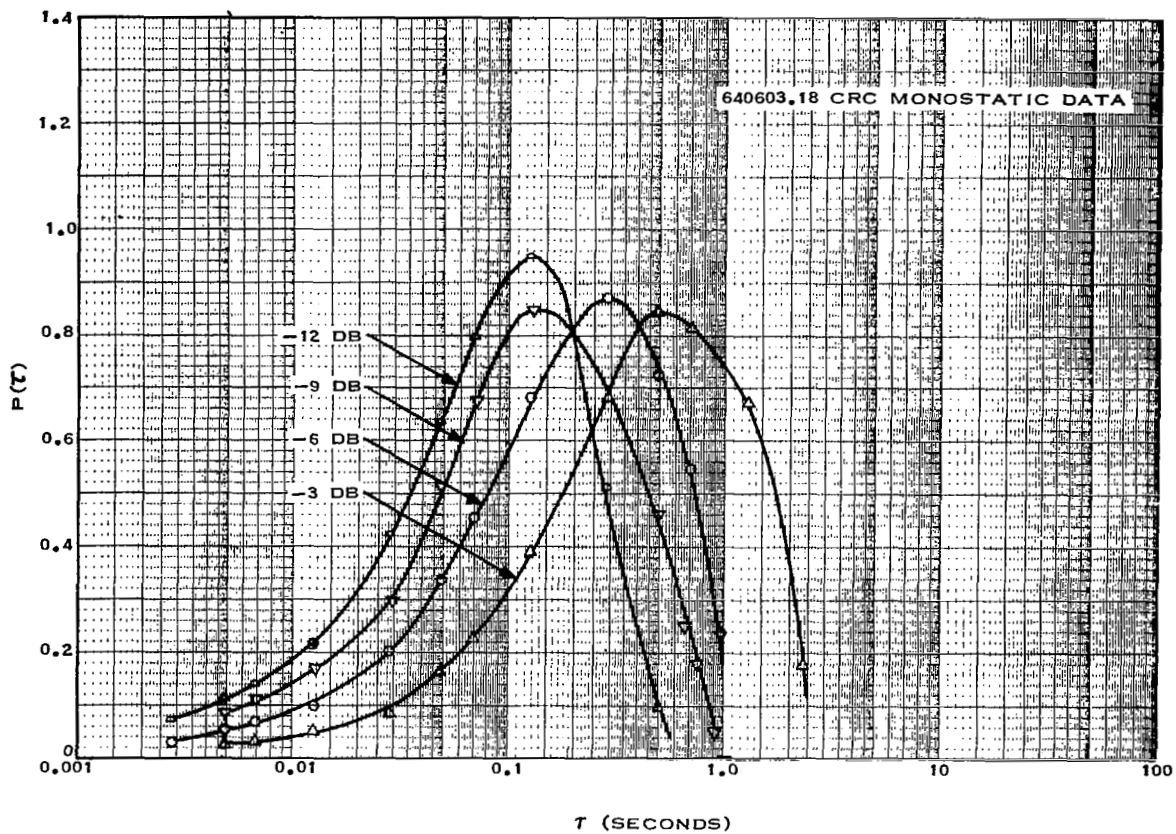


Figure 59. Probability Density of Fade Duration, Pass No. 1717,  
 $P(\tau)$  Vs  $\tau$ , -12, -9, -6, -3 Db

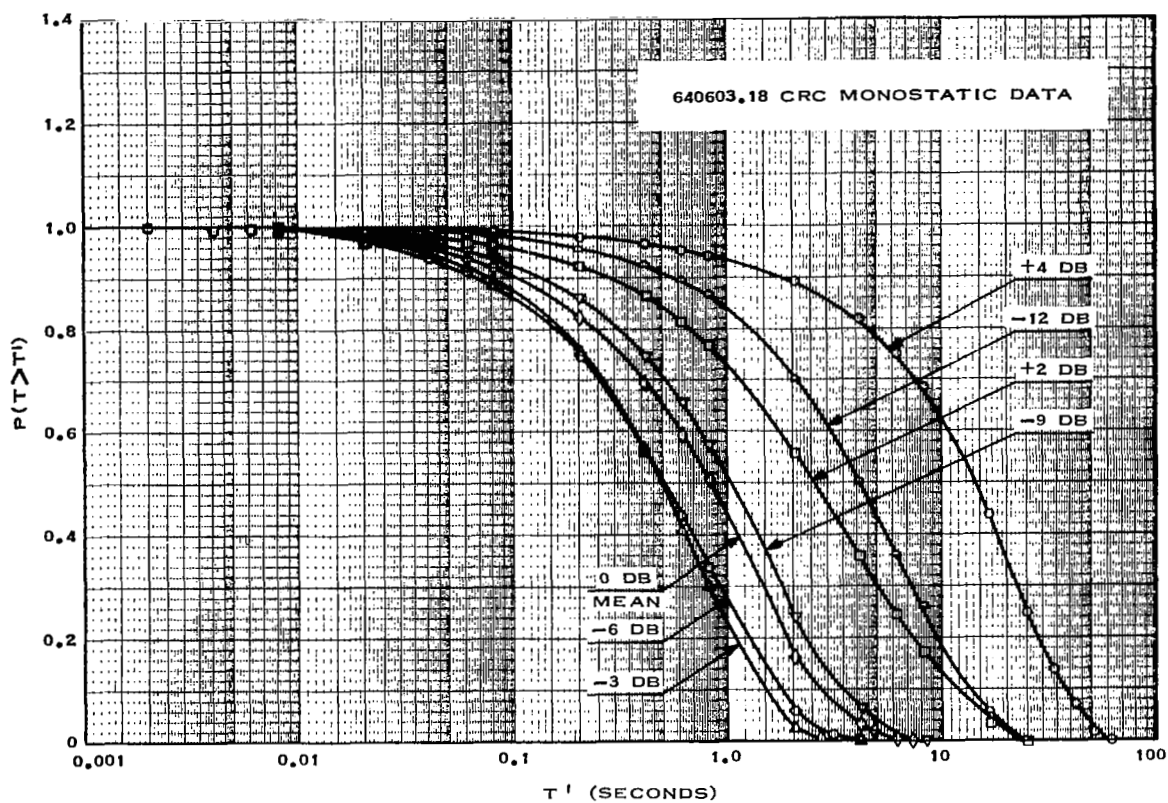


Figure 60. Probability Distribution of Fade Period, Pass No. 1717,  
 $P(T > T')$  Vs  $T'$ , 0, -6, -3 Db, +4, -12, +2, -9 Db

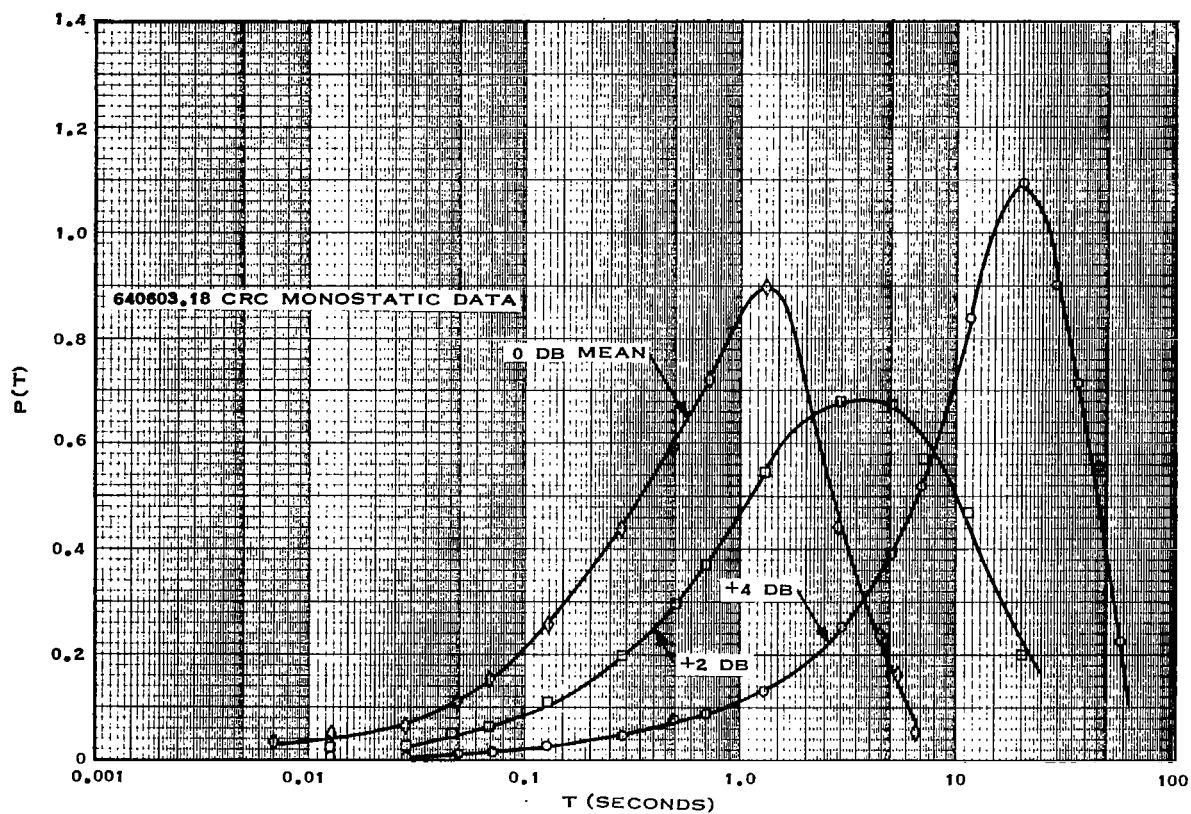


Figure 61. Probability Density of Fade Period, Pass No. 1717,  
 $P(T)$  Vs  $T$ , 0, +2, +4 Db

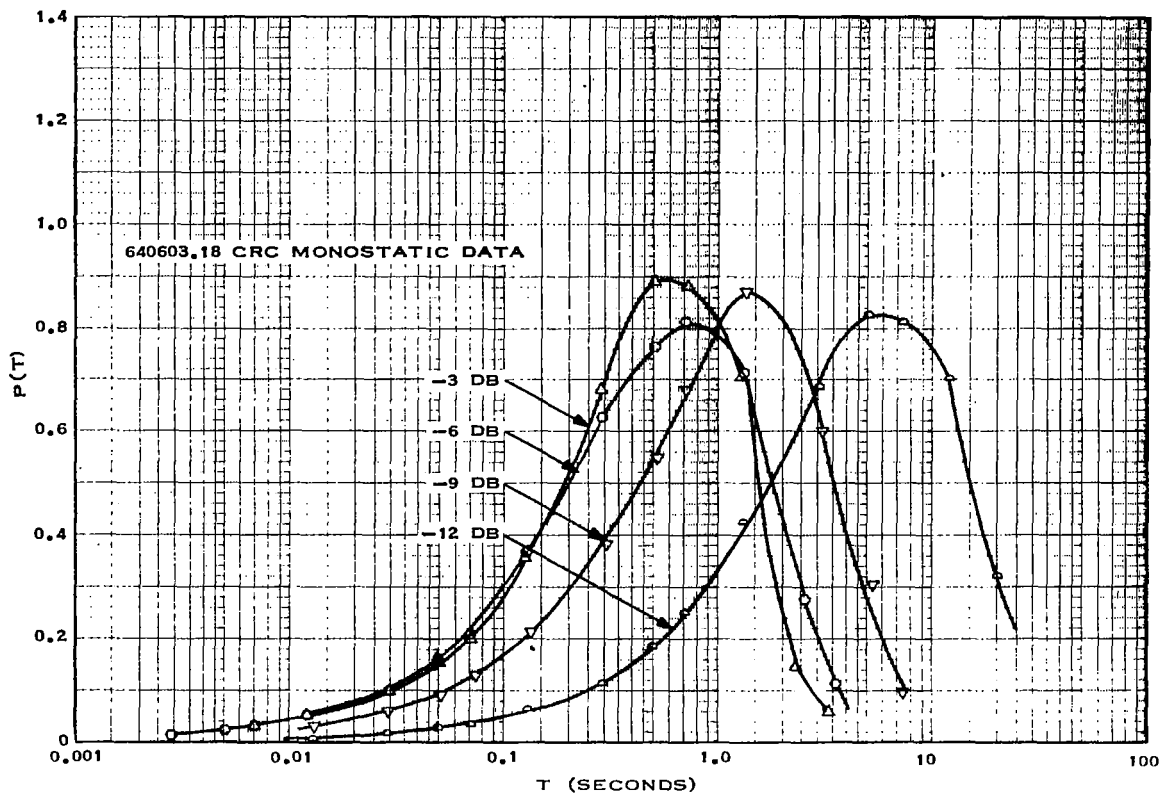


Figure 62. Probability Density of Fade Period, Pass No. 1717,  
 $P(T)$  Vs  $T$ , -3, -6, -9, -12 Db

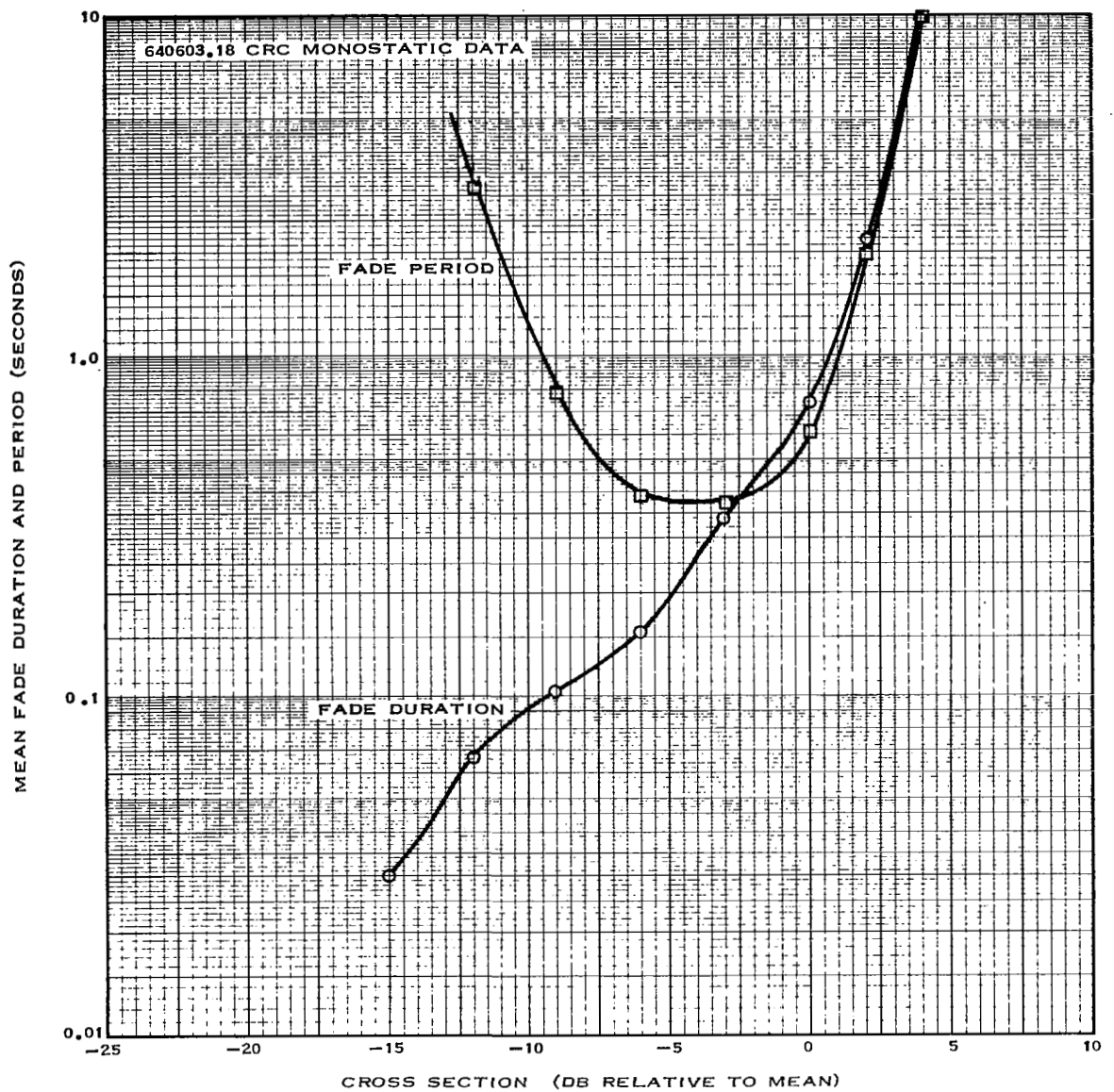


Figure 63. Mean Fade Duration and Fade Period Vs Cross-Section Level, Pass No. 1717

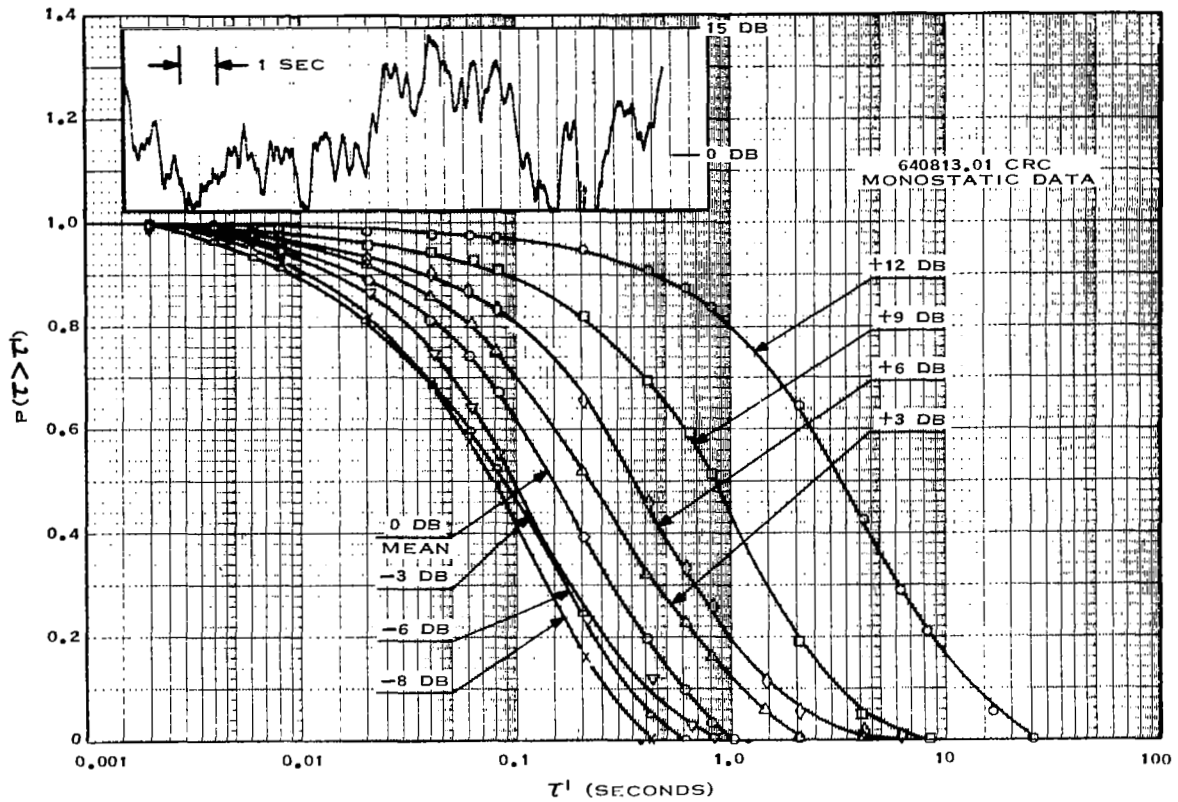


Figure 64. Probability Distribution of Fade Duration, Pass No. 2653,  
 $P(\tau > \tau')$  Vs  $\tau'$ , 0, -3, -6, -8 Db, +12, +9, +6, +3 Db

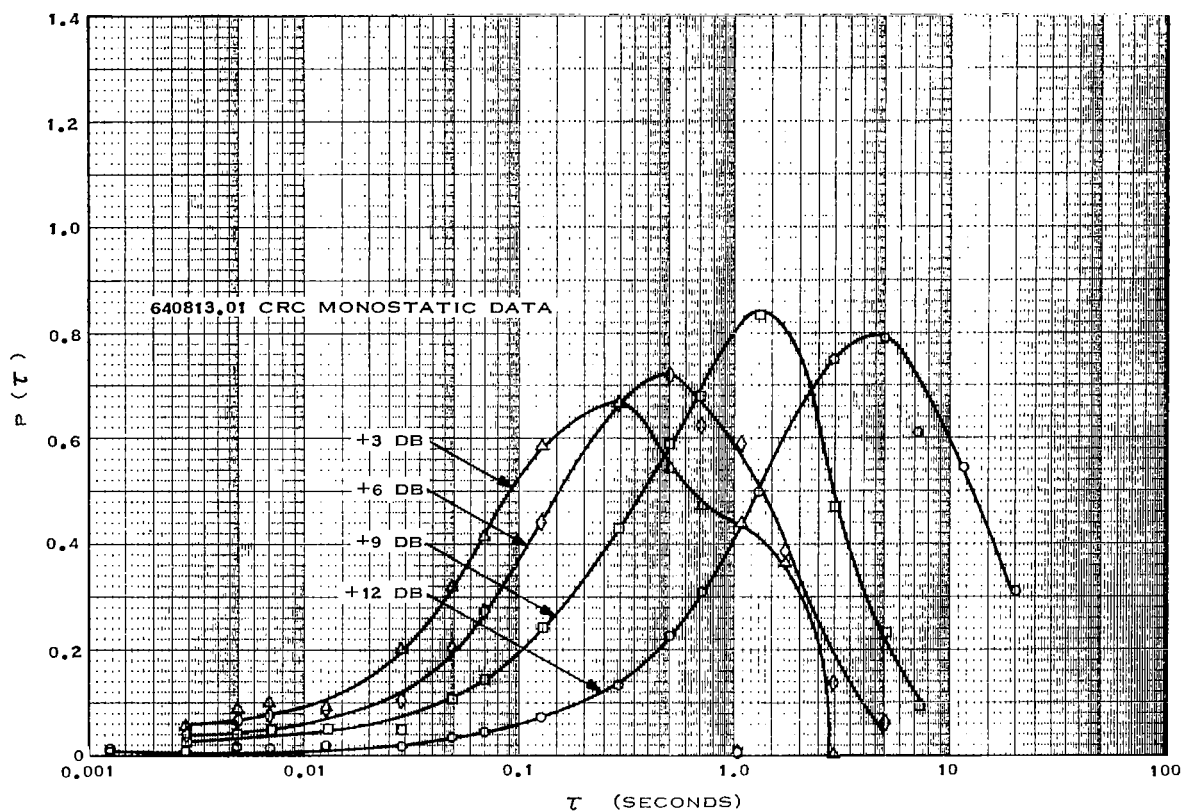


Figure 65. Probability Density of Fade Duration, Pass No. 2653,  
 $P(\tau)$  Vs  $\tau$ , +3, +6, +9, +12 Db

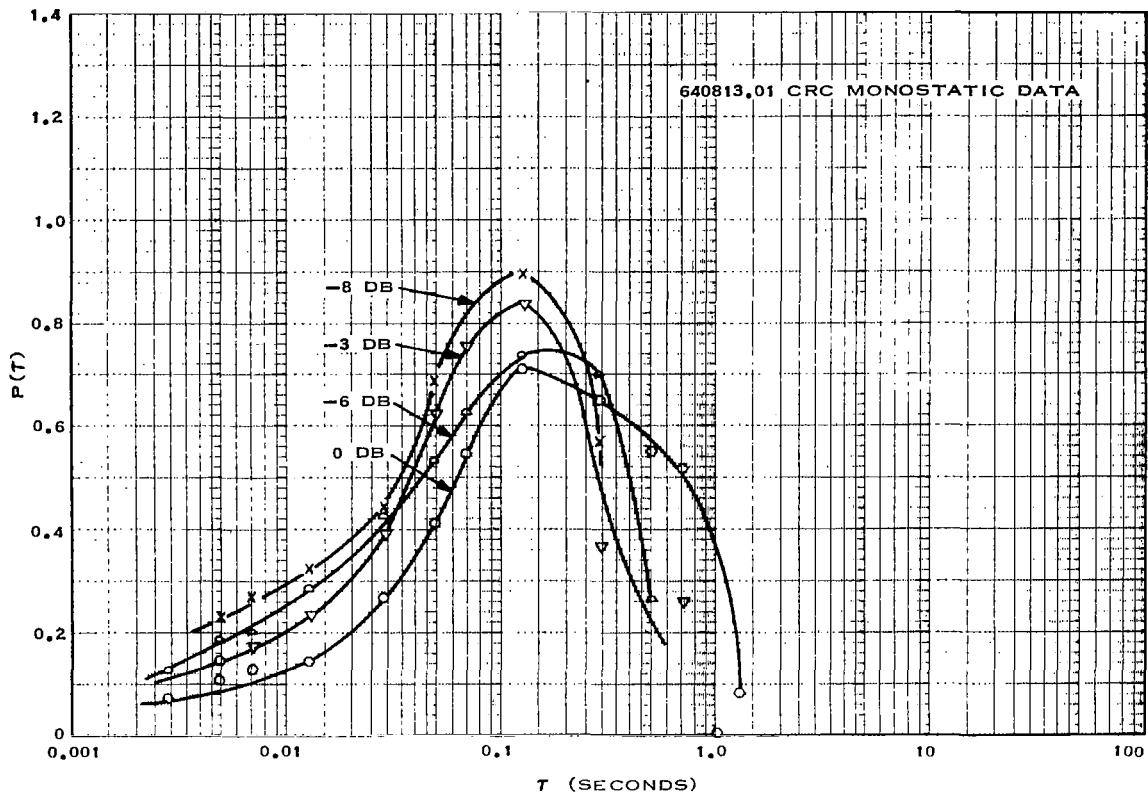


Figure 66. Probability Density of Fade Duration, Pass No. 2653,  
 $P(\tau)$  Vs  $\tau$ , -8, -3, -6, 0 Db

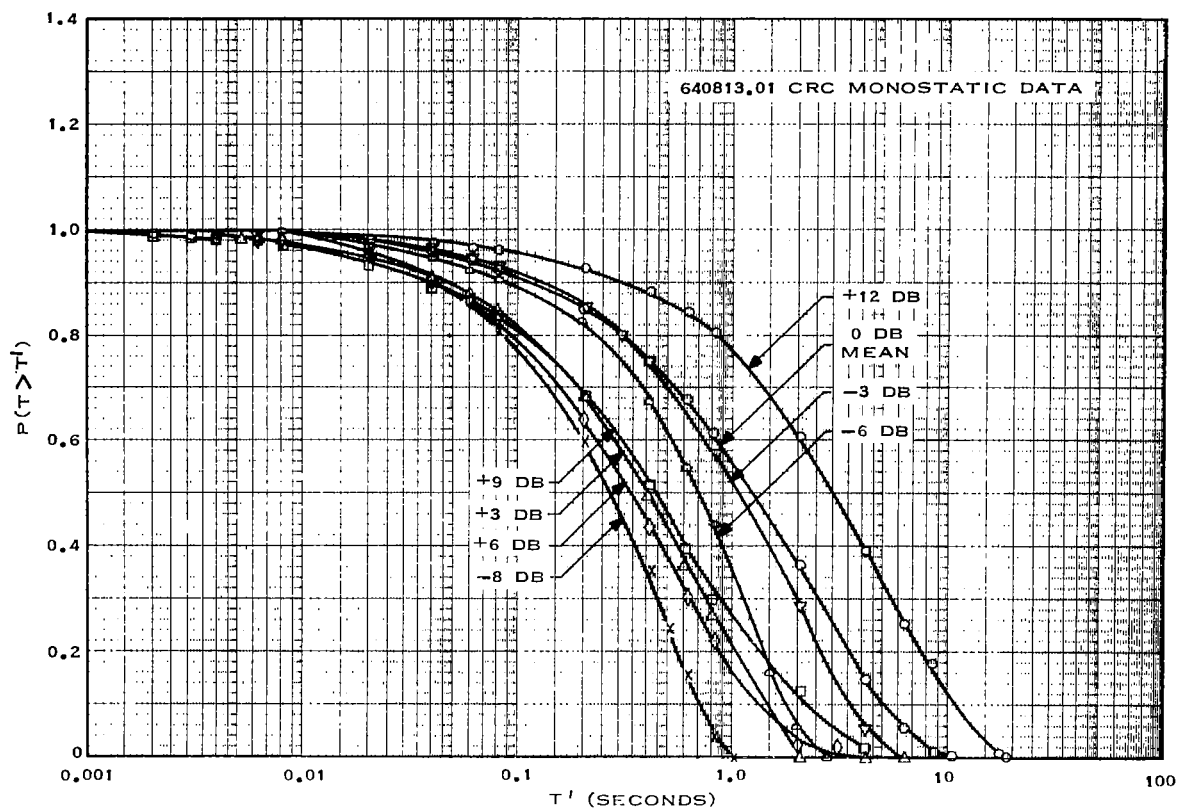


Figure 67. Probability Distribution of Fade Period, Pass No. 2653,  
 $P(T > T')$  Vs  $T'$ , +9, +3, +6, -8 Db, +12, 0, -3, -6 Db

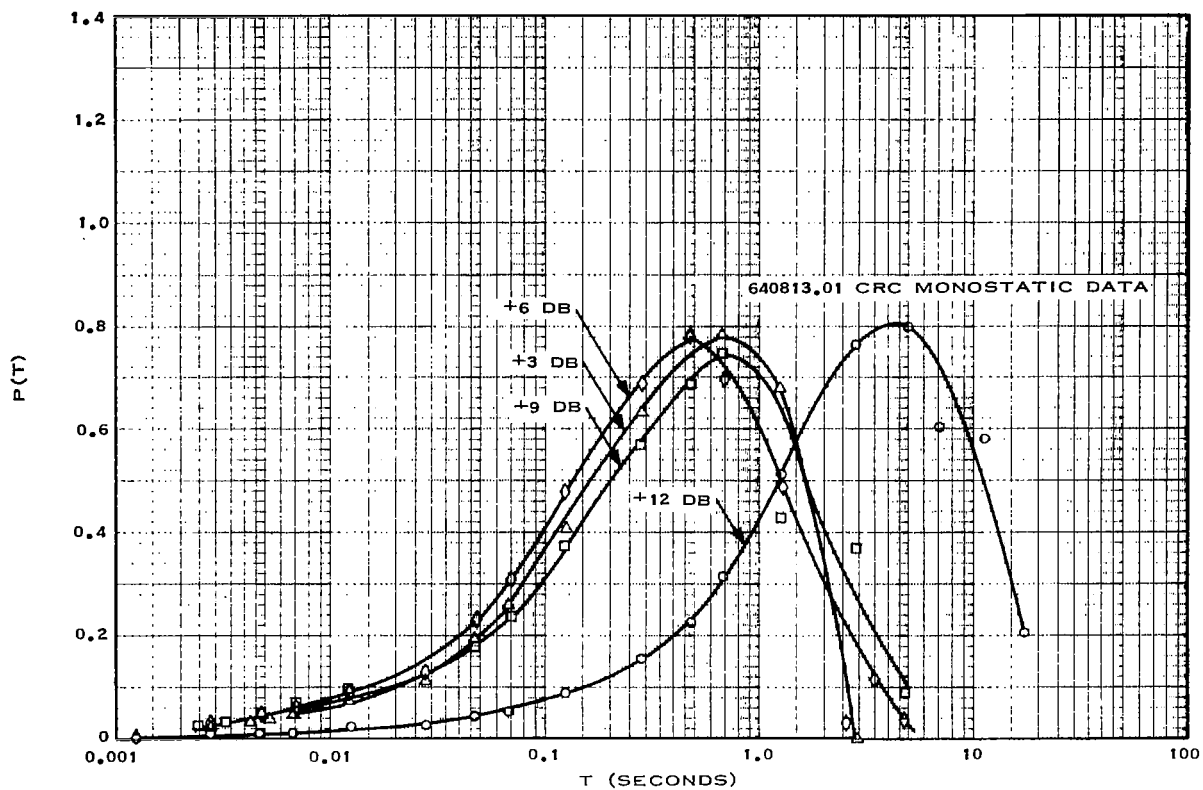


Figure 68. Probability Density of Fade Period, Pass No. 2653,  
 $P(T)$  Vs  $T$ , +6, +3, +9, +12 Db

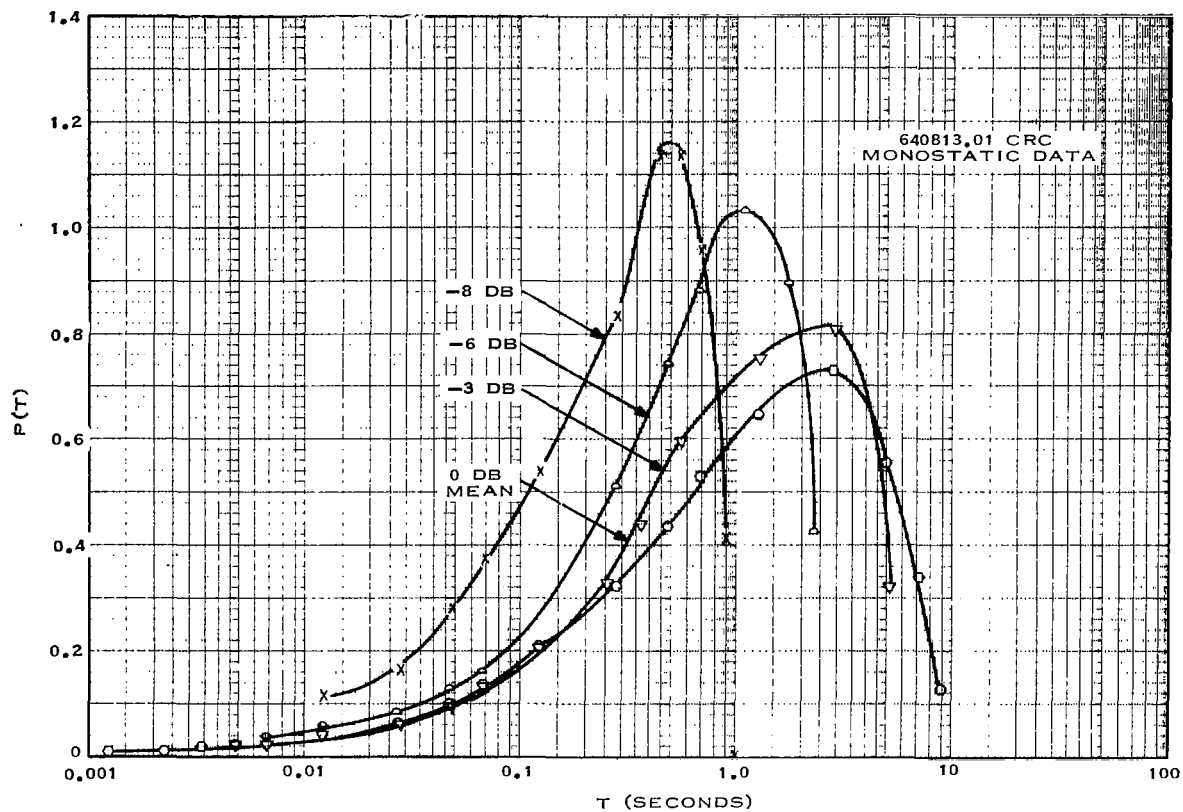


Figure 69. Probability Density of Fade Period, Pass No. 2653,  
 $P(T)$  Vs  $T$ , -8, -6, -3, 0 Db

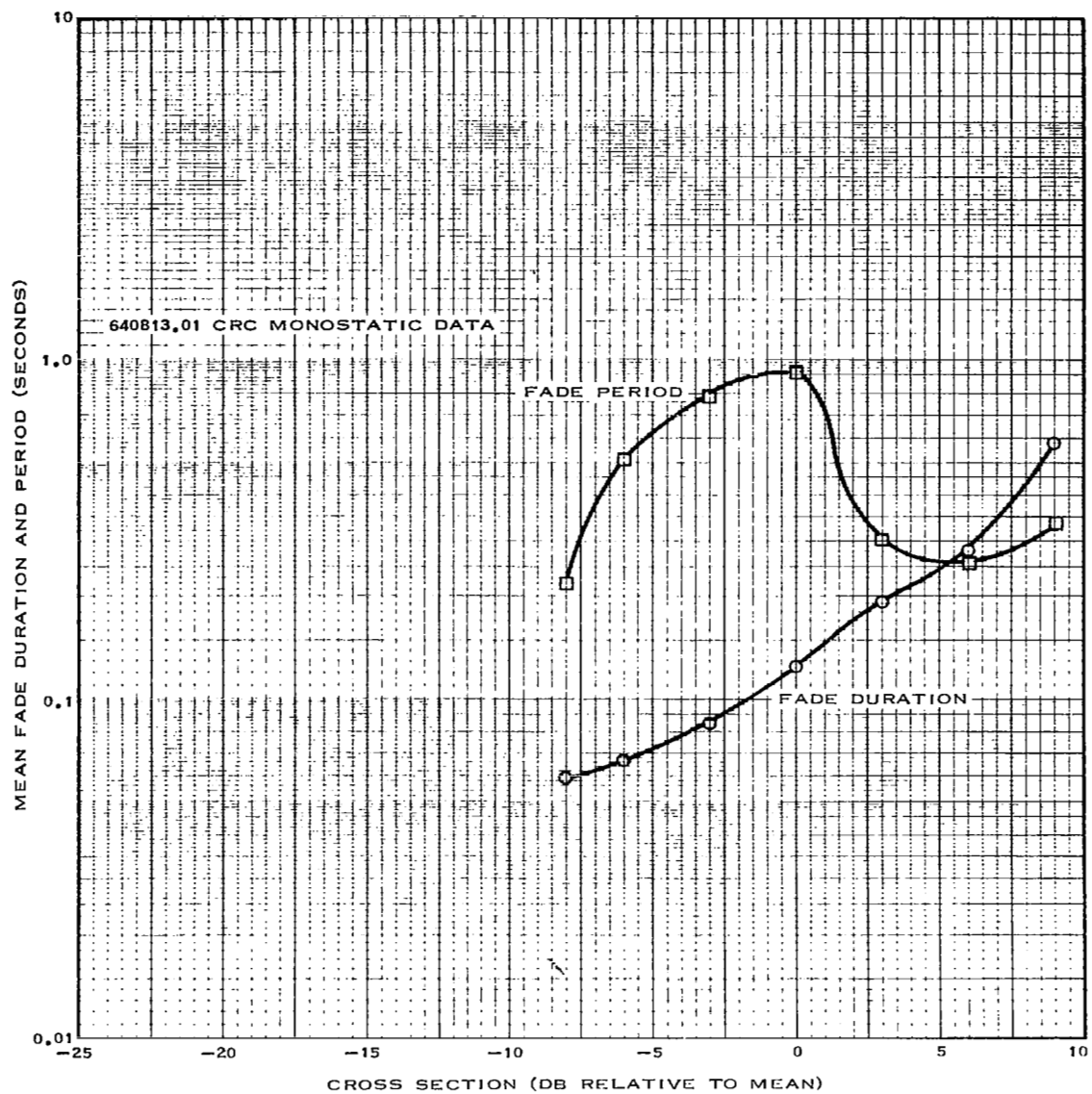


Figure 70. Mean Fade Duration and Fade Period Vs Cross-Section Level, Pass No. 2653

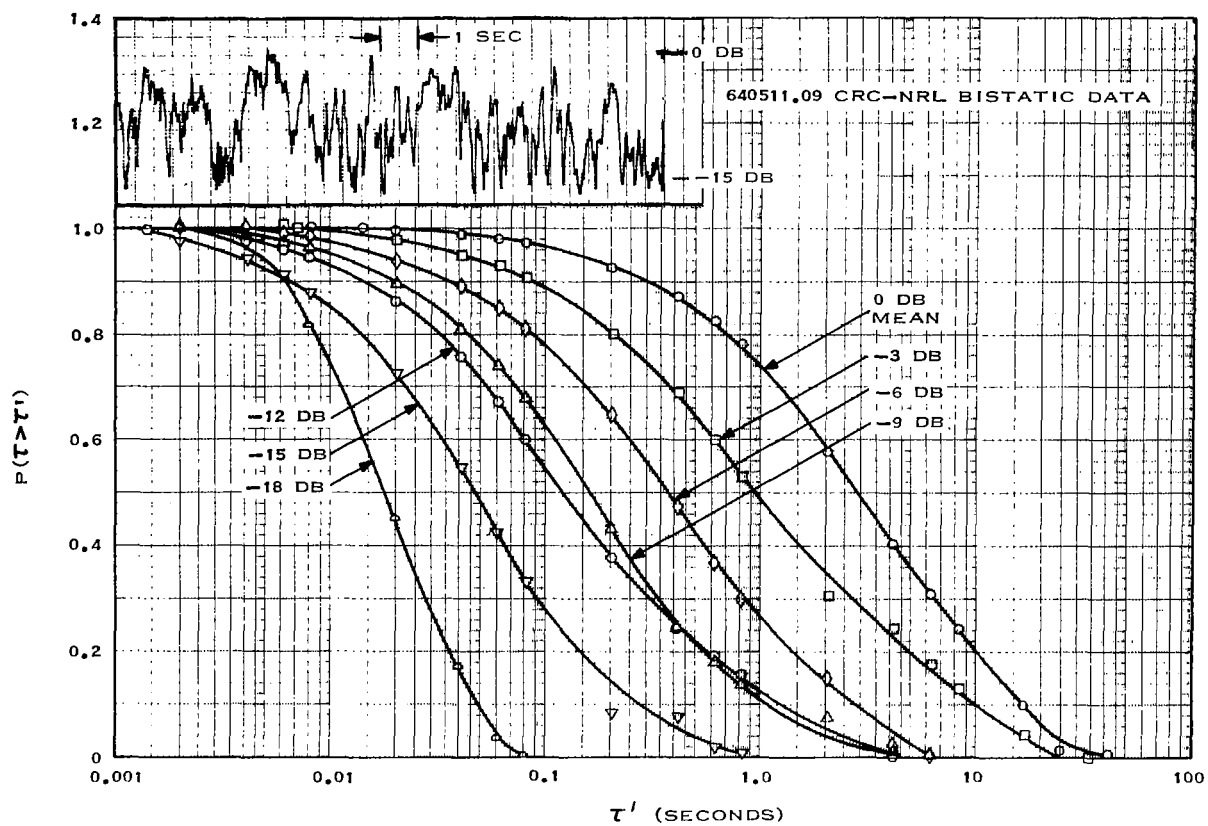


Figure 71. Probability Distribution of Fade Duration, Pass No. 16983,  
 $P(\tau > \tau')$  Vs  $\tau'$ , -12, -15, -18 Db, 0, -3, -6, -9 Db

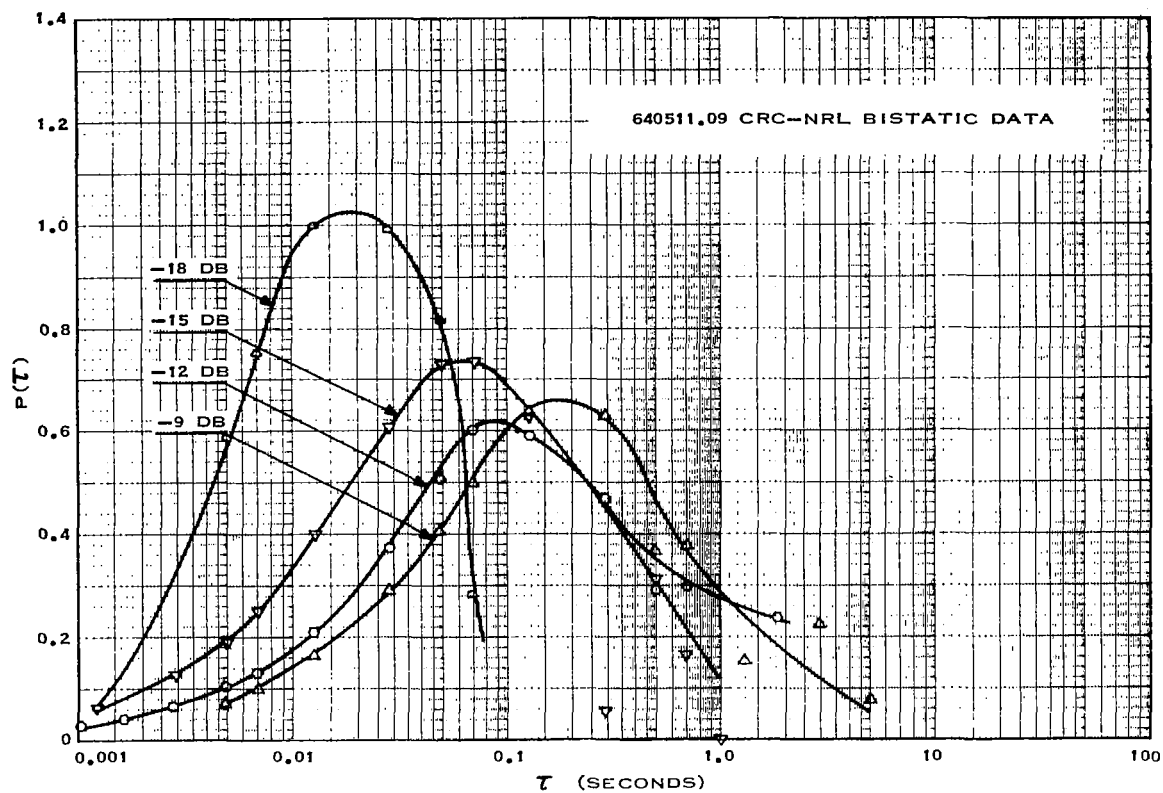


Figure 72. Probability Density of Fade Duration, Pass No. 16983,  
 $P(\tau)$  Vs  $\tau$ , -18, -15, -12, -9 Db

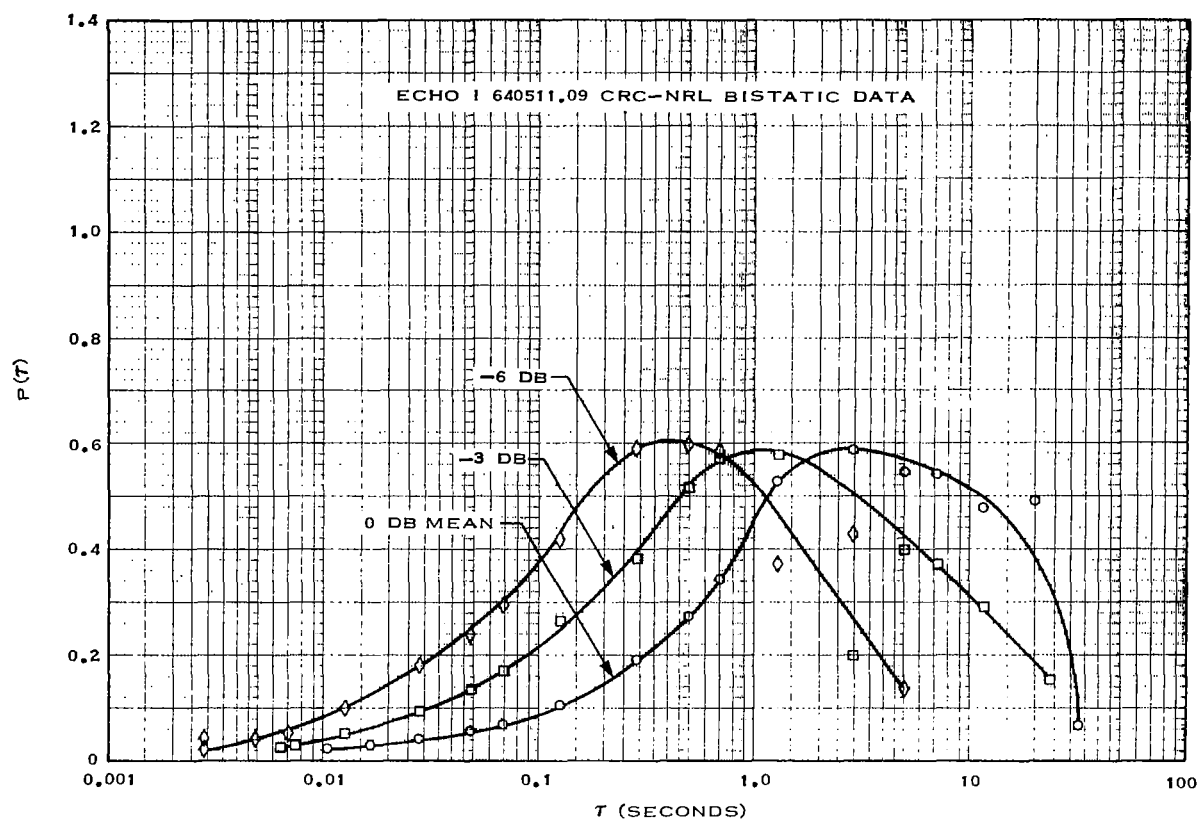


Figure 73. Probability Density of Fade Duration, Pass No. 16983,  
 $P(\tau)$  Vs  $\tau$ , -6, -3, 0 Db

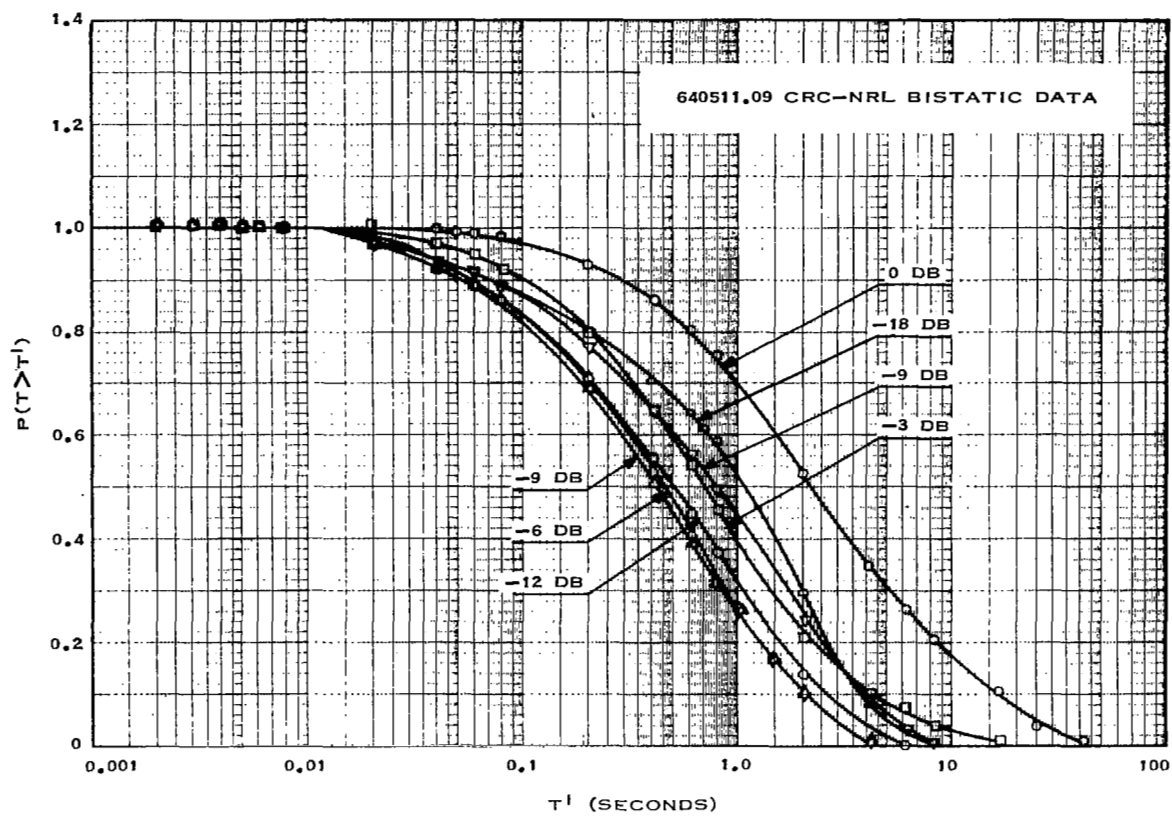


Figure 74. Probability Distribution of Fade Period, Pass No. 16983,  
 $P(T > T')$  Vs  $T'$ , -9, -6, -12 Db, 0, -18, -9, -3 Db

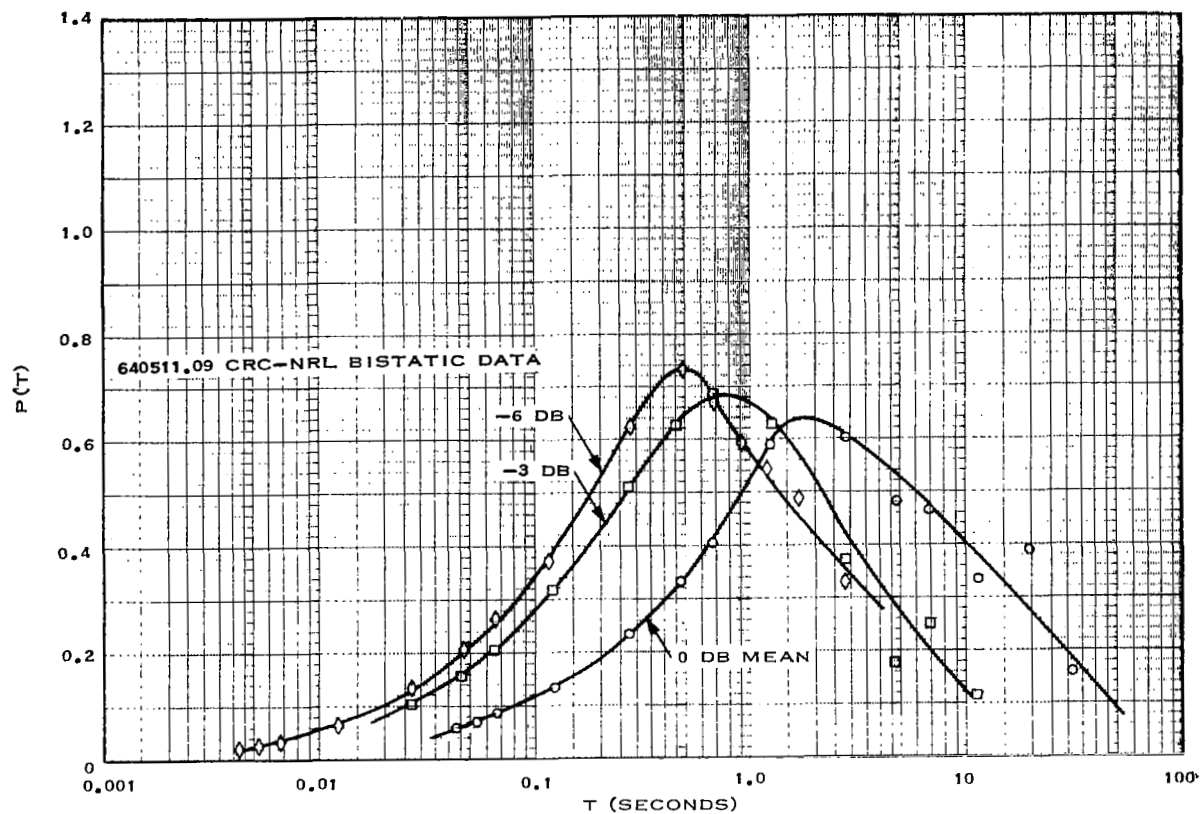


Figure 75. Probability of Density of Fade Period, Pass No. 16983,  
 $P(T)$  Vs  $T$ , -6, -3, 0 Db

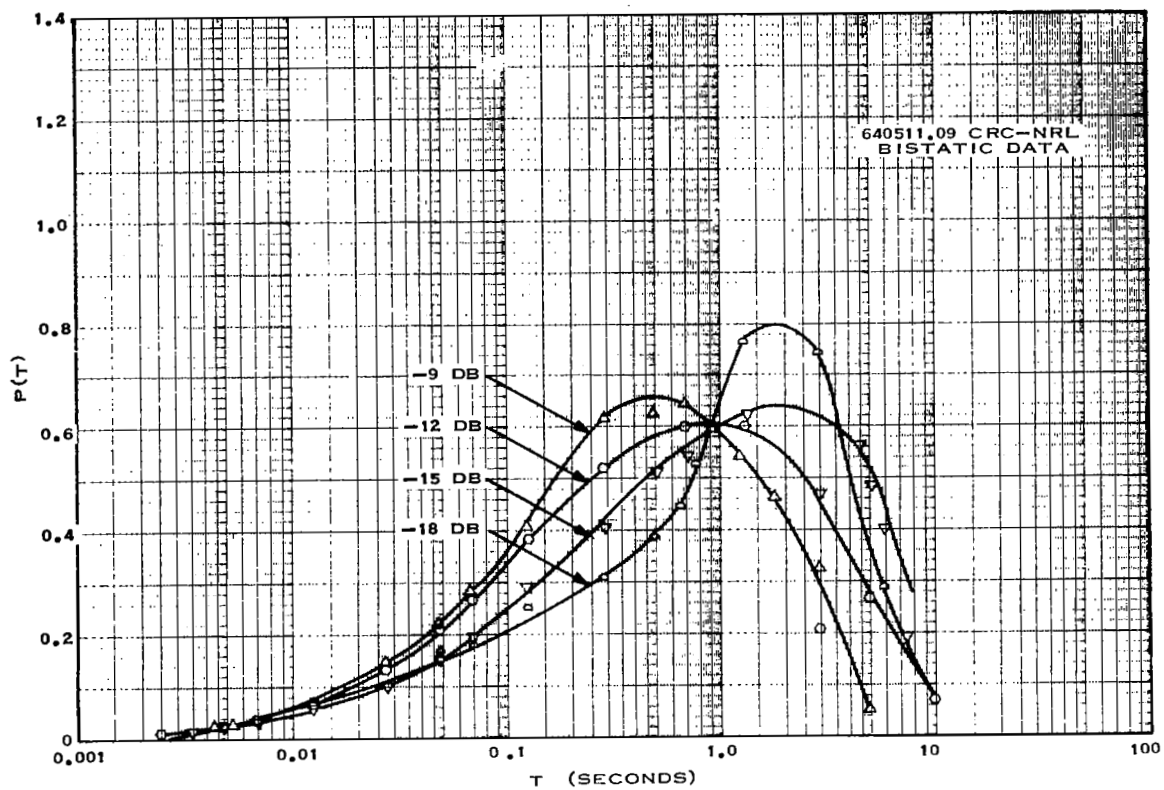


Figure 76. Probability of Density of Fade Period, Pass No. 16983,  
 $P(T)$  Vs  $T$ , -9, -12, -15, -18 Db

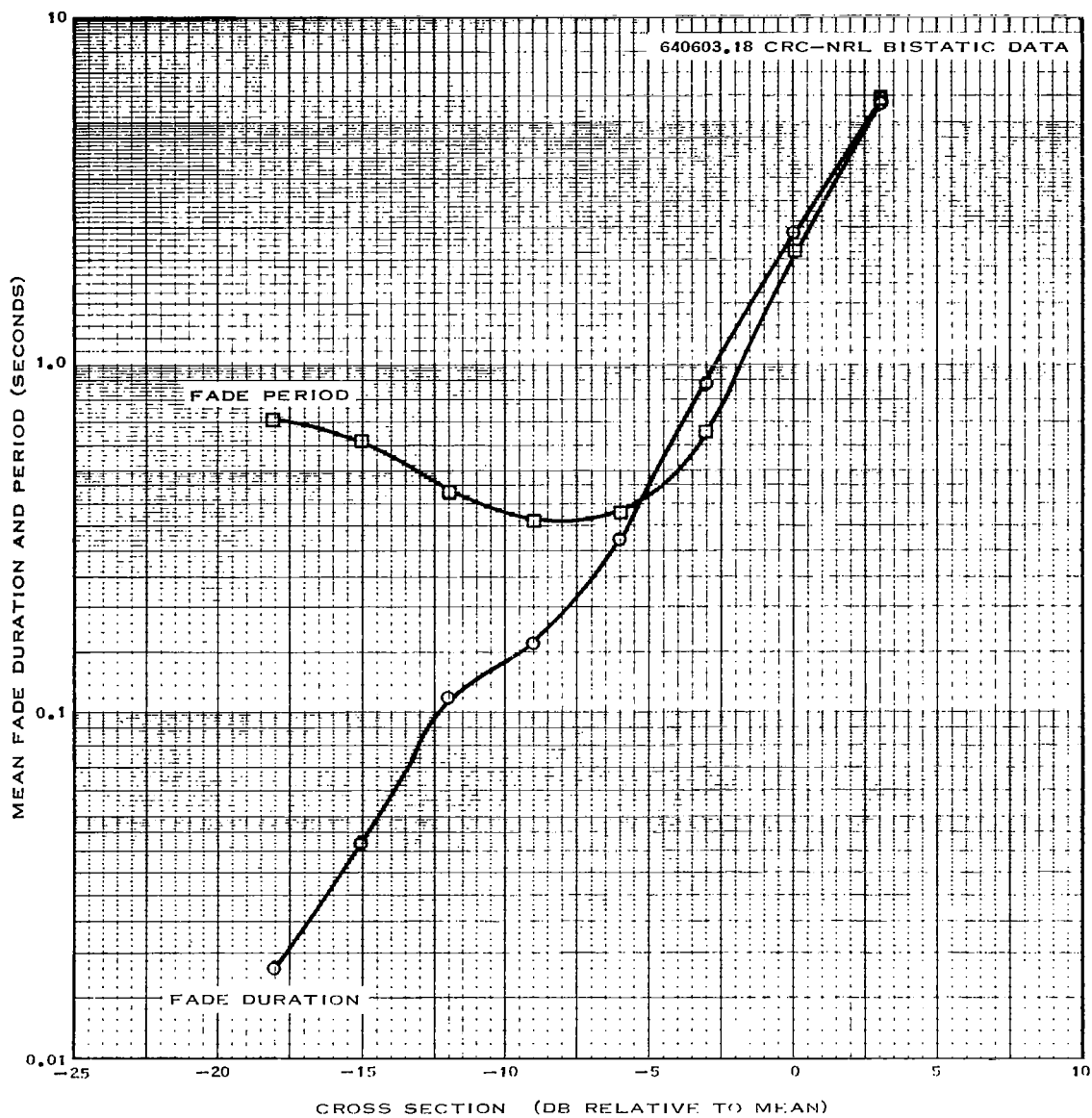


Figure 77. Mean Fade Duration and Fade Period Vs Cross-Section Level, Pass No. 16983

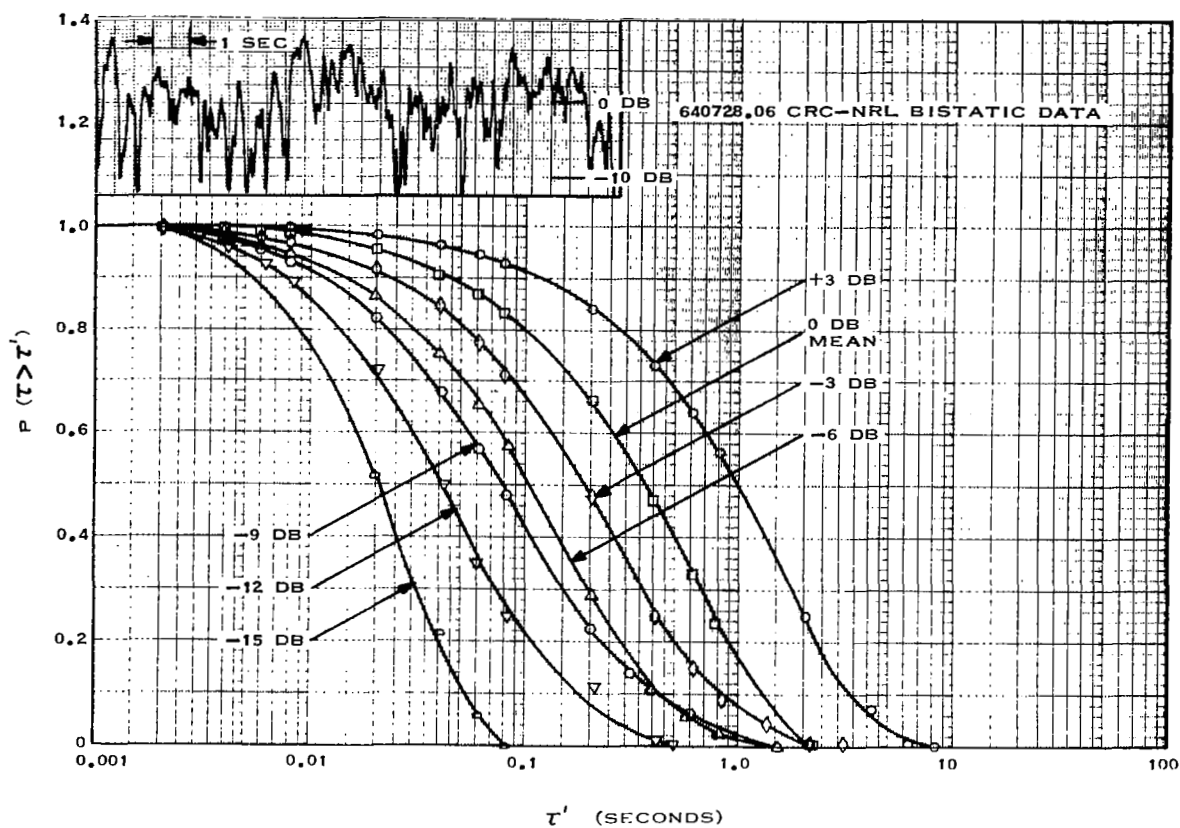


Figure 78. Probability Distribution of Fade Duration, Pass No. 17965,  
 $P(\tau > \tau')$  Vs  $\tau'$ , -9, -12, -15 Db, +3, 0, -3, -6 Db

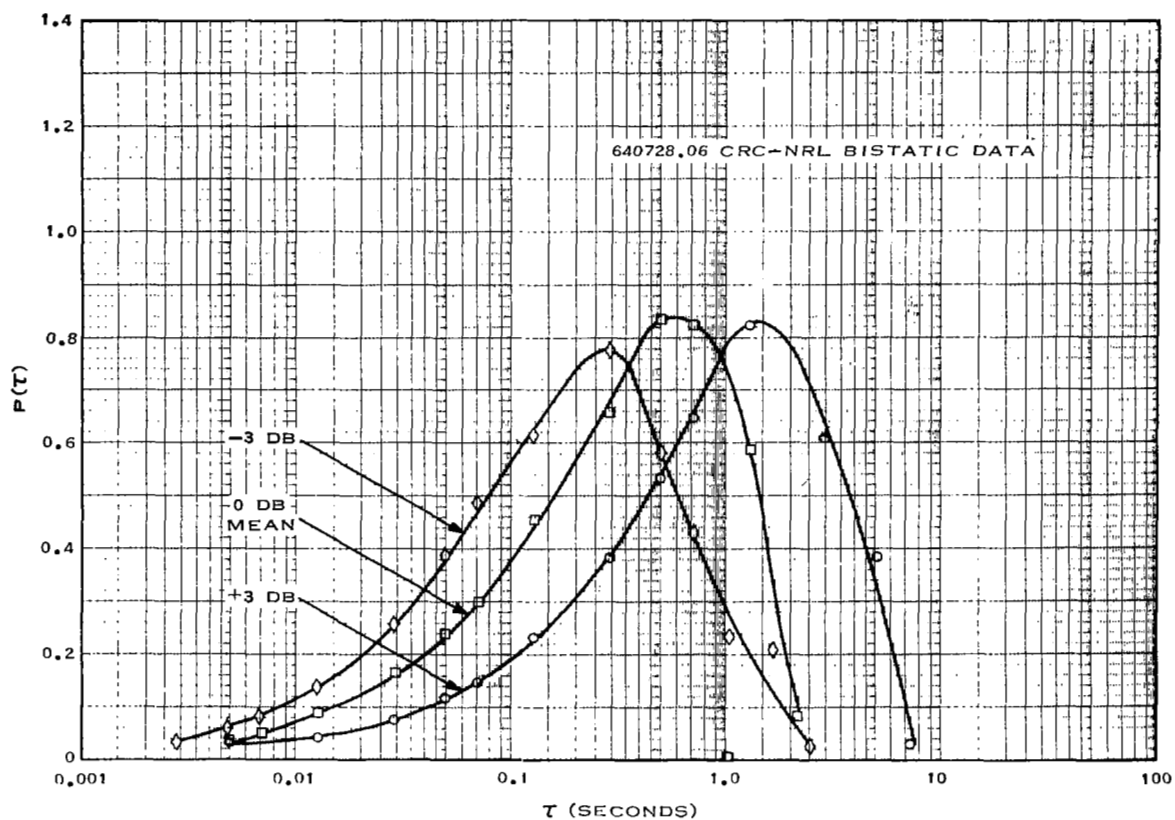


Figure 79. Probability Density of Fade Duration, Pass No. 17965,  
 $P(\tau)$  Vs  $\tau$ , -3, 0, +3 Db

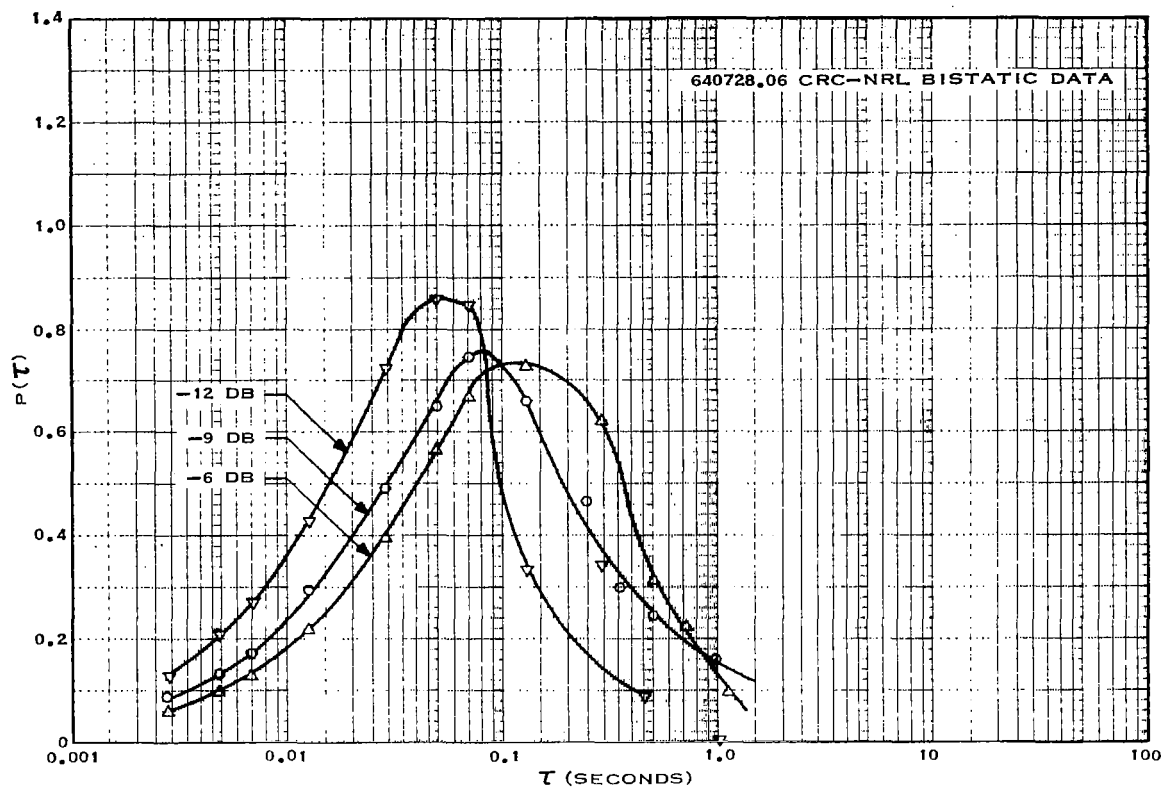


Figure 80. Probability Density of Fade Duration, Pass No. 17965,  
 $P(\tau)$  Vs  $\tau$ , -12, -9, -6 Db

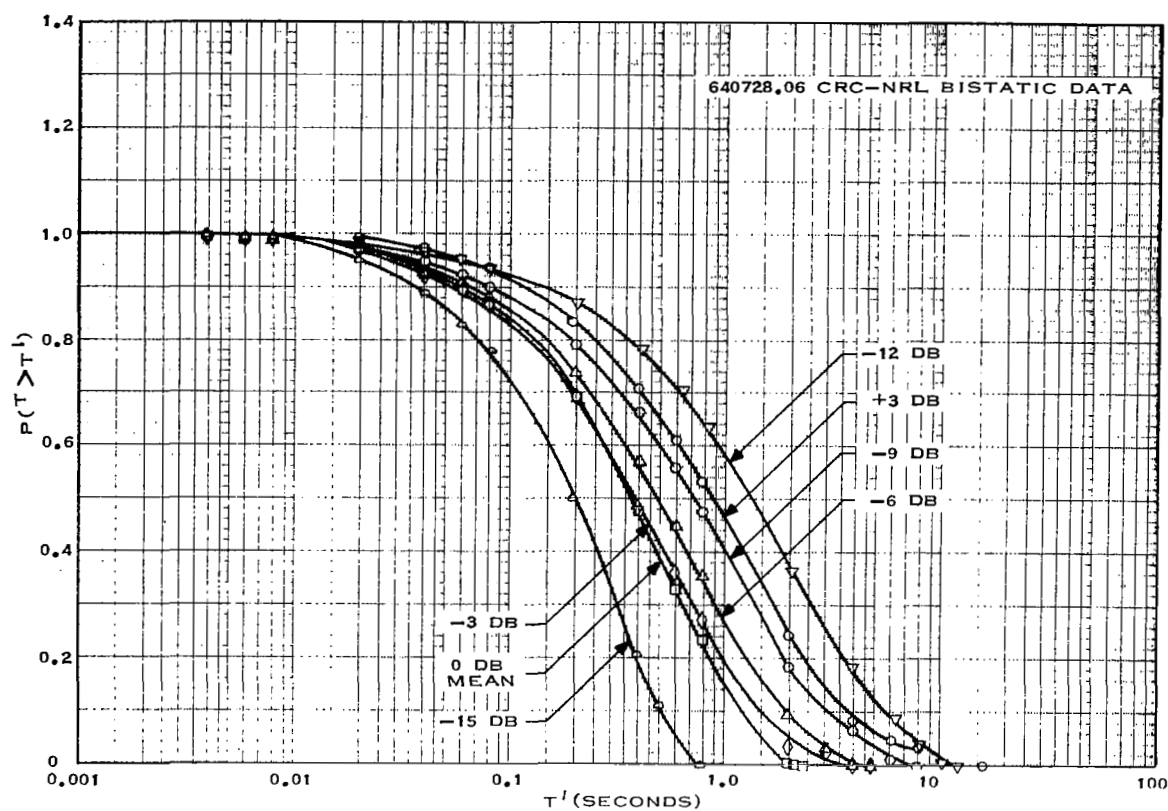


Figure 81. Probability Distribution of Fade Period, Pass No. 17965,  
 $P(T > T')$  Vs  $T'$ , -3, 0, -15 Db, -12, +3, -9, -6 Db

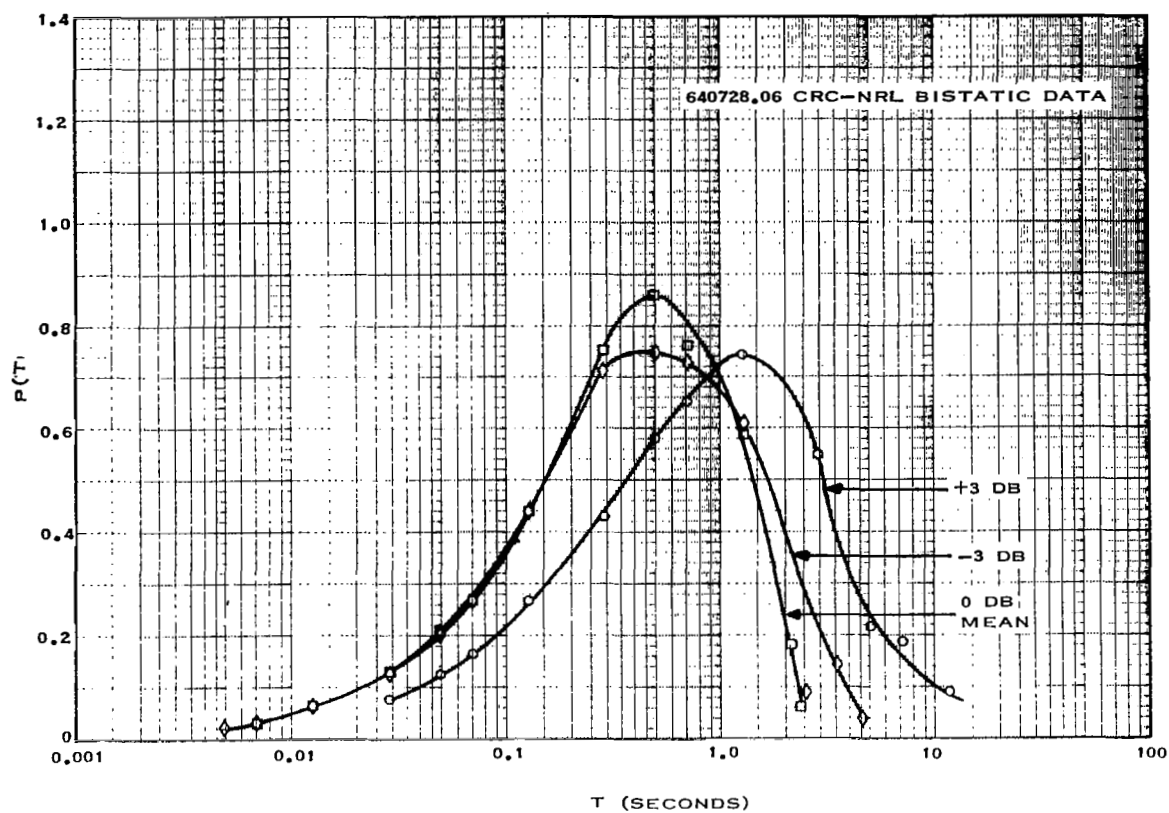


Figure 82. Probability of Density of Fade Period, Pass No. 17965,  
 $P(T)$  Vs  $T$ , +3, -3, 0 Db

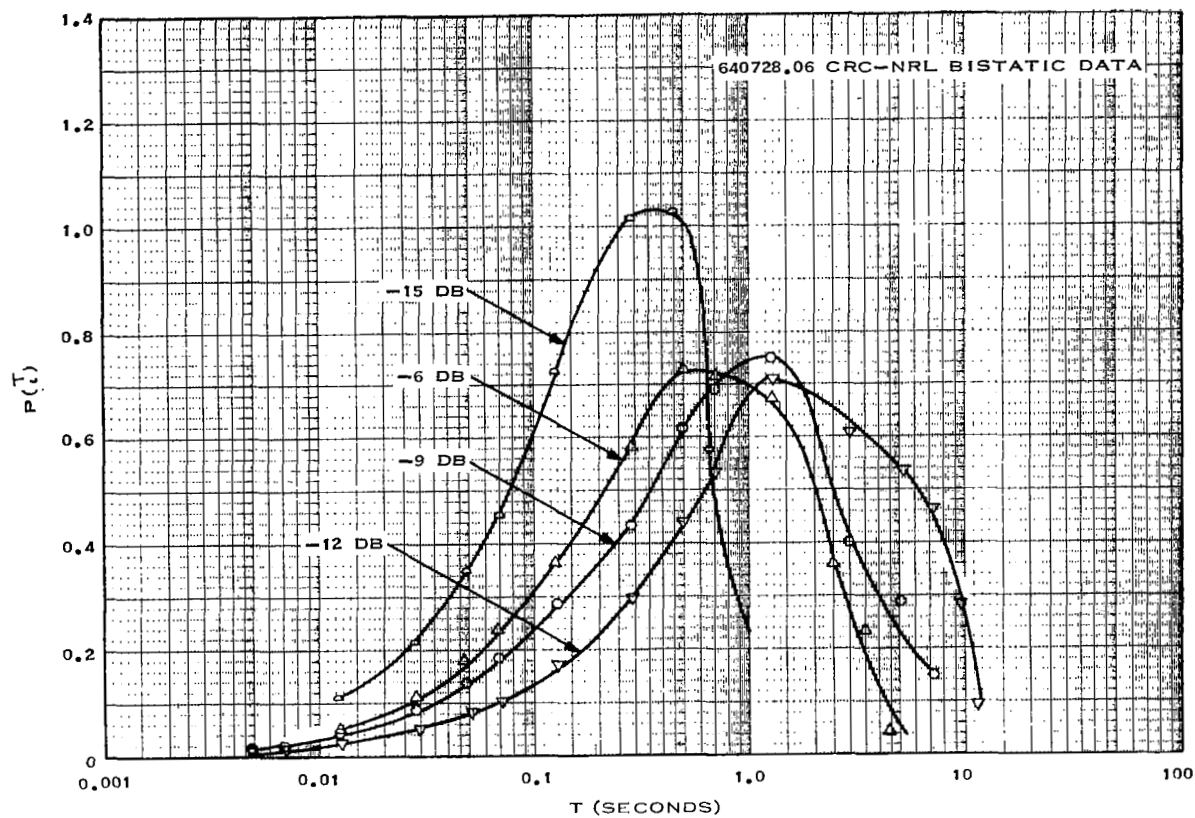


Figure 83. Probability of Density of Fade Period, Pass No. 17965,  
 $P(T)$  Vs  $T$ , -15, -6, -9, -12 Db

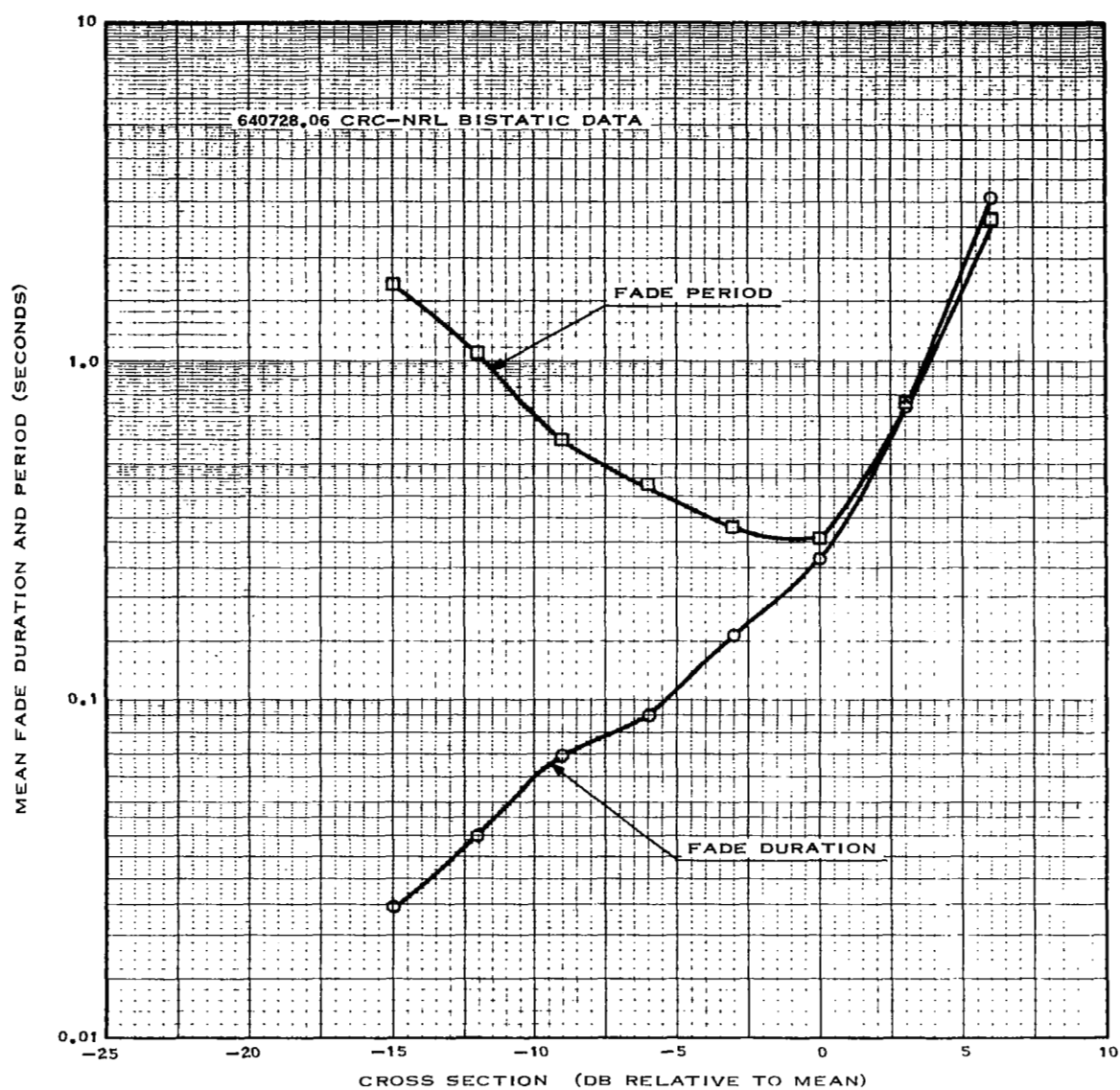


Figure 84. Mean Fade Duration and Fade Period Vs Cross-Section Level, Pass No. 17965

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RESULTS AND CONCLUSIONS

By selecting portions of the reduced data and grouping it appropriately, it is possible to exhibit some information about the Echo II satellite. The effects of the age of Echo II from launch on the fading characteristics of the satellite can be shown, and a comparison between Echo I and Echo II can be made.

An indication of a change in the fading characteristics of Echo II with time after launch can be obtained by comparing the fade duration and period probability distributions. Figure 85 shows the fade duration probability distributions for six Echo II passes taken at their respective mean cross-section values. Figure 86 shows the fade duration probability distributions for the same passes at a level of -15 db relative to the respective mean cross-section values. Figures 87 and 88 illustrate the corresponding results for the fade period probability distributions. It is apparent from these curves that no simple relationship exists between the fading characteristic of Echo II and the time from launch up to one year. There appears to be a slight tendency toward shorter fades occurring more rapidly; however, without data obtained over a much longer period of time, this cannot be confirmed. Invariance with time would be considered a valuable property for the design of a communications system using Echo II.

The following tabulation lists typical ranges of fade duration and fade period and their respective mean values for Echo II cross-section levels +4 db, 0 db, and -20 db relative to the mean cross section.

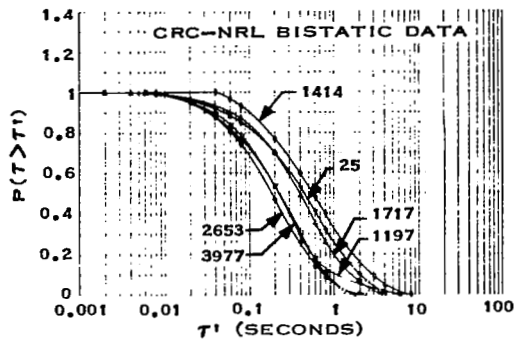


Figure 85. Probability Distribution of Fade Duration at the Mean Cross-Section (0 Db) Level, Pass No. 25, 1197, 1414, 1717, 2653, 3977,  $P(\tau > \tau') \text{ Vs } \tau'$

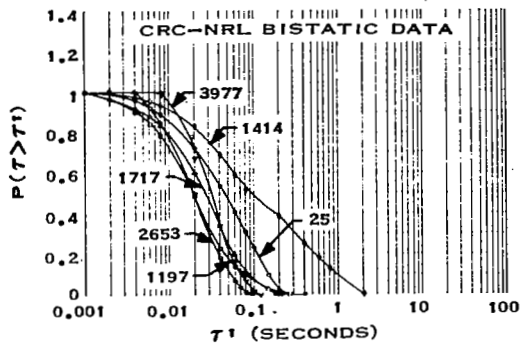


Figure 86. Probability Distribution of Fade Duration at the -15 Db Cross-Section Level, Pass No. 25, 1197, 1414, 1717, 2653, 3977,  $P(\tau > \tau') \text{ Vs } \tau'$

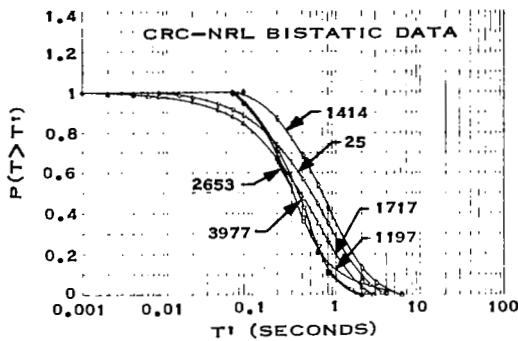


Figure 87. Probability Distribution of Fade Period at the Mean Cross-Section (0 Db) Level, Pass No. 25, 1197, 1414, 1717, 2653, 3977,  $P(T > T') \text{ Vs } T'$

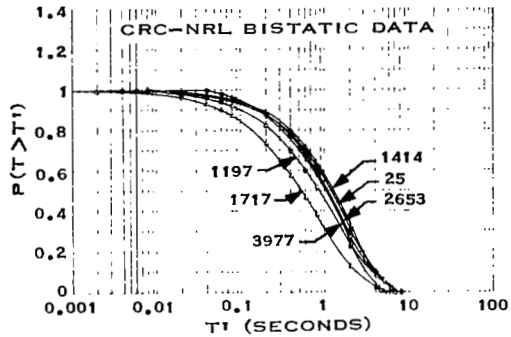


Figure 88. Probability Distribution of Fade Period at the -15 Db Cross-Section Level, Pass No. 25, 1197, 1414, 1717, 2653, 3977,  $P(T > T') \text{ Vs } T'$

| CROSS-SECTION<br>LEVEL | FADE DURATION<br>RANGE<br>(seconds) | MEAN<br>DURATION | FADE PERIOD<br>RANGE<br>(seconds) | MEAN<br>PERIOD |
|------------------------|-------------------------------------|------------------|-----------------------------------|----------------|
| +4 db                  | 0.1 to 10                           | 1.5              | 0.1 to 10                         | 2.0            |
| 0 db                   | 0.01 to 1.0                         | 0.30             | 0.1 to 1.0                        | 0.41           |
| -20 db                 | 0.001 to 0.1                        | 0.014            | 0.1 to 10                         | 1.8            |

The fade durations become shorter with decreasing amplitude levels. The fade periods decrease with decreasing amplitude to a level of approximately -4.0 db relative to the mean cross section. Below this level the fade periods increase with decreasing amplitude. At the minimum fade period level, the average fade period is about 0.32 seconds. Both Echo II and Echo I exhibit this characteristic.

A comparison between the fading of Echo II in bistatic and monostatic operational configurations is provided by figures 89 and 90. Figure 89 shows the probability distributions of fade duration from Echo II pass no. 1717 at the mean cross-section levels for both bistatic and monostatic data. Figure 90 illustrates the same quantities for fade period. The distributions are of nearly the same shape in both cases. There is a shift in the fade duration distribution of about 0.6 second, and a shift in the fade period distribution of about 0.4 second. This difference may be due to slight errors in the original received power calibrations. For Echo II pass 2653, there is a large apparent error in calibration of the monostatic data. Only a rather superficial comparison can be made with the limited amount of monostatic data available.

A comparison between the fading behavior of Echo II and Echo I is provided by figures 91, 92, 93, and 94. For this comparison, Echo II pass numbers 25 and 1717 are taken as representative passes, and are plotted with Echo I pass numbers 16983 and 17965. Figure 91 shows the probability distributions of fade duration at the respective mean cross-section levels for the four passes. Figure 92 shows the corresponding probability distributions for the fade period. A remarkable similarity can be noted between the two Echo II passes and Echo I pass number 17965 for both duration and period. Figures 93 and 94 show the

probability distributions of fade duration and period for the level of -15 db relative to the mean cross-section values for the same passes. At this level, the results for Echo I pass number 16983 appear very similar to those from the two Echo II passes. From this comparison, it appears that the fade characteristics of Echo II during the first year from launch are very similar to those of Echo I about three years from launch.

A comparison between Echo II and Echo I data and typical data from hf and tropospheric scatter links is provided by figure 95. The received signal traces are approximately linear in voltage, and the chart speed was 10 mm per second in all cases. It is apparent that the fading characteristics of Echo II and Echo I are similar in nature to those of hf and tropospheric scatter. Thus, many of the communication system design techniques used in the design of hf and tropospheric systems will be applicable in the design of systems using Echo II.

The results of this investigation can be applied to the design of communication systems employing the Echo II type of passive satellites. The Echo II data reduced by Collins has been referenced to the satellite cross section. Therefore, if the communication system performance requirements and the orbit of the satellite are known, the necessary code format, modulation form, and threshold level of the system can be determined. The probability distributions of satellite cross section determined during the 1964 Echo II Program provide information as to the fraction of time the radio cross section of the satellite spends below any level. The fade analysis presented here gives information as to the durations of cross-section fades below any level and their frequency of occurrence. It is felt that this information is sufficient to be used to design the proper form of information redundancy (error correcting codes, diversity, etc.) necessary for satisfactory system performance.

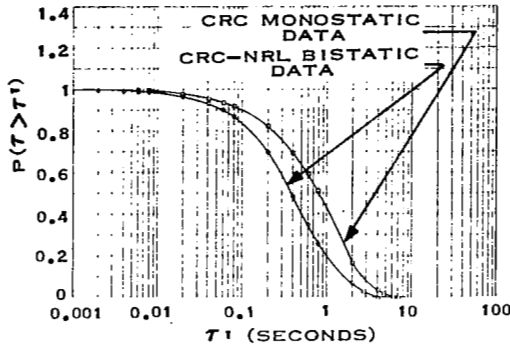


Figure 89. Probability Distribution of Fade Duration at the Mean (0 Db) Cross-Section Level, Pass No. 1717,  $P(T > T')$  Vs  $T'$

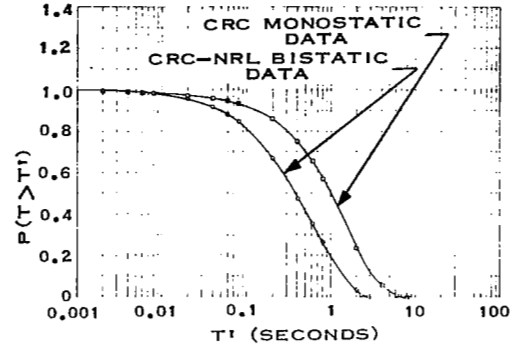


Figure 90. Probability Distribution of Fade Period at the Mean (0 Db) Cross-Section Level, Pass No. 1717,  $P(T > T')$  Vs  $T'$

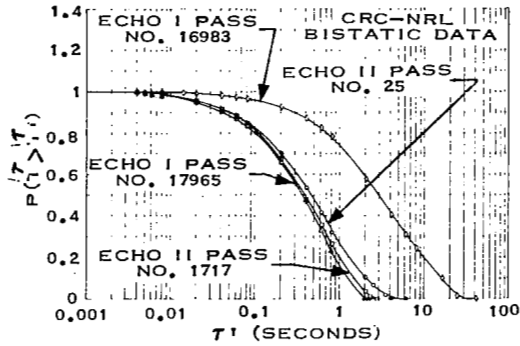


Figure 91. Probability Distribution of Fade Duration at the Mean (0 Db) Cross-Section Level, Pass No. 25, 1717 and Echo I Pass No. 16983, 17965,  $P(T > T')$  Vs  $T'$

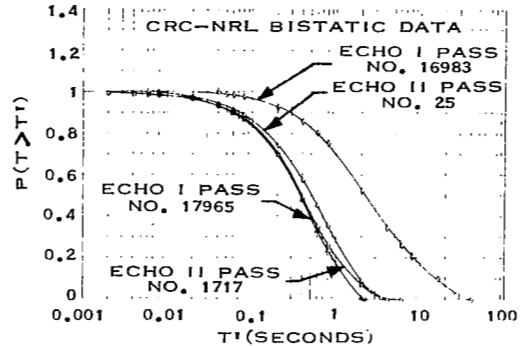


Figure 92. Probability Distribution of Fade Period at the Mean (0 Db) Cross-Section Level, Pass No. 16983, 17965,  $P(T > T')$  Vs  $T'$

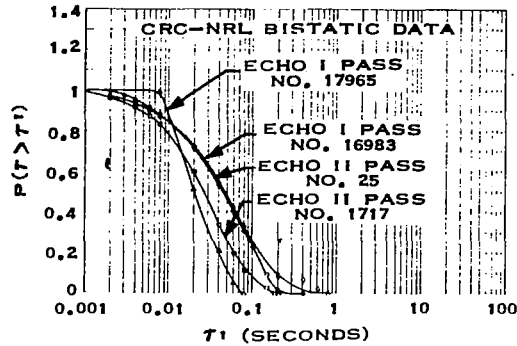


Figure 93. Probability Distribution  
of Fade Duration at the -15 Db  
Cross-Section Level, Pass  
No. 25, 1717, and Echo I  
Pass No. 16983, 17965,  
 $P(T > T') \text{ Vs } T'$

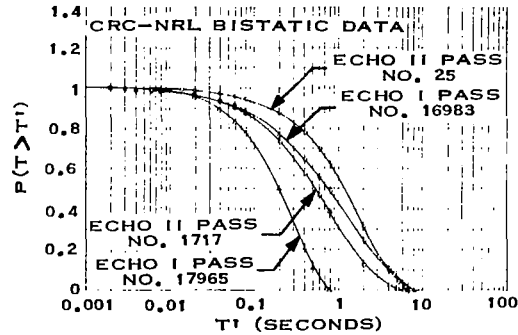


Figure 94. Probability Distribution  
of Fade Period at the -15 Db  
Cross-Section Level, Pass  
No. 25, 1717, and Echo I  
Pass No. 16983, 17965,  
 $P(T > T') \text{ Vs } T'$

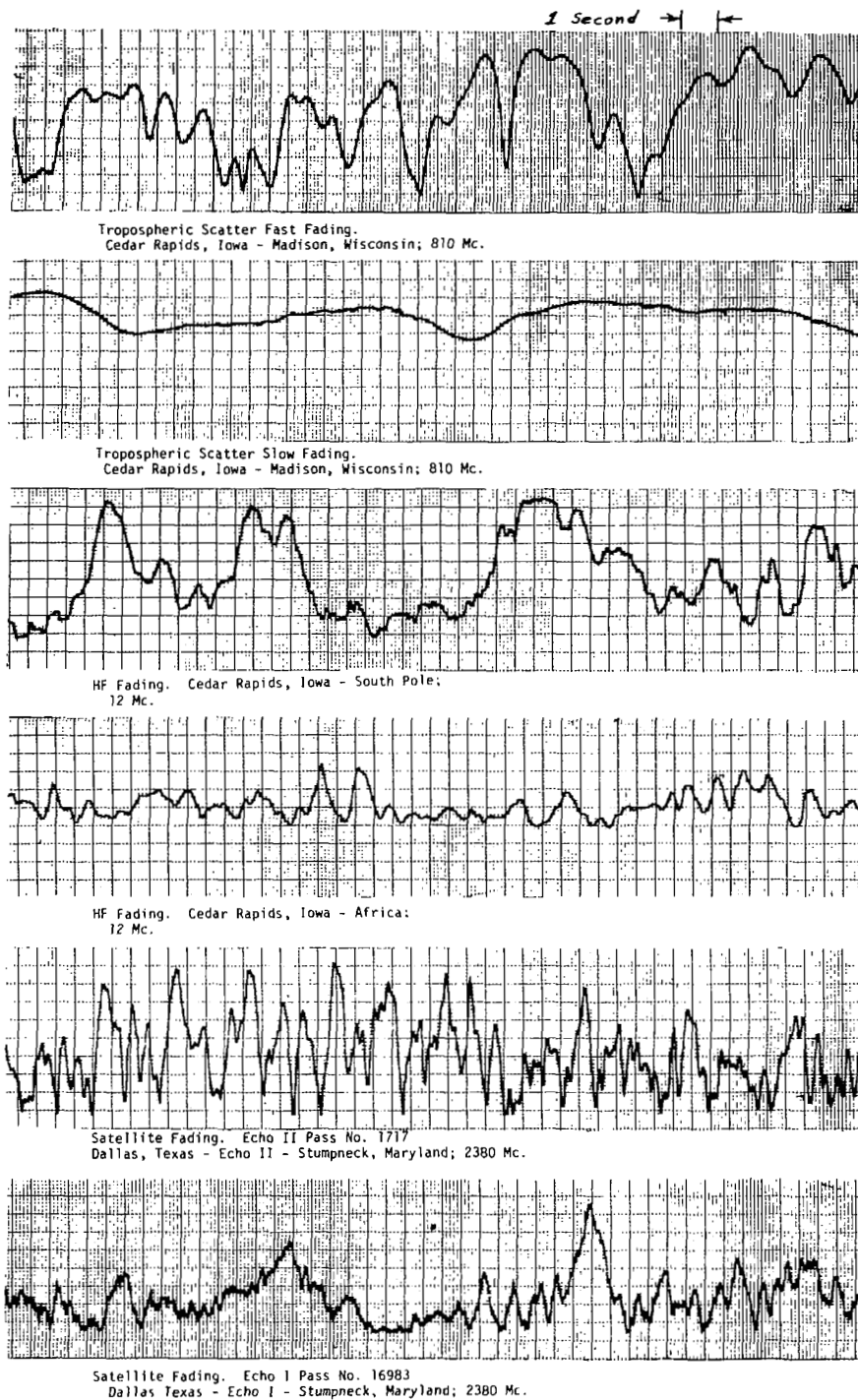


Figure 95. Examples of Typical Fading on Tropospheric Scatter, HF, and Passive Satellite Links

CONCLUSIONS

The following conclusions can be drawn about the Echo II satellite from data taken during the first year from launch.

1. There were no apparent changes in the behavior of the radio cross section of the satellite during the first year from launch.
2. The fading characteristics of Echo II and Echo I appear very similar when Echo II during the first year from launch is compared with Echo I approximately three years from launch.
3. The fading behavior of Echo II appears very similar to that observed on other types of communications links. Standard communications system design techniques should be applicable to the design of systems using the Echo II satellite.