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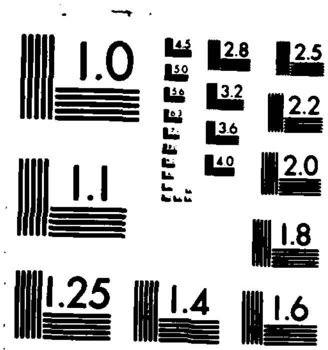

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SUPPORT FOR THE NAVAL RESEARCH LABORATORY PASSIVE MICROWAVE CLUTTER ANALYSIS PROGRAM

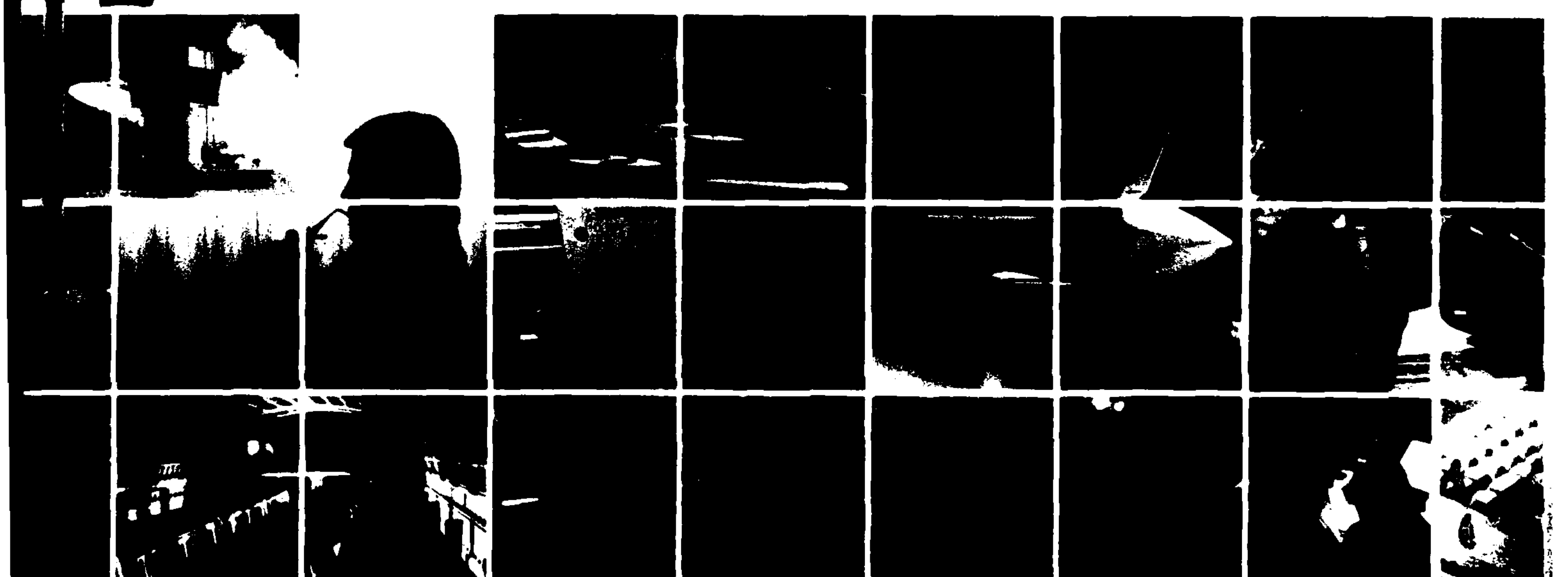
FINAL CONTRACTOR REPORT

AD-A146 771

Prepared for
DEPARTMENT OF THE NAVY
NAVAL RESEARCH LABORATORY
Washington, D.C.

CONTRACT N00014-83-C-2316
Task Assignment 5104

OCTOBER 1984



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October 11, 1984

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Dear Sirs:

Enclosed are 12 copies of the unclassified, unlimited distribution Final Contractor Report required by NRL Contract N00014-83-C-2316.

Yours truly,

R. A. Nieman

R. A. Nieman
Project Manager

RAN:gls

Enclosures (12)

SUPPORT FOR THE NAVAL RESEARCH LABORATORY
PASSIVE MICROWAVE CLUTTER ANALYSIS
PROGRAM - FINAL CONTRACTOR REPORT

Prepared for

THE NAVAL RESEARCH LABORATORY

By

COMPUTER SCIENCES CORPORATION

Under

Contract N00014-83-C-2316
Task Assignment 5104

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ABSTRACT

This document summarizes the data acquisition, reduction, and processing support CSC provided Code 7911 of the Naval Research Laboratory (NRL) under contract N00014-83-C-2316. The support for the NRL Passive Microwave Clutter Program included development of algorithms for processing and analyzing data obtained by a ground-based microwave radiometer observing thermal radiation from various targets. Data reduction and analysis techniques are discussed.

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SECTION 1 - INTRODUCTION

The Computer Sciences Corporation (CSC) supported the Passive Microwave Clutter Analysis Program for Code 7911 (recently reorganized as Code 7780) of the Naval Research Laboratory (NRL) under contract N00014-83-C-2316 from October 1, 1983, to August 31, 1984. This report summarizes the support provided by CSC on this contract.

The objective of the project is to evaluate the amount of clutter rejection required in order to reach instrumental noise limits for target detection in the presense of atmospheric and background clutter with a multiple beam step-stare passive microwave space surveillance system. Data to be analyzed were collected in October and November 1983 and February 1984, using existing 37 gigahertz (GHz) radiometer and data collection equipment. This hardware required little or no modification; it has been described in Reference 1. The clutter data analyzed are comprised of long stares (approximately five minutes in duration) by the radiometer at stationary targets and at the sky. Data obtained during the 1983 observing period were of targets located at NRL. The targets included asphalt, grass, water, metal foil, mirror, and the sky at zenith and the horizon. Data obtained during the 1984 observing period consisted of sky and absorber (enclosure) observations at the Patuxent River Naval Air Test Center (NATC-PAX) near Lexington Park, Maryland. A summary of all observation and calibration data available for the Clutter Analysis project is presented in Table 1-1.

Computer programs for data reduction and analysis were written by CSC personnel to operate on the DECsystem-10 computer at NRL. A summary and brief description of these programs is presented in Table 1-2. The reduction techniques are discussed in Section 2.

The target data have been statistically analyzed to obtain an estimate of temporal instrumentation and background noise levels. Four methods of statistical analysis were utilized: Fourier transformation analysis, auto-correlation analysis, temporal structure analysis, and temperature averaging and differencing. A discussion of data analysis techniques is presented in Section 3.

Finally, the computer programs developed for this project have been documented using standardized procedures. The in-code software documentation is described in Appendix A.

TABLE 1-1 SUMMARY OF AVAILABLE CLUTTER ANALYSIS DATA

DATE OF MEASUREMENT	LOCATION	TAPE#	FILE#	RADIOMETER TARGET	COMMENT
27 October 1983	NRL	1 1	1 2	liquid N_2 and enclosure liquid N_2 and enclosure	37H Lab calibration 37V Lab calibration
31 October 1983	NRL	1 1	1 3	mirror, screen, sky mirror, asphalt, absorber	preliminary measurement to determine T_{BACK} and η
1 November 1983	NRL	1	1	sky, screen mirror	initial calibration and reference measurements
		1	2	mirror, asphalt, enclosure	asphalt target #1; power failure
		2	1	mirror, asphalt, enclosure	continuation of 1st asphalt target
		2	2	mirror, asphalt, enclosure	2nd asphalt run
		3	7	mirror, enclosure	continuation of 2nd asphalt run
		3	8	mirror, asphalt, enclosure	3rd run on asphalt
		4	1	mirror, sky, screen	final calibration and reference measurements
2 November 1983	NRL	1	1	sky, mirror, screen	initial cal & ref measurements
		1	2	mirror, water, enclosure	1st run on water target
		2	1	mirror, water, enclosure	2nd run on water target

TABLE 1-1 SUMMARY OF AVAILABLE CLUTTER ANALYSIS DATA (con'd)

DATE OF MEASUREMENT	LOCATION	TAPE#	FILE#	RADIOMETER TARGET	COMMENT
2 November 1983	NRL	3	1	mirror, water, enclosure	3rd run on water target
		4	1	mirror, woods, enclosure	1st run on wood target
		5	1	mirror, woods, enclosure	2nd run on wood target
		6	1	mirror, woods, enclosure, sky, screen	3rd run on wood target and final ref & cal measurement
3 November 1983	NRL	1	1	sky, screen, mirror, grass, enclosure	initial ref & cal measurements, and 1st run on grass target
		2	1	mirror, grass, enclosure	2nd run on grass
		3	1	mirror, grass, enclosure, sky, screen	3rd run on grass and final ref & cal measurement
4 November 1983	NRL	1	2	sky, horizon	South, West, East Horizon targets
17 November 1983	NRL	1	1	sky, screen, mirror, absorber	initial cal & ref measurement. η determination.
		2	1	sky, screen, mirror, absorber	
		3	1	mirror, asphalt, enclosure	asphalt rerun
		4	1	mirror, asphalt, foil	
		4	2	enclosure, sky	
		5	1	sky, screen, mirror, absorber	final cal & ref measurement. η determination.

TABLE 1-1 SUMMARY OF AVAILABLE CLUTTER ANALYSIS DATA (con'd)

DATE OF MEASUREMENT	LOCATION	TAPE#	FILE#	RADIOMETER TARGET	COMMENT
10 Jaunary 1984	NRL	1	1	antenna	lab test on sampling rate
25 January 1984	NRL	1	1, 2, 3, 4, 5, 6, 7, 8	antenna	lab test on L. P. filters
22 February 1984	NRL	1	1, 2, 3	antenna	lab test on dynamic amplifiers
23 February 1984	NRL	1	1, 2, 3	liquid Nitrogen and enclosure	22 GHz calibration
		2	1, 2, 3	liquid Nitrogen and enclosure	37 GHz calibration
27 February 1984	NATC-PAX	1	1, 2	sky and enclosure	sky runs #1, #2 from file 1
28 February 1984	NATC-PAX	2	1, 2	sky and enclosure	sky runs #3, #4
		3	1	sky, enclosure	sky runs #5
		4	1	sky, enclosure	sky runs #6, #7, #8, #9

TABLE 1-2. FORTRAN SOFTWARE FOR NRL PASSIVE MICROWAVE TEMPORAL CLUTTER PROJECT

PROGRAM	PURPOSE
RADCAL	Obtain calibration data
RADDAT	Convert 1984 raw data into Brightness Temperatures.
RDDAT	Convert 1983 raw data into Brightness Temperatures
RADOUT	DARPA statistical analysis, 1984 Data
RDOUT	DARPA statistical analysis, 1983 Data
RADCO	Calculate calibration coefficients for RADCAL data.
RADADD	Calculates spectral interval power for given range of FFT coefficients
RADAVG	Calculates average sky and enclosure FFT or Temporal Structure spectra from individual data files on tape, normalizes enclosure data, calculates sky contribution and plots using CalComp graphics
RADCOR	Corrects windowed FFT files by multiplying normalization factors
RADNOR	Calculates sky component of clutter data from individual disk files
FFTEST	Test FFT subroutine by using several input spectra with known FFT structures
TPREAD	Copies clutter data files from tape to disk
TPSTOR	Copies clutter data files from disk to tape.
TRANS	Reads mixed format tapes files from RADDAT and generates formatted files of 4096 samples.

SECTION 2 - MICROWAVE TEMPORAL CLUTTER DATA REDUCTION PROGRAMS

CSC has developed the data reduction programs that aided in interpreting and evaluating the 37GHz microwave temporal clutter data. The data acquisition system obtains the raw radiometric data from the microwave sensor; and the reduction programs convert the raw data into brightness temperature data, which are stored on magnetic tape files, and other output products: computer-generated graphic plots, line printer data listings, and disk files. The FORTRAN programs (RADCAL, RADDAT and RDDAT) operate on the NRL DECsystem-10 computer and are discussed below.

2.1 RADCAL DATA REDUCTION PROGRAM

The RADCAL program reduces the laboratory and field experiment 37GHz radiometer calibration data, providing the statistical information representing instrumentation operational and gain setting characteristics. This information is required to calculate the count (raw data)-to-antenna temperature and antenna-to-brightness temperature conversion coefficients. RADCAL produces line printer listings and histograms of the raw analog-to-digital (A/D) converter counts for the radiometer output. It also generates averages and standard deviations of these A/D counts along with the thermistor measurements of ambient and instrumention reference temperatures.

2.2 RADDAT DATA REDUCTION PROGRAM

The RADDAT program performs the actual conversion of A/D counts into antenna temperatures and then into brightness temperatures for a user-specified set of data records from the 1984 observation data sets. RADDAT calculates record scene temperatures using both field experiment and laboratory calibration coefficients calculated in RADCAL. These coefficients, obtained for the beginning and end of the specified record range, are linearly interpolated to obtain a time dependent equation for antenna temperature calculations. It is assumed that brightness temperature equaled the antenna temperature for the 1984 data. Several output products are produced by the program, including histograms and computer-generated graphic plots of brightness temperatures for each data record, and a computer tape containing brightness temperatures, record numbers and timekeeping information.

2.3 RDDAT DATA REDUCTION PROGRAM

The program RDDAT is similar to RADDAT with software changes to enable the input of 1983 target data.

During the 1983 experiment period, the data acquisition system was adjusted to sample and store the radiometer signal at twice the specified sampling rate. The raw data tapes produced during this observing period contained data records with individual samples spaced 0.020 seconds apart instead of the specified rate of sampling every 0.040 seconds. The RDDAT program was modified to input every other sample point to conform to the specified sampling rate. This modification reduced the number of samples per record from 26 to 13, storing on tape one-half the expected number of brightness temperature values for a given record range. Antenna-to-brightness temperature calibration coefficients were calculated for the 1983 data, and used in time dependent linear regression equations to calculate brightness temperatures from the antenna temperature data. In all other aspects, RDDAT is identical to RADDAT.

SECTION 3. - MICROWAVE TEMPORAL CLUTTER DATA ANALYSIS PROGRAMS

Brightness temperature data, reduced from 37GHz microwave radiometer raw data tapes, have been analyzed using a series of computer programs written by CSC. The brightness temperature data have been processed using the computer programs RADOUT for 1984 experimental data; RDOUT for 1983 experimental data; and one or more of the normalization and averaging programs RADADD, RADAVG, RADCOR and RADNOR. These programs are discussed below.

3.1 RADOUT DATA ANALYSIS PROGRAM

The RADOUT analysis program performs the bulk of the microwave brightness temperature temporal clutter data analysis. RADOUT is a modified version of PROOUT (Reference 2), and was written specifically for the temporal clutter project. The operating characteristics of RADOUT along with detailed discussions of the four statistical analysis procedures are presented below.

Magnetic tape data files, generated by the RADDAT computer program, were input data for RADOUT. Any data sets containing a power of two (2^n) elements could be analyzed, but data sets which contained 4096 elements or brightness temperature values were selected for the final data base. A list of the data sets in the data base is presented in Table 3-1. Each data set contained at least 4096 elements. If more than 4096 elements were available, only the first 4096 elements were used for analysis.

The subprogram DARPA is driver for the temporal clutter data analysis, processing the data sets and controlling access to the various statistical analysis modules. Parameters within DARPA must be set by the program user to define data set size, analysis procedure, and output products. Output products from RADOUT included disk and magnetic tape data files, line printer listings, and computer-generated graphic plots. The output products produced depended on which analysis module was accessed.

TABLE 3-1 BRIGHTNESS TEMPERATURE DATA BASE
FOR MICROWAVE TEMPORAL CLUTTER ANALYSIS

DATE	TAPE/FILE	RECORD RANGE	TARGET FILENAME
November 1,1983	3/8	473-1052	Asphalt #1
November 1,1983	3/8	1167-1733	Enclosure #1-83
November 2,1983	1/2	510-1088	Water #1
November 2,1983	2/1	538-1109	Water #2
November 2,1983	3/1	810-1383	Water #3
November 2,1983	4/1	500-1052	Wood #1
November 2,1983	5/1	460-1011	Wood #2
November 2,1983	6/1	432- 984	Wood #3
November 2,1983	2/1	1395-2057	Enclosure #6-83
November 2,1983	4/1	1276-1841	Enclosure #7-83
November 2,1983	6/1	1143-1721	Enclosure #8-83
November 3,1983	1/1	1811-2393	Grass #1
November 3,1983	2/1	670-1240	Grass #2
November 3,1983	3/1	888-1565	Grass #3
November 3,1983	1/1	2586-3155	Enclosure #3-83
November 3,1983	2/1	1486-2096	Enclosure #4-83
November 3,1983	3/1	1826-2368	Enclosure #5-83
November 17,1983	3/1	608-1037	Asphalt #2
November 17,1983	3/1	2388-3058	Enclosure #2-83
February 27,1984	1/1	306- 506	Sky #1A
February 27,1984	1/1	507- 723	Sky #1B
February 27,1984	1/1	851-1011	Enclosure #1
February 27,1984	1/1	1040-1200	Enclosure #2
February 28,1984	2/2	720-1049	Sky #2
February 28,1984	3/1	2272-2473	Sky #3
February 28,1984	4/1	955-1115	Sky #4-1A
February 28,1984	4/1	1116-1276	Sky #4-1B
February 28,1984	4/1	1277-1495	Sky #4-1C
February 28,1984	4/1	1677-1837	Sky #4-2A
February 28,1984	4/1	1838-2052	Sky #4-2B
February 28,1984	4/1	2855-3025	Sky #4-3A
February 28,1984	4/1	3026-3200	Sky #4-3B
February 28,1984	4/1	3535-3715	Sky #4-4A
February 28,1984	4/1	3716-3906	Sky #4-4B
February 28,1984	2/2	300- 460	Enclosure #3
February 28,1984	2/2	452- 612	Enclosure #7
February 28,1984	3/1	2830-2990	Enclosure #4
February 28,1984	3/1	2691-2851	Enclosure #8
February 28,1984	4/1	202- 361	Enclosure #5
February 28,1984	4/1	2475-2635	Enclosure #6

3.1.1 THE FAST FOURIER TRANSFORM ANALYSIS MODULE

Fourier Transformation statistical analysis incorporates a Fast Fourier Transform (FFT) coded into the subroutines FFT and HANN. The FFT algorithm was developed to analyze each 4096-element brightness temperature data set, representing a time series of 163.84 seconds in duration. The FFT algorithm defines the spectrum of this time series, and is similarly structured to the International Mathematical and Statistical Library (IMSL) subroutine, FFTRC. (Reference 3).

The spectrum obtained from the FFT algorithm is representative of a finite section of a infinite time series. Analysis of the background scene based on this finite section introduces erroneous signals or spectral leakage into the FFT spectrum (Reference 4). The spectral leakage results from frequency discontinuities at the boundaries of finite time series. Several schemes have been implemented to filter and reduce the spectral leakage introduced into the data sets during the FFT calculations. These schemes include overlapping correlations and window weighting of the data.

Reduction of spectral leakage can be obtained by multiplying each temperature series by a weighting or filter factor. Two types of filtering were used for this project. The first is a window function called the cosine squared, raised cosine, or Hanning window function. The Hanning window function is defined by Harris (Reference 6):

$$\omega(n) = \left[0.5 \quad 1.0 - \cos\left(\frac{2n \quad \pi}{N}\right) \right] \quad \text{for } n = 0, 1, 2, ..N-1 \tag{3-1}$$

where $\omega(n)$ = Hanning function for element n+1

n = individual element in data time series

N = number of elements in time series

The second window function, the Hamming window, does not reduce the boundary data points to zero as does the Hanning window function. The Hamming window function is defined by Harris (Reference 7):

$$\omega'(n) = 0.54 - 0.46 \left[\cos \left(\frac{2n \quad \pi}{N}\right) \right] \tag{3-2}$$

for n = 0, 1, 2, 3...,N-1 and

where $\omega'(n)$=Hamming function for element n+1 and n and N are as above.

When windowing of data is required, the brightness temperature series are multiplied by either $\omega(n)$ or $\omega'(n)$, producing the weighted brightness temperature $T'_B(n)$:

$$T'_B(n) = T_B(n) \times \omega(n) \text{ or} \qquad (3\text{-}3)$$

$$T'_B(n) = T_B(n) \times \omega'(n) \qquad (3\text{-}4)$$

The overlapping correlation scheme is incorporated to recover time series boundary data lost during window filtering. This procedure is outlined in Harris (Reference 5). The original brightness temperature time series was broken up into several user-designated overlapping subseries. The program user specifies in the subroutine HANN his choice of 0, 3, or 6 overlapping subseries. For example, if the original 4096-element series was divided into three overlapping subseries, the first subseries would contain elements numbered 1-2048, the second subseries would contain elements numbered 1025-3072, and the third would contain elements numbered 2049-4096.

The FFT spectrum is calculated for each overlapping T'_B time series and then averaged. This averaged overlapping filtered power spectrum is plotted versus frequency after a normalization factor is applied to adjust the spectrum amplitude back to its original level (see Section 3.2). Figure 3-1 is an example of a averaged normalized overlapping HANN-filtered FFT power spectrum for a background target.

3.1.2 THE TEMPORAL STRUCTURE FUNCTION ANALYSIS MODULE

The Temporal Structure Function algorithms are executed by accessing the subroutine TSFUNC. The Temporal Structure Function is a method in which the intensity of baseline fluctuations or background clutter can be calculated. The temporal structure D_{T_B} was calculated using the formula from Gagarin and Kutuza (Reference 8).

$$D_{T_B}(t) = \overline{(T_B(t) - T_B(t+\Delta t))^2} \qquad (3\text{-}5)$$

where $D_{T_B}(t)$ = temporal structure coefficient for TIME = Δt

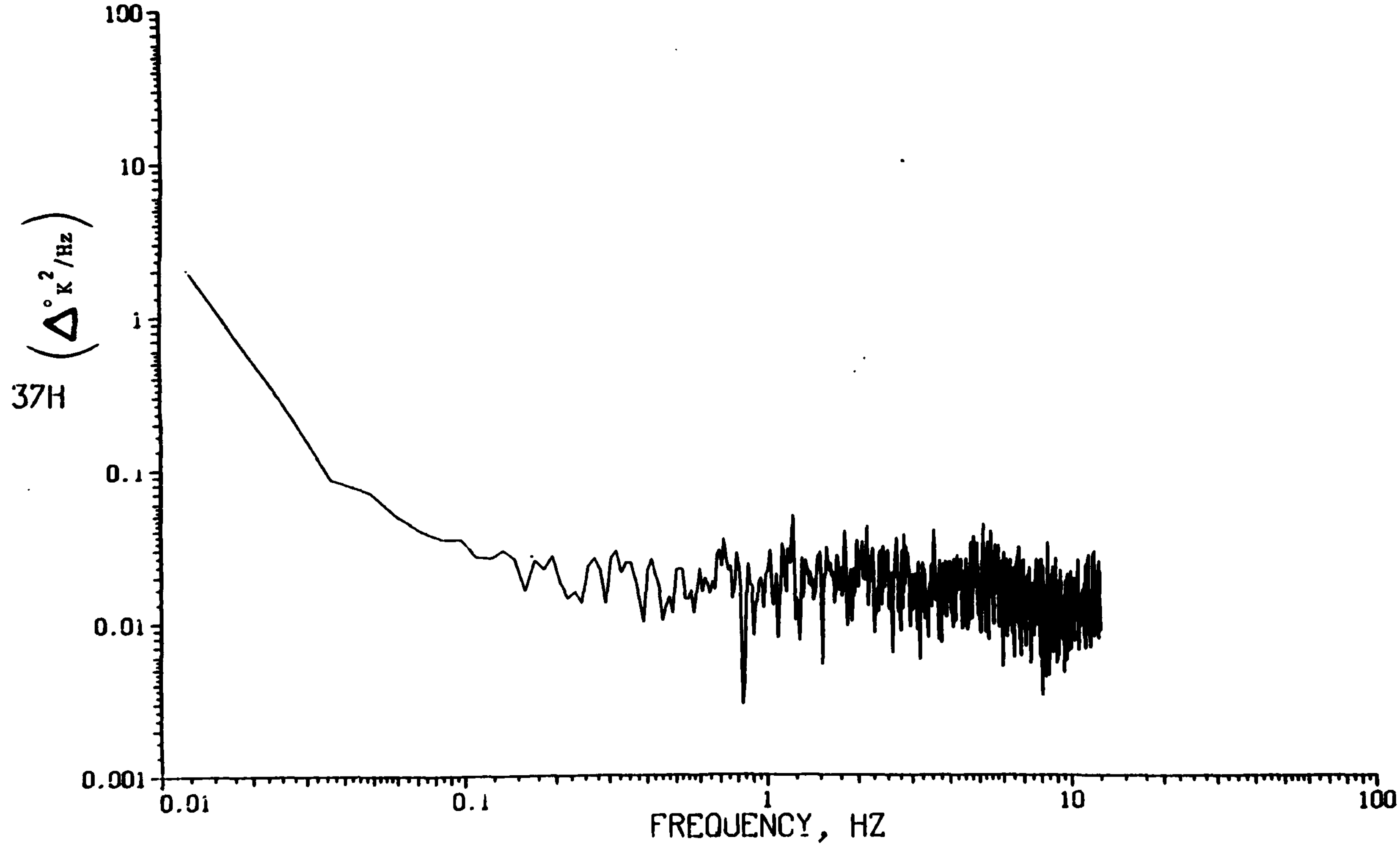
$T_B(t)$ = brightness temperature at time t

$T_B(t+\Delta t)$ = brightness temperature at time $t+\Delta t$

and Δt = increment of time, seconds.

The temporal structure coefficients were calculated to obtain averaged square temperature differences for time differences ranging from 0.040 seconds to 40.96 seconds. The Temporal Structure Function was then graphically plotted versus time. Figure 3-2 shows the temporal structure of a typical background.

FIGURE 3-1 NORMALIZED HANN-WINDOWED AVERAGED GRASS SCENE FFT POWER SPECTRUM FOR 37GHz HORIZONTAL (H) POLARIZATION



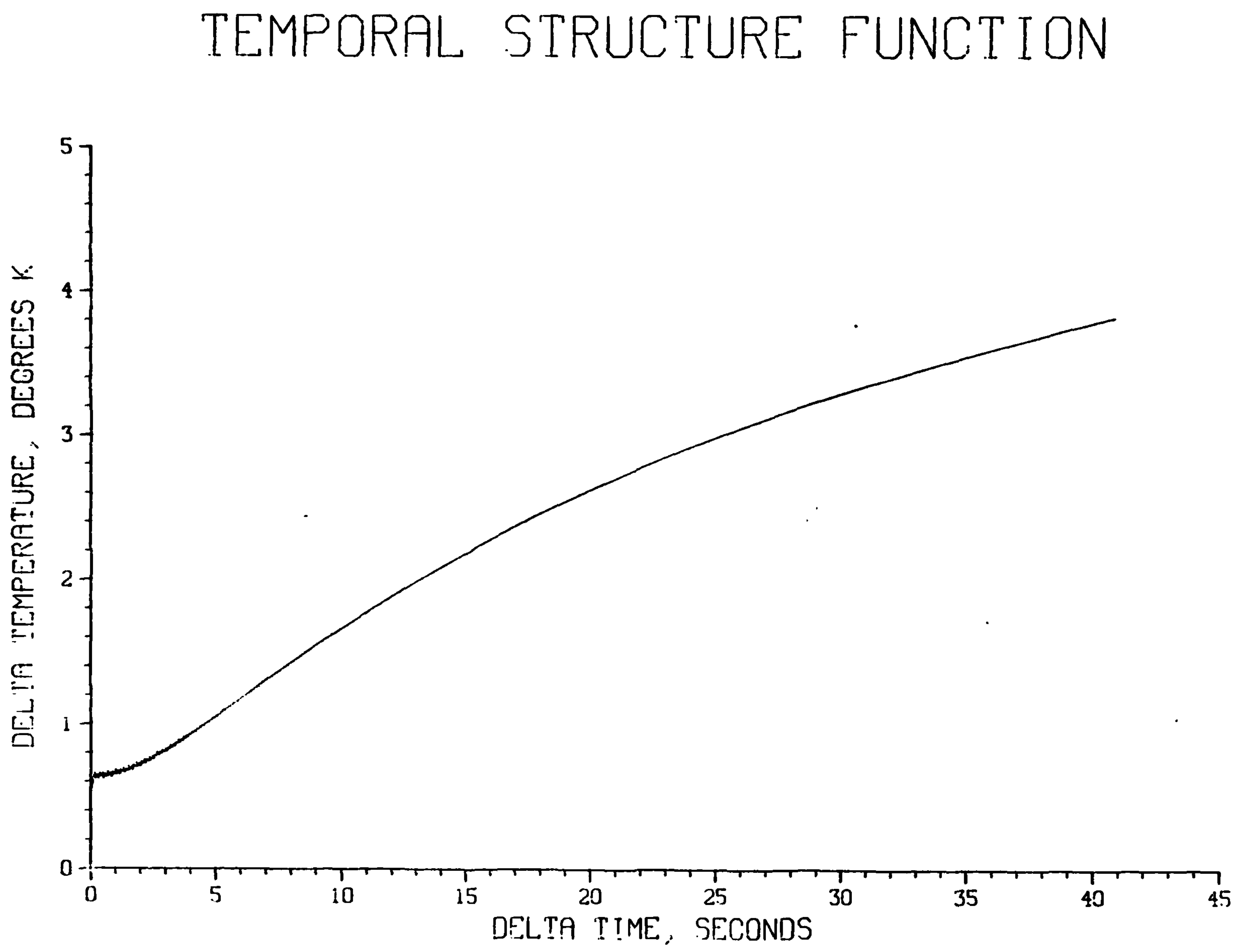


FIGURE 3-2 BACKGROUND SCENE TEMPORAL STRUCTURE VERSUS TIME, $\sqrt{\bar{D}_S}$ VERSUS Δ TIME, WHERE $\bar{D}_S$ = AVERAGED SCENE TEMPORAL STRUCTURE FUNCTION

3.1.3 TEMPERATURE AVERAGING AND DIFFERENCING ANALYSIS MODULE

Temperature averaging and differencing is a statistical method based on an analysis presented by Gagarin and Kutuza (Reference 9). This analysis is initiated by calculating the average brightness temperature and standard deviation for the 4096-element data set. Also, an average temperature difference between adjacent elements and the associated standard deviation are calculated. The second step in this analysis averages adjacent elements together to obtain a new data set comprised of one-half the original number of elements. The averaging and differencing calculations are then performed on the new data set. This scheme is repeated until less than four elements remain to be averaged together. At that point, the results is stored on disk file for line printer output. Table 3-2 is an example of a typical target printout of the averaging and differencing analysis. As shown in the table, the integration time is increased by averaging elements together. The effect of longer integration on the data statistical averages and standard deviations can be analyzed using this method.

3.1.4 AUTO-CORRELATION ANALYSIS MODULE

Auto-correlation is the fourth statistical algorithm in RADOUT accessed by calling the subroutine AUTO. The auto-correlation analysis allows the detection of a known signal in the presense of noise. The technique also helps to analyze background clutter noise characteristics and temporal variations. The auto-correlation algorithm was based on the formula from Clay and Medwin (Reference 10):

$$C_{xx}(k) = \frac{1}{N\sigma_{xx}^2} \sum_{n=0}^{N-k} X_n X_{n+k}$$

where

$C_{xx}(k)$ = auto-correlation coefficient

k = spacing parameter

σ_{xx}^2 = variance of brightness temperatures

N = number of elements in data set

X_n = brightness temperature for element n

X_{n+k} = brightness temperature for element n+k

After the auto-correlation coefficients were calculated for values of k ranging from 1 to N/4, the auto-correlation coefficients were graphically plotted versus time or k. Figure 3-3 represents an auto-correlation analysis with a known signal present. The auto-correlation analysis was not used to analyze the entire data base because it was so time-consuming and costly.

TABLE 3-2

BRIGHTNESS TEMPERATURE ANALYSIS

FOR SAMPLE AVERAGING AND TEMP. DIFFERENCING

# OF SAMPS	TIME PERIOD (SEC)	37H CHANNEL AVG. BRT. TEMP (°K)	37H CHANNEL STD. DEV. (°K)	37H CHANNEL AVG. TEMP DIFF (°K)	37H CHANNEL STD DEV. (°K)	37V CHANNEL AVG. BRT. TEMP (°K)	37V CHANNEL STD. DEV. (°K)	37V CHANNEL AVG. TEMP DIFF (°K)	37V CHANNEL STD. DEV. (°K)
4096	0.040	135.86	0.72	0.00	0.78	161.73	1.29	0.00	2.26
2048	0.080	135.86	0.58	0.00	0.59	161.73	0.61	-0.00	0.76
1024	0.160	135.86	0.49	0.00	0.43	161.73	0.49	-0.00	0.71
512	0.320	135.86	0.44	0.00	0.40	161.73	0.33	-0.00	0.36
256	0.640	135.86	0.40	0.00	0.50	161.73	0.29	-0.00	0.38
128	1.280	135.86	0.31	0.01	0.38	161.73	0.21	-0.00	0.39
64	2.560	135.86	0.12	0.00	0.14	161.73	0.09	0.00	0.11
32	5.120	135.86	0.10	0.01	0.15	161.73	0.08	0.00	0.11
16	10.240	135.86	0.07	0.01	0.09	161.73	0.05	0.00	0.08
8	20.480	135.86	0.06	0.03	0.05	161.73	0.03	0.00	0.04
4	40.960	135.86	0.05	0.03	0.04	161.73	0.04	0.02	0.05

AUTO-CORRELATION 3 NOV. 1983 TAPE 1 FILE 1

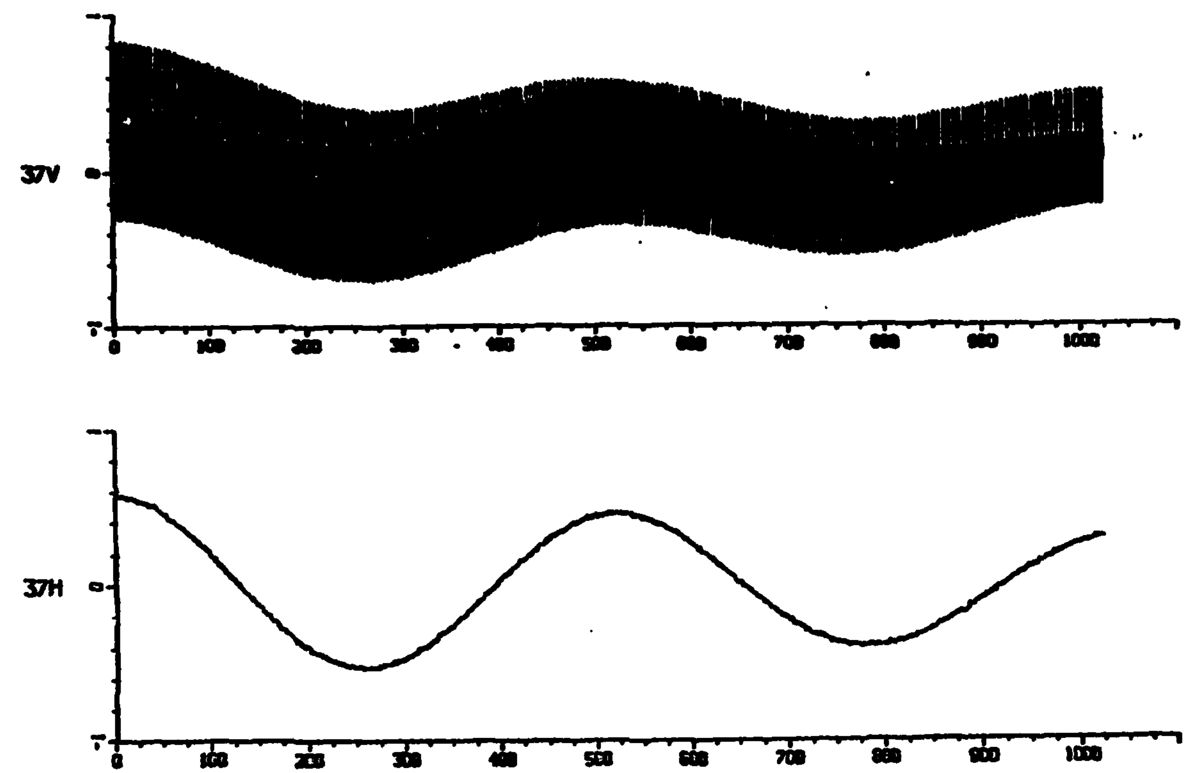


FIGURE 3-3 AUTO-CORRELATION GRAPH: AUTO-CORRELATION OF A KNOWN SIGNAL VERSUS RECORD NUMBER FOR 37 GHz (HORIZONTAL AND VERTICAL POLARIZATION). A CORRELATION OF ± 1 REPRESENTS PERFECT CORRELATION.

3.2 RDOUT DATA ANALYSIS PROGRAM

The RDOUT computer program is a modified version of RADOUT; RDOUT was developed to accept data tapes generated from the RDDAT program. As stated in Section 2, all data collected during the 1983 experiments must be separately processed because there are 13 samples per record instead of the standard 26 samples per record. All statistical analysis modules in RDOUT are identical to those in the RADOUT modules.

3.3 AVERAGING AND NORMALIZATION PROGRAMS

The analysis programs (RADADD, RADAVG, RADCOR, and RADNOR) were written by CSC to analyze FFT and temporal structure data generated by the RADOUT and RDOUT programs. The Data Normalization, Averaging, and Differencing (DNAD) procedure utilized these programs to perform the following tasks:

- Average together similar background target data sets
- Average horizontal (H) and vertical (V) polarization data together (1984 data only)
- Normalize associated enclosure data
- Subtract normalized enclosure data from the target data sets to obtain a differenced target data set

Enclosure data were normalized to compensate for temperature variations between the target scene and the enclosure absorber.

The target or background scene data is comprised of two temporal clutter components: the target temporal clutter and instrumental noise temporal clutter. Instrumental noise temporal clutter is identified from the normalized enclosure data. Target temporal clutter can be calculated by subtracting the normalized enclosure data from the original target scene data. Target Scene data sets used in the DNAD procedure are listed in Table 3-3. Representative FFT spectra processed through DNAD are graphically illustrated in Figures 3-1, 3-4, and 3-5. Figure 3-1 illustrates a FFT spectrum of an average target scene which was fully processed enclosure associated with the target scene Figure 3-1. Figure 3-5 graphically displays the difference spectrum between Figure 3-1 and 3-4. This FFT spectrum represents the target temporal clutter contribution of background noise.

The processing procedure for the temporal structure data was similar to that for the FFT data with an additional step. The target clutter component temporal structure array was divided by the normalized target clutter component temporal structure array. This additional step pinpoints the time lag necessary for background target noise to dominate instrumentation noise. If the amplitude of the temporal structure curve was greater than 1, target temporal clutter dominated. When the temporal structure curve amplitude was less than 1, instrumental noise was dominant.

The fully processed temporal structure arrays are graphically plotted versus time between samples. Figure 3-2 illustrates an averaged target scene temporal structure signature. Figure 3-6 illustrates the enclosure temporal structure, and the difference or target component temporal structure signature is displayed in Figure 3-7. The temporal structure for the normalized target clutter component is illustrated in Figure 3-8. As shown in Figure 3-8, target clutter or background noise dominate the measurement for sample lag times greater than approxiately 3 seconds. For lag times less than 3 seconds, instrumental noise dominates the target clutter.

TABLE 3-3
BRIGHTNESS TEMPERATURE DATA SETS USED FOR TARGET AVERAGING

AVERAGE FILE NAME	TARGETS AVERAGED
Asphalt	Asphalt #1; November 1, 1983 Asphalt #2; November 17, 1983
Water	Water #1, #2, 3; November 2, 1983
Wood	Wood #1, #2, #3; November 2, 1983
Grass	Grass #1, #2, #3; November 3, 1983
Enclosure83A	Enclosure #1-83; November 1, 1983 Enclosure #2-83; November 17, 1983
Enclosure83B	Enclosure #6-83; #7-83, #8-83 November 2, 1983
Enclosure83C	Enclosure #3-83, #4-83, #5-83; November 3, 1983
Sky Feb.27	Sky #1A, #1B; February 27, 1984
Sky Feb.28A	Sky #4-1A, #4-1B, #4-1C, #4-2A, #4-2B, #4-3A, #4-3B, #4-4A; February 28, 1984
Enclosure84A	Enclosure #1, #2; February 27, 1984
Enclosure84B	Enclosure #1, #2; February 27, 1984 Enclosure #3, #4, #5, #6, #7, #8; February 28, 1984

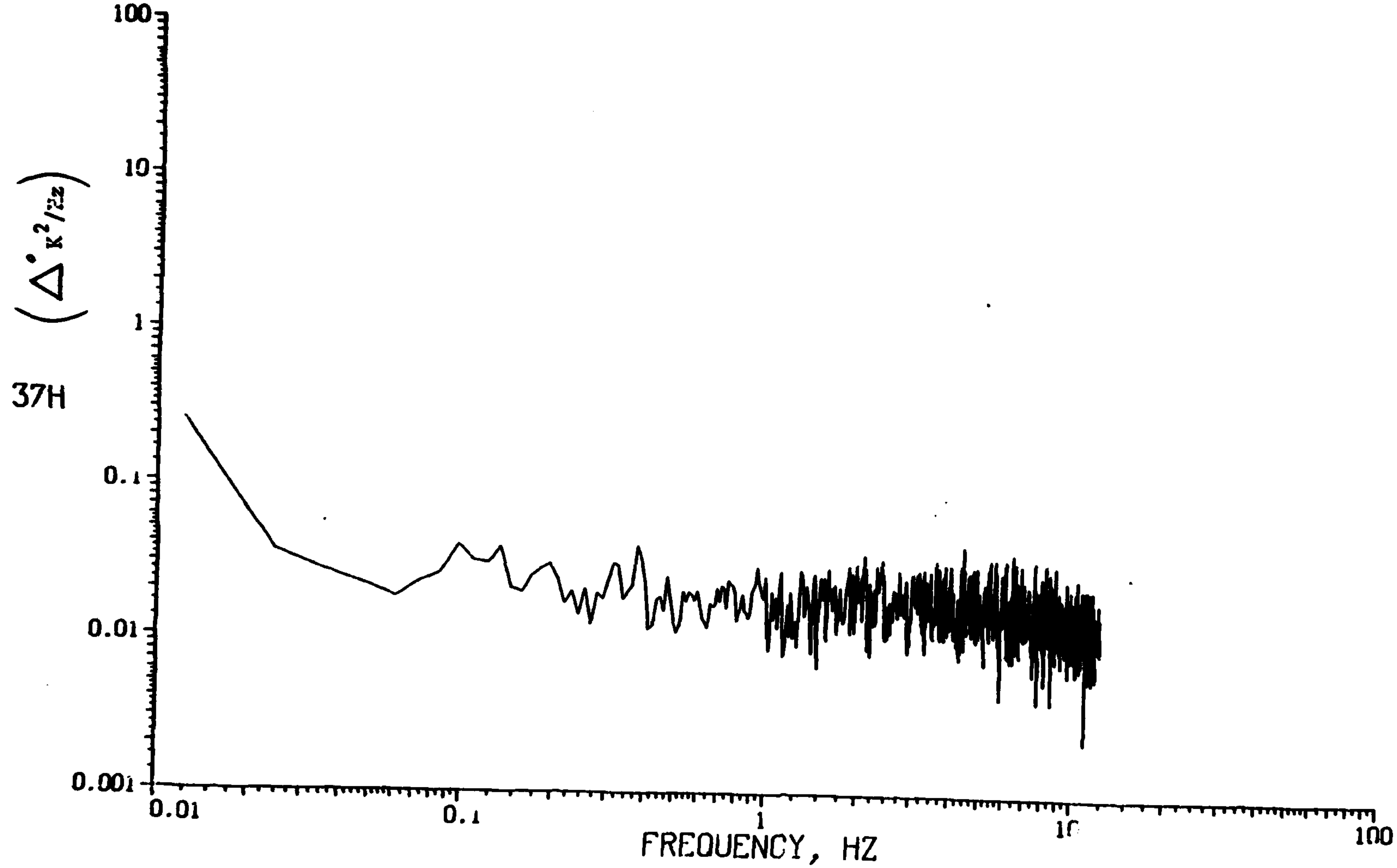


FIGURE 3-4 NORMALIZED HANN-WINDOWED ENCLOSURE FFT POWER SPECTRUM 37GHz H-POLARIZATION ENCLOSURE SIGNATURE.

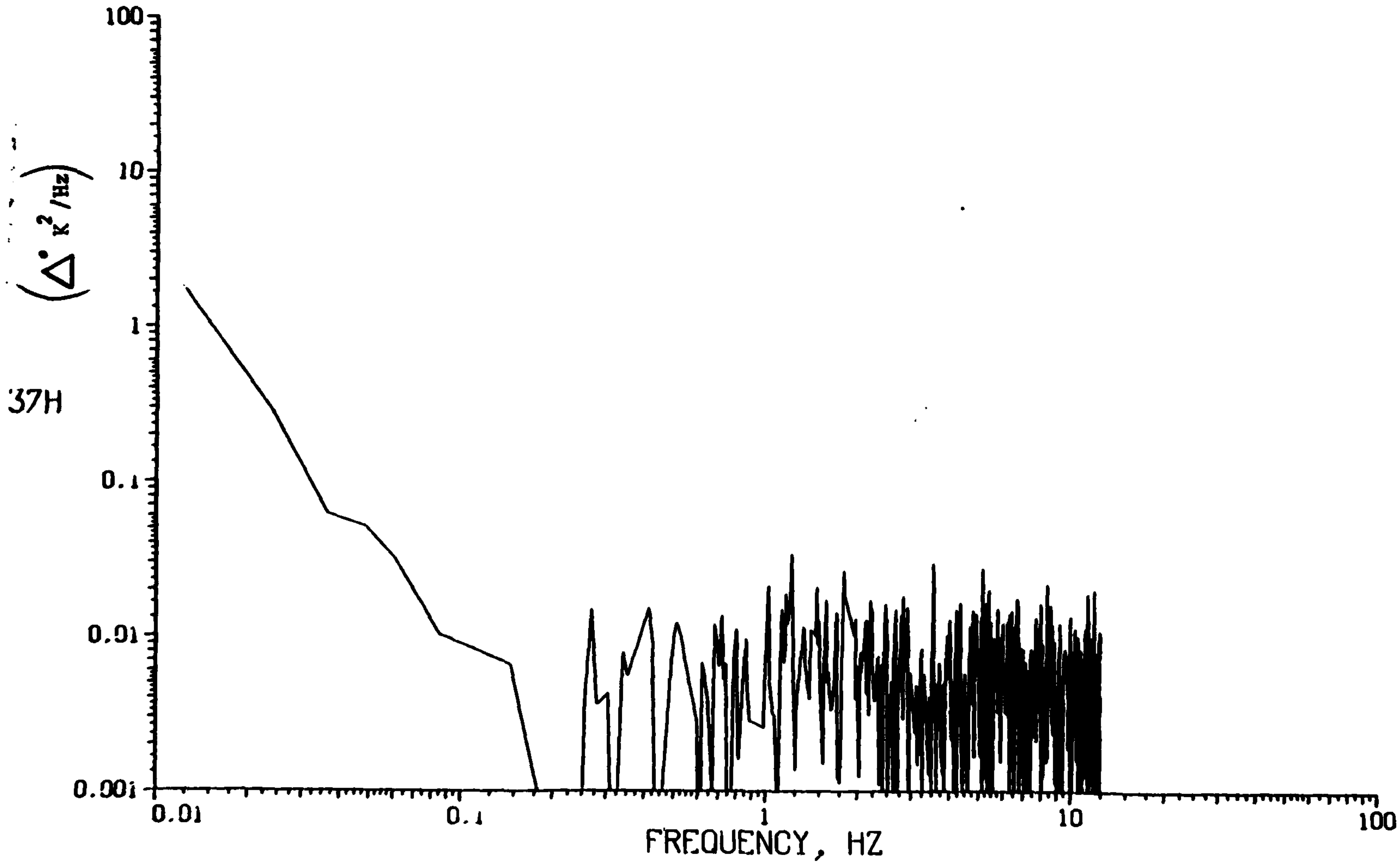


FIGURE 3-5 TARGET DIFFERENCED HANN-WINDOWED FFT POWER SPECTRUM FOR 37GHz, H-POLARIZATION: THIS FIGURE SHOWS THE GRASS BACKGROUND CONTRIBUTION TO THE FFT SPECTRUM. (GRASS - NORM. ENCLOSURE)

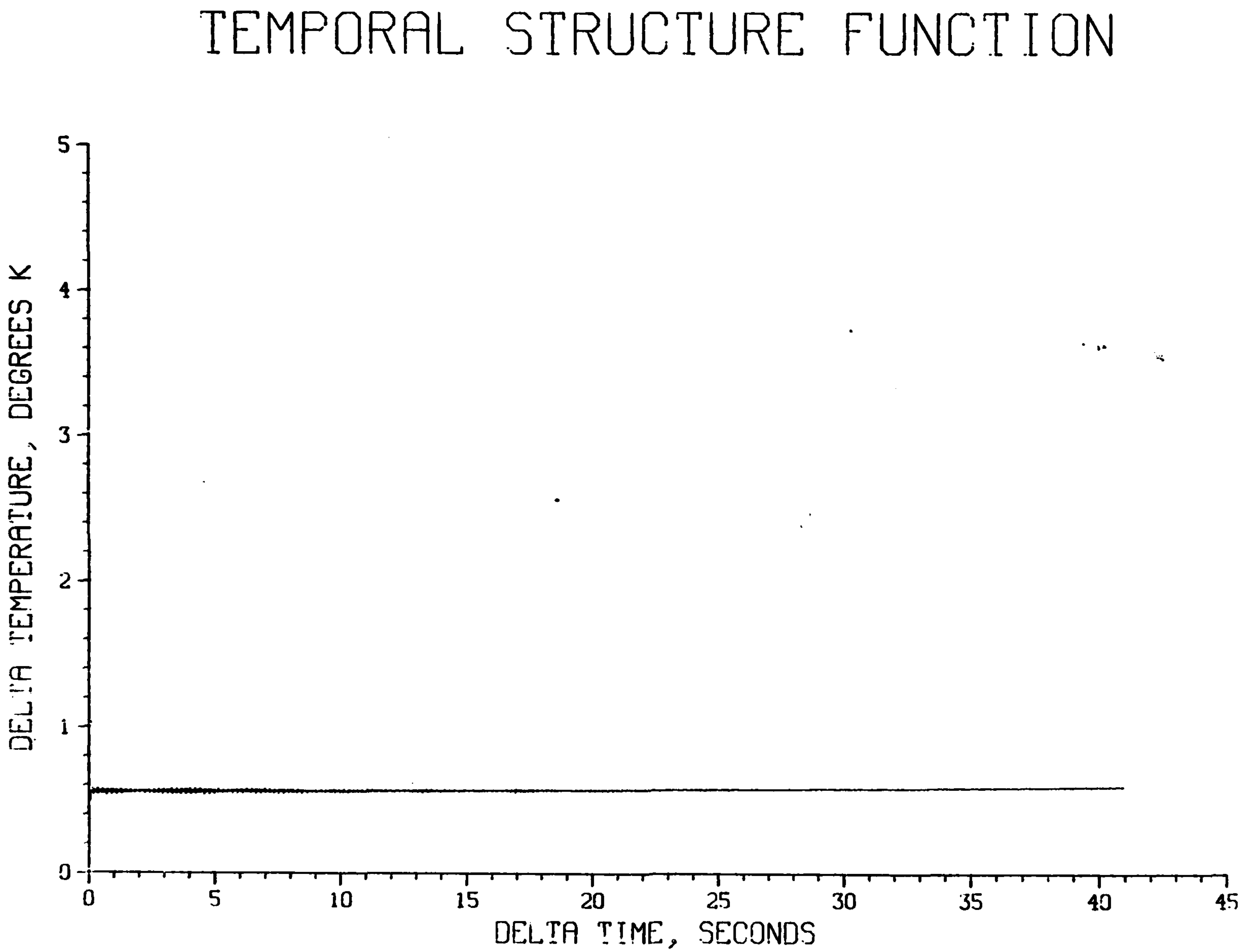


FIGURE 3-6 NORMALIZED ENCLOSURE TEMPORAL STRUCTURE VERSUS TIME $\sqrt{\overline{D}_{NE}}$ vs. ΔTIME, WHERE $\overline{D}_{NE}$ = NORMALIZED AVERAGE ENCLOSURE TEMPORAL STRUCTURE FUNCTION

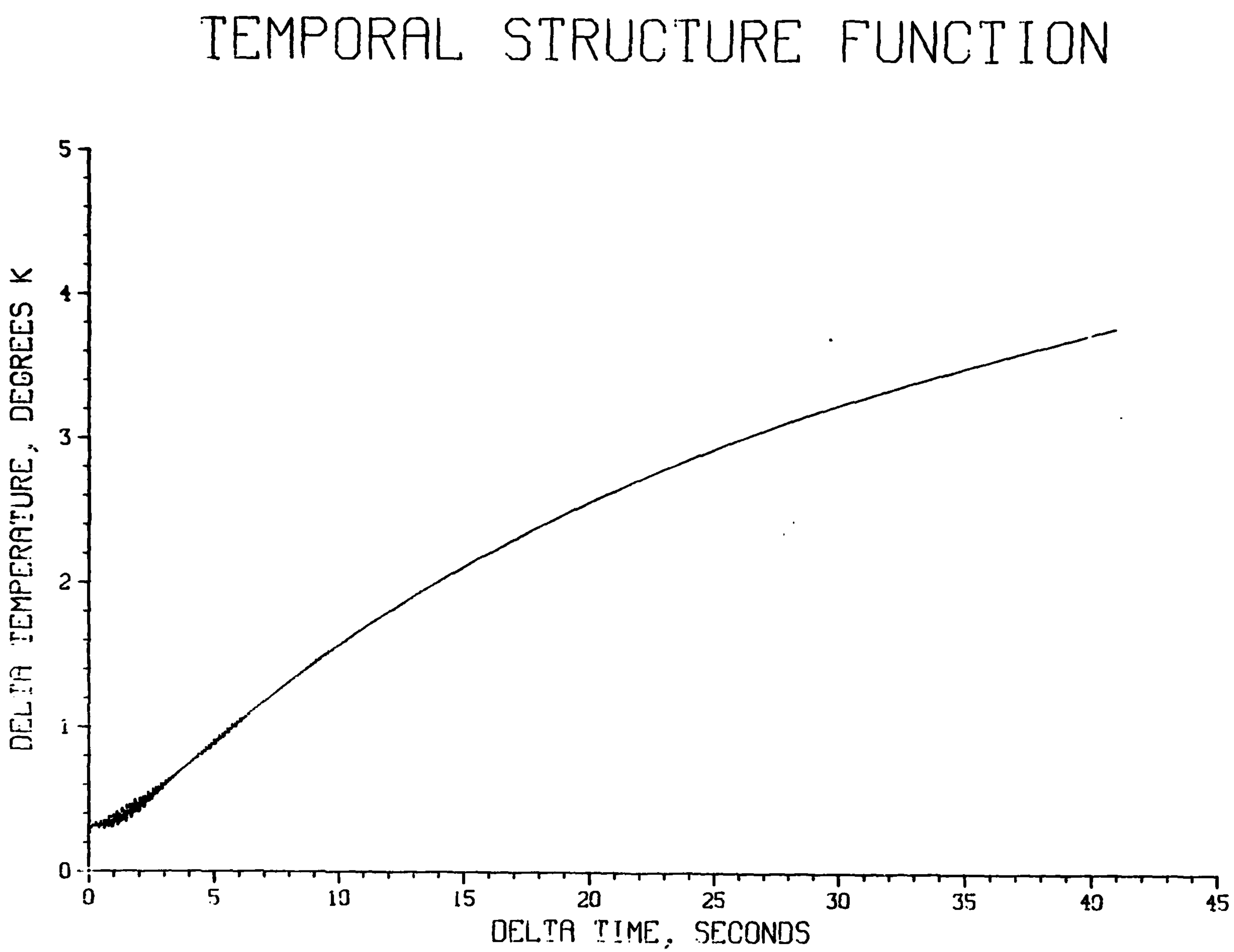


FIGURE 3-7 TARGET DIFFERENCED CLUTTER TEMPORAL STRUCTURE VS. TIME, $\sqrt{\bar{D}_S - \bar{D}_{NE}}$ vs. ΔTIME, WHERE $\bar{D}_S$ = AVERAGED SCENE TEMPORAL STRUCTURE AND D_{NE} = AVERAGED NORMALIZED ENCLOSURE TEMPORAL STRUCTURE.

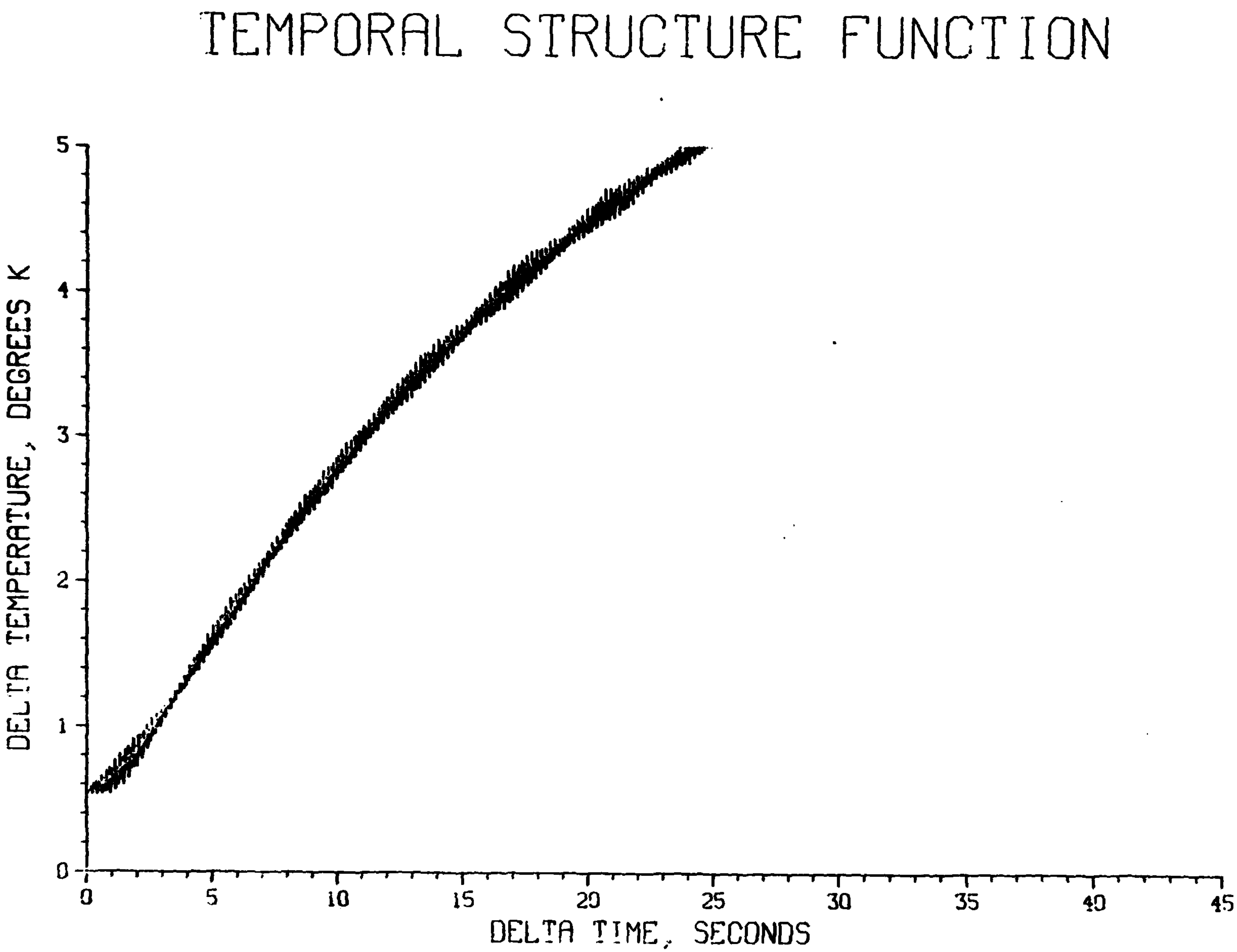


FIGURE 3-8 NORMALIZED DIFFERENCE TEMPORAL STRUCTURE vs. TIME. $\sqrt{\overline{D}_S - \overline{D}_{NE}} - \sqrt{\overline{D}_{NE}}$, where D_S = averaged target temporal structure and $\overline{D}_{NE}$ = averaged normalized enclosure temporal structure

APPENDIX A - SOFTWARE DOCUMENTATION

CSC has provided instruction on the use of the software developed for the microwave temporal clutter project. This instruction included in-code program documentation and an orientation seminar held at the NRL.

In-code documentation was provided to enable the software user to follow the coded logic. The documentation consisted of prologue descriptions and in-line comment statements. Prologue descriptions were written for main programs and subroutines. The prologues followed a standard format and identified the code function, the accessed arguments and COMMON statements, and the subprograms calling and being called. In-line comment statements were written throughout the code to describe functional areas of the program and explain the flow of specific algorithms.

A software orientation seminar was held for NRL personnel on August 6, 1984. CSC personnel provided instructions in software program execution and discussed specific aspects of all software developed for the temporal clutter project.

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