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Overwater Line-Of-Sight Fade Measurements at 37 GHZ

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ABSTRACT

The short-term fading on an overwater line-of-sight path at 37 GHz has been characterized. Fade depths of 8 db were typical, although fade depths from 3 db to 14 db were observed (measured between the median and the 98% value of the distribution). The fading generally displayed a fast and a slow component with typical average values of about 0.5 fade per second and 1.5 fades per minute. The corresponding average fade durations were 1 sec and 20 sec, respectively.

The importance of the specular reflection from the water surface was clearly evident in the results. The typical value of the specular reflection coefficient was about 0.7, but the extreme values varied from almost 0 to 1. The reflection coefficient of the diffusely scattered component showed less variation and was typically about 0.25.

The use of a 15-db fade margin would be sufficient to maintain the received signal above a desired threshold for at least 98% of the time for every sample of data examined. For effective time diversity operation, a time delay of about 10 sec would likewise be sufficient for every sample examined.

PROBLEM STATUS

This is an interim report; work continues on other phases of the problem.

AUTHORIZATION

NRL Problem R01-42
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OVERWATER LINE-OF-SIGHT FADE MEASUREMENTS AT 37 GHZ

INTRODUCTION

An accurate knowledge of the transmission properties of a radio path is an essential prerequisite to reliable systems planning. Since these properties, which are time varying and random in nature, can only be described statistically, a complete description requires detailed measurements over an extended period of time. However, by concentrating on a particular facet of the problem, a meaningful description can be obtained, for practical purposes, even from a relatively modest undertaking. The experiments described in this report were performed to determine the statistical nature of short-term fading on an overwater line-of-sight path at 37 GHz.

TEST SITE

The experiments were performed on the 8.76-naut mi overwater path between the Chesapeake Bay Division of NRL and Tilghman Island, Maryland. Using a transmitter height of 88 ft* and a receiver height of 135 ft* the calculated path clearance at the point of reflection, under standard propagation conditions, is 95 ft (about 27 Fresnel zones), which allows ample clearance even during severe deviations from standard conditions.

INSTRUMENTATION

With a transmitter output of 1 w, a combined transmitter and receiver antenna gain of 75 db, and a receiver noise figure of 14 db, the system is capable of detecting maximum fade depths of approximately 45 db. The overall frequency response is limited to a maximum of 2500 Hz by the (magnetic tape) instrumentation recorder used. A block diagram of the equipment is shown in Fig. 1.

GROSS STATISTICS

Sample strip chart recordings of the detected signal are shown in Fig. 2. A visual examination of approximately 300 hr of data shows that (a) deep fades of 40 db or more, which last for much less than a second, occur during very active fading periods, (b) slow fades (a few minutes or more) are frequently accompanied by fast fades (a few seconds or less), and (c) fade depths exceeding 5 db, 10 db, and 20 db were observed for approximately 54%, 24%, and 7% of the time, respectively. These percentages represent the total time that bursts of fading occurred (i.e., individual fades were not resolved) and are subject to considerable personal (reading) interpretation. Nevertheless, these figures are indicative of the gross fade characteristics observed.

*Above mean low water level.

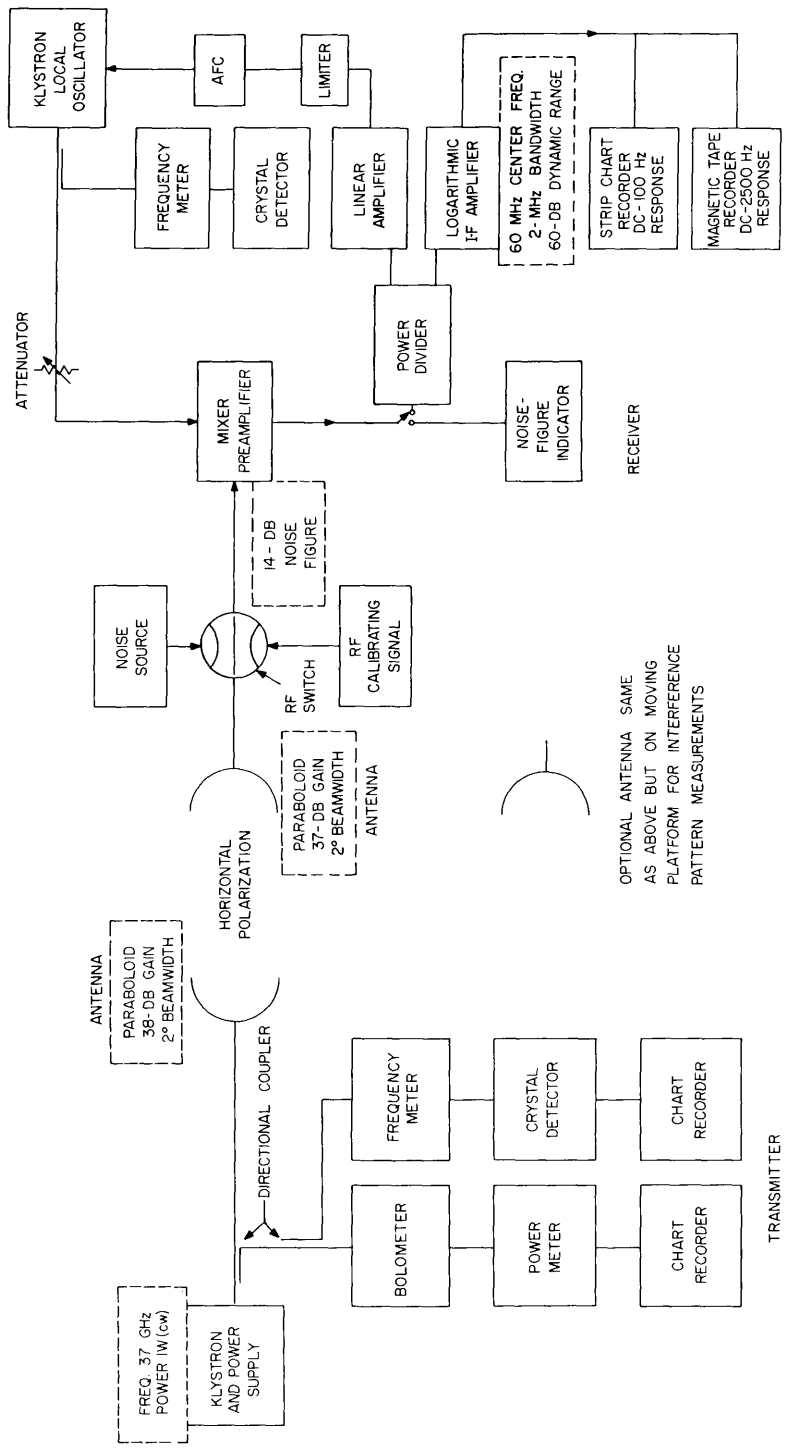


Fig. 1 - Instrumentation

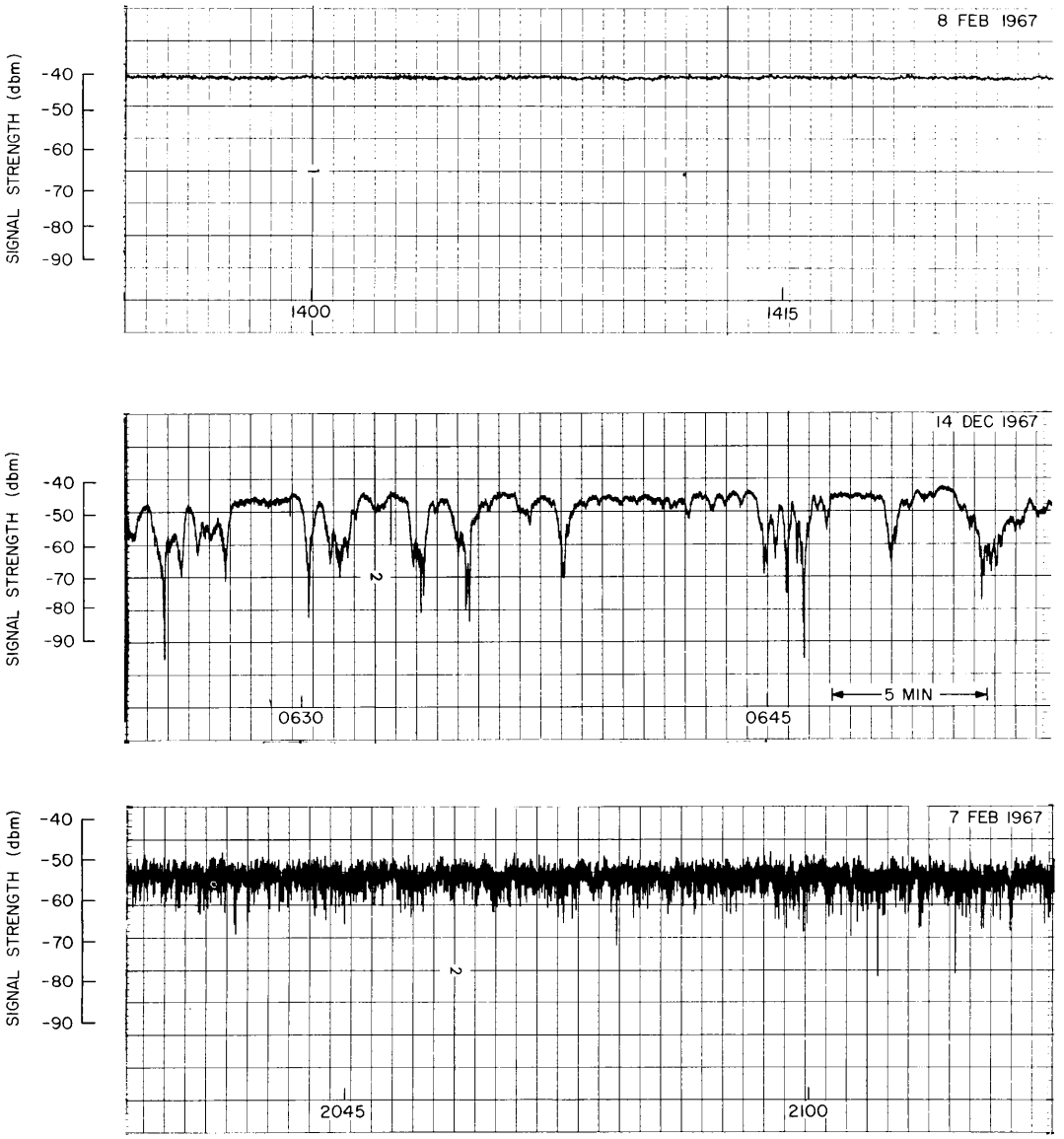


Fig. 2 - Sample strip chart recordings

SHORT-TERM STATISTICS

A more detailed knowledge of the fade structure was obtained by resolving the individual fades and measuring the total time that the signal remained below various specified levels and by observing the number of times specific fade durations occurred at each level. For practical reasons, short aperiodic data samples, varying in length from about 3 sec to 5 min were used for this purpose. These samples were converted to digital form, using sampling rates from 50 per second to 5000 per second, and then processed by computer. A low pass filter, with appropriate cutoff, was used before the digitizer to minimize the eliasing error*.

*Error that would be introduced by sampling below the Nyquist limit.

Sample Length

The effect of sample length on the measured fade amplitude distribution is shown in Fig. 3. The distribution and median level for the typical fading case remain substantially unchanged for sample lengths between 2 and 5 min, indicating that a good sampling of the short-term statistics is obtained with these values. For the worst fading case the results are not as consistent but are sufficiently good to be included for practical purposes. Most of the data were reduced using sample lengths of about 4 to 5 min.

Sampling Rate

For reasons of economy, most of the data were sampled at the relatively slow rate of approximately 50 samples per second, thereby limiting the minimum resolvable fade duration to about 20 ms. However, the data were examined for shorter fades by processing short samples at higher rates. The shortest fade duration examined, using various sampling rates, is shown in Fig. 4. As is evident from this figure, a definite loss of resolution is introduced by lowering the sampling rate from 5000 to 50 per second. This eliminates the very deep narrow fades from the analysis and tends to raise the extreme left-hand portion of the amplitude distribution curves.

Fade Distributions

Shallow, typical, and worst case amplitude distributions are shown in Fig. 5. The corresponding fade duration distributions for the typical and worst cases are shown in Fig. 6. The curves labeled typical and worst cases are to be interpreted as being representative of these cases rather than literally indicating typical and worst case characteristics in every detail. All similarly labeled curves represent the analysis of one specific data sample, selected as being representative, rather than an average of many samples. This approach was selected as providing a more realistic view of the fading characteristics, since all of the average characteristics (of each class of fade) could not be found simultaneously in any actual sample. *

Fade Depth vs Specular Interference Pattern

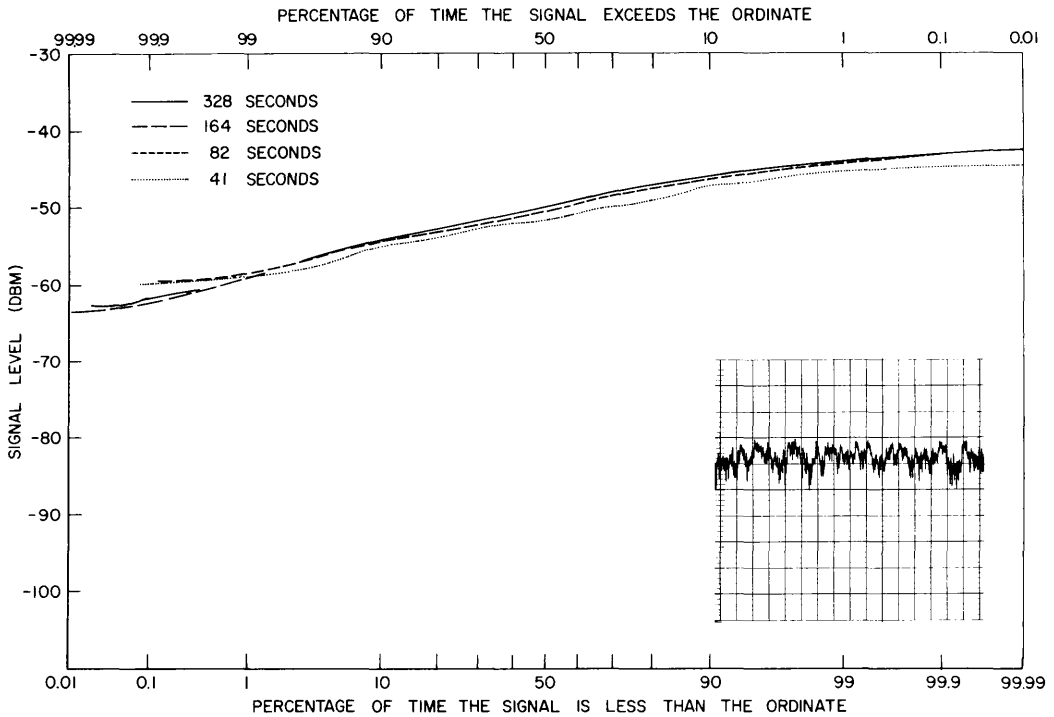
The relationship between the fade depth, as measured by the standard deviation, and the antenna position relative to the (vertical) specular interference pattern is shown in Fig. 7 for different null depths. As may be seen from the figure, the standard deviation increases as the antenna approaches the null, but its variation with position decreases as the null decreases. The reference channel (fixed antenna) indicates the "normal" spread of values during the course of these experiments. †

Autocorrelation

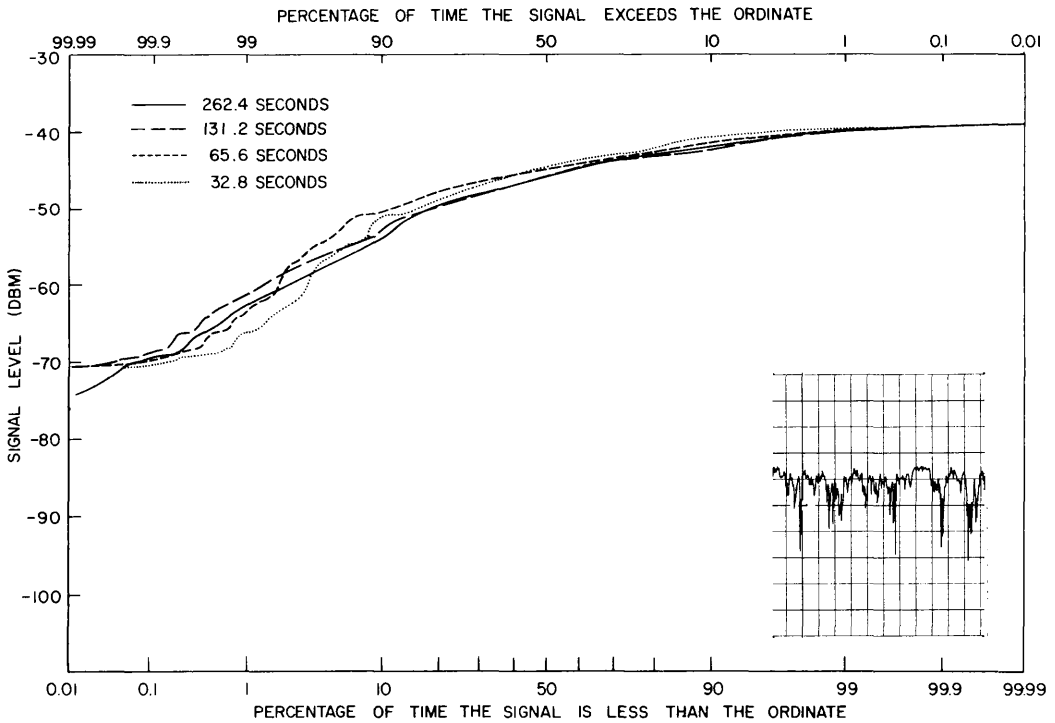
Considerable information about the fade structure can be obtained from the autocorrelation function. A short correlation time (i.e., a fast decay) indicates the existence of fast fades; conversely, a long correlation time indicates slow fades, and periodicity in the function reflects periodicity in the fading. The correlation time is also a measure of the interdependence of the fading at different instants of time and therefore indicates

*In making these selections about 300 data samples were examined.

†The reference channel receiver is a duplicate of the receiver shown in Fig. 1.



(a) Typical fading case



(b) Worst fading case

Fig. 3 - Effect of sample length on measured fade amplitude distribution

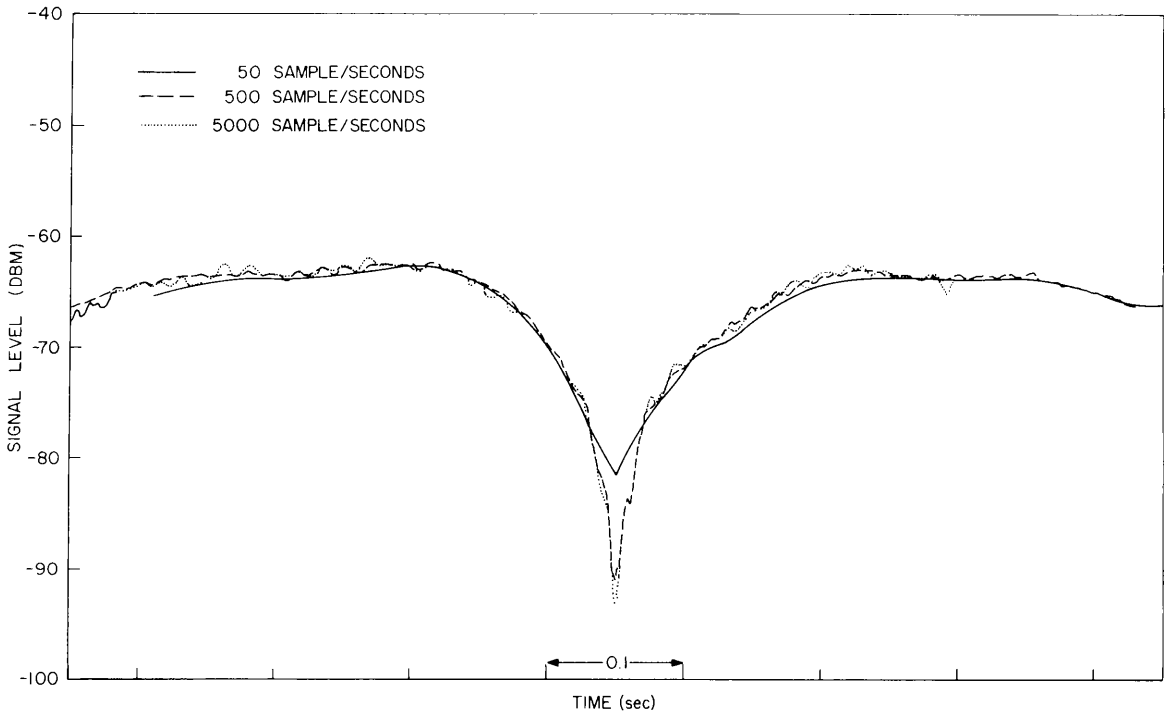
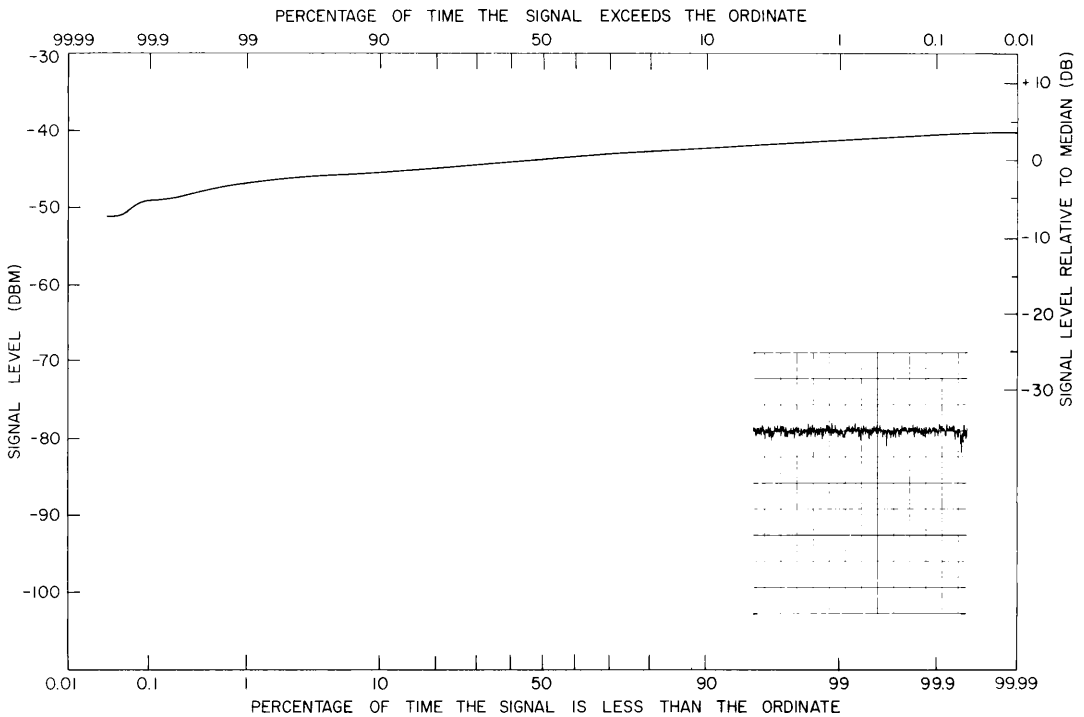
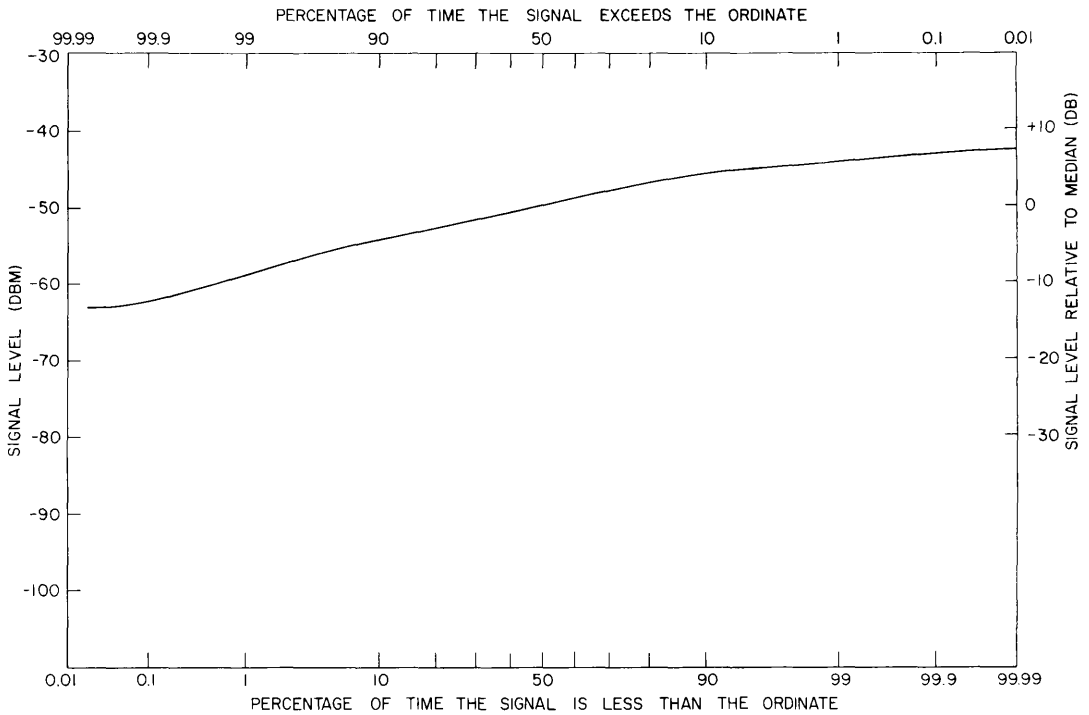


Fig. 4 - Effect of sampling rate

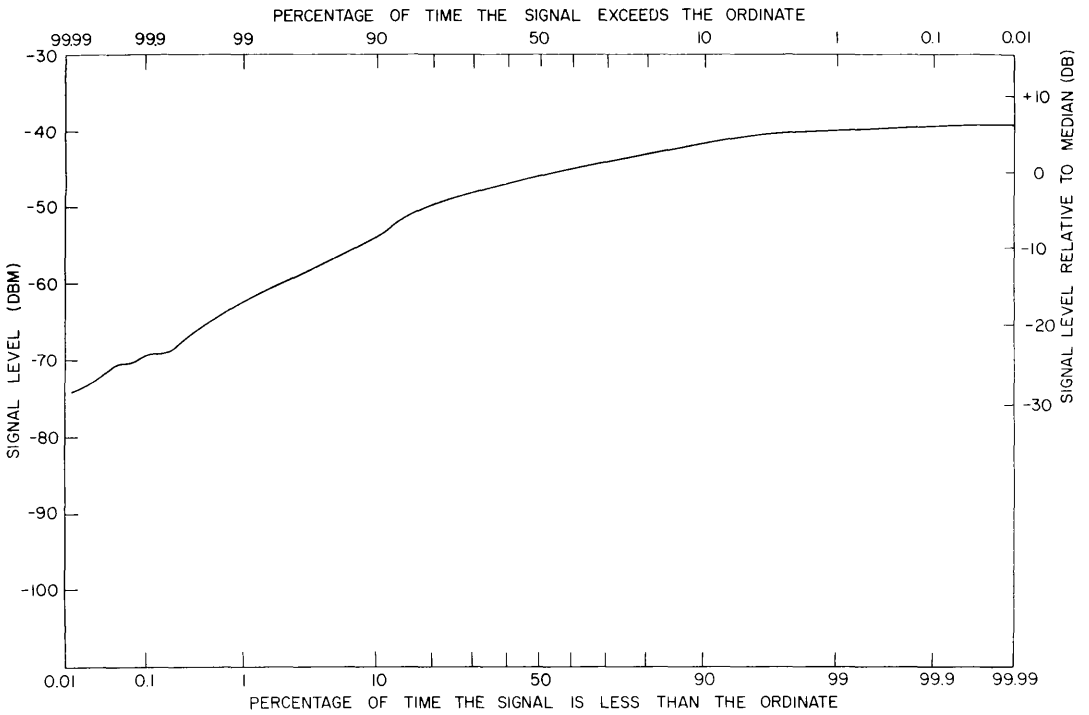


(a) Shallow fading case

Fig. 5 - Fade amplitude distribution



(b) Typical fading case



(c) Worst Fading case

Fig. 5(Continued) - Fade amplitude distribution

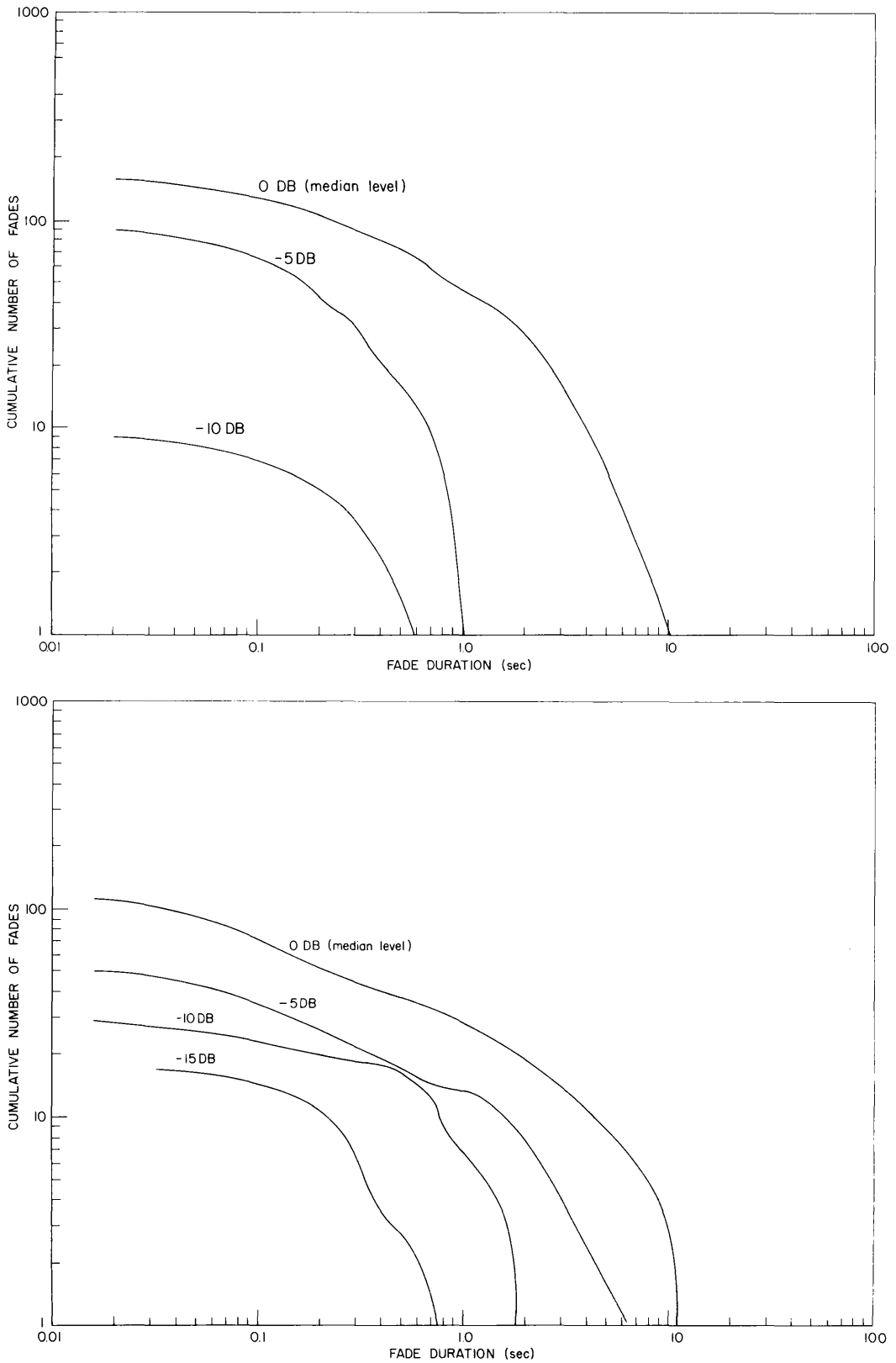
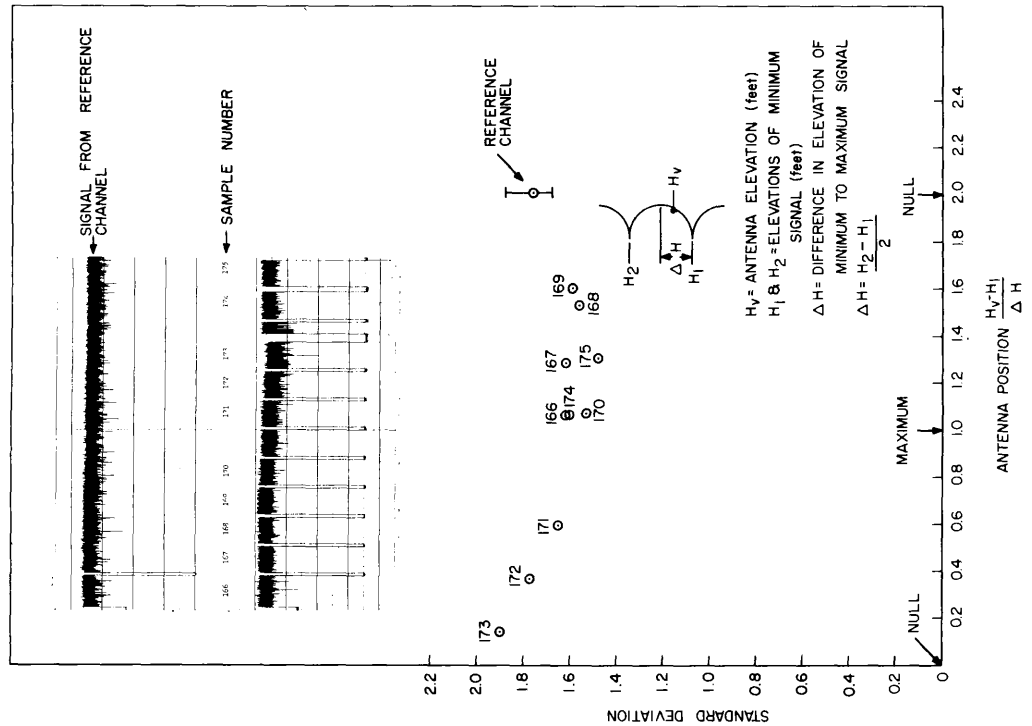
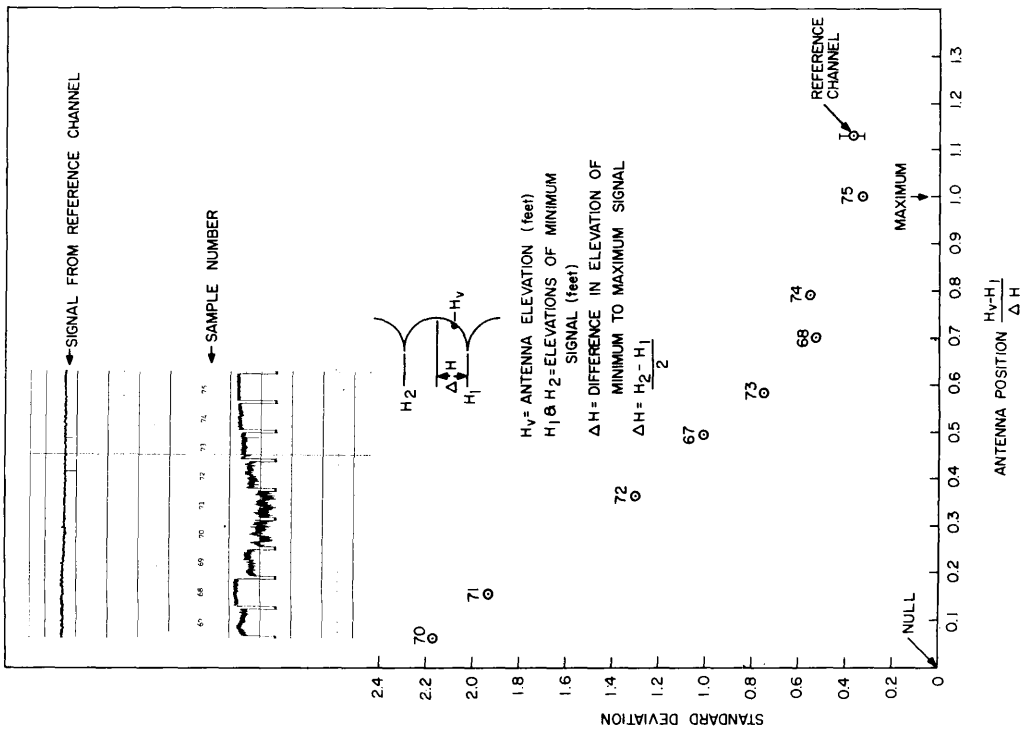


Fig. 6 - Fade duration distribution, (a) typical fading case for sample length of 328 sec, (b) worst fading case for sample length of 262 sec



(b) Depth of null is approximately 5 db



(a) Depth of null is 15 to 20 db

Fig. 7 - Fade depth vs specular interference pattern

the time delay that is needed for effective time diversity operation. Correlation curves corresponding to the typical and worst case distributions of Figs. 5 and 6 are shown in Fig. 8. The shortest and longest correlation times observed are shown in the curves of Fig. 9. These curves were calculated by a computer from the experimental data using the expression

$$\rho_\tau = \frac{\overline{(x - \bar{x})\,[x(\tau) - \bar{x}]}}{\sigma^2},$$

where ρ_τ is the autocorrelation coefficient, $x(\tau)$ is the time-delayed version of the signal x, the term $\overline{(x - \bar{x})\,[x(\tau) - \bar{x}]}$ is

$$\frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})\,(x_i(\tau) - \bar{x}),$$

and the variance σ^2 is

$$\frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})^2.$$

Time Diversity

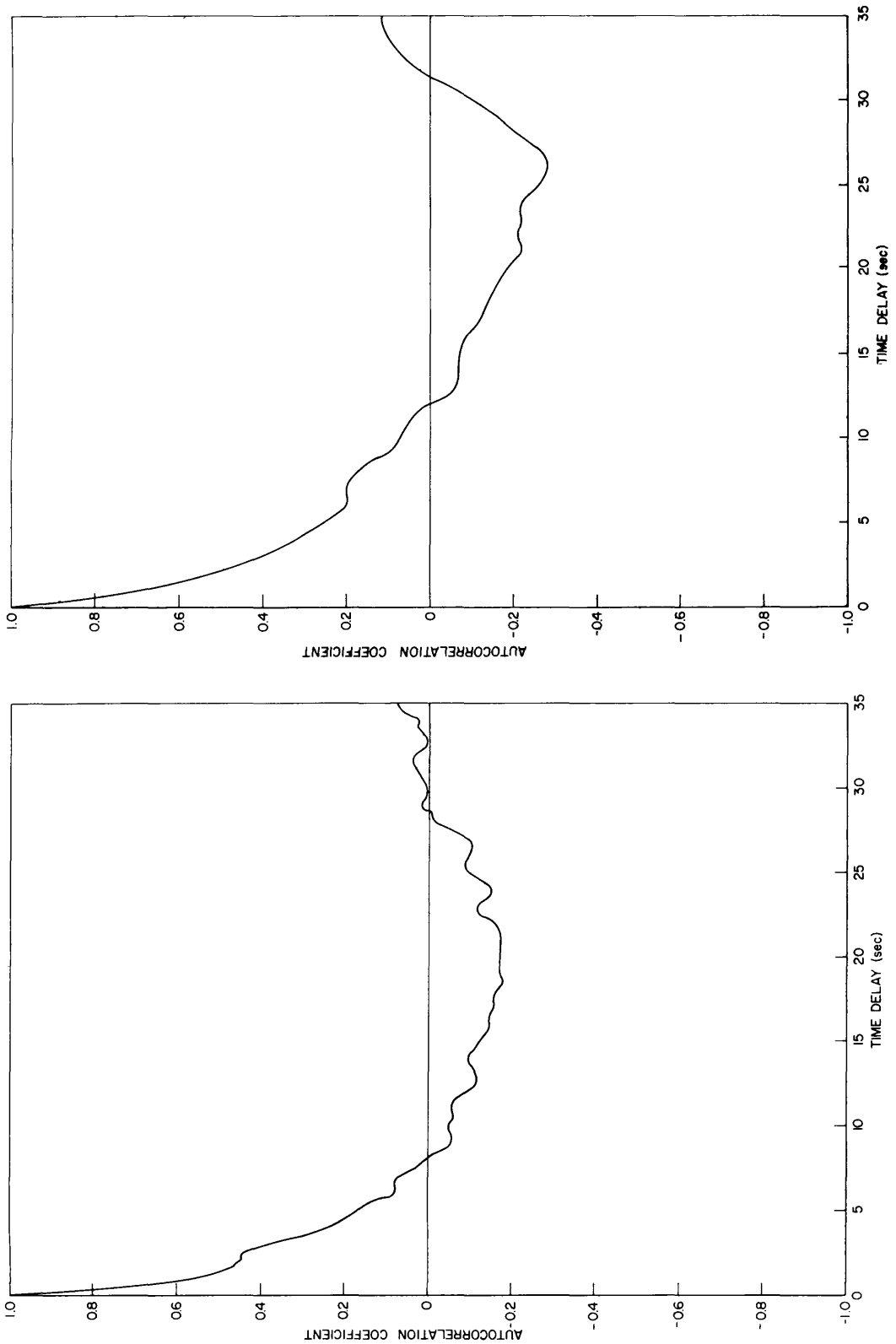
To demonstrate the advantage of time-diversity operation the joint distribution of the signal and a time-delayed replica of itself was generated by a computer.* Since this is the mathematical equivalent of optimal switch selection, the improvement obtained in this manner could be obtained in practice using this technique under ideal conditions. Joint distribution curves for various conditions are shown in Fig. 10; the improvement is indicated by the difference between the joint and single channel curves.

DISCUSSION

There is general agreement that short-term fading may be explained by multipath interference effects. In the simplest model the phenomenon is represented by a direct wave and an indirect wave, arriving at the receiver over an alternate path, which combine to produce the total received signal. Since the properties of the transmission medium vary with time, the relationship between the direct and indirect waves also varies, resulting in a fluctuating signal. The primary sources of alternate paths are ground reflections—both specular and diffuse—and atmospheric reflection, refraction, and scattering. Although several sources of alternate paths may exist simultaneously, for overwater paths with ample clearance, the primary alternate path is, in general, due to the water surface (1).

The indirect wave that is reflected by the water surface can be resolved into a specular component and a diffusely scattered component. The specular component consists of a "constant" or slowly varying part and a variable or rapidly fluctuating part.

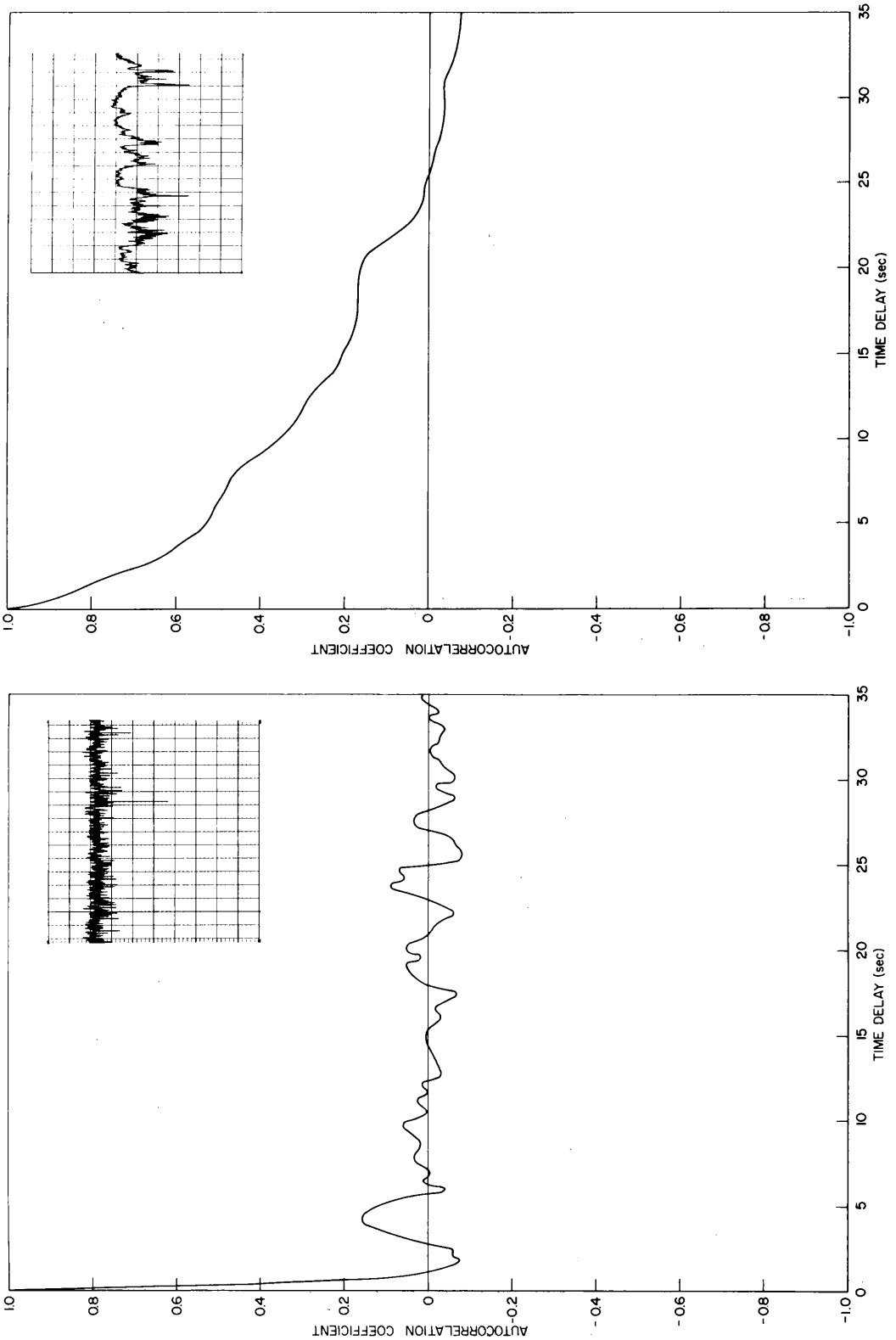
*The joint distribution indicates the percentage of time that both signals fade simultaneously below a specified level.



(a) Typical case

(b) Worst case

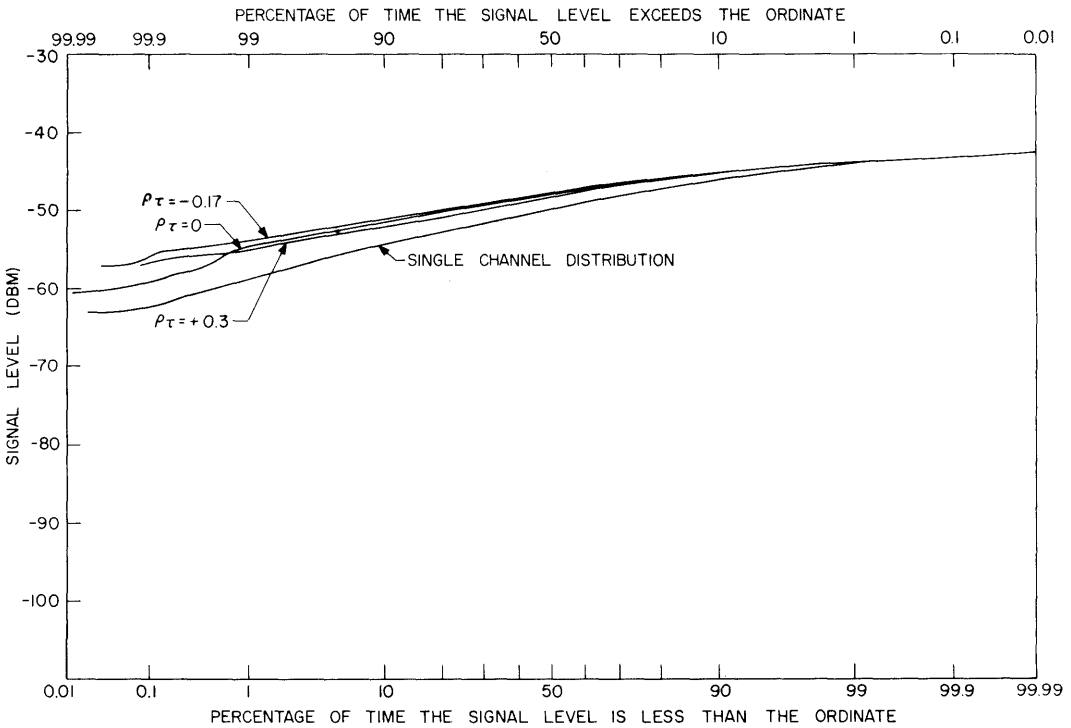
Fig. 8 - Autocorrelation curves



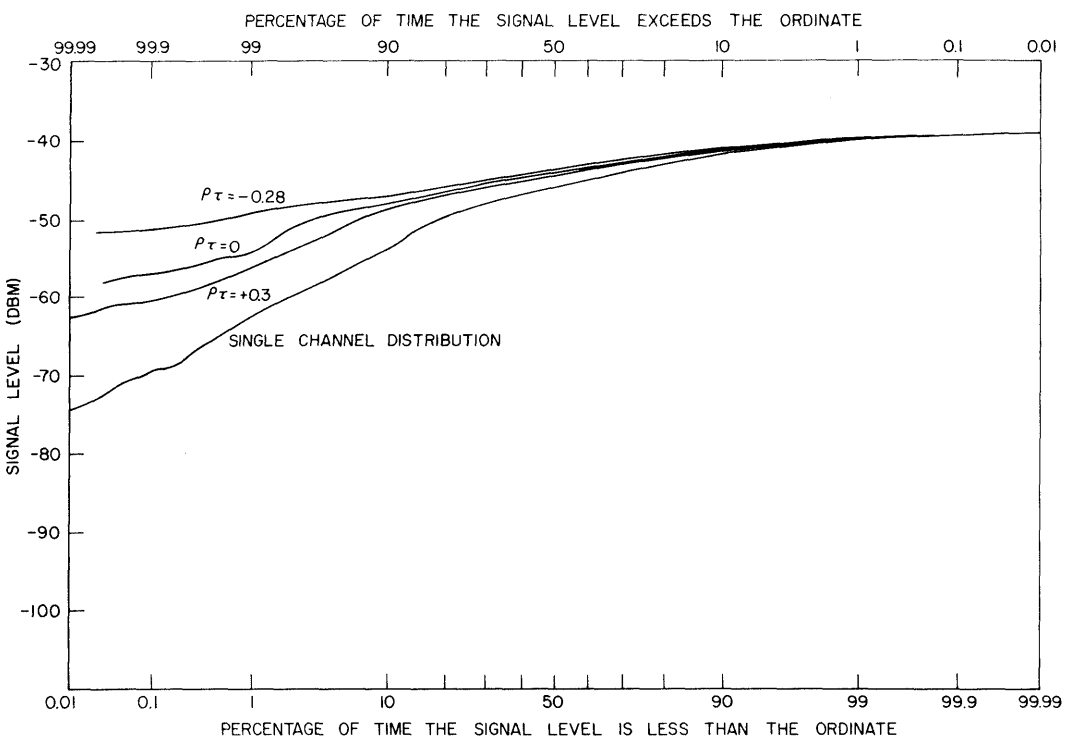
(a) Shortest correlation time observed

(b) Longest correlation time observed

Fig. 9 – Autocorrelation curves



(a) Typical case



(b) Worst case

Fig. 10 - Joint distribution curves demonstrating the advantage of the time-diversity operation

Both parts are coherent and obey the laws of geometrical optics. The diffusely scattered component is incoherent and scatters in all directions, depending on the scattering surface. In practice, the distinction between the variable specular and the diffusely scattered components is frequently ignored, and the combination is called the variable component or more loosely the diffusely scattered component.

When only the variable component of the indirect wave interferes with the direct wave, it produces rapid shallow fades. However, when in addition the slowly varying specular component of the indirect wave also interferes with the direct wave, then the fades can be very deep. The magnitude of the fades in an actual situation depends on the prevailing conditions and especially on the magnitude of the specular reflection coefficient. Although no attempt was made during the course of these experiments to resolve these components, their effect is apparent in the data.

An examination of the strip charts shows that the fading varied over a wide range from substantially no fading, to fast and shallow fading, to deep fading with fast and slow components. The short-term computer analysis revealed that fade depths of about 3 db (median to 98% value) are typical of the shallow fades (variable component only), and fade depths of 14 db (median to 98% value) are typical of the deeper fades (variable plus specular components). The average fade rates observed varied from extremes of about 2.5 fades per second to 0.5 fade per minute. The corresponding extremes of the average fade durations were about 0.2 sec to 1.0 min. The more common values are given in Table 1.

Table 1
Short-Term Fade Summary

Fade Type	Fade Depth, 50%-98% Value (db)	Average Fade Rate		Average Fade Duration	
		All Components (Fades per Second)	Slow Components Only (Fades per Minute)	All Components (sec)	Slow Components Only (sec)
Shallow	3	1.3	-	0.4	-
Typical	8	0.48	1.5-2.0	1.0	15-20
Worst	14	0.43	1.2-1.5	1.2	20-25

In addition to the short-term fading, an intermediate-term component was also observed (Fig. 11). It was not uncommon for these fades to last for several minutes, and occasionally for as long as 1 hr, and to have short-term components superimposed on them. Since these fades were too long for the 5-minute sample length used in the data reduction, no statistical measurements, other than the gross visual estimates, were obtained. However, some general conclusions concerning these fades can be made. The depth of the slow component was comparable to the depth of the null in the specular interference pattern, but the fast component greatly increased the overall fade depth. Because of their duration, these fades could not have been produced by a change in the tide level, since this occurs much more slowly, and, judging from visual observations, they could not be attributed to surface conditions. Unfortunately, the meteorological data taken during these periods were inadequate, and no firm cause and effect relationship could be discovered. However, it is quite likely that these fades were produced by changes in the vertical gradient of the index of refraction which in turn changed the path clearance,

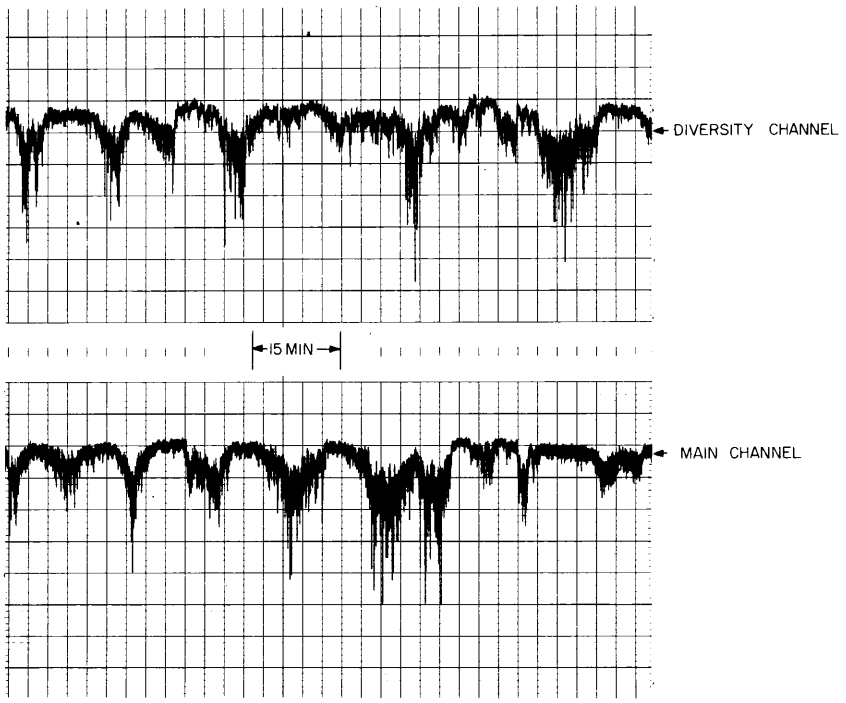


Fig. 11 - Sample strip chart of intermediate-term fading

exposing different Fresnel zones at the point of reflection, thereby making the contribution of the specular component more prominent (1).* This fade type is therefore a good illustration of the importance of the reflected specular component in the fading phenomenon.

An examination of the fading versus the antenna position relative to a null, which is an experimental way of demonstrating the importance of the reflected specular component, confirms that the fading is deepest in the region of the null. The magnitude of the null depth, and therefore of the fading, depends critically on the specular reflection coefficient. The largest value of the specular reflection coefficient measured under almost ideal conditions (dense fog, no fading, and a strong, "clean" vertical interference pattern) was 0.98 (maximum to minimum of 40 db).† Typical values ranged from 0.6 to 0.8. However, on some occasions no appreciable specular interference pattern could be found, indicating for practical purposes, a coefficient of zero. The largest value of the reflection coefficient of the diffusely scattered component, measured when the effect of the specular reflection could not be observed, was about 0.3 (a 10% to 90% value of 4 db). Typical values were between 0.2 and 0.25.

*Diversity measurements that were performed concurrently with these experiments eliminate sudden, brief changes in atmospheric absorption as a possible explanation, since these fades were not observed simultaneously in both diversity channels. (The complete results of the diversity experiments will be reported at a later date.)

†It is interesting to note that the simple two-ray model, which cannot be used to derive the statistical properties of the fading (since at least six components are needed to reasonably describe the deeper fading (2)), is remarkably useful in predicting the specular multipath interference pattern. Calculations of the maximum-to-minimum separation were within 10% of the measured value.

SUMMARY

The short-term fading on an overwater line-of-sight path at 37 GHz has been characterized. Fade depths of 8 db were typical, although fade depths from 3 db to 14 db were observed (measured between the median and the 98% value of the distribution). The fading generally displayed a fast and a slow component with typical average values of about 0.5 fade per second and 1.5 fades per minute. The corresponding average fade durations were 1 sec and 20 sec, respectively.

The importance of the specular reflection from the water surface was clearly evident in the results. The typical value of the specular reflection coefficient was about 0.7, but the extreme values varied from almost 0 to 1. The reflection coefficient of the diffusely scattered component showed less variation and was typically about 0.25.

CONCLUSION

The use of a 15-db fade margin would be sufficient to maintain the received signal above a desired threshold for at least 98% of the time for every sample of data examined. With a 10-db fade margin the 98% value would be exceeded during typical fading, but a value of only 93% would be achieved during the worst fading periods.

The use of time diversity, as a substitute for fade margin, would require a time delay of about 10 sec to achieve effective performance with all data samples examined. A time delay of 5 sec would give slightly degraded but satisfactory performance in almost every case, and a value of about 20 sec would achieve the best diversity performance because of the negative correlation generally obtained with this delay.

REFERENCES

1. Beckmann, P., and Spizzichino, A., "The Scattering of Electromagnetic Waves from Rough Surfaces," Part II, New York: Pergamon, 1963

2. Schwartz, M., Bennett, W., Stein, S., Section 9.2 in "Communication Systems and Techniques," New York: McGraw-Hill, 1966

Appendix

FORTRAN PROGRAM FOR DATA REDUCTION

The input consists of one or two channels of digitized data on magnetic tape written in the binary mode with 2050 words per record. On dual channel tapes the data must be interlaced. The output consists of the cross-correlation coefficient, the autocorrelation coefficient, the fade amplitude distribution, the fade duration distribution, and the joint distribution. "Short circuits" are distributed throughout the program to permit deletion of unwanted operations.

PROGRAM

```
FTN5.4A                                                          07/18/68

      PROGRAM  DATANAL2
C        3 JAN 1968   KMD
C        MOD   11  APRIL 1968   CHANGED  NAME    KMD
C        MOD  10 JULY 1968    KMD
C
C        THIS  PROGRAM  REQUIRES  SUBROUTINES  DSTRFADE, DISTRIB2, SORT
C        FADE2, TPHILE, TPHANDLE, TPREAD, AND  FUNCTION   CORCF
C
C        COMMONS  ARE  USED  IN  THE  SUBROUTINES  AS  FOLLOWS ---
C           A  IS  IN  TPHANDLE  AND  TPREAD
C           B  IS  IN  DSTRFADE,  FADE3,  AND  TPREAD
C           C  IS  IN  DISTRIB2
C           E  IS  IN  DSTRFADE  AND  DISTRIB2
C           F  IS  IN DSTRFADE  AND  FADE3
C           1  IS  IN CORCF
C           2  IS  IN CORCF
C           3  IS  IN  DSTRFADE  AND  FADE3
C           4  IS  IN  DSTRFADE  AND  FADE3
C
      COMMON/A/POSNFL(5),POSNRC(5),FILENO,RECNO,STORE(8)
      COMMON/B/A(4100),KPLXH(100),KPLXL(100),KPLYH(100),KPLYL(100),
     1INT(6,1000), NNF
      COMMON/C/DLOW(10,4), DMEAN(10,4), DHIGH(10,4)
     1, DFILE(10), DREC(10), DDREC(10), NDSAMPL(10)
     2,DDELTAH(10), DDELTAF(10)
      COMMON/E/DLOTEN(10,4), DMEDN(10,4), DUPTEN(10,4), DDISP(10,4)
      COMMON/F/IPNT,IPRNT,RLNGTH,KCH,DINC,GAPINC,NLV,LV(6),NCHL(10,4)
      COMMON/1/X(16400)/2/Y(16400)
      COMMON/3/ JMAX(6),              GAP(1000)/4/LMAX(6), UPINT(6,1000)
      DIMENSION  NTYPKO(4), KO(4,20), NKO(4), DRXY(10), KKGR(10)
      EQUIVALENCE (A,INT)
      DIMENSION T(20), ITH(20), ITM(20), TS(20), TDIFF(20)                A2
      TYPE REAL  LV, INT
      TYPE INTEGER FILENO,RECNO,POSNFL,POSNRC,STORE,DFILE,DREC,DDREC
C
C
C
      KNTIME = 1                                                          A3
      TI = TIMEF(KNTIME)    $    PRINT 83, TI                             T 1
      T(KNTIME)=TI     $    IF(KNTIME .LT. 20)  KNTIME=KNTIME+1           S 1
      PRINT  1
      REWIND  1
      LCH = 1    $    MCH = 2    $    KLV=0    $    NKGR=0    $    IEOF=0
  899 READ  3, DINC, JPRNT, INCPRINT, IPRNT
C
C        THE  FOLLOWING  VARIABLES  SUPPRESS  VARIOUS
C        SECTIONS  OF  THE  PROGRAM
C
      READ 50, NCAC, NXY, NAC, NXX, NYY, NDF, NDX, NDY, NDCA,
     1KDCA, NFX, NFY, NFCJ, NFAJX, NFAJY, NNF
C
C        FOUR  GROUPS  OF  OFF-SETS  ARE  REQUIRED.
C        THE  FIRST  GROUP  CONTAINS  THREE  VALUES  THAT  ARE
C        USED  IN  CHOOSING  ONE  OF  THE  OTHER  THREE  GROUPS
C        (CONTAINING  1  TO  20  VALUES  EACH)  AS  OFF-SETS
C        IN  CALCULATING  AUTO-CORRELATION  COEFFICIENTS.


FTN5.4A                                                          07/18/68

C        THE  SECOND  GROUP  IS  ALWAYS  USED  AS  OFF-SETS
C        IN  AUTO-JOINT  CALCULATIONS.
C
C        CHOICE  OF  OFF-SET  GROUP  IS  MADE  AS  FOLLOWS ---
C           IF  A  COEFFICIENT  LESS  THAN  0.1  IS  CALCULATED
C              WHEN  USING  THE  FIRST  VALUE  FROM  THE  FIRST
C              GROUP,  THEN  VALUES  2  AND  3  ARE  OMITTED
C              FROM  THIS  GROUP  AND  OFF-SETS  FROM  GROUP  2
C              ARE  USED.
C           IF  A  COEFFICIENT  LESS  THAN  0.1  IS  CALCULATED
C              WHEN  USING  THE  SECOND  VALUE  FROM  THE  FIRST
C              GROUP,  THEN  VALUE  3  IS  OMITTED  FROM  THIS
C              GROUP  AND  OFF-SETS  FROM  GROUP  3  ARE  USED.
C           OTHERWISE  ALL  VALUES  OF  GROUPS  1  AND  4  ARE  USED
```

```
C
      DO 20  J=1,4
      READ 52, NK, (KO(J,I), I=1,NK)
      NKO(J) = NK
   20 CONTINUE
C
      READ 4, NLV, (LV(N),  N=1,NLV)
  999 READ 58,  FILENO, RECNO, NCH, NPT, NOCREEL, SMPLRT, DELTAH, DELTAF
     1, NSAMPL
      IF (EOF,60)                          99, 9
    9 IF (FILENO .GT. 16400)               GOTO  899
      NNPT = NPT
      IRECNO = RECNO
      RLNGTH = NPT/SMPLRT
      PRINT 60, NOCREEL, FILENO, NSAMPL, SMPLRT, NPT
      PRINT 66, DELTAH, DELTAF
C
C        POSITION TAPE TO READ DATA FROM FILE AND RECORD INDICATED
C
      CALL  TPHANDLE (1,1)
      PRINT 62
      TI = TIMEF(KNTIME)    $    PRINT 83, TI                                    T 2
      T(KNTIME)=TI     $    IF(KNTIME .LT. 20)  KNTIME=KNTIME+1                  S 2
      IF (NCH .EQ. 2)                      GOTO  21
C
C        SINGLE CHANNEL DATA IS STORED IN ARRAY Y
C
      DO 29  M=1,4
      CALL  TPREAD (1,1,4100,NPP)
      IF (NPP .NE. 0)                      101, 102
C
C        ELIMINATE  CARDS  NOT  USED  IF  THERE  IS  A
C        PARITY  ERROR
C
  101 READ 4, NPT
      IF (NPT .EQ. 0)                      GOTO  999
      IF (NPT .GT. 16400)                  GOTO  899
      GOTO  101
  102 JJJ = POSNRC(1) - 1
      PRINT 63, JJJ, (A(J), J=1,4)
      IF(JPRNT.NE.1)                       GOTO  11
      PRINT 5, INCPRINT
```



```
      IF (INCPRINT .EQ. 0)                 GOTO  11
      PRINT 7, (A(I),  I=1,4100,INCPRINT)
C
   11 DO 29  N=1,4100
      KNT = (M-1)*4100+N
      Y(KNT) = A(N)
      IF (KNT .GE. NPT)                    GOTO  8
   29 CONTINUE
      PRINT 6    $    STOP
C
C        DUAL CHANNEL DATA -- CHANNEL 1 IS STORED IN ARRAY X
C                             CHANNEL 2 IS STORED IN ARRAY Y
C
   21 DO 30  M=1,8
      CALL  TPREAD (1,1,4100,NPP)
      IF (NPP .NE. 0)                      103, 104
C
C        ELIMINATE  CARDS  NOT  USED  IF  THERE  IS  A
C        PARITY  ERROR
C
  103 READ 4, NPT
      IF (NPT .EQ. 0)                      GOTO  999
      IF (NPT .GT. 16400)                  GOTO  899
      GOTO  103
  104 JJJ = POSNRC(1) - 1
      PRINT 63, JJJ, (A(J), J=1,4)
      IF(JPRNT.NE.1)                       GOTO  24
      PRINT 5, INCPRINT
      IF (INCPRINT .EQ. 0)                 GOTO  24
      PRINT 7, (A(I),  I=1,4100,INCPRINT)
C
   24 DO 30  N=2,4100,2
      KNT = (M-1)*2050 + N/2
```

```
      X(KNT) = A(N-1)
      Y(KNT) = A(N)
      IF (KNT .GE. NPT)                    GOTO  8
   30 CONTINUE
      PRINT 6   $   STOP
C
C        SET POINTS THAT ARE GREATER THAN -35 DBM OR LESS THAN -90 DBM
C        TO THE PREVIOUS POINT
C
    8 KOUNTX=0   $   KKOUNTX=0   $   KOUNTY=0   $   KKOUNTY=0
      TI = TIMEF(KNTIME)   $    PRINT 83, TI                                T 3
      T(KNTIME)=TI    $    IF(KNTIME .LT. 20)  KNTIME=KNTIME+1              S 3
      IF (NCH .NE. 2)                      GOTO  26
      CALL TPHILO (X, NPT, KOUNTX, KKOUNTX, KPLXL, KPLXH)
   26 CALL TPHILO (Y, NPT, KOUNTY, KKOUNTY, KPLYL, KPLYH)
C
C        PRINT LOCATION OF POINTS THAT WERE CHANGED
C        BY SUBROUTINE TPHILO
C
      PRINT 75, KOUNTX, KKOUNTX, KOUNTY, KKOUNTY
C
      IF (KOUNTX .EQ. 0 .AND. KKOUNTX .EQ. 0)     GOTO  44
      IF(KKOUNTX .EQ. 0)                          GOTO  42
```



```
      IF (KKOUNTX .GT. 100)  13, 15
   13 KKOUNTX = 100
   15 N = KKOUNTX
      PRINT 82, LCH
      PRINT 79, (KPLXH(I), I=1,N)
C
   42 IF (KOUNTX .EQ. 0)                   GOTO  44
      IF (KOUNTX .GT. 100)   18, 19
   18 KOUNTX = 100
   19 N = KOUNTX
      PRINT 84, LCH
      PRINT 79, (KPLXL(I), I=1,N)
C
   44 IF ( KOUNTY .EQ. 0 .AND. KKOUNTY .EQ. 0)    GOTO  80
      IF (KKOUNTY .EQ. 0)                         GOTO  45
      IF (KKOUNTY .GT. 100)  27, 28
   27 KKOUNTY = 100
   28 N = KKOUNTY
      PRINT 82, MCH
      PRINT 79, (KPLYH(I), I=1,N)
C
   45 IF ( KOUNTY .EQ. 0)                         GOTO  80
      IF(KOUNTY .GT. 100)     35, 36
   35 KOUNTY = 100
   36 N = KOUNTY
      PRINT 84,  MCH
      PRINT 79, (KPLYL(I), I=1,N)
   80 PRINT 73
C
C        READ THE NUMBER OF POINTS TO BE USED IN THE ANALYSIS
C
  100 READ 4,  NPT, DIFFLV
      IF (NPT .EQ. 0)                     GOTO  999
      IF (KLV .EQ. 10)                    GOTO  55
      KLV=KLV+1
    7 DFILE(KLV)=FILENO   $   DREC(KLV)=IRECNO   $   NDSAMPL(KLV)=NSAMPL
      DDELTAH(KLV)=DELTAH   $   DDELTAF(KLV)=DELTAF   $   DDREC(KLV)=JJJ
      RLNGTH = NPT/SMPLRT
      TI = TIMEF(KNTIME)   $    PRINT 83, TI                                T 4
      T(KNTIME)=TI    $    IF(KNTIME .LT. 20)  KNTIME=KNTIME+1              S 4
      IF (NCAC .EQ. 1)                    GOTO  46
      IF (NXY .EQ. 1)                     GOTO  37
C
C
C        CALCULATE CROSS-CORRELATION
C
      PRINT 71, NPT, RLNGTH
      RXY = CORCF(0, NPT)
      DRXY(KLV) = RXY
```

```
C
      PRINT 72, RXY
      TI = TIMEF(KNTIME)    $     PRINT 83, TI                                T 5
      T(KNTIME)=TI     $     IF(KNTIME .LT. 20)  KNTIME=KNTIME+1              S 5
C
   37 IF (NAC .EQ. 1)                    GOTO  46
C
```



```
C
C        CALCULATE  AUTOCORRELATION
C
      PRINT 74
      PRINT 71, NPT, RLNGTH
      PRINT 76, LCH, MCH
C
C        SELECTION  OF  OFF-SET  GROUP  IS  MADE
C        AS  DESCRIBE  ABOVE
C
      DO 40  I=1,3
      K = KO(1,I)
      OFFSET = K/SMPLRT
      NP= NPT - K
      NTYPE = I+1
      IF (NXX .EQ. 0 .AND. NYY .EQ. 0)  48, 38
C
   48 RXX = ACORX(K,NPT)
      RYY = ACORY(K,NPT)
      PRINT 77, K, NP, OFFSET, RXX, RYY
      IF (RXX .LT. 0.1 .OR. RYY .LT. 0.1)  34,40
   38 IF(NXX .EQ. 1)                    GOTO  43
C
      RXX = ACORX(K,NPT)
      PRINT 77, K, NP, OFFSET, RXX
      IF (RXX .LT. 0.1)                 41, 40
   43 IF(NYY .EQ. 1)                    GOTO  46
C
      RYY = ACORY(K,NPT)
      PRINT 70, K, NP, OFFSET, RYY
      IF (RYY .LT. 0.1)                 39, 40
   40 CONTINUE
C
      IF (NXX .EQ. 0 .AND. NYY .EQ. 0)  34, 51
   51 IF (NXX .EQ. 1)                   39, 41
   34 CONTINUE
C
C        CALCULATE AUTOCORRELATION OF CHANNEL 1 AND 2
C
      NK = NKO(NTYPE)
C
      DO 31  I=1,NK
      K = KO(NTYPE,I)
      OFFSET = K/SMPLRT
      NP = NPT - K
      RXX = ACORX(K,NPT)
      RYY = ACORY(K,NPT)
      PRINT 77, K, NP, OFFSET, RXX, RYY
   31 CONTINUE
      GOTO  46
C
C        CALCULATE AUTOCORRELATION OF CHANNEL 2
C
   39 NK = NKO(NTYPE)
C
      DO 32  I=1,NK
```



```
      K = KO(NTYPE,I)
      OFFSET = K/SMPLRT
      NP = NPT - K
      RYY = ACORY(K,NPT)
      PRINT 70, K, NP, OFFSET, RYY
   32 CONTINUE
```

```
      GOTO  46
C
C        CALCULATE AUTOCORRELATION OF CHANNEL 1
C
   41 NK = NKO(NTYPE)
C
      DO 33  I=1,NK
      K = KO(NTYPE,I)
      OFFSET = K/SMPLRT
      NP = NPT - K
      RXX = ACORX(K,NPT)
      PRINT 77, K, NP, OFFSET, RXX
   33 CONTINUE
C
   46 CONTINUE
      TI = TIMEF(KNTIME)    $    PRINT 83, TI                                T 6
      T(KNTIME)=TI     $    IF(KNTIME .LT. 20)  KNTIME=KNTIME+1              S 6
C
C
C-----------------DISTRIBUTION-------------------
C
      KGR = 0
      IF (NDF .EQ. 1)                    GOTO  100
C
      IF (NDX  .EQ.  1)                  GOTO  12
C
C
C        CALCULATE  DISTRIBUTION  OF  DATA  IN  CHANNEL  1
C
      PRINT 65, NOCREEL, FILENO, NSAMPL, SMPLRT, NPT
      PRINT 66, DELTAH, DELTAF
      KGR = KGR + 1    $    NCHL(KLV,KGR) = 8H     1
      KKGR(KLV) = KGR     $    NKGR = NKGR + 1
      PRINT 61, NCHL(KLV,KGR)
      CALL DSTRFADE (X, NPT, NFX, KLV, KGR)
C
      TI = TIMEF(KNTIME)    $    PRINT 83, TI                                T 7
      T(KNTIME)=TI     $    IF(KNTIME .LT. 20)  KNTIME=KNTIME+1              S 7
C
   12 IF (NDY  .EQ.  1)                  GOTO  16
C
C
C        CALCULATE  DISTRIBUTION  OF  DATA  IN  CHANNEL  2
C
      PRINT 65, NOCREEL, FILENO, NSAMPL, SMPLRT, NPT
      PRINT 66, DELTAH, DELTAF
      KGR = KGR + 1    $    NCHL(KLV,KGR) = 8H     2
      KKGR(KLV) = KGR     $    NKGR = NKGR + 1
      PRINT 61, NCHL(KLV,KGR)
      CALL DSTRFADE (Y, NPT, NFY, KLV, KGR)
```



```
C
      TI = TIMEF(KNTIME)    $    PRINT 83, TI                                T 8
      T(KNTIME)=TI     $    IF(KNTIME .LT. 20)  KNTIME=KNTIME+1              S 8
C
   16 IF (NDCA .EQ. 1)                   GOTO  100
      IF (KDCA)                          14, 56, 17
C
C
C        CALCULATE  CROSS-JOINT  DISTRIBUTION
C
   56 PRINT 65, NOCREEL, FILENO, NSAMPL, SMPLRT, NPT
      PRINT 66, DELTAH, DELTAF
      KGR = KGR + 1    $    NCHL(KLV,KGR) = 8H C-JOINT
      KKGR(KLV) = KGR     $    NKGR = NKGR + 1
   64 DO 22  I=1,NPT
       IF ((Y(I)+DIFFLV) .GT. X(I))    X(I)=Y(I)+DIFFLV
   22 CONTINUE
      PRINT 61, NCHL(KLV,KGR)
      CALL DSTRFADE (X, NPT, NFCJ, KLV, KGR)
C
      TI = TIMEF(KNTIME)    $    PRINT 83, TI                                T 9
      T(KNTIME)=TI     $    IF(KNTIME .LT. 20)  KNTIME=KNTIME+1              S 9
C
      GOTO  100
C
C
```

```
C        CALCULATE   AUTO-JOINT  DISTRIBUTION  CHANNEL  1
C        THE  SECOND  GROUP  OF  OFF-SETS  READ-IN  ARE  USED
C
   17 PRINT 65, NOCREEL, FILENO, NSAMPL, SMPLRT, NPT
      PRINT 66, DELTAH, DELTAF
      KGR = KGR + 1    $    NCHL(KLV,KGR) = 8H1A-JOINT
      KKGR(KLV) = KGR     $     NKGR = NKGR + 1
      NK = NKO(2)
      DO 49  J=1,NK
      K = KO(2,J)
      NP = NPT - K
      DO 25  I=1,NP
      IF (X(I) .LT. X(I+K))                57, 67
   57 Y(I) = X(I+K)            $           GOTO  25
   67 Y(I) = X(I)
   25 CONTINUE
      PRINT 61, NCHL(KLV,KGR)
      OFFSET = K/SMPLRT
      PRINT 69, K, NP, OFFSET
      CALL DSTREADE (Y, NP, NFAJX, KLV, KGR)
   49 CONTINUE
C
      TI = TIMEF(KNTIME)    $    PRINT 83, TI                                T10
      T(KNTIME)=TI     $    IF(KNTIME .LT. 20)  KNTIME=KNTIME+1             S10
C
      GOTO  100
C
C
C        CALCULATE   AUTO-JOINT  DISTRIBUTION  CHANNEL  2
C        THE  SECOND  GROUP  OF  OFF-SETS  READ-IN  ARE  USED
```



```
C
   14 PRINT 65, NOCREEL, FILENO, NSAMPL, SMPLRT, NPT
      PRINT 66, DELTAH, DELTAF
      KGR = KGR + 1    $    NCHL(KLV,KGR) = 8H2A-JOINT
      KKGR(KLV) = KGR     $     NKGR = NKGR + 1
      NK = NKO(2)
      DO 47  J=1,NK
      K = KO(2,J)
      NP = NPT - K
      DO 23  I=1,NP
      IF (Y(I) .LT. Y(I+K))                86, 89
   86 X(I) = Y(I+K)            $           GOTO  23
   89 X(I) = Y(I)
   23 CONTINUE
      PRINT 61, NCHL(KLV,KGR)
      OFFSET = K/SMPLRT
      PRINT 69, K, NP, OFFSET
      CALL DSTREADE (X, NP, NFAJY, KLV, KGR)
   47 CONTINUE
C
      TI = TIMEF(KNTIME)    $    PRINT 83, TI                                T11
      T(KNTIME)=TI     $    IF(KNTIME .LT. 20)  KNTIME=KNTIME+1             S11
C
      GOTO  100
   99 IEOF = 1
C
C        PRINT SUMMARY TABLE FOR EVERY 10 DATA-GROUPS
C
   55 IF (NKGR .EQ. 0)                     GOTO  54
      PRINT 64, NOCREEL, NNPT, SMPLRT
      PRINT  87
      DO 53  I=1,KLV
      KGR = KKGR(I)
      DO 53  J=1,KGR
      PRINT 88, DFILE(I),DREC(I),DDREC(I),NCHL(I,J),
     CDLOW(I,J),DLOTEN(I,J),
     1DMEDN(I,J),DMEAN(I,J),DDISP(I,J),DUPTEN(I,J),DHIGH(I,J),
     2DRXY(I), DDELTAH(I), DDELTAF(I), NDSAMPL(I)
   53 CONTINUE
C
      TI = TIMEF(KNTIME)    $    PRINT 83, TI                                T12
      T(KNTIME)=TI     $    IF(KNTIME .LT. 20)  KNTIME=KNTIME+1             S12
C
      PRINT 2
```

```
      IF (IEOF .EQ. 1)                    GOTO  54
      KLV = 1    $    GOTO   7
C
   54 CONTINUE
C
C        CALCULATE  AND  PRINT  TABLE  OF  TIME  DIFFERENCES
C        (FIRST  19  VALUES  ONLY)
C
      TDIFF(1) = 111111111.                                                C1
      ITH(1) = TH = T(1)/3600000.                                          C2
      ITM(1) = TM = (TH-ITH(1))*60.                                        C3
      TS(1) = (TM-ITM(1))*60.                                              C4
```



```
      KNTIME = KNTIME - 1                                                  C5
      DO 85   I=2,KNTIME                                                   C6
      TDIFF(I) = (T(I) - T(I-1))/1000.                                     C7
      ITH(I) = TH = T(I)/3600000.                                          C8
      ITM(I) = TM = (TH-ITH(I))*60.                                        C9
      TS(I) = (TM-ITM(I))*60.                                              C10
   85 CONTINUE                                                             C11
      PRINT 80                                                             C12
      PRINT 81,(I, ITH(I), ITM(I), TS(I), TDIFF(I), I=1,KNTIME)            C13
C
C
    1 FORMAT (1H*)
    2 FORMAT (*1*)
    3 FORMAT (F10.2, 3I10)
    4 FORMAT (I10, (7F10.2))
    5 FORMAT (3X,*TABLE  OF  DATA  READ  IN -----  EVERY*I5*TH  POINT*)
    6 FORMAT (3X*ASK FOR TOO MANY DATA POINTS*)
    7 FORMAT (10F8.3)
   50 FORMAT (20I4)
   52 FORMAT (11I5)
   58 FORMAT (3I5, 2I10, 3F10.2, I10)
   60 FORMAT (*1  CALIBRATED  TAPE *I5/*   FILE  NUMBER*I4/
     C*   SAMPLE  NUMBER =*I6/
     1*   SAMPLING  RATE =*F9.3*  SAMPLES  PER  SECOND*/
     2*   NUMBER  OF  POINTS  READ  FROM  TAPE =*I7*  PER  CHANNEL*//)
   61 FORMAT (//3X*CUMULATIVE  FREQUENCY  DISTRIBUTION ----- CHANNEL  *
     1  A8)
   62 FORMAT (/3X*FIRST  FOUR   POINTS  OF  EACH  RECORD*//7X
     1*RECORD*/7X*NUMBER*12X*DATA  POINTS*/)
   63 FORMAT (6X, I4, 1X 4F10.2)
   64 FORMAT (*1  CALIBRATED  TAPE *I5//
     1*   NUMBER  OF  POINTS  READ  FROM  TAPE =*I7*  PER  CHANNEL*/
     2*   SAMPLING  RATE =*F9.3*  SAMPLES  PER  SECOND*//)
   65 FORMAT (*1  CALIBRATED  TAPE *I5/*   FILE  NUMBER*I4/
     C*   SAMPLE  NUMBER =*I6/
     1*   SAMPLING  RATE =*F9.3*  SAMPLES  PER  SECOND*/
     2*   NUMBER  OF  POINTS  USED =*I7*  PER  CHANNEL*//)
   66 FORMAT (/3X*DELTAH =*F6.2* FT*/3X*DELTAF =*F8.0* MC*//)
   69 FORMAT (/3X*POINT  OFF-SET =*I7/3X*NUMBER  OF  POINTS  USED =*
     1I7/3X*OFF-SET  TIME =*F10.3*  (SEC)*)
   70 FORMAT (1X, 2I10, F10.3, 10X, F10.3)
   71 FORMAT (/  3X*SAMPLE  LENGTH =*I7* POINTS  OR *F9.3* (SEC)*/)
   72 FORMAT (///3X*CROSS  CORRELATION  COEFFICIENT =*F7.3//)
   73 FORMAT(1X*-------------------------------------------------------
     1-------------------------------------------------------------
     2-----------*)
   74 FORMAT (3X*AUTOCORRELATION  COEFFICIENTS ----------*)
   75 FORMAT (/3X*CHANNEL  1 --- NUMBER  OF  POINTS  UNDER  -90 DBM =*
     1I6/39X*OVER  -35 DBM =*I6/3X
     2*CHANNEL  2 --- NUMBER  OF  POINTS  UNDER  -90 DBM =*I6/39X
     3*OVER  -35 DBM =*I6)
   76 FORMAT (16X*NUMBER      TIME*/7X*POINT      OF      OFF-SET*7X
     1*CHANNEL*/6X*OFF-SET   POINTS     (SEC)*I6,I9)
   77 FORMAT (1X, 2I10, 3F10.3)
   79 FORMAT (11X, 10I8)
   80 FORMAT (1H1*   TIMING ---*//7X*TIME*10X*TIME*8X*TIME  DIFF*/7X          F1
```

```
     1*POINT*5X*HR  MIN   SEC*6X*SEC*)                                    F2
   81 FORMAT (6X,I4, I9, I5, F7.1, 2X, F7.3)                              F3
   82 FORMAT (//3X*LOCATION  OF  POINTS  GREATER  THAN  -35 DBM  IN  CHA
     1NNEL*I2)
   83 FORMAT (100X*TIME =*F15.1* MILLI-SEC*)
   84 FORMAT (//3X*LOCATION  OF  POINTS  LESS  THAN  -90 DBM  IN  CHANNE
     1L*I2)
   87 FORMAT (43X*LOWER*36X*UPPER*/44X*TEN*38X*TEN*/42X*PERCENT*23X
     1*STANDARD   PERCENT*28X*DELTA*/*  FILE    RECORD      CHANNEL
     2 LOW     LEVEL     MEDIAN     MEAN    DEVIATION   LEVEL     HIGH
     3    CROSS       H       F    NUMBER*/34X*(DBM)    (DBM)      (DBM)
     4     (DBM)      (DB)     (DBM)     (DBM)     (DBM)      (FT)    (M
     5C)*/)
   88 FORMAT ( 1X,I4,I5* TO*I4,4X,A8,7F10.2,F10.3,F10,2,F8,0,I7)
C
C
C
      END
```

```
      SUBROUTINE  DSTRFADE (Z, NPT, NFZ, KLV, KGR)
C
C        18 JAN 1968      KMD
C        MOD  2 JULY 1968     KMD
C
C
      COMMON/B/A(4100),KPLXH(100),KPLXL(100),KPLYH(100),KPLYL(100),
     1INT(6,1000), NNF
      COMMON/E/DLOTEN(10,4), DMEDN(10,4), DUPTEN(10,4), DDISP(10,4)
      COMMON/F/IPNT,IPRNT,RLNGTH,KCH,DINC,GAPINC,NLV,LV(6),NCHL(10,4)
      COMMON/3/ JMAX(6),              GAP(1000)/4/LMAX(6), UPINT(6,1000)
      DIMENSION Z(NPT)
      EQUIVALENCE (A,INT)
      TYPE REAL  MDN, INT, LV
      TYPE INTEGER UNITS
C
C
C        DISTRIBUTION  ANALYSIS
C
      PRINT 70, NPT, RLNGTH
      TI = TIMEF(KNTIME)   $    PRINT 83, TI
C
      CALL DISTRIB2 (Z, NPT, DINC, IPRNT,KLV, KGR)
C
      MDN = DMEDN(KLV,KGR)
      IF (NFZ .EQ. 1)                    RETURN
C
C
C        FADE  ANALYSIS
C
      TI = TIMEF(KNTIME)   $    PRINT 83, TI
C
      CALL FADE3 (NPT,Z,MDN)
C
      TI = TIMEF(KNTIME)   $    PRINT 83, TI
C
      DO 30  N=1,NLV
      NN=JMAX(N)
      IF (NN .EQ. 0)                     GOTO  48
      DO 32 I=1,NN
   32 GAP(I)=INT(N,I)
C
C
C
      KKNT = 0
      PRINT 65, NCHL(KLV,KGR)
      PRINT 63,  LV(N)
      PRINT 62, NN
      IUNT = 5H(SEC)
      TI = TIMEF(KNTIME)   $    PRINT 83, TI
C
      CALL SORT (GAP, NN)
C
      TI = TIMEF(KNTIME)   $    PRINT 83, TI
      PRINT 60
   38 PRINT 61, (GAP(I), I=1,NN)
```



```
      SUM=0.   $   SSUM=0.   $   JJ=0
      PRINT 68
      DO 55,  J=1,NN
      SUM = SUM + GAP(J)
      IF (J .EQ. NN)                     56, 58
   58 IF (GAP(J) .LT. GAP(J+1))          56, 55
   56 ICUM = J   $   IICUM = NN-JJ
      PCFADE = 100.0-ICUM/NN*100.0
      PTFADE = SUM/RLNGTH*100.0
      PPTFADE = SSUM/RLNGTH*100.0
      PRINT 57, ICUM, GAP(J), PCFADE, PTFADE, PPTFADE, IICUM
      JJ = J   $   SSUM = SUM
   55 CONTINUE
      IF (KKNT .LT. 1)                   48, 34
```

```
   48 IF (NNF .EQ. 1)                    GOTO  34
      KKNT = KKNT + 1
C
C
C        NON-FADE  ANALYSIS
C
      TI = TIMEF(KNTIME)    $     PRINT 83, TI
      NN = LMAX(N)
      IF (NN .EQ. 0)                     RETURN
      DO 36  I=1,NN
   36 GAP(I) = UPINT(N,I)
C
C
C
      PRINT 66, NCHL(KLV,KGR)
      PRINT 63, LV(N)
      PRINT 62,  NN
      CALL SORT (GAP, NN)
      PRINT 59
      GOTO  38
C
   34 CONTINUE
C
   30 CONTINUE
      TI = TIMEF(KNTIME)    $     PRINT 83, TI
      PRINT 64
      RETURN
C
   57 FORMAT (  2X, I/, F11.5, F13.5, 2F12.5, I10)
   59 FORMAT (3X*LIST  OF  NON-FADE  DURATIONS  (SEC) ----- SORTED*)
   60 FORMAT (3X*LIST  OF  FADE  DURATIONS  (SEC) ----- SORTED*)
   61 FORMAT (3X,8F10.5)
   62 FORMAT (  /3X*NUMBER  OF  POINTS =*I7)
   63 FORMAT (///3X, F7.2* DB  LEVEL*)
   64 FORMAT(/* ----------------------------------------------------*)
   65 FORMAT (//3X*CUMULATIVE  DISTRIBUTION  OF  FADE  DURATIONS*
     1* ----- CHANNEL  *A8)
   66 FORMAT (//3X*CUMULATIVE  DISTRIBUTION  OF  NON-FADE  DURATIONS*
     1* ----- CHANNEL  *A8)
   68 FORMAT (//3X
     1*NUMBER*16X* PERCENT      PERCENT      PERCENT      NUMBER*/3X
     2*POINTS      FADE*/X*OF FADES*7X*OF*10X*OF*8X*POINTS*/3X
```

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```
     3*BELOW      DURATION      ABOVE*7X* TIME *8X*TIME*7X*ABOVE*/3X
     4*INTERVAL    (SEC)       DURATION      BELOW*7X*ABOVE*6X*INTERVAL*)
   70 FORMAT (///3X*SAMPLE  LENGTH =*I7* POINTS  OR *F9.3
     1* (SEC)*//3X*NUMBER     ABSOLUTE     PRECENT        LEVEL*/3X
     2*POINTS      SIGNAL      POINTS        FROM*/3X
     3*BELOW       LEVEL        BELOW       MEDIAN*/3X
     4*LEVEL       (DBM)        LEVEL        (DB)*)
C
   83 FORMAT (100X*TIME =*F15.0* MILLI-SEC*/116X*FROM  DSTRFADE*)
      END
```

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```
      SUBROUTINE DISTRIB2 (D, ND, SDINC, IPRNT, KLV, KGR)
C     HPC 25 NOV 1966, MOD 3 AUG 1967, MOD 15 SEPT 1967                    20
C     MOD AND CHANGED NAME  JAN 18 1968    KMD
C        MOD    27 MARCH 1968    KMD
C     STATISTICAL PARAMETERS OF A SET OF DATA                              30
C                                                                          40
      COMMON/C/DLOW(10,4), DMEAN(10,4), DHIGH(10,4)
     1, DFILE(10), DREC(10), DDREC(10)
      COMMON/E/DLOTEN(10,4), DMEDN(10,4),DUPTEN(10,4), DDISP(10,4)
      DIMENSION D(ND),COUNT(500)                                           50
      TYPE REAL      MEAN,MEDN,LOW,LOTEN,LOTENY,LEVEL,MEDY,LEVELN          60
      TYPE INTEGER COUNT                                                   70
C                                                                          80
      DINC =SDINC                                                          81
      PRINT 3,   DINC
      IF(ND.EQ.0)                        RETURN                          A120
      IF(IPRNT.NE.1)                     GO TO 19
      PRINT 5
      PRINT 2,(D(I),I=1,ND)
```

```
C
   19 SUM=0
      DO 31 I=1,ND
   31 SUM=SUM+D(I)
      MEAN=SUM/ FLOATF(ND)
      DMEAN(KLV,KGR) = MEAN
C
      LOW=D(1) $ HIGH=D(1)
      DO 33 I=2,ND
      IF(D(I).LT.LOW) LOW=D(I)
   33 IF(D(I).GT.HIGH)HIGH=D(I)
      HHIGH = IHIGH = HIGH
      XLOW = ILOW = LOW
C
      IF (LOW .LT. 0)   27, 46
   27 IF (XLOW-DINC .GT. LOW)   47,49
   47 XLOW = XLOW - DINC
      GOTO  27
   46 IF (XLOW+DINC .GT. LOW)   48, 50
   50 XLOW = XLOW + DINC
      GOTO  46
   49 XLOW = XLOW - DINC
   48 DLOW(KLV,KGR) =  LOW
      IF (HIGH .LT. 0)   25, 34
   25 IF (HHIGH-DINC .GT. HIGH)   36, 54
   36 HHIGH = HHIGH - DINC
      GOTO  25
   34 IF (HHIGH+DINC .GT. HIGH)   42, 44
   44 HHIGH = HHIGH + DINC
      GOTO  34
   42 HHIGH = HHIGH + DINC
   54 DHIGH(KLV,KGR) =  HIGH
      NBIN = (HHIGH - XLOW)/DINC
C
      IF(NBIN.GT.500)                    21,23
   21 PRINT 10  $  RETURN
   23 CONTINUE
```



```
      DO 35 J=1,NBIN
      LEVEL=FLOATF(J)*DINC+XLOW
      COUNT(J)=0
      DO 37 I=1,ND
      IF(D(I).LE.LEVEL)  COUNT(J)=COUNT(J)+1
   37 CONTINUE
      COUNTN=FLOATF(COUNT(J))/ND
   35 CONTINUE
C
      MID=ND/2 $ FMID=FLOATF(ND)/2.
C
C     COMPUTE MEDIAN
C
      DO 39 J=1,NBIN
      IF(COUNT(J).LT.MID)                GOTO  39
      IF (J .EQ. 1)    12, 40
   12 X1=0   $   X2=COUNT(J)   $   GOTO  16
   40 X1=COUNT(J-1) $ X2=COUNT(J)
   16 IF (X2 .EQ. MID)    20, 22
   20 MEDY = J    $    GOTO  41
   22 MEDY = (J-1) + (MID-X1)/(X2-X1)
      GO TO 41
   39 CONTINUE
   41 MEDN=MEDY*DINC+XLOW
      DMEDN(KLV,KGR) = MEDN
C
      DO 43 J=1,NBIN
      LEVEL=FLOATF(J)*DINC+XLOW
      LEVELN=LEVEL-MEDN
      COUNTN=FLOATF(COUNT(J))/ND*100.
   43 PRINT 72, COUNT(J), LEVEL, COUNTN, LEVELN
C
C     COMPUTE LOW TEN PERCENT LEVEL
C
      KNST = (ND+5)/10
      DO 51 J=1,NBIN
      IF(COUNT(J).LT.KNST) GO TO 51
```

```
      IF (J .EQ. 1)     13, 30
   13 X1=0    $    X2=COUNT(J)    $    GOTO  17
   30 X1=COUNT(J-1) $ X2=COUNT(J)
   17 IF (X2 .EQ. KNST)     24, 26
   24 LOTENY = J     $     GOTO  57
   26 LOTENY = (J-1) + (KNST-X1)/(X2-X1)
      GO TO 57                                                          600
   51 CONTINUE                                                          610
   57 LOTEN=LOTENY*DINC+XLOW
      DLOTEN(KLV,KGR) = LOTEN
C                                                                       630
C     COMPUTE UPPER TEN PERCENT LEVEL                                   640
C
      KNST=ND-KNST                                                      650
      DO 61 J=1,NBIN                                                    660
      IF(COUNT(J).LT.KNST) GO TO 61                                     670
      IF (J .EQ. 1)     14, 38
   14 X1=0    $    X2=COUNT(J)    $    GOTO  18
   38 X1=COUNT(J-1) $ X2=COUNT(J)
```

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```
   18 IF (X2 .EQ. KNST)     28, 29
   28 UPTENY = J     $     GOTO  67
   29 UPTENY = (J-1) + (KNST-X1)/(X2-X1)
      GO TO 67                                                          760
   61 CONTINUE                                                          770
   67 UPTEN=UPTENY*DINC+XLOW
      DUPTEN(KLV,KGR) = UPTEN
C                                                                       790
C     COMPUTE  STANDARD  DEVIATION
C
      SUM=0                                                             810
      DO 71 I=1,ND                                                      820
   71 SUM=SUM+(D(I)-MEAN)**2                                            830
      DISP=SQRTF(SUM/ND)                                                840
      DDISP(KLV,KGR) = DISP
C                                                                       850
      PRINT 73, LOW, LOTEN, MEAN, DISP, HIGH, UPTEN, MEDN
C                                                                       900
C                                                                       910
C                                                                       920
    2 FORMAT (10F8.3)
    3 FORMAT (50X*INCREMENT =*F6.1* (DB)*)
    5 FORMAT(*0TABLE OF DATA*)
   10 FORMAT (///3X*INC. REQ. FOR CUM. FREQ. DISTRIB. IS TOO SMALL*)
   72 FORMAT (1X,I7, F11.2, F13.5, F12.2)
   73 FORMAT (//4X*LOW =*F8.2,6X*LOTEN =*F8.2,8X*MEAN =*F8.2,6X
     1*STANDARD  DEVIATION =*F6.2/3X*HIGH =*F8.2,6X*UPTEN =*F8.2,6X
     2*MEDIAN =*F8.2)
C                                                                      1030
C                                                                      1040
      END                                                              1050
```

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```
      SUBROUTINE FADE3 (NPT,S,MDN)
C     HPC 21 NOV 1966,  MOD 4 AUG 1967
C     MOD  2 OCT 1967   KMD
C     MOD AND CHANGED NAME  JAN 18 1968    KMD
C     MOD AND CHANGED NAME  JULY 2, 1968    KMD
      COMMON/B/A(4100),KPLXH(100),KPLXL(100),KPLYH(100),KPLYL(100),
     1INT(6,1000), NNF
      COMMON/F/IPNT,IPRNT,RLNGTH,KCH,DINC,GAPINC,NLV,LV(6),NCHL(10,4)
      COMMON/3/ JMAX(6),            GAP(1000)/4/LMAX(6), UPINT(6,1000)
      TYPE INTEGER BOT,TOP
      TYPE REAL    MDN,LV,INT,LVN
      DIMENSION S(NPT)
      EQUIVALENCE (A,INT)
C
C
      KOUNT = 0    $    KKOUNT = 0
C
      PRINT 62,  MDN
      DO 15 N=1,NLV
```

```
      LVN=MDN*LV(N)
      PRINT 8, LVN
      KPT=NPT-1 $ BOT=1 $ J=1   $   L=1   $   TOP=1
      DO 31 I=1,KPT
      SA=S(I) $ SB=S(I+1)
      IF(SA.GT.LVN.AND.SB.LE.LVN.OR.I.EQ.KPT.AND.SA.GT.LVN) 41,43
   41 BOT=I
      UPINT(N,L) = (BOT-TOP)*RLNGTH/NPT
      L = L+1
      IF (L .GT. 1000)                    GOTO  58
   43 IF(SA.LE.LVN.AND.SB.GT.LVN.OR.I.EQ.KPT.AND.SA.LE.LVN) 51,31
   51 TOP = I
      INT(N,J)=(TOP-BOT)*RLNGTH/NPT
      J = J + 1
      IF (J .GT. 1000)                    GOTO  59
   31 CONTINUE
      IF (J .EQ. 1 .AND. KOUNT.EQ. 0)  20, 21
   20 PRINT 91, LV(N)     $     KOUNT = KOUNT + 1
   21 IF (L .EQ. 1 .AND. KKOUNT .EQ. 0)  22, 23
   22 PRINT 92, LV(N)     $     KKOUNT = KKOUNT + 1
   23 JMAX(N)=J - 1
   15 LMAX(N) = L - 1
C
C
      PRINT  85
      PRINT  83
      DO 61 N=1,NLV
      KMAX=JMAX(N)
      SUM=0
      DO 60 J=1,KMAX
   60 SUM=SUM+INT(N,J)     $     SLNGTH = RLNGTH
      TFADE=SUM/SLNGTH*100.0  $  FDRT=FLOATF(KMAX)/SLNGTH
      IF( JMAX(N) .EQ. 0)                 GOTO   67
      PRINT 86,    LV(N), TFADE, FDRT, (INT(N,J), J=1,KMAX)
      PRINT 80,  KMAX
   61 CONTINUE
   67 IF (NNF .EQ. 1)                     GOTO  68
```



```
C
C
      PRINT  87
      PRINT  83
      DO 65  N=1,NLV
      KMAX = LMAX(N)
      SUM = 0
      DO 66  J=1,KMAX
   66 SUM = SUM + UPINT(N,J)
      UPTFADE = SUM/SLNGTH*100.
      FDRT = KMAX/SLNGTH
      IF (LMAX(N) .EQ. 0)                 RETURN
      PRINT  86,  LV(N), UPTFADE, FDRT, (UPINT(N,J), J=1,KMAX)
      PRINT 80,  KMAX
   65 CONTINUE
   68 RETURN
   58 PRINT  88    $     RETURN
   59 PRINT  89
C
C
    6 FORMAT(*0 NUMBER OF PTS=*I5,*   MEDIAN=*F10.3,*   SAMPLE LENGTH=*
     1F10.3)
    8 FORMAT (3X*ABSOLUTE LEVEL*F8.2)
   62 FORMAT (3X*MEDIAN =*F8.2)
   80 FORMAT (/105X*NUMBER  OF  POINTS =*I4)
   83 FORMAT (//18X*FADE*/18X*LEVEL*17X*AVERAGE*
     1/18X*FROM*6X*PERCENT*6X*FADING*/17X*MEDIAN*7X*OF*9X*RATE*
     2/18X*(DB)*7X*FADE*19X*LIST  OF  DURATIONS  (SEC)*)
   85 FORMAT (//3X*FADE  DURATION*)
   86 FORMAT (        15X, F7.2, 5X, F7.3, 5X, F7.3/(50X, 8F10.5))
   87 FORMAT (//3X*NON-FADE  DURATION*)
   88 FORMAT (//3X*TOO  MANY  NON-FADE  INTERVALS*)
   89 FORMAT (//3X*TOO  MANY  FADE  INTERVALS*)
   91 FORMAT (3X*NO  FADES  BELOW*F7.2* DB  LEVEL*)
   92 FORMAT (3X*NO  SIGNAL  ABOVE*F7.2* DB  LEVEL*)
C
      END
```

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```
      FUNCTION CORCF(K,N)
C     HPC 9 JAN 1967
C        MOD   APRIL 2, 1968    KMD
C     AUTO AND CROSS CORRELATION COEFFICENTS, TWO SETS OF DATA
C     WITH VARIABLE OFFSET
C
      COMMON/1/X(16400)/2/Y(16400)
      TYPE REAL NUM
C
      M=1 $ GO TO 15
      ENTRY CORCFR
      M=2 $ GO TO 15
      ENTRY ACORX
      M=3 $ GO TO 15
      ENTRY ACORY
      M=4
C
   15 LL=1+K $ ND=N-K
      SA=0. $ SB=0. $ SC=0. $ SD=0. $ SE=0.
C
      DO 31 I=LL,N
      J=I-K
      GO TO (41,42,43,44) M
   41 A=X(J) $ B=Y(I) $ GO TO 45
   42 A=Y(J) $ B=X(I) $ GO TO 45
   43 A=X(J) $ B=X(I) $ GO TO 45
   44 A=Y(J) $ B=Y(I)
   45 SA=SA+A*B $ SB=SB+A $ SC=SC+B $ SD=SD+A**2
   31 SE=SE+B**2
      NUM = ND*SA-SB*SC
      DNOM = SQRTF((ND*SD-SB**2)*(ND*SE-SC**2))
      PRINT 10, NUM, DNOM
      CORCF = NUM/DNOM
   10 FORMAT (83X*COEFFICENT =*E15.6*/*E15.6)
      END
```

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```
      SUBROUTINE TPHILO (Z, NPT, KOUNTL, KOUNTH, KPLZL, KPLZH)
C     KMD 2 JAN  1968
C        MOD    2  APRIL 1968    KMD
C     THIS SUBROUTINE SETS EXTRAINIOUS POINTS TO PREVIOUS POINT
      DIMENSION Z(NPT), KPLZL(100), KPLZH(100)
      KOUNTH = 0   $   KOUNTL = 0
      DO 34  I=1,NPT
      IF (Z(I) .LT. -90.0 .OR. Z(I) .GT. -35.0)  GOTO  34
      Z(1) = Z(I)
      IF (I .EQ. 1)                      GOTO 24
      IF (Z(I) .LT. -90.0)               GOTO  14
      KPLZH(1) = I   $   KOUNTH = 1   $   GOTO 24
   14 KPLZL(1) = I   $   KOUNTL = 1
      GOTO  24
   34 CONTINUE
C
   24 CONTINUE
C
      DO 35  I=2,NPT
      IF (Z(I) .LT. -90.0)               GOTO  22
      IF (Z(I) .GT. -35.0)               GOTO  20
      GOTO  35
C
   20 Z(I) = Z(I-1)
      KOUNTH = KOUNTH + 1
      IF (KOUNTH .LE. 100)  KPLZH(KOUNTH) = I
      GOTO  35
C
   22 Z(I) = Z(I-1)
      KOUNTL = KOUNTL + 1
      IF (KOUNTL .LE. 100)  KPLZL(KOUNTL) = I
   35 CONTINUE
C
      END
```

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```
      SUBROUTINE TPHANDLE(I,MODE)
C     HPC 19 JULY 1967  ,MOD 24 AUG 1967
C
C     ADVANCES TAPE ON UNIT I TO GIVEN FILENO AND RECNO
C     CALLS MUST BE MADE TO AN INCREASING SEQUENCE OF RECORDS
C
      COMMON/A/POSNFL(5),POSNRC(5),FILENO,RECNO,STORE(8)
      TYPE INTEGER FILENO,RECNO,SKIPFL,SKIPRC,POSNFL,POSNRC,STORE
C
      DATA((POSNFL(K),K=1,5)=5(1)),((POSNRC(K),K=1,5)=5(1))
C
C
C
      SKIPFL=FILENO-POSNFL(I)
      IF(SKIPFL)                          31,32,33
   32 SKIPRC=RECNO-POSNRC(I)
      IF(SKIPRC)                          31,43,43
C
   43 DO 45 J=1,SKIPRC
      BUFFER IN(I,MODE)(STORE,STORE(8))
   42 IF(UNIT,I)                          42,45,67,45
   45 POSNRC(I)=POSNRC(I)+1
      GO TO 57
C
C
   33 POSNRC(I)=1
      DO 47 J=1,SKIPFL
      CALL SKIPFILE(I)
   47 POSNFL(I)=POSNFL(I)+1
      SKIPRC=RECNO-1
      IF(SKIPRC)                          31,53,53
C
   53 DO 55 J=1,SKIPRC
      BUFFER IN(I,MODE)(STORE,STORE(8))
   52 IF(UNIT,I)                          52,55,67,55
   55 POSNRC(I)=POSNRC(I)+1
C
C
   57 RETURN
C
   31 PRINT 1,FILENO,RECNO,I                $  STOP
   67 PRINT 5,FILENO,RECNO,I                $  STOP
C
C
    1 FORMAT(*1FILENO=*I3,*   RECNO=*I3,*   ERROR IN REQUEST TO TPHANDLE
     C ON UNIT*I3)
    5 FORMAT(*1FILENO=*I3,*   RECNO=*I3,*   EOF ON UNIT*I3,
     C*   REF BY TPHANDLE*)
C
C
      END
```

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```
      SUBROUTINE TPREAD(I,MODE,N,NP)
C     HPC  20 JULY 1967
C        MOD  12  JUNE  1968    KMD
C
C
      COMMON/A/POSNFL(5),POSNRC(5),FILENO,RECNO,STORE(8)
      COMMON/B/A(4100),KPLXH(100),KPLXL(100),KPLYH(100),KPLYL(100),
     1INT(6,1000), NNF
      EQUIVALENCE (A,INT)
      TYPE INTEGER A,POSNFL,POSNRC,FILENO,RECNO
C
      NP = 0
C
      BUFFER IN (I,MODE)(A,A(N))  $  POSNRC(I)=POSNRC(I)+1
   13 IF(UNIT,I)                          13, 15, 17, 19
   15 RETURN
   17 PRINT 5,FILENO,RECNO,I                $  STOP
   19 PRINT 6,FILENO,RECNO,I                $   NP = 1
C
    5 FORMAT(*1FILENO=*I3,*   RECNO=*I3,*   EOF ON UNIT*I3,
     C*   REF BY TPREAD*)
    6 FORMAT(*1FILENO=*I3,*   RECNO=*I3,*   PARITY ERROR ON UNIT*I3,
     C*   REF BY TPREAD*)
C
C
      END
```

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```
      SUBROUTINE SQRT(X, NO)                                    SQRT   1
C     M1 UCSD SQRT                                                 F 63
C        MOD  19 MARCH 1968     KMD
      DIMENSION X(NO)
      MO=NO                                                     SQRT   5
    2 IF(MO-15)21,21,23                                         SQRT   6
   21 IF(MO-1)9,9,22                                            SQRT   7
   22 MO=2*(MO/4)+1                                             SQRT   8
      GO TO 24                                                  SQRT   9
   23 MO=2*(MO/8)+1                                             SQRT  10
   24 KO=NO-MO                                                  SQRT  11
      JO=1                                                      SQRT  12
   25 I=JO                                                      SQRT  13
   26 IF(X(I)-X(I+MO))28,28,27                                  SQRT  14
   27 TEMP=X(I)                                                 SQRT  15
 2701 X(I)=X(I+MO)                                              SQRT  16
 2702 X(I+MO)=TEMP                                              SQRT  17
      I=I-MO                                                    SQRT  21
      IF(I-1)28,26,26                                           SQRT  22
   28 JO=JO+1                                                   SQRT  23
      IF(JO-KO)25,25,2                                          SQRT  24
    9 RETURN                                                    SQRT  25
      END                                                       SQRT  26
```

ALTOCORRELATION COEFFICIENTS ----------

SAMPLE LENGTH = 16400 POINTS OR 328.000 (SEC)

POINT OFF-SET	NUMBER OF POINTS	TIME OFF-SET (SEC)	CHANNEL 1	CHANNEL 2		
25	16375	0.500		0.723	COEFFICENT = 2.073705+009/	2.866875+009
175	16225	3.500		0.296	COEFFICENT = 8.371478+008/	2.823575+009
275	16125	5.500		0.134	COEFFICENT = 3.734650+008/	2.784578+009
325	16075	6.500		0.081	COEFFICENT = 2.235262+008/	2.772329+009
375	16025	7.500		0.028	COEFFICENT = 7.602669+007/	2.761571+009
425	15975	8.500		-0.036	COEFFICENT = -9.841190+007/	2.749894+009
475	15925	9.500		-0.053	COEFFICENT = -1.450345+008/	2.733755+009
550	15850	11.000		-0.055	COEFFICENT = -1.487340+008/	2.714321+009
600	15800	12.000		-0.087	COEFFICENT = -2.362444+008/	2.703988+009
650	15750	13.000		-0.115	COEFFICENT = -3.094321+008/	2.680082+009
700	15700	14.000		-0.094	COEFFICENT = -2.521956+008/	2.669301+009
750	15650	15.000		-0.115	COEFFICENT = -3.041706+008/	2.642871+009
800	15600	16.000		-0.147	COEFFICENT = -3.848595+008/	2.626156+009
850	15550	17.000		-0.155	COEFFICENT = -4.047057+008/	2.617180+009
1050	15350	21.000		-0.171	COEFFICENT = -4.374069+008/	2.552222+009
1100	15300	22.000		-0.155	COEFFICENT = -3.905279+008/	2.526679+009
1150	15250	23.000		-0.117	COEFFICENT = -2.940184+008/	2.503182+009
1200	15200	24.000		-0.151	COEFFICENT = -3.730920+008/	2.477631+009
1300	15100	26.000		-0.094	COEFFICENT = -2.277850+008/	2.435433+009
1350	15050	27.000		-0.093	COEFFICENT = -2.259473+008/	2.417628+009
1400	15000	28.000		-0.013	COEFFICENT = -3.172195+007/	2.406143+009
1450	14950	29.000		0.019	COEFFICENT = 4.464066+007/	2.381393+009
1550	14850	31.000		0.025	COEFFICENT = 5.889229+007/	2.342497+009

CALIBRATED TAPE 974
FILE NUMBER 1
SAMPLE NUMBER = 270
SAMPLING RATE = 50.000 SAMPLES PER SECOND
NUMBER OF POINTS USED = 16400 PER CHANNEL

CUMULATIVE FREQUENCY DISTRIBUTION ----- CHANNEL 2

SAMPLE LENGTH = 16400 POINTS OR 328.000 (SEC)

INCREMENT = 0.5 (DB)

NUMBER POINTS BELOW LEVEL	ABSOLUTE SIGNAL LEVEL (DBM)	PRECENT POINTS BELOW LEVEL	LEVEL FROM MEDIAN (DB)
1	-63.50	0.00610	-13.76
3	-63.00	0.01829	-13.26
11	-62.50	0.06707	-12.76
22	-62.00	0.13415	-12.26
28	-61.50	0.17073	-11.76
38	-61.00	0.23171	-11.26
59	-60.50	0.35976	-10.76
90	-60.00	0.54878	-10.26
109	-59.50	0.66463	-9.76
146	-59.00	0.89024	-9.26
194	-58.50	1.18293	-8.76
257	-58.00	1.56707	-8.26
338	-57.50	2.06098	-7.76
434	-57.00	2.64634	-7.26
564	-56.50	3.43902	-6.76
668	-56.00	4.07317	-6.26
828	-55.50	5.04878	-5.76
1101	-55.00	6.71341	-5.26
1364	-54.50	8.31707	-4.76
1838	-54.00	11.20732	-4.26
2294	-53.50	13.98780	-3.76
2904	-53.00	17.70732	-3.26
3468	-52.50	21.14634	-2.76
4172	-52.00	25.43902	-2.26
5061	-51.50	30.85976	-1.76
5977	-51.00	36.44512	-1.26
6832	-50.50	41.65854	-0.76
7704	-50.00	46.97561	-0.26
8666	-49.50	52.84146	0.24
9639	-49.00	58.77439	0.74
10458	-48.50	63.76829	1.24
11194	-48.00	68.25610	1.74
12159	-47.50	74.14024	2.24
12974	-47.00	79.10976	2.74
13941	-46.50	85.00610	3.24
14637	-46.00	89.25000	3.74
15219	-45.50	92.79878	4.24
15663	-45.00	95.50610	4.74
15997	-44.50	97.54268	5.24
16232	-44.00	98.97561	5.74
16353	-43.50	99.71341	6.24
16383	-43.00	99.89634	6.74
16399	-42.50	99.99390	7.24
16400	-42.00	100.00000	7.74

LOW = -63.82 LOTEN = -54.21 MEAN = -49.94 STANDARD DEVIATION = 3.27
HIGH = -42.49 UPTEN = -45.89 MEDIAN = -49.74

NUMBER POINTS BELOW INTERVAL	FADE DURATION (SEC)	PERCENT OF FADES ABOVE DURATION	PERCENT OF TIME BELOW	PERCENT OF TIME ABOVE	NUMBER POINTS ABOVE INTERVAL
15	0.02000	90.44586	0.09146	0.00000	157
24	0.04000	84.71338	0.20122	0.09146	142
25	0.06000	84.07643	0.21951	0.20122	133

26	0.08000	83.43949	0,24390	0.21951	132
35	0.10000	77.70701	0,51829	0.24390	131
37	0.12000	76.43312	0,59146	0.51829	122
44	0.14000	71.97452	0,89024	0.59146	120
47	0.16000	70.06369	1,03659	0.89024	113
56	0.18000	64.33121	1,53049	1.03659	110
57	0.20000	63.69427	1,59146	1.53049	101
61	0.22000	61.14650	1,85976	1.59146	100
63	0.24000	59.87261	2,00610	1.85976	96
65	0.26000	58.59873	2,16463	2.00610	94
69	0.30000	56.05096	2,53049	2.16463	92
73	0.32000	53.50318	2,92073	2.53049	88
75	0.34000	52.22930	3,12805	2.92073	84
76	0.36000	51.59236	3,23780	3.12805	82
80	0.38000	49.04459	3,70122	3.23780	81
83	0.42000	47.13376	4,08537	3 70122	77
84	0.44000	46.49682	4,21951	4.08537	74
85	0.48000	45.85987	4,36585	4.21951	73
88	0.50000	43.94904	4,82317	4.36585	72
90	0.54000	42.67516	5,15244	4.82317	69
91	0.56000	42.03822	5.32317	5.15244	67
92	0.58000	41.40127	5,50000	5.32317	66
93	0.60000	40.76433	5.68293	5.50000	65
94	0.62000	40.12739	5,87195	5.68293	64
97	0.64000	38.21656	6,45732	5,87195	63
98	0.66000	37.57962	6,65854	6.45732	60
102	0.68000	35.03185	7,48780	6.65854	59
103	0.70000	34.39490	7,70122	7.48780	55
105	0.76000	33.12102	8,16463	7.70122	54
106	0.80000	32.48408	8,40854	8.16463	52
107	0.82000	31.84713	8,65854	8.40854	51
109	0.84000	30.57325	9,17073	8.65854	50
110	0.90000	29.93631	9,44512	9.17073	48
114	0.98000	27.38854	10,64024	9.44512	47
115	1.00000	26.75159	10,94512	10.64024	43
116	1.02000	26.11465	11.25610	10.94512	42
117	1.20000	25.47771	11,62195	11.25610	41
118	1.26000	24.84076	12,00610	11.62195	40
119	1.34000	24.20382	12,41463	12.00610	39
120	1.36000	23.56688	12,82927	12.41463	38
121	1.44000	22.92994	13,26829	12.82927	37
122	1.52000	22.29299	13,73171	13.26829	36
123	1.56000	21.65605	14,20732	13.73171	35
125	1.58000	20.38217	15,17073	14.20732	34
126	1.66000	19.74522	15,67683	15.17073	32
127	1.70000	19.10828	16,19512	15.67683	31
128	1.76000	18.47134	16,73171	16.19512	30
129	1.90000	17.83439	17,31098	16.73171	29
130	1.94000	17.19745	17,90244	17.31098	28
131	2.18000	16.56051	18,56707	17.90244	27
132	2.22000	15.92357	19,24390	18.56707	26
133	2.30000	15.28662	19,94512	19.24390	25
134	2.36000	14.64968	20,66463	19.94512	24
135	2.44000	14.01274	21,40854	20.66463	23
136	2.46000	13.37580	22,15854	21.40854	22
137	2.48000	12.73885	22,91463	22.15854	21
138	2.50000	12.10191	23,67683	22.91463	20
139	2.76000	11 46497	24,51829	23.67683	19
140	2.80000	10.82803	25,37195	24.51829	18
141	2.84000	10.19108	26,23780	25.37195	17
142	2.86000	9.55414	27,10976	26.23780	16
143	2.88000	8.91720	27,98780	27.10976	15
144	3.18000	8.28025	28,95732	27.98780	14
145	3.32000	7.64331	29,96951	28.95732	13
146	3.60000	7.00637	31,06707	29.96951	12
147	3.92000	6.36943	32,26220	31.06707	11
148	3.96000	5.73248	33,46951	32.26220	10
149	4.10000	5.09554	34,71951	33.46951	9
150	4.54000	4.45860	36,10366	34.71951	8
151	4.58000	3.82166	37,50000	36.10366	7
152	4.62000	3.18471	38,90854	37.50000	6
153	4.78000	2.54777	40,36585	38.90854	5
155	6.04000	1.27389	44,04878	40.36585	4
156	9.88000	0.63694	47,06098	44.04878	2
157	10.28000	0.00000	50,19512	47.06098	1

CUMULATIVE DISTRIBUTION OF FADE DURATIONS ----- CHANNEL 2

-5.00 DB LEVEL

NUMBER OF POINTS = 90

NUMBER POINTS BELOW INTERVAL	FADE DURATION (SEC)	PERCENT OF FADES ABOVE DURATION	PERCENT OF TIME BELOW	PERCENT OF TIME ABOVE	NUMBER POINTS ABOVE INTERVAL
9	0.02000	90.00000	0.05488	0.00000	90
14	0.04000	84.44444	0.11585	0.05488	81
18	0.06000	80.00000	0.18902	0.11585	76
26	0.08000	71.11111	0.38415	0.18902	72
31	0.10000	65.55556	0.53659	0.38415	64
33	0.12000	63.33333	0.60976	0.53659	59
37	0.14000	58.88889	0.78049	0.60976	57
44	0.16000	51.11111	1.12195	0.78049	53
48	0.18000	46.66667	1.34146	1.12195	46
51	0.20000	43.33333	1.52439	1.34146	42
54	0.22000	40.00000	1.72561	1.52439	39
55	0.24000	38.88889	1.79878	1.72561	36
57	0.26000	36.66667	1.95732	1.79878	35
59	0.28000	34.44444	2.12805	1.95732	33
60	0.30000	33.33333	2.21951	2.12805	31
65	0.32000	27.77778	2.70732	2.21951	30
67	0.34000	25.55556	2.91463	2.70732	25
68	0.36000	24.44444	3.02439	2.91463	23
70	0.38000	22.22222	3.25610	3.02439	22
72	0.42000	20.00000	3.51220	3.25610	20
73	0.44000	18.88889	3.64634	3.51220	18
75	0.48000	16.66667	3.93902	3.64634	17
76	0.50000	15.55556	4.09146	3.93902	15
78	0.54000	13.33333	4.42073	4.09146	14
80	0.62000	11.11111	4.79878	4.42073	12
81	0.66000	10.00000	5.00000	4.79878	10
83	0.76000	7.77778	5.46341	5.00000	9
84	0.82000	6.66667	5.71341	5.46341	7
86	0.84000	4.44444	6.22561	5.71341	6
87	0.86000	3.33333	6.48780	6.22561	4
88	0.90000	2.22222	6.76220	6.48780	3
89	0.96000	1.11111	7.05488	6.76220	2
90	1.02000	0.00000	7.36585	7.05488	1

CUMULATIVE DISTRIBUTION OF FADE DURATIONS ----- CHANNEL 2

-10.00 DB LEVEL

NUMBER OF POINTS = 9

LIST OF FADE DURATIONS (SEC) ----- SORTED
0.02000 0.08000 0.08000 0.10000 0.10000 0.26000 0.38000 0.40000
0.58000

NUMBER POINTS BELOW INTERVAL	FADE DURATION (SEC)	PERCENT OF FADES ABOVE DURATION	PERCENT OF TIME BELOW	PERCENT OF TIME ABOVE	NUMBER POINTS ABOVE INTERVAL
1	0.02000	88.88889	0.00610	0.00000	9
3	0.08000	66.66667	0.05488	0.00610	8
5	0.10000	44.44444	0.11585	0.05488	6
6	0.26000	33.33333	0.19512	0.11585	4
7	0.38000	22.22222	0.31098	0.19512	3
8	0.40000	11.11111	0.43293	0.31098	2
9	0.58000	0.00000	0.60976	0.43293	1

CALIBRATED TAPE 974
FILE NUMBER 1
SAMPLE NUMBER = 270
SAMPLING RATE = 50.000 SAMPLES PER SECOND
NUMBER OF POINTS USED = 16400 PER CHANNEL

CUMULATIVE FREQUENCY DISTRIBUTION ----- CHANNEL 2A-JOINT

POINT OFF-SET = 175
NUMBER OF POINTS USED = 16225
OFF-SET TIME = 3.500 (SEC)

SAMPLE LENGTH = 16225 POINTS OR 328.000 (SEC)

INCREMENT = 0.5 (DB)

NUMBER POINTS BELOW LEVEL	ABSOLUTE SIGNAL LEVEL (DBM)	PRECENT POINTS BELOW LEVEL	LEVEL FROM MEDIAN (DB)
12	-57.00	0.07396	-8.95
19	-56.50	0.11710	-8.45
32	-56.00	0.19723	-7.95
69	-55.50	0.42527	-7.45
134	-55.00	0.82589	-6.95
196	-54.50	1.20801	-6.45
352	-54.00	2.16949	-5.95
514	-53.50	3.16795	-5.45
822	-53.00	5.06626	-4.95
1153	-52.50	7.10632	-4.45
1600	-52.00	9.86133	-3.95
2297	-51.50	14.15716	-3.45
3032	-51.00	18.68721	-2.95
3810	-50.50	23.48228	-2.45
4550	-50.00	28.04314	-1.95
5444	-49.50	33.55316	-1.45
6417	-49.00	39.55008	-0.95
7322	-48.50	45.12789	-0.45
8201	-48.00	50.54545	0.05
9446	-47.50	58.21880	0.55
10501	-47.00	64.72111	1.05
11852	-46.50	73.04777	1.55
12968	-46.00	79.92604	2.05
13967	-45.50	86.08320	2.55
14806	-45.00	91.25424	3.05
15438	-44.50	95.14946	3.55
15889	-44.00	97.92912	4.05
16131	-43.50	99.42065	4.55
16191	-43.00	99.79045	5.05
16223	-42.50	99.98767	5.55
16225	-42.00	100.00000	6.05

LOW = -57.48 LOTEN = -51.98 MEAN = -48.40 STANDARD DEVIATION = 2.63
HIGH = -42.49 UPTEN = -45.12 MEDIAN = -48.05

CUMULATIVE FREQUENCY DISTRIBUTION ----- CHANNEL 2A-JOINT

POINT OFF-SET = 400
NUMBER OF POINTS USED = 16000
OFF-SET TIME = 8.000 (SEC)

SAMPLE LENGTH = 16000 POINTS OR 328.000 (SEC)

INCREMENT = 0.5 (DB)

NUMBER POINTS BELOW LEVEL	ABSOLUTE SIGNAL LEVEL (DBM)	PRECENT POINTS BELOW LEVEL	LEVEL FROM MEDIAN (DB)
2	-60.50	0.01250	-12.77
6	-60.00	0.03750	-12.27
12	-59.50	0.07500	-11.77
18	-59.00	0.11250	-11.27
25	-58.50	0.15625	-10.77
34	-58.00	0.21250	-10.27
51	-57.50	0.31875	-9.77

64	-57.00	0.40000	-9.27
76	-56.50	0.47500	-8.77
82	-56.00	0.51250	-8.27
96	-55.50	0.60000	-7.77
117	-55.00	0.73125	-7.27
168	-54.50	1.05000	-6.77
247	-54.00	1.54375	-6.27
325	-53.50	2.03125	-5.77
479	-53.00	2.99375	-5.27
689	-52.50	4.30625	-4.77
982	-52.00	6.13750	-4.27
1474	-51.50	9.21250	-3.77
1981	-51.00	12.38125	-3.27
2631	-50.50	16.44375	-2.77
3366	-50.00	21.03750	-2.27
4317	-49.50	26.98125	-1.77
5397	-49.00	33.73125	-1.27
6411	-48.50	40.06875	-0.77
7352	-48.00	45.95000	-0.27
8568	-47.50	53.55000	0.23
9748	-47.00	60.92500	0.73
11402	-46.50	71.26250	1.23
12648	-46.00	79.05000	1.73
13719	-45.50	85.74375	2.23
14553	-45.00	90.95625	2.73
15206	-44.50	95.03750	3.23
15664	-44.00	97.90000	3.73
15906	-43.50	99.41250	4.23
15966	-43.00	99.78750	4.73
15998	-42.50	99.98750	5.23
16000	-42.00	100.00000	5.73

LOW = -60.89 LOTEN = -51.38 MEAN = -48.06 STANDARD DEVIATION = 2.45
HIGH = -42.49 UPTEN = -45.09 MEDIAN = -47.73

CUMULATIVE FREQUENCY DISTRIBUTION ----- CHANNEL 2A-JOINT

POINT OFF-SET = 1000
NUMBER OF POINTS USED = 15400
OFF-SET TIME = 20.000 (SEC)

SAMPLE LENGTH = 15400 POINTS OR 328.000 (SEC)

INCREMENT = 0.5 (DB)

NUMBER POINTS BELOW LEVEL	ABSOLUTE SIGNAL LEVEL (DBM)	PRECENT POINTS BELOW LEVEL	LEVEL FROM MEDIAN (DB)
4	-57.00	0.02597	-9.47
12	-56.50	0.07792	-8.97
14	-56.00	0.09091	-8.47
17	-55.50	0.11039	-7.97
32	-55.00	0.20779	-7.47
73	-54.50	0.47403	-6.97
125	-54.00	0.81169	-6.47
209	-53.50	1.35714	-5.97
340	-53.00	2.20779	-5.47
507	-52.50	3.29221	-4.97
787	-52.00	5.11039	-4.47
1126	-51.50	7.31169	-3.97
1617	-51.00	10.50000	-3.47
2077	-50.50	13.48701	-2.97
2668	-50.00	17.32468	-2.47
3462	-49.50	22.48052	-1.97
4453	-49.00	28.91558	-1.47
5387	-48.50	34.98052	-0.97
6344	-48.00	41.19481	-0.47
7777	-47.50	50.50000	0.03
9048	-47.00	58.75325	0.53
10711	-46.50	69.55195	1.03
12007	-46.00	77.96753	1.53
13114	-45.50	85.15584	2.03
13971	-45.00	90.72078	2.53
14630	-44.50	95.00000	3.03
15091	-44.00	97.99351	3.53
15310	-43.50	99.41558	4.03
15366	-43.00	99.77922	4.53
15398	-42.50	99.98701	5.03
15400	-42.00	100.00000	5.53

LOW = -57.19 LOTEN = -51.08 MEAN = -47.83 STANDARD DEVIATION = 2.28
HIGH = -42.49 UPTEN = -45.06 MEDIAN = -47.53

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J. A. Vignali, K. M. Decker, and R. C. Dodson

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13. ABSTRACT

The short-term fading on an overwater line-of-sight path at 37 GHz has been characterized. Fade depths of 8 db were typical, although fade depths from 3 db to 14 db were observed (measured between the median and the 98% value of the distribution). The fading generally displayed a fast and a slow component with typical average values of about 0.5 fade per second and 1.5 fades per minute. The corresponding average fade durations were 1 sec and 20 sec, respectively.

The importance of the specular reflection from the water surface was clearly evident in the results. The typical value of the specular reflection coefficient was about 0.7, but the extreme values varied from almost 0 to 1. The reflection coefficient of the diffusely scattered component showed less variation and was typically about 0.25.

The use of a 15-db fade margin would be sufficient to maintain the received signal above a desired threshold for at least 98% of the time for every sample of data examined. For effective time diversity operation, a time delay of about 10 sec would likewise be sufficient for every sample examined.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
EHF line-of-sight propagation						
EHF overwater propagation						
Short-term fade statistics						
Extremely high frequencies						
Communications						
Line of sight						
Overwater propagation						
Statistical study						

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Security Classification