DATA ANALYSIS SOFTWARE FOR THE AUTORADIOGRAPHIC ENHANCEMENT PROCESS, Vols. 1, 2, and 3, and Appendix

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Marshall Space Flight Center, Alabama 35812
This report presents the computer software developed to set up a method for Wiener spectrum analysis of photographic films. This method is used for the quantitative analysis of the autoradiographic enhancement process.

Volume 1 presents the software requirements and design for the autoradiographic enhancement process, Volume 2 contains the program listings, and Volume 3 is the users manual. The Appendix, containing a software description and program listings, is a modification of the data analysis software presented in the main text of the report and should be used in conjunction with it.
VOLUME 1

SOFTWARE REQUIREMENTS AND DESIGN
FOR EVALUATION OF
THE AUTORADIOGRAPHIC ENHANCEMENT PROCESS
PREFACE

This is the Software Requirements and Software Design Document for the evaluation of the Wiener Spectrum and Modulation Transfer Function of the Autoradiographic Enhancement Process.

This report is Volume 1 of the Final Report prepared by ESPEE, INC. under Contract No. NAS8-33405 for the Space Sciences Laboratory of the George C. Marshall Space Flight Center. This Volume 1 is an update of and supersedes an earlier report dated December 31, 1978. The NASA COR for this contract is Dr. C. A. Lundquist.
**TABLE OF CONTENTS**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Objective</td>
<td>1</td>
</tr>
<tr>
<td>2. System Configuration</td>
<td>2</td>
</tr>
<tr>
<td>3. Requirements for Software Development</td>
<td>4</td>
</tr>
<tr>
<td>3.1 Inputs</td>
<td>4</td>
</tr>
<tr>
<td>3.1.1 Microdensitometer Output Tape</td>
<td>4</td>
</tr>
<tr>
<td>3.1.2 User-Specified Variables</td>
<td>5</td>
</tr>
<tr>
<td>3.2 Analysis Capabilities</td>
<td>7</td>
</tr>
<tr>
<td>3.2.1 Histograms</td>
<td>7</td>
</tr>
<tr>
<td>3.2.2 Filters</td>
<td>7</td>
</tr>
<tr>
<td>3.2.3 Means</td>
<td>7</td>
</tr>
<tr>
<td>3.2.4 Standard Deviation</td>
<td>7</td>
</tr>
<tr>
<td>3.2.5 Autocorrelation Functions</td>
<td>8</td>
</tr>
<tr>
<td>3.2.6 Power Spectral Density</td>
<td>8</td>
</tr>
<tr>
<td>3.3 Outputs</td>
<td>8</td>
</tr>
<tr>
<td>4. Preliminary Software Design</td>
<td>9</td>
</tr>
<tr>
<td>4.1 Structure Charts</td>
<td>9</td>
</tr>
<tr>
<td>4.2 HIPO's</td>
<td>13</td>
</tr>
<tr>
<td>4.2.1 HIPO-MAIN</td>
<td>14</td>
</tr>
<tr>
<td>4.2.2 HIPO-PTDT</td>
<td>15</td>
</tr>
<tr>
<td>4.2.3 HIPO-SKPFL</td>
<td>16</td>
</tr>
<tr>
<td>4.2.4 HIPO-RDFL</td>
<td>17</td>
</tr>
<tr>
<td>4.2.5 HIPO-HDR</td>
<td>18</td>
</tr>
<tr>
<td>4.2.6 HIPO-CORD</td>
<td>19</td>
</tr>
<tr>
<td>4.2.7 HIPO-RFMT</td>
<td>20</td>
</tr>
<tr>
<td>4.2.8 HIPO-HIST</td>
<td>21</td>
</tr>
<tr>
<td>4.2.9 HIPO-DCLS</td>
<td>22</td>
</tr>
<tr>
<td>4.2.10 HIPO-MEANS</td>
<td>23</td>
</tr>
<tr>
<td>4.2.11 HIPO-AVG</td>
<td>24</td>
</tr>
<tr>
<td>4.2.12 HIPO-NRMLZ</td>
<td>25</td>
</tr>
<tr>
<td>4.2.13 HIPO-ZMEAN</td>
<td>26</td>
</tr>
<tr>
<td>4.2.14 HIPO-SIGMA</td>
<td>27</td>
</tr>
<tr>
<td>4.2.15 HIPO-AUTOCOR</td>
<td>28</td>
</tr>
<tr>
<td>4.2.16 HIPO-LFF</td>
<td>29</td>
</tr>
<tr>
<td>4.2.17 HIPO-HFF</td>
<td>30</td>
</tr>
<tr>
<td>4.2.18 HIPO-PSDF</td>
<td>31</td>
</tr>
<tr>
<td>4.2.19 HIPO-INF</td>
<td>32</td>
</tr>
<tr>
<td>4.2.20 HIPO-AC</td>
<td>33</td>
</tr>
<tr>
<td>4.2.21 HIPO-SPDF</td>
<td>34</td>
</tr>
<tr>
<td>APPENDIX A</td>
<td>A1</td>
</tr>
<tr>
<td>Notation</td>
<td>A1</td>
</tr>
<tr>
<td>Formulae</td>
<td>A2</td>
</tr>
<tr>
<td>Typical Values</td>
<td>A4</td>
</tr>
</tbody>
</table>
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>TITLE</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>SYSTEM CONFIGURATION</td>
<td>3</td>
</tr>
<tr>
<td>3.1</td>
<td>DATA FORMAT OF THE MICRODENSITOMETER OUTPUT TAPE</td>
<td>9</td>
</tr>
<tr>
<td>4.1</td>
<td>MICRODENSITOMETER DATA ANALYSIS SOFTWARE DESIGN OVERVIEW</td>
<td>10</td>
</tr>
<tr>
<td>4.2</td>
<td>PARTIAL STRUCTURE CHART - DATA PREPARATION MODULES</td>
<td>11</td>
</tr>
<tr>
<td>4.3</td>
<td>PARTIAL STRUCTURE CHART - DATA ANALYSIS MODULES (PART 1)</td>
<td>12</td>
</tr>
<tr>
<td>4.4</td>
<td>PARTIAL STRUCTURE CHART - DATA ANALYSIS MODULES (PART 2)</td>
<td>12a</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

1.1 Objective: The objective of this work is to develop capabilities to evaluate the Wiener Spectrum and Modulation Transfer Function of the autoradiographic enhancement process. The autoradiographic enhancement process is a technique for increasing the amount of information which is recovered from photographic film, plates and prints. The technique consists of radioactivating the image silver by chemically combining it with a beta emitting isotope, sulfur-35; the autoradiograph, an enhanced copy of the underexposed image, is made by exposing a second film to the radiation from the underexposed original. The efficient response of the photographic emulsion to beta radiation produces an autoradiograph image which is enhanced in density and contrast so that images which were invisible or only faintly visible on the original film can be easily seen on the autoradiograph.

The Perkin-Elmer 1010A Microdensitometer is used to generate raw data from film.

Evaluation of the Wiener Spectrum and Modulation Transfer Function provides a measure of effectiveness of image recovery in terms of signal-to-noise ratio and detective quantum efficiency. It is the quantitative evaluation of the information transfer due to autoradiographic intensification.

Software is being developed to provide data analysis capabilities for autoradiographic image processing and other image processing applications where the microdensitometer is being used. The data analysis capabilities shall be developed on the NOVA 2 computer located in room 369 of building 4481. While IDAPS provides many of the analysis capabilities to be developed on the NOVA, IDAPS is designed for only 8-bits of resolution while the microdensitometer output provides 12-bits of resolution. For the autoradiographic enhancement process, the 12-bits of resolution is definitely needed, especially for signal to noise ratio calculations. Also, the data on microdensitometer output tape cannot be used as is with IDAPS because of header information included in each data record and because of the 12-bit length of the data.

The effort reported in this document is the software requirements definition and the preliminary software design of the analysis capabilities to be implemented on NOVA 2.
2. SYSTEM CONFIGURATION

Figure 2.1 illustrates the system configuration for data analysis. The piece of film is scanned by the microdensitometer and the image density is recorded on a 9-track, 800 BPI magnetic tape. The tape is input to the NOVA 2 where the data is analyzed and a copy of the results is obtained from the Textronix 4014 hard copy unit.
Figure 2.1 System Configuration
3. REQUIREMENTS FOR SOFTWARE DEVELOPMENT

The software shall be designed to analyze the film-scan data obtained from the Perkin-Elmer Microdensitometer.

3.1 Inputs

The Inputs to the software shall be:

1. The microdensitometer output tape
2. User-specified variables

3.1.1 Microdensitometer Output Tape

The data from the microdensitometer output tape is obtained via a 9-track magnetic tape. The tape data format is illustrated in Figure 3.1.

A magnetic tape record is generated by the microdensitometer control system at the conclusion of each scan line, or segment thereof. Termination of the record consists of an IBM-compatible Inter-Record-Gap.

After the last record has been written for a given scanning program, the microdensitometer control system causes the writing of an IBM-compatible standard End of File Mark.

Tape Format:

1. **Start of Record** - Two tape characters containing the hexadecimal characters "FFFF". These characters have no relation or value relative to any of the data to follow.

2. **Identification** - Forty tape characters, each containing an eight-bit byte representing the ASCII code for the alphanumeric characters entered during the IDENT mode of operation.

3. **Number of Samples** - Two tape characters containing a sixteen-bit binary number representing the (positive) number of data values included in the record, following completion of the coordinate information.
Figure 3.1 Data Format of the Microdensitometer Output Tape
Tape Format (cont'd):

4. **X-Coordinate** - Four tape characters containing a thirty-two bit binary number representing the position along the X-axis at which the current scan line commenced. The number is justified to the LSB end of the word; a negative position is indicated as a two's complement of the absolute value. All position readings are in microns.

5. **Y-Coordinate** - Four tape characters containing a thirty-two bit binary number representing the Y-axis coordinate at which the current scan line commenced. Interpretation as noted above.

6. **Delta X** - Four tape characters containing a thirty-two bit binary number representing the sampling interval along the X-axis. Interpretation as above. (A negative number indicates that the direction of scanning was negative.)

7. **Data Values in Buffer** - Two tape characters for each of the data values enumerated in "3" above. Each pair of characters contains a sixteen-bit binary number, the leading twelve bits of which are significant. The final four bits are to be discarded. Interpretation of the data is as follows: Convert the binary number to decimal and divide by 800. The quotient is the data value for the density or transmittance reading, as recorded during the scan.

The data corresponding to a scan line is stored on one record provided the number of samples is no greater than 3200. If the number of samples per scan line is greater than 3200, then the scan line data is segmented and stored on more than one record on tape. Start of each new scan line, however, causes a new record to be written.

3.1.2 User-Specified Variables

The following user-specified variables are supplied in response to software-query:

(a) No. of File NF, to be read from the microdensitometer tape.

(b) The Diffuse Density Factor, DD

(c) The Maximum Lag Factor, M

(d) The Length of the scanning slit, SL
3.2 Analysis Capabilities

The software shall be designed to have the following data analysis capabilities:

1. Compute Histograms
2. Filter Data
3. Compute Means
4. Compute Standard Deviation
5. Compute Autocorrelation Functions
6. Compute Power Spectral Density Functions

The software shall be designed to permit future capabilities to be developed and integrated with the existing software.

3.2.1 Histograms

The density data range from a scan frame shall be divided into fifty classes. The data from a scan frame shall be distributed over these classes to generate a histogram.

3.2.2 Filters

The software shall have the capability to filter raw data from the microdensitometer. The specific filter or filters are yet to be determined.

3.2.3 Means

The software shall have the capability to compute mean of the raw data and mean of the data normalized by a diffuse density factor. The software shall normalize data to zero mean.

3.2.4 Standard Deviation

The software shall have the capability to compute mean square value and standard deviation of the data.
3.2.5 Autocorrelation Functions

Using the user-specified maximum lag factor, the software shall be capable of computing autocorrelation functions and also of normalizing autocorrelations functions with respect to zero-lag autocorrelation function.

3.2.6 Power Spectral Density

The software shall be capable of computing power spectral density functions. It shall also compute smoothed power spectral density functions.

3.3 Outputs

The software shall have the following outputs:

1. Data Identification from Microdensitometer Tape
2. Raw data mean
3. Mean Square Value
4. Standard Deviation Value
5. Histogram table
6. Autocorrelation and Normalized Autocorrelation Functions
4. PRELIMINARY SOFTWARE DESIGN

The software design is modular. An overview of the preliminary software design showing the top-modules is illustrated in Figure 4.1. The main program calls independent modules which implement unique data input, data preparation and data analysis capabilities. The sequence of execution is top-down and left to right.

4.1 Structure Charts

The detailed software design is presented in structure charts shown in Figures 4.2 thru 4.4 and the HIPO's of section 4.2. The sequence of execution of modules in the structure chart is top-down and left to right. Each module has one entry and one exit. Control always returns to the next statement in the calling module. Arrows on a line indicate multiple calls. Arrows on a group of lines indicate multiple sequence of calls.
Figure 4.1 Microdensitometer Data Analysis Software Design Overview
Figure 4.2 Partial Structure Chart – Data Preparation Modules
Figure 4.3 Partial Structure Chart — Data Analysis Modules (Part 1)
Figure 4.4 Partial Structure Chart – Data Analysis Modules (Part 2).
4.2 HIPO'S

The Hierarchical Input-Process-Output (HIPO) charts are given for the modules shown on the structure charts. A HIPO gives an overview of the actions performed within a module.
### 4.2.1 HIPO-MAIN

**PURPOSE:** Main accepts the user-supplied data and calls other modules for preparation of tape data and data analysis.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>User supplied data</td>
<td>Ask for and Read from programmer's console the File No. NF, the diffuse density factor KDD, the max lag factor M and length of scanning slit L.</td>
<td>NF, KDD, M, L</td>
</tr>
<tr>
<td>2.</td>
<td>NF, tape</td>
<td>Call (a module) PTDT to prepare disk file from tape data and to get H = Delta X.</td>
<td>RD, NP, H</td>
</tr>
<tr>
<td>3.</td>
<td>RD, NP, A, B, NC</td>
<td>Call HIST to prepare histogram</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>RD, NP</td>
<td>Call FILT to filter raw data</td>
<td>FD</td>
</tr>
<tr>
<td>5.</td>
<td>RD, NP, KDD</td>
<td>Call MEANS to compute mean, convert data to density units and to normalize data to zero mean</td>
<td>ZRD</td>
</tr>
<tr>
<td>6.</td>
<td>ZRD, NP</td>
<td>Call SIGMA to compute standard deviation and Mean Square Value</td>
<td>RRH</td>
</tr>
<tr>
<td>7.</td>
<td>ZRD, NP, M</td>
<td>Call AUTOCOR to compute ((M + 1)) autocorrelation functions and to normalize w.r.t. autocorrelation with (r = 0).</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>RRH, H, L, M</td>
<td>Call PSDF to compute (\tilde{G}_k) AND (\hat{G}_k).</td>
<td>GKC, GKH</td>
</tr>
<tr>
<td>9.</td>
<td>STOP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 1.2.2 HIFQ-PTDT

**Purpose:** PTDT prepares disk file of raw data from tape data.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tape</td>
<td>Call MTOPD to position tape at device MTφ</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>NF</td>
<td>If (NF, GT, 1) call SKPFL to skip files on tape to come to file no. NF</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Call RDFL to read File No. NF from tape into disk file TD. NR is number of records. NW is array of no. of words in each record.</td>
<td>TD, NW, NR</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Call HDR to print header information and get delta X = NH</td>
<td>NH</td>
</tr>
<tr>
<td>5</td>
<td>TD, NW</td>
<td>Call RFMT to reformat data in disk file TD to raw data in disk file RD</td>
<td>RD, NP</td>
</tr>
<tr>
<td>6</td>
<td>NR</td>
<td>RETURN</td>
<td></td>
</tr>
</tbody>
</table>
### 1.2.3 HIFO-SKPFL

**Purpose:** SKPFL skips files on tape to read file no. NF.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>NF</td>
<td>Call MTDIO to read one record from tape and word-count ICNT in that record.</td>
<td>ICNT</td>
</tr>
<tr>
<td>2.</td>
<td>ICNT</td>
<td>If ICNT is greater than 1, go to step 1</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>ICNT</td>
<td>If ICNT = 1, this indicates EOF.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>KFL</td>
<td>Increment file counter KFL.</td>
<td>KFL</td>
</tr>
<tr>
<td>5.</td>
<td>NF</td>
<td>If KFL = NF, RETURN</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>Else go to step 1</td>
<td></td>
</tr>
</tbody>
</table>
## 4.2.4 HiPO-RDFL

**Purpose:** RDFL reads data from a tape file into a disk file

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td>Call <code>FOPEN</code> to open a disk file <code>TD</code> to receive tape data</td>
<td><code>TD</code></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>Call <code>MTDIO</code> to read one record from tape into temporary array <code>INPBUF</code></td>
<td><code>INPBUF</code>, <code>ICNT</code></td>
</tr>
<tr>
<td>3.</td>
<td><code>ICNT</code></td>
<td>If <code>ICNT = 1</code> (EOF), then go to step 6.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td><code>INPBUF</code></td>
<td>Else record number of records, no. of words per record and call <code>WRITR</code> to put data in file <code>TD</code>.</td>
<td><code>TD</code></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>Go to step 2</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>Return</td>
<td></td>
</tr>
</tbody>
</table>
4.2.5 H:PO-HDR

Purpose: HDR reads first record in disk file TD and prints I.D. and computes
H = Delta X.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>TD</td>
<td>Call READR to read first record from disk file TD to Temp. array ITEMP</td>
<td>ITEMP</td>
</tr>
<tr>
<td>2.</td>
<td>ITEMP</td>
<td>Print ID in words 2 through 21 of ITEMP</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>ITEMP</td>
<td>Print no. of samples = ITEMP (22)</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>ITEMP</td>
<td>Call CORD 3 times to compute X, Y coordinates and Delta X. After each call, print the coordinates and Delta X = NH.</td>
<td>NH</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>Return</td>
<td></td>
</tr>
</tbody>
</table>
### 1.2.6 HIPQ-CORD

**Purpose:** CORD computes X, Y coordinates and Delta X from 2 input words for each value.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>ITEMP, J</td>
<td>Load a double precision word IWD with 2 input words</td>
<td>IWD</td>
</tr>
<tr>
<td>2.</td>
<td>IWD</td>
<td>If an input word is negative, use special techniques for loading into IWD.</td>
<td>IWD</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>Return</td>
<td></td>
</tr>
</tbody>
</table>

I-20
### 4.2.7 HIPO-RFMT

**Purpose:** RFMT reformats sample values data in disk file TD and loads the data values only into disk file RD.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td>Call FOPEN to open disk file RD</td>
<td>RD</td>
</tr>
<tr>
<td>2.</td>
<td>TD</td>
<td>Call READR to read a record from file TD into temporary array ITEMP</td>
<td>ITEMP</td>
</tr>
<tr>
<td>3.</td>
<td>ITEMP,</td>
<td>Call GBYTE to get 12 most significant bits from each data point (words 29 through NW for each of NR records) and store them in Temp. array JTEMP.</td>
<td>JTEMP</td>
</tr>
<tr>
<td></td>
<td>NR, NW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>JTEMP,</td>
<td>Call WRITR to write JTEMP in file RD.</td>
<td>RD</td>
</tr>
<tr>
<td></td>
<td>NR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>Repeat steps 3 and 4 NR times</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>NW</td>
<td>Compute No. of data points NP in each record</td>
<td>NP</td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td>READ a record from file RD and print it for verification.</td>
<td>ITEMP</td>
</tr>
<tr>
<td>8.</td>
<td></td>
<td>RETURN</td>
<td></td>
</tr>
</tbody>
</table>
### 4.2.8 HIPO-HIST

**Purpose:** HIPO-HIST computes the histogram for the raw data.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RD, NW</td>
<td>Call READS to read a record from RD file into temporary array ITEMP</td>
<td>ITEMP</td>
</tr>
<tr>
<td>2</td>
<td>ITEMP, IC, NFI</td>
<td>Call DCLS to distribute data in ITEMP into class intervals.</td>
<td>NHST</td>
</tr>
<tr>
<td>3</td>
<td>NHST</td>
<td>Sum NHST into MST by repeating steps 1 and 2 for NR records</td>
<td>MST</td>
</tr>
<tr>
<td>4</td>
<td>MST</td>
<td>Find IMIN and IMAX such that MST has nonzero entries between IMIN and IMAX</td>
<td>IMIN, IMAX</td>
</tr>
<tr>
<td>5</td>
<td>IMIN, IMAX, MST</td>
<td>Type MST values</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Return</td>
<td></td>
</tr>
</tbody>
</table>
4.2.9 HIPO-DCLS

Purpose: DCLS assigns each data value to a class interval for calculating histogram.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>ITEMP, IC, NPI</td>
<td>Compute integer part of ((\text{ITEM} ,(j) / \text{IC}) = 1) for one value of (j).</td>
<td>I</td>
</tr>
<tr>
<td>2.</td>
<td>I</td>
<td>Increment NHST ((i)) by 1.</td>
<td>NHST</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>Repeat steps 1 and 2 for NPI points</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td>Return</td>
<td></td>
</tr>
</tbody>
</table>
### 4.2.10 HIPO-MEANS

Purpose: MEANS calls other modules to compute mean of raw data and normalize data to diffuse density units and zero mean.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>ICH, NR, NP</td>
<td>Call AVG to compute raw mean.</td>
<td>RAWM</td>
</tr>
<tr>
<td>2.</td>
<td>KDD</td>
<td>Compute the diffuse density multiplier DDM from KDD as DDM = KDD/RAWM</td>
<td>DDM</td>
</tr>
<tr>
<td>3.</td>
<td>DDM, ICHR, NR, NP, ICHN</td>
<td>Call NRMLZ to normalize data to diffuse density units.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>KDD</td>
<td>Print mean of normalized data KDD.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>ICHN, ICHZ, NR, NP, KDD</td>
<td>Call ZMEAN to normalize data to zero mean</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Return</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.2.11 HIPO-AVG

**Purpose:** AVG computes the mean (average) of a group of records on a disk file.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td>Call READR to read a record from file RD into Temp. array ITEMP.</td>
<td>ITEM</td>
</tr>
<tr>
<td>2.</td>
<td>NP, ITEMP</td>
<td>Compute cumulative sum ISUM of points in ITEMP</td>
<td>ISUM</td>
</tr>
<tr>
<td>3.</td>
<td>NP</td>
<td>Compute cumulative sum of number of points in each record.</td>
<td>INP</td>
</tr>
<tr>
<td>4.</td>
<td>NR</td>
<td>Repeat steps 1, 2 and 3 for NR records</td>
<td>ISUM</td>
</tr>
<tr>
<td>5.</td>
<td>INP, ISUM</td>
<td>Compute Mean RAWM = ISUM/INP</td>
<td>RAWM</td>
</tr>
<tr>
<td>6.</td>
<td>RAWM</td>
<td>Print RAWM</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td>Return</td>
<td></td>
</tr>
</tbody>
</table>
4.2.12 HIPO-NRMLZ

Purpose: NRMLZ normalizes data in a disk file by multiplying it with a factor and stores it in another disk file.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>ICHN</td>
<td>Call fopen to open a file on disk</td>
<td>TEMP</td>
</tr>
<tr>
<td>2.</td>
<td>DDM</td>
<td>Call READ to read a record into Temp array</td>
<td>TEMP</td>
</tr>
<tr>
<td>3.</td>
<td>TEMP</td>
<td>Multiply each of NPI data values by DDM</td>
<td>TEMP</td>
</tr>
<tr>
<td>4.</td>
<td>NR</td>
<td>Call WRITR to write TEMP in disk file NRD</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>NR</td>
<td>Repeat steps 2, 3 and 4 for NR records</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>Return</td>
<td></td>
</tr>
</tbody>
</table>
**4.2.13 HIPO-ZMEAN**

**Purpose:** ZMEAN normalizes data on a disk file by subtracting the data mean factor from each value. It stores the resulting data in another disk file.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>ICHZ</td>
<td>Call OPEN to open a file on disk</td>
<td>TEMP</td>
</tr>
<tr>
<td>2.</td>
<td>ICHN</td>
<td>Call READR to read a record into temporary array</td>
<td>TEMP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TEMP</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>KDD,</td>
<td>Subtract KDD from each of NPI data values</td>
<td>TEMP</td>
</tr>
<tr>
<td></td>
<td>NPI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>TEMP</td>
<td>Call WRITR to write TEMP into a disk file ZRD</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>NR</td>
<td>Repeat steps 2, 3 and 4 for NR records</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>Return</td>
<td></td>
</tr>
</tbody>
</table>
**4.2.14 HIPO-SIGMA**

**Purpose:** SIGMA computes the mean square value and root mean square value of data in a disk file.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ICH</td>
<td>Call READR to read a record from file ZRD into Temp array TEMP</td>
<td>TEMP</td>
</tr>
<tr>
<td>2</td>
<td>NPI, TEMP</td>
<td>Compute cumulative sum of squares, SSQ for NPI data values in TEMP</td>
<td>SSQ</td>
</tr>
<tr>
<td>3</td>
<td>NP</td>
<td>Compute sum of no. of values for NR records</td>
<td>INP</td>
</tr>
<tr>
<td>4</td>
<td>NR</td>
<td>Repeat steps 1, 2 and 3 for NR records</td>
<td>SSQ</td>
</tr>
<tr>
<td>5</td>
<td>INP, SSQ</td>
<td>Compute XSQ = SSQ/INP</td>
<td>XSQ</td>
</tr>
<tr>
<td>6</td>
<td>XSQ, INP</td>
<td>Compute SIG = ((XSQ*NP/ (NP-1))^{1/2})</td>
<td>SIG</td>
</tr>
<tr>
<td>7</td>
<td>XSQ, SIG</td>
<td>Print XSQ and SIG</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Return</td>
<td></td>
</tr>
</tbody>
</table>
4.2.15 HIPO-AUTOCOR

Purpose: AUTOCOR computes the autocorrelation and normalized autocorrelation functions.

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Set XT, RAT, TEMP to zero</td>
<td>XT</td>
</tr>
<tr>
<td>2</td>
<td>ICHZ</td>
<td>Call READR to read a record from file ZRD into Temp</td>
<td>TEMP</td>
</tr>
<tr>
<td>3</td>
<td>NP</td>
<td>Compute cumulative sum INP</td>
<td>INP</td>
</tr>
<tr>
<td>4</td>
<td>TEMP, M</td>
<td>Shift data value contents of TEMP down by M</td>
<td>TEMP</td>
</tr>
<tr>
<td>5</td>
<td>M, XT, TEMP</td>
<td>Transfer contents of XT into first M values of TEMP</td>
<td>TEMP</td>
</tr>
<tr>
<td>6</td>
<td>M, XT, TEMP</td>
<td>Transfer last M data values in TEMP to XT</td>
<td>XT</td>
</tr>
<tr>
<td>7</td>
<td>RAT, TEMP</td>
<td>For JR = 0 through M, compute cumulative sum for I = 1 to NPI, RAT (JR+1) = RAT (JR+1) + TEMP (I) * TEMP (I + JR)</td>
<td>RAT</td>
</tr>
<tr>
<td>8</td>
<td>NR</td>
<td>Repeat steps 2 through 7 for NR records</td>
<td>RAT</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Set TEMP to zero and do steps 5 and 7 one time</td>
<td>RAT</td>
</tr>
<tr>
<td>10</td>
<td>RAT, MR</td>
<td>Compute RAT (J)/(INP-J+1) for J = 1, MR</td>
<td>RAT</td>
</tr>
<tr>
<td>11</td>
<td>RAT, MR</td>
<td>Compute normalized autocorrelations function RATN (J) = RAT (J)/RAT (1) for J = 1 through MR</td>
<td>RATN</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Print J, RAT(J) and RATN(J)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>Return</td>
<td></td>
</tr>
</tbody>
</table>
4.2.16 HIPO: LFF

**Purpose:** LFF is the low frequency filter applied to raw data before standard deviation, autocorrelation and power spectral density functions are computed.

<table>
<thead>
<tr>
<th>Step No</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NP, P</td>
<td>Compute number of records in which the first ((2P+1)) points lie.</td>
<td>NREC</td>
</tr>
<tr>
<td>2</td>
<td>P, NP</td>
<td>Compute the record number in which the ((P+1))th point lies.</td>
<td>QUO</td>
</tr>
<tr>
<td>3</td>
<td>TEMP1, P</td>
<td>Calculate sum of first ((2P+1)) points.</td>
<td>SUM</td>
</tr>
<tr>
<td>4</td>
<td>QUO, P, NP</td>
<td>Calculate location of ((P+1))th point in record no. QUO.</td>
<td>LOC1</td>
</tr>
<tr>
<td>5</td>
<td>TEMP1, LOC1, SUM, P</td>
<td>Compute new ((P+1))th point as (\text{TEMP1(LOC1)} = \text{TEMP1(LOC1)} - \text{SUM}/(2P+1)) and store TEMP1 on disk.</td>
<td>TEMP1</td>
</tr>
<tr>
<td>6</td>
<td>NP, N, P</td>
<td>For (I = (P+2)) to ((N-P)), where (N) is the total number of points, compute record nos. in which points (I), (I-P-1) and (I+P) lie.</td>
<td>REC1, REC2, REC3</td>
</tr>
<tr>
<td>7</td>
<td>REC1, REC2, REC3, NP</td>
<td>Calculate location of points (I), (I-P-1) and (I+P) in their respective records.</td>
<td>LOC1, LOC2, LOC3</td>
</tr>
<tr>
<td>8</td>
<td>REC1, REC2, REC3</td>
<td>Read respective records from disk.</td>
<td>TEMP1, TEMP2, TEMP3</td>
</tr>
<tr>
<td>9</td>
<td>LOC2, LOC3 TEMP2, TEMP3</td>
<td>Calculate (\text{SUM} = \text{SUM-TEMP2(LOC2)} + \text{TEMP3(LOC3)})</td>
<td>SUM</td>
</tr>
<tr>
<td>10</td>
<td>TEMP1, LOC1 SUM, P</td>
<td>Calculate (\text{XT} = \text{TEMP1(LOC1)} - \text{SUM}/(2P+1)) and store on disk at TEMP1(LOC1).</td>
<td>XT, TEMP1</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>Repeat steps 6 through 10 till done.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Return.</td>
<td></td>
</tr>
</tbody>
</table>
4.2.17 HIPO:HFF

Purpose: HFF is the high frequency filter applied to output data of the low frequency filter.

<table>
<thead>
<tr>
<th>Step No</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NP,Q</td>
<td>Calculate number of records in which the first (2Q+1) points lie.</td>
<td>NREC</td>
</tr>
<tr>
<td>2</td>
<td>Q,NP</td>
<td>Compute the record number in which the (Q+1)th point lies.</td>
<td>QUO</td>
</tr>
<tr>
<td>3</td>
<td>TEMP1,Q</td>
<td>Calculate sum of first (2Q+1) points</td>
<td>SUM</td>
</tr>
<tr>
<td>4</td>
<td>QUO,Q,NP</td>
<td>Calculate location of (Q+1)th point in record No. QUO.</td>
<td>LOC1</td>
</tr>
<tr>
<td>5</td>
<td>Q,SUM</td>
<td>Calculate new (Q+1)th point as TEMP1(LOC1) = SUM/(2Q+1) and store TEMP1 on disk.</td>
<td>TEMP1(LOC1)</td>
</tr>
<tr>
<td>6</td>
<td>NP,N,Q</td>
<td>For I = (Q+2) to (N-Q), where N is the total number of points, compute record numbers in which points I, I-Q-1 and I+Q lie.</td>
<td>REC1, REC2, REC3</td>
</tr>
<tr>
<td>7</td>
<td>REC1, REC2, REC3,NP</td>
<td>Calculate location of points I, I-Q-1 and I+Q in their respective records.</td>
<td>LOC1, LOC2, LOC3</td>
</tr>
<tr>
<td>8</td>
<td>REC1, REC2, REC3</td>
<td>Read REC1, REC2 and REC3 from disk.</td>
<td>TEMP1, TEMP2, TEMP3</td>
</tr>
<tr>
<td>9</td>
<td>LOC2, LOC3, TEMP2, TEMP3</td>
<td>Calculate SUM = SUM - TEMP2(LOC2) + TEMP3(LOC3)</td>
<td>SUM</td>
</tr>
<tr>
<td>10</td>
<td>SUM,Q</td>
<td>Calculate XT = SUM/(2Q+1) and store on disk at TEMP1(LOC1)</td>
<td>XT,TEMP1</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>Repeat steps 6 though 10 till done.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Return.</td>
<td></td>
</tr>
</tbody>
</table>
Purpose: PSDF computes the power spectral densities from the autocorrelation function.

<table>
<thead>
<tr>
<th>Step No</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RAT, MR, L, H</td>
<td>For ( KR = 1, \ldots, MR ), compute</td>
<td>GKC</td>
</tr>
</tbody>
</table>
|         |                  | \[ GKC(KR) = 2HL \left[ RAT(1) + 2 \sum_{JR=1}^{MR-2} RAT(JR+1) \cdot \right. \]
|         |                  | \[ \left. \cos \left( \pi \cdot JR \cdot (KR-1)/(MR-1) + RAT(MR)(-1) \right) \right] \] |        |
| 2       |                  | Return.                                                                 |        |
Purpose: INF is the inverse filter used on power spectral density function $\sigma_k^2$ as computed from filtered data.

<table>
<thead>
<tr>
<th>Step No</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GKC, Q</td>
<td>For $K = 0$, Set $GKCP(K+1) = (2Q+1)^2$</td>
<td>GKCP(1)</td>
</tr>
<tr>
<td>2</td>
<td>GKC, Q, M</td>
<td>For $K = 1, 2, ..., M$, Compute $GKCP(K+1) = \frac{GKC(K+1) \cdot \left( (2Q+1) \cdot \sin\left(\frac{K\pi}{2M}\right) \right)}{\sin \left( (2Q+1) \cdot \frac{K\pi}{2M} \right)}$</td>
<td>GKCP</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Return.</td>
<td></td>
</tr>
</tbody>
</table>
4.2.20 HIPO: AC

Purpose: AC is the Aperture Compensation applied to the power spectral density data output from INF.

<table>
<thead>
<tr>
<th>Step No</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GKCP</td>
<td>For K=0, Set GKC3P(K+1) = 0</td>
<td>GKC3P(1)</td>
</tr>
<tr>
<td>2</td>
<td>GKCP, M, H, XA</td>
<td>For K=1,2,...,M, compute GKC3P(k+1) = GKC3P(K+1) \cdot \left( (K \cdot \pi \cdot XA/2H \cdot M \cdot \text{Sin}(k \cdot \pi \cdot XA/2H \cdot M))^2 \right)</td>
<td>GKC3P</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Return.</td>
<td></td>
</tr>
</tbody>
</table>
### 4.2.21 HIPO - SPDF

**Purpose:** SPDF computes the smoothed power spectral density functions from the power spectral density functions.

<table>
<thead>
<tr>
<th>Step No</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GKC, MR</td>
<td>Compute</td>
<td>GKH(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GKH(1) = 0.5 [GKC(1) + GKC(2)]</td>
<td>GKH(MR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GKH(MR) = 0.5 [GKC(MR-1) + GKC(MR)]</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>For KR = 2, ..., (MR - 1), compute</td>
<td>GKH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GKH(KR) = 0.25(GKC(KR-1) + GKC(KR+1)) + 0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GKC(KR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GKH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Return</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX A

Appendix A contains the mathematical formulae and notations used for analysis of autoradiographic image data. These mathematical formulae form the basis for implementation into programs.

Notation

* \( l \) = Slit height
* \( a \) = Slit width
\( \Delta \) or \( H \) = Sampling Interval
\( D_n \) = Raw Data Point
\( N \) = Total number of data points
\( \bar{D}_n \) = Mean of raw data, \( D_n \)
\( \text{SIG} \) = Standard Deviation
\( d_n \) = Raw Data converted to diffuse density
\( Z_n \) = Zero Mean Data (in diffuse density)
\( Z'_n \) = Zero Mean Data after low frequency filtering
\( Z''_n \) = Zero Mean Data after high frequency filtering
* \( p \) = Parameter in low frequency filter
* \( q \) = Parameter in high frequency filter
\( R(r) \) = Autocorrelation function
\( r \) = lag factor
* \( m \) = Maximum lag factor
* \( \text{DDF} \) = Diffuse density factor
\( \tilde{\zeta}_k \) = Spectral density function
\( \tilde{\zeta}'_k \) = Spectral density function after inverse filter
\( \tilde{\zeta}''_k \) = Spectral density function after aperture compensation
\( \tilde{\zeta}_k \) = Smoothed spectral density function
\( k = 0, 1, 2, \ldots, m \)
\( f = \text{Frequency} = \frac{k}{2 \cdot \Delta \cdot m} \)

* User-specified variables.
**Raw Mean**

\[ \bar{D}_n = \frac{1}{N} \sum_{n=1}^{N} D_n \]

**Normalized Data**

\[ U_n = \frac{D_n}{DDF} \]

**Zero-Mean Data**

\[ Z_n = U_n - U_n \]

**Mean Square Value**

\[ MSV = \frac{1}{N} \sum_{n=1}^{N} D_n^2 \]

**Standard Deviation**

\[ \text{SIG} = \left( \frac{1}{N} \sum_{n=1}^{N} \left( \frac{D_n^2}{N-1} \right) \right)^{\frac{1}{2}} \]

\[ = \left( \frac{N}{N-1} \text{MSV} \right)^{\frac{1}{2}} \]

**Low-frequency Filter**

\[ Z'_n = Z_n - \frac{1}{2p+1} \sum_{j=-p}^{p} Z_{j+n}, \quad n = p+1, p+2, \ldots, N-p \]

**High Frequency Filter**

\[ Z''_n = \frac{1}{2q+1} \sum_{j=-q}^{q} Z'_{j+n}, \quad n = q+1, q+2, \ldots, N-q \]

**Autocorrelation Function**

\[ \hat{R}_r = \frac{1}{N-r} \sum_{n=1}^{N-r} Z''_n \cdot Z''_{n+r}, \quad r = 0, 1, \ldots, m \]
Normalized Autocorrelation Function

\[ \hat{R}_r / \hat{R}_o, \ r=0,1,2,\ldots,m \]

Note that: \[-1 \leq \hat{R}_r / \hat{R}_o \leq 1\]

Spectral Density Function

\[ \tilde{G}_k' = 2Hl (\hat{R}_o + 2 \sum_{r=1}^{m-1} \hat{R}_r \cos (\frac{\pi r k}{m}) + (-1)^k R_m ) \]

\[ k = 0,1,\ldots,m \]

Inverse Filter

\[ \tilde{G}_k' = \tilde{G}_k'' \left[ (2q+1) \frac{\sin(k \frac{\pi}{2m})}{\sin(k \frac{\pi}{2m} \cdot (2q+1))} \right]^2 \]

\[ k = 1,2,\ldots,m \]

\[ \tilde{G}_0' = \tilde{G}_0'' (2q+1)^2 \]

Aperture Compensation

\[ \tilde{\tilde{G}}_k = \tilde{G}_k'' \left[ \frac{k \frac{\pi}{2H_m}}{\sin(k \frac{\pi}{2H_m} a/2H_m)} \right]^2 \]

\[ k = 1,2,\ldots,m \]

\[ \tilde{\tilde{G}}_0 = 0 \]

Smooth Power Spectral Density Function

\[ \hat{G}_o = 0.5 (\tilde{\tilde{G}}_o + \tilde{\tilde{G}}_1) \]

\[ \hat{G}_m = 0.5 (\tilde{\tilde{G}}_{m-1} + \tilde{\tilde{G}}_m) \]

\[ \hat{G}_k = 0.5 \tilde{\tilde{G}}_k + 0.25 (\tilde{\tilde{G}}_{k-1} + \tilde{\tilde{G}}_{k+1}) \]

\[ k = 1,2,\ldots,m-1 \]

I-38
Typical Values

.5mm x 20mm ................. Actual Slit Size
(4x) x (10x) = 40x ........ System Magnification
12.5 \mu \times 500 \mu \quad \text{Effective Aperture}
\text{50mm}^{-1} \quad \text{Max. Spatial Frequency}
10\text{mm}^{-1} \quad \Delta \omega \quad \text{(band width)}
5\% \quad \text{Error}
20\text{mm} \quad \text{Required Data Length (X)}
\frac{X}{\delta x} = 2 \times 10^3 \quad \text{N = no. of data points}

10 \mu \quad \delta x = \frac{1}{2 \pi \text{max}} = \frac{1}{(2)(50\text{mm}^{-1})}

1200 \quad \text{DDF}
10 \quad m = \frac{1}{\delta x \cdot \Delta \omega} = \frac{1}{.01\text{mm} \times 10\text{mm}^{-1}}
VOLUME 2
PROGRAM LISTINGS
FOR
AUTORADIOGRAPHIC ENHANCEMENT PROCESS
DATA ANALYSIS SOFTWARE
PREFACE

This is the Program Listings for the software developed for the evaluation of the Wiener Spectrum and Modulation Transfer Function of the Autoradiographic Enhancement Process.

This report is Volume 2 of the Final Report prepared by ESPEE, INC. under Contract No. NAS8-33405 for the Space Sciences Laboratory of the George C. Marshall Space Flight Center. The NASA COR for this contract is Dr. C. A. Lundquist.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>SPLIST</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP1A</td>
<td>2</td>
</tr>
<tr>
<td>SP2A</td>
<td>2</td>
</tr>
<tr>
<td>SPLA</td>
<td>2</td>
</tr>
<tr>
<td>SPHA</td>
<td>2</td>
</tr>
<tr>
<td>SP23A</td>
<td>2</td>
</tr>
<tr>
<td>SP24A</td>
<td>2</td>
</tr>
<tr>
<td>SP1</td>
<td>3</td>
</tr>
<tr>
<td>SP2</td>
<td>5</td>
</tr>
<tr>
<td>SPL</td>
<td>7</td>
</tr>
<tr>
<td>SPH</td>
<td>9</td>
</tr>
<tr>
<td>SP3</td>
<td>11</td>
</tr>
<tr>
<td>SP4</td>
<td>12</td>
</tr>
<tr>
<td>SP5</td>
<td>13</td>
</tr>
<tr>
<td>SP6</td>
<td>15</td>
</tr>
<tr>
<td>SP7</td>
<td>16</td>
</tr>
<tr>
<td>SP8</td>
<td>18</td>
</tr>
<tr>
<td>SP9</td>
<td>20</td>
</tr>
<tr>
<td>SP10</td>
<td>21</td>
</tr>
<tr>
<td>SP11</td>
<td>22</td>
</tr>
<tr>
<td>SP12</td>
<td>23</td>
</tr>
<tr>
<td>SP14</td>
<td>25</td>
</tr>
<tr>
<td>SP15</td>
<td>27</td>
</tr>
<tr>
<td>SP16</td>
<td>28</td>
</tr>
<tr>
<td>SP17</td>
<td>29</td>
</tr>
<tr>
<td>SP18</td>
<td>30</td>
</tr>
<tr>
<td>SP19</td>
<td>31</td>
</tr>
<tr>
<td>SP20</td>
<td>32</td>
</tr>
<tr>
<td>SP21</td>
<td>33</td>
</tr>
<tr>
<td>SP22</td>
<td>34</td>
</tr>
<tr>
<td>SP23</td>
<td>35</td>
</tr>
<tr>
<td>SP24</td>
<td>39</td>
</tr>
<tr>
<td>SP25</td>
<td>43</td>
</tr>
<tr>
<td>EXAMPLE RUN OUTPUTS</td>
<td>44</td>
</tr>
</tbody>
</table>
**TYPE SPLIST**

<table>
<thead>
<tr>
<th>FILE SPLIST</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP1A=RLDR/M FOR SP1</td>
</tr>
<tr>
<td>SP2A=RLDR/M FOR SP2</td>
</tr>
<tr>
<td>SPLA=RLDR/M FOR SPL</td>
</tr>
<tr>
<td>SPHA=RLDR/M FOR SPH</td>
</tr>
<tr>
<td>SP23A=RLDR/M FOR SP23</td>
</tr>
<tr>
<td>SP24A=RLDR/M FOR SP24</td>
</tr>
<tr>
<td>SP1=MAIN WITHOUT FILTERS</td>
</tr>
<tr>
<td>SP2=MAIN WITH FILTERS</td>
</tr>
<tr>
<td>SPL=MAIN WITH LOW FREQ. FILTER</td>
</tr>
<tr>
<td>SP3=PTDT</td>
</tr>
<tr>
<td>SP4=SKPFL</td>
</tr>
<tr>
<td>SP5=RDFL</td>
</tr>
<tr>
<td>SP6=HDR</td>
</tr>
<tr>
<td>SP7=CORD</td>
</tr>
<tr>
<td>SP8=RFMT</td>
</tr>
<tr>
<td>SP9=BYTE</td>
</tr>
<tr>
<td>SP10=MEANS</td>
</tr>
<tr>
<td>SP11=SIGMA</td>
</tr>
<tr>
<td>SP12=AUTOCOR</td>
</tr>
<tr>
<td>SP13=(DELETED)</td>
</tr>
<tr>
<td>SP14=HIST</td>
</tr>
<tr>
<td>SP15=DCLS</td>
</tr>
<tr>
<td>SP16=AUG</td>
</tr>
<tr>
<td>SP17=NRLNZ</td>
</tr>
<tr>
<td>SP18=ZMEAN</td>
</tr>
<tr>
<td>SP19=PSDF</td>
</tr>
<tr>
<td>SP20=SPDF</td>
</tr>
<tr>
<td>SP21=INF</td>
</tr>
<tr>
<td>SP22=AC</td>
</tr>
<tr>
<td>SP23=LFF</td>
</tr>
<tr>
<td>SP24=HFF</td>
</tr>
<tr>
<td>SP25=AC1</td>
</tr>
</tbody>
</table>
TYPE SP1A
RLDR/M SP1 SP3 SP4 SP5 SP6 SP7 SP8 SP9 SP10 SP11 SP12 SP14 SP15 ~
SP16 SP17 SP18 SP19 SP25 SP20 FORT.LB
R

TYPE SP2A
RLDR/M SP2 SP3 SP4 SP5 SP6 SP7 SP8 SP9 SP10 SP11 SP12 SP14 SP15 ~
SP16 SP17 SP18 SP19 SP21 SP22 SP20 FORT.LB
R

TYPE SPLA
RLDR/M SPL SP3 SP4 SP5 SP6 SP7 SP8 SP9 SP10 SP11 SP12 SP14 SP15 ~
SP16 SP17 SP18 SP19 SP21 SP25 SP20 FORT.LB
R

TYPE SPHA
RLDR/M SPH SP3 SP4 SP5 SP6 SP7 SP8 SP9 SP10 SP11 SP12 SP14 SP15 ~
SP16 SP17 SP18 SP19 SP21 SP22 SP20 FORT.LB
R

TYPE SP23A
RLDR/M SP23 FORT.LB
R

TYPE SP24A
RLDR/M SP24 FORT.LB
R
FILE SP1-MAIN WITHOUT FILTERS

PROGRAMMER NAME: S.P. SINGH

REVISION: 2

DATE: 4/19/79

PURPOSE: THIS MODULE ACCEPTS USER INPUTS AND CALLS ALL SUBSEQUENT MODULES

RRH IS AUTOCORRELATION VALUES OF DATA

GKC IS POWER SPECTRAL DENSITY FUNCTION

GKH IS SMOOTHED POWER SPECTRAL DENSITY

GKCP IS THE INVERSE FILTER FUNCTION

GKC3P IS THE APERTURE COMPENSATION FUNCTION

ITEMP, XTEMP ARE BUFFERS

NW IS THE NUMBER OF WORDS PER RECORD

NP IS THE NUMBER OF POINTS PER RECORD

INTEGER P,Q

DIMENSION RRH(101),ITEMP(1000),
     1    GKC(101),GKH(101)

DIMENSION GKCP(101),GKC3P(101)

DIMENSION NW(50),NP(50)

DIMENSION XTEMP(1000)

ACCEPT 'FILE NUMBER,NF=*',NF

ACCEPT 'DIFFUSE DENSITY FACTOR,DDF=*',DDF

ACCEPT 'MAXIMUM LAG FACTOR, M=*',M

ACCEPT 'HEIGHT OF SCANNING SLIT, XL=*',XL

ACCEPT 'WIDTH OF SCANNING SLIT, XA=*',XA

ACCEPT 'LOW FREQUENCY FILTER PARAMETER,P=*',P

P=0

Q=0

CALL PTDT (ITEMP,NF,H,NR,NH,NP)

CALL FOPEN(4,'PAR')

WRITE BINARY (4) NP,P,Q,NR

CALL FCLOS(4)

A=0

B=3200

NC=100

CALL HIST (ITEMP,A,B,NC,NR,NP)
CALL MEANS (ITEMP, XTEMP, NP, NR, DDF)
CALL SWAP ('SP23.SU', IER); CALL LFF (XTEMP, TEMP2, TEMP3, NP, P, NR)
CALL SWAP ('SP24.SU', IER); CALL HFF (XTEMP, TEMP2, TEMP3, NP, Q, NR)
CALL SIGMA (XTEMP, NR, NP)
CALL AUTOCOR (XTEMP, NP, NR, M, RRH, P, Q)
CALL PSDF (RRH, M, H, XL, GKC)
CALL INFCGKC, GKCP, Q, M
CALL AC1 (GKC, GKCP3P, M, H, XA)
CALL SPDF (M, GKCP3P, GKH)
CALL DELETE ('RD')
CALL DELETE ('NRD')
CALL DELETE ('ZRD')
CALL DELETE ('ZP')
CALL DELETE ('TD')
CALL DELETE ('PAR')
STOP
END
TYPE SP2

FILE SP2=MAIN WITH FILTERS

PROGRAMMER NAME: S.P. SINGH

REVISION:2

DATE:4/23/79

PURPOSE: THIS MODULE ACCEPTS USER INPUTS AND CALL ALL

SUBSEQUENT MODULES

RRH IS AUTOCORRELATION VALUES OF DATA

GKC IS POWER SPECTRAL DENSITY FUNCTION

GHK IS SMOOTHED POWER SPECTRAL DENSITY

GKCP IS THE INVERSE FILTER FUNCTION

GKC3P IS THE APERTURE COMPENSATION FUNCTION

ITEMP, XTEMP ARE BUFFERS

NW IS THE NUMBER OF WORDS PER RECORD

NP IS THE NUMBER OF POINTS PER RECORD

INTEGER P,Q

DIMENSION RRH(101),ITEMP(1000),

GKC(101),GHK(101)

DIMENSION GKCP(101),GKC3P(101)

DIMENSION NW(50),NP(50)

DIMENSION XTEMP(1000)

ACCEPT "FILE NUMBER,NF="NF

ACCEPT "DIFFUSE DENSITY FACTOR,DDF="DDF

ACCEPT "MAXIMUM LAG FACTOR,M="M

ACCEPT "HEIGHT OF SCANNING SLIT,XL="XL

ACCEPT "WIDTH OF SCANNING SLIT,XA="XA

ACCEPT "LOW FREQUENCY FILTER PARAMETER,P="P

ACCEPT "HIGH FREQUENCY FILTER PARAMETER,Q="Q

CALL PTDT (ITEMP,NF,H,NR,NW,NP)

CALL FOPEN(4,"PAR")

WRITE BINARY (4) NP,P,Q,NR

CALL FCLOS(4)

A=0

B=3200

NC=100

CALL HIST (ITEMP,A,B,NC,NR,NP)

CALL MEANS (ITEMP,XTEMP,NP,NR,DDF)

CALL SWAP("SP23.SU",IER); CALL LFF(XTEMP,TEMP2,TEMP3,NP,P,NR)
CALL SWAP("SP24.SU",IER); CALL HFF(XTEMP,TEMP2,TEMP3,NP,Q,NR)
CALL DELETE ("ZRD")
CALL RENAM ("ZPP","ZRD",IER)
CALL SIGMA(XTEMP,NR,NP)
CALL AUTOCOR(XTEMP,NP,NR,M,RRH,P,Q)
CALL PSDF(RRH,M,H,QL,GKC)
CALL INF(GKC,GKCP,Q,M)
CALL AC(GKCP,GKC3P,M,H,XA)
CALL SPDF(M,GKC3P,GTKH)
CALL DELETE("RD")
CALL DELETE("NRD")
CALL DELETE("ZRD")
CALL DELETE("ZP")
CALL DELETE("TD")
CALL DELETE("PAR")
STOP
END
TYPE SPL

FILE SPL=MAIN WITH LOW FREQUENCY FILTER
PROGRAMMER NAME: S.P. SINGH
REVISION: 0
DATE: 4/19/79
PURPOSE: THIS MODULE ACCEPTS USER INPUTS AND CALL ALL
SUBSEQUENT MODULES
RRH IS AUTOCORRELATION VALUES OF DATA
GKC IS POWER SPECTRAL DENSITY FUNCTION
GKH IS SMOOTHED POWER SPECTRAL DENSITY
GKCP IS THE INVERSE FILTER FUNCTION
GKC3P IS THE APERTURE COMPENSATION FUNCTION
ITEMP, XTEMP ARE BUFFERS
NW IS THE NUMBER OF WORDS PER RECORD
NP IS THE NUMBER OF POINTS PER RECORD
INTEGER P, Q
DIMENSION RRH(101), ITEMP(1000),
GKC(101), GKH(101)
DIMENSION GKCP(101), GKC3P(101)
DIMENSION NW(50), NP(50)
DIMENSION XTEMP(1000)
ACCEPT "FILE NUMBER, NF=", NF
ACCEPT "DIFFUSE DENSITY FACTOR, DDF=", DDF
ACCEPT "MAXIMUM LAG FACTOR, M=", M
ACCEPT "HEIGHT OF SCANNING SLIT, XL=", XL
ACCEPT "WIDTH OF SCANNING SLIT, XA=", XA
ACCEPT "LOW FREQUENCY FILTER PARAMETER, P=", P
ACCEPT "HIGH FREQUENCY FILTER PARAMETER, Q=", Q
Q=0
CALL PTDT (ITEMP, NF, H, NR, NW, NP)
CALL FOPEN(4, "PAR")
WRITE BINARY ( 4 ) NP, P, Q, NR
CALL FCLOS(4)
A=0
B=3200
NC=100
CALL HIST (ITEMP, A, B, NC, NR, NP)
CALL MEANS(ITEMP, XTEMP, NP, NR, DDF)
CALL SWAP("SP23.SV",IER); CALL LFF(XTEMP,TEMP2,TEMP3,NP,P,NR)
CALL DELETE("ZRD")
CALL RENAME("ZP","ZRD",IER)
CALL SWAP("SP24.SV",IER); CALL HFF(XTEMP,TEMP2,TEMP3,NP,Q,NR)
CALL SIGMA(XTEMP,NR,NP)
CALL AUTOCOR(XTEMP,NP,NR,M,RRH,P,Q)
CALL PSDF(RRH,M,H,XL,GKC)
CALL INF(GKC,GKCP,Q,M)
CALL AC1(GKC,GKC3P,M,H,XA)
CALL SPDF(M,GKC3P,GKH)
CALL DELETE("RD")
CALL DELETE("NRD")
CALL DELETE("ZRD")
CALL DELETE("ZP")
CALL DELETE("TD")
CALL DELETE("PAR")
STOP
END
TYPE SPH
C FILE SPH=MAIN WITH HIGH FREQ. FILTER ONLY
C PROGRAMMER NAME: S.P. SINGH
C REVISION: 0
C DATE: 4/24/79
C PURPOSE: THIS MODULE ACCEPTS USER INPUTS AND CALL ALL
C SUBSEQUENT MODULES
C RRH IS AUTOCORRELATION VALUES OF DATA
C GKC IS POWER SPECTRAL DENSITY FUNCTION
C GKH IS SMOOTHED POWER SPECTRAL DENSITY
C GKCP IS THE INVERSE FILTER FUNCTION
C GKC3P IS THE APERTURE COMPENSATION FUNCTION
C ITMP, XTEMP ARE BUFFERS
C NW IS THE NUMBER OF WORDS PER RECORD
C NP IS THE NUMBER OF POINTS PER RECORD
C INTEGER P, Q
C DIMENSION RRH(101), ITMP(1000),
1 GKC(101), GKH(101)
DIMENSION GKCP(101), GKC3P(101)
DIMENSION NW(50), NP(50)
DIMENSION XTEMP(1000)
ACCEPT 'FILE NUMBER', NF='NF
ACCEPT 'DIFFUSE DENSITY FACTOR', DDF='DF
ACCEPT 'MAXIMUM LAG FACTOR', M='M
ACCEPT 'HEIGHT OF SCANNING SLIT', XL='XL
ACCEPT 'WIDTH OF SCANNING SLIT', XA='XA
ACCEPT 'LOW FREQUENCY FILTER PARAMETER', P='P
P=0
ACCEPT 'HIGH FREQUENCY FILTER PARAMETER', Q='Q
CALL PTDT (ITMP, NF, H, NR, NW, NP)
CALL FOPEN(4, 'PAR')
WRITE BINARY (4) NP, P, Q, NR
CALL FCLOS(4)
A=0
B=3200
NC=100
CALL HIST (ITMP, A, B, NC, NR, NP)
CALL MEANS (ITMP, XTEMP, NP, NR, DDF)
CALL SWAP("SP23.SV",IER); CALL LFF(XTEMP,TEMP2,TEMP3,NP,P,NR)
CALL RENAM("ZRD","ZP",IER)
CALL SWAP("SP24.SV",IER); CALL HFF(XTEMP,TEMP2,TEMP3,NP,Q,NR)
CALL DELETE("ZRD")
CALL RENAM("ZPP","ZRD",IER)
CALL SIGMA(XTEMP,NR,NP)
CALL AUTOCOR(XTEMP,NP,NR,M,RRH,P,Q)
CALL PSDF(RRH,M,H,HL,GKC)
CALL INF(GKC,GKCP,Q,M)
CALL AC(GKCP,GKC3P,M,H,QA)
CALL SPDF(M,GKC3P,GKH)
CALL DELETE("RD")
CALL DELETE("NRD")
CALL DELETE("ZRD")
CALL DELETE("ZP")
CALL DELETE("TD")
CALL DELETE("PAR")
STOP
END
FILE SP3-PTDT

PROGRAMMER NAME: S.P. SINGH

REVISION: 0

DATE: 1/26/73

PURPOSE: THIS MODULE CALLS MODULES TO READ THE TAPE, REFORMAT IT, AND PRINT HEADER INFORMATION.

COMPILER NOSTACK

SUBROUTINE PTDT(ITEMP,NF,H,NR,NW,NP)

DIMENSION ITEMP(1000)

DIMENSION NW(50),NP(50)

TYPE "DATA PREPARATION COMMENCED"

CALL MTDAPD(13, "MT0:0", 256, IER)

IF (NF.EQ.1) GO TO 10

CALL SKPFL(ITEMP,NF)

CALL RDFL(ITEMP,NR,NW)

IREC=1

CALL HDR(ITEMP, IREC, H)

CALL RFMT(ITEMP, NR, NW, NP)

TYPE "RAW DATA STORED ON DISK."

RETURN

END
TYPE SP4
C FILE SP4=SKPFL
C PROGRAMMER NAME: S.P. SINGH
C REVISION: 0
C DATE: 1/30/79
C PURPOSE: THIS MODULE SKIPS THE NUMBER OF FILES
C SPECIFIED BY THE USER.
C COMPILER NOSTACK
C SUBROUTINE SKPFL (INPBUF,NF)
C DIMENSION INPBUF(1000)
C KFL=1
10 CALL MTDIO(13,0,INPBUF,ISTAT,IER,ICNT)
   IF (ICNT.NE.1) GO TO 10
   KFL=KFL+1
   IF (KFL.EQ.NF) GO TO 20
   GO TO 10
20 CONTINUE
   NF1=NFI-1
   TYPE 'NUMBER OF FILES SKIPPED=',NF1
   RETURN
END
FILE SP5=RDFL R
PROGRAMMER NAME: S.P. SINGH
REVISION: 0
DATE: 2/2/79
COMPILER: NOSTACK
SUBROUTINE RDFL (INPBUF, NR, NW)
PURPOSE:
  RDFL reads one file from tape into INPBUF
  and writes it in disk file TD.
  ICNT is no. of words in a record
  DIMENSION NW(50), INPBUF(1000)

NR is no. of records
NW is array containing no. of words in each record
TYPE "FILE IS BEING READ FROM TAPE"
NR=0
CALL FOPEN(2, "TD", 2000)
TYPE "FILE TD OPENED"
DO 10 I=1, 50
   NW(I)=0
   10 CONTINUE
   DO 20 I=1, 1000
      INPBUF(I)=0
      20 CONTINUE
   CALL MTDIO(13, 0, INPBUF, IST, IER, ICNT)
   TYPE "NO OF SAMPLES=", INPBUF(22)
   TYPE "RDFL ICNT=", ICNT
   IF (ICNT.EQ.1) GO TO 100
   NR=NR+1
   NW(NR)=ICNT
   CALL WRITR(2, NR, INPBUF, 1, IER)
   GO TO 10
   CONTINUE
   TYPE "NUMBER OF RECORDS READ=", NR
   TYPE "FILE READ FROM TAPE AND WRITTEN ON DISK"
   CALL FCLOS(2)
   RETURN
TYPE SP6

FILE SP6=HDR
PROGRAMMER NAME:S.P. SINGH
REVISION:0
DATE:2/7/79
PURPOSE: THIS MODULE READS THE TAPE DATA FROM FILE
"TD", PRINTS HEADER INFORMATION, AND COMPUTES \( H-\text{DELTA} \) X
COMPILER NOSTACK

SUBROUTINE HDR(ITEMP,IREC,H)
DIMENSION ITEMP(1000)
DOUBLE PRECISION IWD,IWD1,IWD2,II
CALL FOPEN(2,"TD",2000)
CALL READR(2,IREC,ITEMP,1,IER)
WRITE (10,10) (ITEMP(J),J=2,21)
10 FORMAT (1X,20A2)
TYPE "NUMBER OF SAMPLES-",ITEMP(22)
CALL CORD(ITEMP,23,IWD)
IX=IWD
TYPE "X COORDINATE (MICRONS)=", IX
CALL CORD (ITEMP,25,IWD)
IY=IWD
TYPE "Y COORDINATE (MICRONS)=", IY
CALL CORD(ITEMP,27,IWD)
IX=IWD
TYPE "\text{DELTA} X (H) (MICRONS)=",IX
H=IX
IF (H.LT.0) H=-H
CALL FCLOS(2)
RETURN
END
TYPE SP7

FILE SP7=CORD

PROGRAMMER NAME: S.P. SINGH

REVISION: 0

DATE: 2/14/79

PURPOSE: THIS MODULE DECODES X,Y COORDINATES AND DELTA X FROM 2 INPUT WORDS

COMPILER NONSTACK

SUBROUTINE CORD(ITEMP,J,IWD)

DIMENSION ITEMP(1000)

DOUBLE PRECISION IWD,IWD1,IWD2,II

DOUBLE PRECISION IJ,IK

TYPE 'CORD WAS CALLED'

IK=1.0D0
IJ=32768.0D0
II=65536.0D0
IX1=ITEMP(J)
IX2=ITEMP(J+1)

TYPE 'IX1=',IX1

TYPE 'IX2=',IX2

IF (IX1.LT.0) GO TO 10
IF (IX2.LT.0) GO TO 20
IWD1=IX1
IWD2=IX2
IWD=IWD1+IWD2
GO TO 50

20 CALL ICLR(IX2,15)

TYPE 'IX2 AFTER ICLR',IX2

IWD1=IX1
IWD2=IX2
IWD2=IWD2+IJ
IWD=IWD1+IWD2
GO TO 50

10 IX3=-IX1-1
IX4=-IX2-1
IF (IX4.LT.0) GO TO 30
IWD1=IX3
IWD2=IX4
IUD=IUD1 + IUD2
IUD=IUD+IJK
GO TO 50
CALL ICLR(IK4,15)
IUD1=IJK3
IUD2=IJK4
IUD=IUD1+IUD2
CONTINUE
RETURN
END
TYPE SPB
  FILE SP8=RFMT
  PROGRAMMER NAME: S.P. SINGH
  REVISION: 0
  DATE: 2/12/79
  PURPOSE: THIS MODULE REFORMATS EACH RECORD TO THE
  16 BIT INTEGER FORMAT OF THE NOVA 1200 AND
  PLACES IT IN FILE 'RD'.
  COMPILER NOSTACK
  SUBROUTINE RFMT(ITEMP,NR,NW,NP)
  DIMENSION ITEMP(1000),XT(300)
  DIMENSION NP(50),NW(50)
  COMMON JTEMP(1000)
  EQUVALENCE (ITEMP,JTEMP)
  CALL FOPEN(2,"TD",2000)
  CALL FOPEN (3,"RD",2000)
  TYPE*DATA IS BEING FORMATTED*
  DO 20 JR=1,NR
  DO 10 I=1,1000
    JTEMP(I)=0
    ITEMP(I)=0
    CONTINUE
    CALL READR(2,JR,ITEMP,1,IER)
    NW1=NW(JP)
  10 TYPE *NW1=",NW1
  20 TYPE *ABOUT TO CALL GBYTE*
    INP=ITEMP(J)
    CALL GBYTE(INP,IOU,0,12)
  30 TYPE *GBTYBE WAS CALLED*
    JTEMP(J-28)=IOU
    CONTINUE
  30 TYPE *ABOUT TO CALL WRITR*
    CALL WRITR (3,JR,JTEMP,1,IER)
  40 TYPE *WRITR CALLED*
    NP(JR)=NW(JR)-28
    CONTINUE
    CALL READR (3,1,JTEMP,1,IER)
```
NP1=NP(1)
IF (NP1.GT.300) NP1=300
DO 40 I=1,NP1
   JK=JTEMP(I)/8
   XT(I)=JK/100.
   CONTINUE
40 WRITE (10,50) (XT(I),I=1,NP1)
50 FORMAT (10(1X,F5.2))
   TYPE *DATA FORMATTING COMPLETED*
   CALL FCLOS(2)
   CALL FCLOS(3)
   RETURN
END
```
FILE SP9=BYTE

PROGRAMMER NAME: S.P. SINGH

REVISION: 0

DATE: 2/16/79

PURPOSE: THIS MODULE EXTRACTS BIT PATTERNS FROM

A 16 BIT INTEGER WORD.

IPK IS THE 16 BIT WORD

IUPK IS THE BIT PATTERN REMOVED FROM IPK

OFF IS THE STARTING BIT POSITION IN IPK

NBTS IS THE NUMBER OF BITS TO BE REMOVED FROM IPK

SUBROUTINE GBYTE(IPK,IUPK,NOFF,NBTS)

INTEGER MASK(15),LOC(15)

DATA LOC/1K,2K,4K,10K,20K,40K,100K,200K,400K,

1000K,2000K,4000K,10000K,20000K,40000K/

DATA MASK/77777K,37777K,17777K,7777K,3777K,1777K,

777K,377K,177K,77K,37K,17K,7K,3K,1K/

IUPK=IPK.AND.MASK(1)

IF (NOFF.LT.2) GO TO 5

IUPK=IUPK.AND.MASK(NOFF)

NSHFT=16-(NOFF+NBTS)

IF(NSHFT.EQ.0.OR.NSHFT.EQ.15) GO TO 12

IUPK=IUPK/(2**NSHFT)

CONTINUE

IF(NSHFT.EQ.15) IUPK=0

IF(NOFF.GT.0.OR.IPK.GE.0) RETURN

IUPK=IUPK.OR.LOC(NBTS)

END
TYPE SP10
C     FILE SP10-MEANS
C     PROGRAMMER NAME: S.P. SINGH
C     REVISION: 1
C     DATE: 3/19/79
C     PURPOSE: THIS MODULE CALLS OTHER MODULES TO COMPUTE MEAN OF
C     RAW DATA AND NORMALIZE DATA TO DIFFUSE DENSITY UNITS AND ZERO MEAN
C     COMPILER NOSTACK
C     SUBROUTINE MEANS(ITEMP,XTEMP,NP,NR,DDF)
C     SS10 IS MEANS
C     DIMENSION ITEMP(1000)
C     DIMENSION XTEMP(1000)
C     DIMENSION NP(50)
C     ICHR=3
C     ICHN=4
C     ICHZ=5
C     CALL AVG(ITEMP,ICHR,NR,NP,RAWM)
C     CALL NRMLZ(ITEMP,XTEMP,DDF,ICHR,NR,NP,ICHN,RAWM)
C     DDM=DDF
C     TYPE "MEAN OF NORMALIZED DATA= ",DDM
C     CALL ZMEAN(XTEMP,ICHN,ICHZ,NR,NP,DDM)
C     RETURN
C     END
TYPE SP11
C FILE SP11=SIGMA
C PROGRAMMER NAME: S.P. SINGH
C REVISION: 0
C DATE: 3/13/79
C PURPOSE: THIS MODULE COMPUTES THE MEAN SQUARE VALUE
C AND THE ROOT MEAN SQUARE VALUE
C COMPILER: NOSTACK
C SUBROUTINE SIGMA (TEMP,NR,NP)
C DIMENSION TEMP(1000),NP(50)
ICHZ=5
CALL FOPEN(ICHZ,"ZRD",4000)
SSQ=0.0
NP=0
DO 10 I=1,NR
CALL READRICHIZ(I,TEMP,1,IER)
NP=NP(I)
C
C THIS COMPUTES THE MEAN SQUARE
DO 20 J=1,NP
SSQ=SSQ+((TEMP(J))**2)
20 CONTINUE
INP=INP+NP
10 CONTINUE
XSQ=SSQ/INP
C
C THIS COMPUTES THE ROOT MEAN SQUARE
SIG=SQR((XSQ*INP/(INP-1)))
TYPE "MEAN SQUARE VALUE = ",XSQ
TYPE "ROOT MEAN SQUARE VALUE = ",SIG
CALL FCLOS(ICHZ)
C
C TYPE "SIGMA WAS CALLED"
RETURN
END
FILE SP12-AUTOCOR

PROGRAM NAME: S.P. SINGH

REVISION: 1

DATE: 4/4/79

PURPOSE: THIS MODULE COMPUTES THE AUTOCORRELATION AND
NORMALIZED AUTOCORRELATION FUNCTION OF ZMEAN DATA.

RAT IS THE AUTOCOR VALUES

RATN IS THE NORMALIZED AUTOCOR VAULES

TEMP,XT ARE BUFFERS

COMPILER NOSTACK

SUBROUTINE AUTOCOR(TEMP,NP,MR,M,RAT,P,Q)

INTEGER P,Q

DIMENSION NP(50)

DIMENSION RATN(101),RAT(101)

DIMENSION XT(101)

DIMENSION TEMP(1000)

TYPE "AUTOCORRELATION IS BEING COMPUTED"

ICHZ=5

CALL FOPEN(ICHZ,"ZRD",4000)

DO 5 I=1,1000

TEMP(I)=0

DO 10 I=1,101

RAT(I)=0.0

XT(I)=0

CONTINUE

MR=M+1

NR1=NR+1

INP=0

DO 20 I=1,MR1

IF(I.EQ.MR1) GO TO 90

CALL READR(ICHZ,I,TEMP,1,IER)

INP=INP+NP(I)

NP1=NP(I)

DO 30 I3=1,NP1

TEMP(NP1+M-I3+1)=TEMP(NP1-I3+1)

30 CONTINUE

CONTINUE

90 CONTINUE
DO 40 I4=1,M
  TEMP(I4)=XT(I4)
40  CONTINUE
  DO 50 I5=1,M
    XT(I5)=TEMP(NP1+I5)
50  CONTINUE
  DO 60 J=1,MR
    SUM=0.0
70  CONTINUE
    JR=J-1
60  CONTINUE
  DO 70 I7=1,NP1
30  CONTINUE
    SUM=SUM+TEMP(I7)+TEMP(I7+JR)
70  CONTINUE
  CONTINUE
  RAT(J)=RAT(J)+SUM
60  CONTINUE
  IF(I.NE.NR) GO TO 20
30  CONTINUE
  DO 80 I8=1,1000
40  CONTINUE
    TEMP(I8)=0.0
80  CONTINUE
  DO 85 J=1,MR
50  CONTINUE
    RAT(J)=RAT(J)/(INP-J+1-(2*(P+Q)))
85  CONTINUE
  DO 100 J=1,MR
60  CONTINUE
    RATN(J)=RAT(J)/RAT(1)
100 CONTINUE
  TYPE = 'R'   R-HAT
100 CONTINUE
  DO 2000 J=1,MR
100 CONTINUE
    IR=J-1
2000 CONTINUE
    WRITE(10,1000) IR,RAT(J),RATN(J)
1000 FORMAT(1X,I3,8X,E11.4,8X,E11.4)
2000 CONTINUE
    CALL FCLOS(ICHZ)
    RETURN
END
TYPE SP14

FILE SP14-HIST

PROGRAMMER NAME: S.P. SINGH

REVISION: 0

DATE: 2/20/79

PURPOSE: THIS MODULE COMPUTES A HISTOGRAM FOR THE DATA

COMPILER NOSTACK

SUBROUTINE HIST (ITEMP,A,B,NC,NR,NP)

DIMENSION ITEMP(1000),NP(50),NHST(101),MST(101)

CALL FOPEN(3,"RD",2000)

TYPE "HISTOGRAM BEING COMPUTED"

CI IS CLASS INTERVAL

NC1=NC+1
CI=(B-A)/NC

DO 5 J=1,NC1
MST(J)=0

CONTINUE

COMPUTE HISTOGRAM

DO 10 J=1,NR
CALL READR(3,J,ITEMP,1,IER)
NP1=NP(J)
CALL DCLS(ITEMP,NP1,CI,NHST)

DO 20 I=1,NC1
MST(I)=MST(I)+NHST(I)

20 CONTINUE

10 CONTINUE

COMPUTE FIRST CLASS CONTAINING AT LEAST ONE POINT

DO 30 I=1,NC1
IF (MST(I).GE.1) GO TO 40

30 CONTINUE

IMIN=I

COMPUTE LAST CLASS CONTAINING AT LEAST ONE POINT
DO 50 I=1,NC1
IF (MST(NC1-I+1).GE.1) GO TO 60
50 CONTINUE
60 IMAX=NC1-I+1
TYPE " "
TYPE "TOTAL NO. OF CLASSES=" ,NC
TYPE " CLASS NO. NO. OF DATA POINTS"
DO 70 I=IMIN,IMAX
TYPE I," " ,MST(I)
70 CONTINUE
CALL FCLOS(3)
RETURN
END
TYPE SP15
C FILE SP15=DCLS
C PROGRAMMER NAME: S.P. SINGH
C REVISION: 0
C DATE: 2/26/79
C PURPOSE: THIS MODULE ASSIGNS A DATA VALUE TO A CLASS INTERVAL FOR COMPUTING HISTOGRAM.
C COMPILER NOSTACK
SUBROUTINE DCLS(ITEMP,NP1,CI,NHST)
DIMENSION ITEMP(1000),NHST(101)
DO 10 I=1,101
   NHST(I)=0
10 CONTINUE
DO 20 I=1,NP1
   J=IFIX(ITEMP(I)/CI)
   NHST(J+1)=NHST(J+1)+1
20 CONTINUE
RETURN
END
TYPE SP16
C FILE SP16=AUG
C PROGRAMMER NAME: S.P. SINGH
C REVISION: 0
C DATE: 3/6/79
C PURPOSE: THIS MODULE COMPUTES THE RAW MEAN OF THE DATA.
C COMPILER NOSTACK
C SUBROUTINE AVG(ITEMP,ICHR,NR,NP,RAWM)
C SP16 IS AVG
C REAL ISUM
C DIMENSION ITEMP(1000),NP(50)
C CALL FOPEN(ICH,R,"RD",2000)
C INP=0
C ISUM=0
C SUM ALL THE POINTS IN THE FILE
C
C DO 10 I=1,NR
C CALL READR(ICH,R,ITEMP,1,IERR)
C NPI=MP(I)
C DO 20 J=1,NPI
C ISUM=ISUM+ITEMP(J)
C 20 CONTINUE
C INP=INP+NPI
C CONTINUE
C RAWM=ISUM/INP
C TYPE "RAW MEAN = ",RAWM
C CALL FCLOS(ICH)
C RETURN
C END
TYPE SP17

FILE SP17-NRMLZ
PROCEDURE NAME: S.P. SINGH
REVISION: 1
DATE: 3/19/79
PURPOSE: THIS MODULE NORMALIZES THE FILE
DATA BY MULTIPLYING THE DATA POINTS
BY THE DIFFUSE DENSITY FACTOR AND CREATES A NEW FILE.

COMPILER: NOSTACK
SUBROUTINE NRMLZ(ITEMP, XTEMP, DDF, ICHR, NR, NP, ICHN, RAUM)

SP17 IS NRMLZ
DIMENSION ITEMP(1000), NP(50)
DIMENSION XTEMP(1000)
CALL FOPEN(ICHN, "NRD", 4000)
CALL FOPEN(ICHN, "RD", 2000)
DO 10 I=1, NR
CALL READR(ICHN, I, ITEMP, 1, IER)
NP=NP(I)
DO 20 J=1, NP
XTEMP(J)*ITEMP(J)*DDF/RAUM
CONTINUE
CALL WRITR(ICHN, I, XTEMP, 1, IER)
CONTINUE
10 CONTINUE
CALL FCLOS(ICHN)
RETURN
END
TYPE SP18

FILE SP18=ZMEAN

PROGRAMMER NAME: S.P. SINGH

REVISION: 0

DATE: 3/9/79

PURPOSE: THIS MODULE NORMALIZES DATA BY SUBTRACTING
THE DIFFUSE DENSITY MULTIPLIER FROM THE NORMALIZED DATA,
CREATING A NEW FILE.

COMPILER NOSTACK

SUBROUTINE ZMEAN(ITEMP,ICHN,ICHZ,NR,NP,DDM)

DIMENSION ITEMP(1000),NP(50)

REAL ITEMP

CALL FOPEN(ICHZ,"ZRD",4000)

CALL FOPEN(ICHN,"NRD",4000)

DO 10 I=1,NR

CALL READR(ICHN,I,ITEMP,1,IER)

NPI=NP(I)

DO 20 J=1,NPI

ITEMP(J)=ITEMP(J)-DDM

20 CONTINUE

CALL WRITR(ICHZ,I,ITEMP,1,IER)

10 CONTINUE

CALL FCLOS(ICHN)

CALL FCLOS(ICHZ)

RETURN

END
SUBROUTINE PSDF(RAT,M,H,XL,GKC)
DIMENSION RAT(181),GKC(181),GKH(181)
MR=M+1

COMPUTE THE POWER SPECTRAL DENSITY FUNCTION

DO 10 KR=1,MR
SUM=0.0
MR2=MR-2
DO 20 JR=1,MR2
SUM=SUM+RAT(JR+1)*COS(3.14159*JR*(KR-1)/(MR-1))
CONTINUE
10 CONTINUE
GKC(KR)=2.*H*XL*(RAT(1)+2.*SUM+RAT(MR)*(-1)**(KR-1))
CONTINUE
RETURN
END
TYPE SP20

FILE SP20=SPDF
PROGRAMMER NAME: S.P. SINGH
REVISION: 1
DATE: 4/20/79
PURPOSE: THIS MODULE COMPUTES THE SMOOTHED POWER DENSITY FUNCTION.
COMPILED NOSTACK
SUBROUTINE SPDF(M,GKC,GKH)
DIMENSION GKC(101),GKH(101)
MR=M+1
GKH(1)=0.5*(GKC(1)+GKC(2))
GKH(MR)=0.5*(GKC(MR-1)+GKC(MR))
MR1=MR-1

C

COMPUTE SMOOTHED DENSITY FUNCTION

DO 10 KR=2,MR1
GKH(KR)=0.25*(GKC(KR-1)+GKC(KR+1))+0.5*(GKC(KR))
CONTINUE
TYPE = K       GKC3P(K)       GH(K)  *
DO 2000 J=1,MR
IR=J-1
WRITE(10,100) IR,GKC(J),GKH(J)
100 FORMAT(1X,I3,8X,E11.4,8X,E11.4)
2000 CONTINUE
RETURN
END
TYPE SP21
C.
C. FILE SP21=INF
C. PROGRAMMER NAME: S.P. SINGH
C. REVISION: 1
C. DATE: 3/19/79
C. PURPOSE: THIS MODULE PERFORMS THE INVERSE FILTER OPERATION
C. ON THE POWER SPECTRAL DENSITY FUNCTION.
C. COMPILED MOSTACK
C. SUBROUTINE INF(GKC, GKCP, Q, M)
C. DIMENSION GKC(101), GKCP(101)
C. INTEGER Q
C. PI=3.14159
C. MR=M+1
C. COMPUTE THE FILTERED PSDF
C.
C. DO 10 K1=1, MR
C. K*K1-1
C. IF(K.GT.0) GO TO 5
C. GKCP(K1)=GKC(K1)
C. DO 10 K1=1, MR
C. IF(SIN((K*PI)*(2*Q+1)/(2*M)).LT.1.E-06) TYPE
C. "THE DENOMINATOR OF SINE FUNCTION BELOW 1.E-06 ENCOUNTERED IN INF"
C. GKCP(K1)*GKC(K1)*((2*Q+1)*SIN((K*PI)/(2*M))/SIN((K*PI)*(2*Q+1))
C. /(2*M))**2
C. CONTINUE
C. TYPE * K
C. DO 2000 J=1, MR
C. IR-J-1
C. WRITE(10,100) IR, GKC(J), GKCP(J)
C. 100 FORMAT(1X,I3,8X,E11.4,8X,E11.4)
C. 2000 CONTINUE
C. RETURN
C. END
TYPE SP22
C  SP22=AC
C  PROGRAMMER NAME : S.P. SINGH
C  REVISION:1
C  DATE:J/19/79
C  PURPOSE: THIS MODULE PERFORMS THE APERTURE COMPENSATION
C  OPERATION ON THE INVERSE FILTERED PSDF.
C  COMPILER NOSTACK
C  SUBROUTINE AC(GKCP,GKC3P,M,H,XA)
C  DIMENSION GKCP(101),GKC3P(101)
C  PI=3.14159
C  MR=M+1
DO 10 K1=1,MR
  K=K1-1
  IF(K.GT.0) GO TO 5
  GKC3P(K1)=GKCP(K1)
  GO TO 10
5  IF(SIN((K*PI*XA)/(2*H*M)).LT.1.0E-06) TYPE
  *THE DENOMINATOR OF SINE FUNCTION BELOW 1.0E-06 ENCOUNTERED IN AC*
  GKC3P(K1)=GKCP(K1)*(((K*PI*XA)/(2*H*M))/SIN((K*PI*XA)/(2*H*M))))**2
10  CONTINUE
  TYPE * K
  GKCP(K) GKC3P(K)*
DO 2000 J=1,MR
  IR=J-1
  WRITE(10,100) IR,GKCP(J),GKC3P(J)
2000 FORMAT(1X,I3,8X,E11.4,8X,E11.4)
CONTINUE
RETURN
END
FILE SP23=LFF
PROGRAMMER NAME: S.P. SINGH
REVISION: 2
DATE: 4/20/79
PURPOSE: THIS MODULE PERFORMS THE LOW FREQUENCY OPERATION
ON THE Z-NORMALIZED DATA.
COMPILER NOSTACK
SUBROUTINE LFF(TEMP1,TEMP2,TEMP3,NP1,P,NR)
DIMENSION TEMP1(1000),TEMP2(1000),TEMP3(1000)
INTEGER QUO,P,Q,P2,NP1(50),REC1,REC2,REC3

CALL FOPEN(2,"ZRD",4000)
CALL FOPEN(3,"ZP",4000)
CALL FOPEN(4,"PAR")
READ BINARY (4) NP1,P,Q,NR
CALL FCLOS(4)

CALCULATE % OF RECORDS TO COMPUTE FIRST SUM AND
FIND REC. % OF FIRST POINT

NP=NP1(1)
NREC=(2*P+1)/NP
IF(MOD(2*P+1,NP).GT.0) NREC=NREC+1
QUO=P/NP
IF(MOD(P,NP).GT.0) QUO=QUO+1
IF (QUO.EQ.1) GO TO 3
JQUO=QUO-1
DO 2 I=1,JQUO
CALL READR (2,I,TEMP1,1,IER)
2 CONTINUE
CALL WRITR (3,I,TEMP1,1,IER)
3 CONTINUE

CALCULATE FIRST SUM (POINT P+1)

NI=0
SUM=0.0
DO 10 I=1,NREC
CALL READR(2,I,TEMP1,1,IER)
DO 20 J=1,MP
SUM=SUM+TEMP1(J)
N1=N1+1
IF(N1.EQ.(2*P+1)) GO TO 5
CONTINUE
CONTINUE
CONTINUE
CONTINUE

FIND LOCATION OF FIRST POINT

CALL READR(2,QUO,TEMP1,1,IER)
LOC1=P+1-(NP%(QUO-1))
TEMP1(LOC1)=TEMP1(LOC1)-(SUM/(FLOAT(2*P+1))
CALL WRITR(3,QUO,TEMP1,1,IER)
P2=P+2
N=NP*NR
NMP=N-P
DO 30 I=P2,NMP

CALCULATE REC $ OF PTS. I,I-P-1,I+P

REC1=I/NP
IF(MOD(I,NP).GT.0) REC1=REC1+1
REC2=(I-P-1)/NP
IF(MOD(I-P-1,NP).GT.0) REC2=REC2+1
REC3=(I+P)/NP
IF(MOD(I+P,NP).GT.0) REC3=REC3+1
IF (I.NE.P2) GO TO 40
IREC1=REC1
IREC2=REC2
IREC3=REC3
CALL READR (2,REC1,TEMP1,1,IER)
CALL READR (2,REC2,TEMP2,1,IER)
CALL READR (2,REC3,TEMP3,1,IER)
CONTINUE
C. CULATE LOC. OF PTS. I, I-P, I+P IN RESPECTIVE RECORDS
LOC1 = I - (NP*(REC1-1))
LOC2 = (I-P) - (NP*(REC2-1))
LOC3 = (I+P) - (NP*(REC3-1))

C

READ RESPECTIVE RECORDS TO OBTAIN I, I-P, I+P
IF (IREC1.EQ.REC1) GO TO 50
CALL READR(2,REC1,TEMP1,1,IER)
IREC1 = REC1
CONTINUE
IF (IREC2.EQ.REC2) GO TO 60
CALL READR(2,REC2,TEMP2,1,IER)
IREC2 = REC2
CONTINUE
IF (IREC3.EQ.REC3) GO TO 70
CALL READR(2,REC3,TEMP3,1,IER)
IREC3 = REC3
CONTINUE
SUM = SUM - TEMP2(LOC2) + TEMP3(LOC3)
XT = TEMP1(LOC1) - (SUM/FLOAT(2*P+1))
CALL READR(3,REC1,TEMP1,1,IER)
TEMP1(LOC1) = XT
CALL WRITR(3,REC1,TEMP1,1,IER)
CONTINUE
IF (REC1.EQ.NR) GO TO 90
IREC1 = REC1 + 1
DO 80 I = REC1, NR
CALL READR(2,I,TEMP1,1,IER)
CALL WRITR(3,I,TEMP1,1,IER)
CONTINUE
80 CONTINUE
CONTINUE
QU0 = P/NP
IF(MOD(P,NP).GT.0) QU0 = QU0 + 1
IP = P - ((QU0-1)*NP)
CALL READR(3,QUO,TEMP1,1,IER)
TYPE 'Z'
CALL WRITR(3,QUO,TEMP1,1,IER)
TYPE (TEMP1(I),I-IP,NP)
CONTINUE

ZERO OUT BEGINNING AND LAST P POINTS FROM FILE ZP

ICNT=0
NP2=NP1(1)
NR2=NR
DO 1 I=1,NR
  CALL READR(3,I,TEMP1,1,IER)
  CALL READR(3,NR2,TEMP2,1,IER)
DO 200 J=1,NP2
  TEMP1(J)=0.0
  TEMP2(J)=0.0
  ICNT=ICNT+1
  IF(ICNT.EQ.P) GO TO 300
200 CONTINUE
CALL WRITR(3,I,TEMP1,1,IER)
CALL WRITR(3,NR2,TEMP2,1,IER)
NR2=NR2-1
300 CONTINUE
CALL WRITR(3,I,TEMP1,1,IER)
CALL WRITR(3,NR2,TEMP2,1,IER)

CALL FCLOS(2)
CALL FCLOS(3)
CALL BACK
END
TYPE SP24
C FILE SP24=HFF
C PROGRAMMER NAME: S.P. SINGH
C REVISION: 2
C DATE: 4/20/79
C PURPOSE: THIS MODULE PERFORMS THE HIGH FREQUENCY OPERATION ON
C THE LOW FREQUENCY DATA.
C COMPILER NOSTACK
C SUBROUTINE HFF(TEMP1,TEMP2,TEMP3,NP1,P,NR)
C DIMENSION TEMP1(1000),TEMP2(1000),TEMP3(1000)
C INTEGER QUO,P,Q,P2,NP1(50),REC1,REC2,REC3
C TYPE "DATA IS BEING FILTERED FOR HIGH FREQUENCY"
C CALL FOPEN(2,"ZP",4000)
C CALL FOPEN(3,"ZPP",4000)
C CALL FOPEN(4,"PAR")
C READ BINARY (4) NP1,Q,P,NR
C CALL FCLOS(4)

C CALCULATE $ OF RECORDS TO COMPUTE FIRST SUM AND
C FIND REC. $ OF FIRST POINT
C
NP=NP1(1)
NREC=(2*P+1)/NP
IF(MOD(2*P+1,NP).GT.0) NREC=NREC+1
QUO=P/NP
IF(MOD(P,NP).GT.0) QUO=QUO+1

C CALCULATE FIRST SUM (POINT P+1)
C
N1=0
SUM=0.0
DO 10 I=1,NREC
CALL READR(2,I,TEMP1,1,IER)
DO 20 J=1,NP
SUM=SUM+TEMP1(J)
N1=N1+1
IF(N1.EQ.(2*P+1)) GO TO 5
10 CONTINUE
10 CONTINUE
CONTINUE

FIND LOCATION OF FIRST POINT

CALL REAPR(2,QUO,TEMP1,1,IER)
LOC1=P+1-(NP%(QUO-1))
TEMP1(LOC1)=SUM/FLOAT(2*P+1)
CALL WRTG(3,QUO,TEMP1,1,IER)
P2=P+2
N=NP%NR
NMP=N-P
DO 30 I=P2,NMP

CALCULATE REC & OF PTS. I,I-P-1,I+P

REC1=I/NP
IF(MOD(I,NP).GT.0) REC1=REC1+1
REC2=(I-P-1)/NP
IF(MOD(I-P-1,NP).GT.0) REC2=REC2+1
REC3=(I+P)/NP
IF(MOD(I+P,NP).GT.0) REC3=REC3+1
IF (I.NE.P2) GO TO 40
IREC1=REC1
IREC2=REC2
IREC3=REC3
CALL READR (2,REC1,TEMP1,1,IER)
CALL READR (2,REC2,TEMP2,1,IER)
CALL READR (2,REC3,TEMP3,1,IER)
CONTINUE

CALCULATE LOC. OF PTS. I,I-P-1,I+P IN RESPECTIVE RECORDS

LOC1=I-(NP%(REC1-1))
LOC2=(I-P-1)-(NP%(REC2-1))
LOC3=(I+P)-(NP%(REC3-1))

READ RESPECTIVE RECORDS TO OBTAIN I,I-P-1,I+P
IF (IREC1.EQ.REC1) GO TO 50
CALL READR (2,REC1,TEMP1,1,IER)
IREC1=REC1
CONTINUE
IF (IREC2.EQ.REC2) GO TO 60
CALL READR (2,REC2,TEMP2,1,IER)
IREC2=REC2
CONTINUE
IF (IREC3.EQ.REC3) GO TO 70
CALL READR (2,REC3,TEMP3,1,IER)
IREC3=REC3
CONTINUE
SUM=SUM-TEMP2(LOC2)+TEMP3(LOC3)
XT=SUM/FLOAT(2*IP+1)
CALL READR(3,REC1,TEMP1,1,IER)
TEMP1(LOC1)=XT
CALL WRITR(3,REC1,TEMP1,1,IER)
CONTINUE
QUO=Q/NP
IF (MOD(Q,NP).GT.0) QUO=QUO+1
IP=Q-(QUO-1)*NP)+P
CALL READR(3,QUO,TEMP1,1,IER)
TYPE 'Z'/''
TYPE (TEMP1(I),I=IP,NP)
ZERO OUT BEGINNING AND LAST P+Q POINTS FROM FILE ZPP
ICNT=0
NP2=NP1(1)
NR1-NR
DO 1 I=1,NR
CALL READR(3,I,TEMP1,1,IER)
CALL READR(3,NR1,TEMP2,1,IER)
1 DO 200 J=1,NP2
TEMP1(J)=0.0
TEMP2(J)=0.0
ICNT=ICNT+1
DO 200 J=1,NP2
TEMP1(J)=0.0
TEMP2(J)=0.0
IF(ICNT.EQ.(P+Q)) GO TO 300
DO 200 J=1,NP2
TEMP1(J)=0.0
TEMP2(J)=0.0
IF(ICNT.EQ.(P+Q)) GO TO 300
200 CONTINUE

200    CONTINUE
       CALL WRITR(3,I,TEMP1,1,IER)
       CALL WRITR(3,NR1,TEMP2,1,IER)
       NR1 = NR1 - 1
100    CONTINUE
300    CALL WRITR(3,I,TEMP1,1,IER)
       CALL WRITR(3,NR1,TEMP2,1,IER)
       CALL FCLOS(2)
       CALL FCLOS(3)
       CALL BACK
       END
**TYPE SP25**

```plaintext
C     SP25=AC1
C     PROGRAMMER NAME: S.P. SINGH
C     REVISION: 0
C     DATE: 4/20/79
C     PURPOSE: THIS MODULE PERFORMS THE APERTURE COMPENSATION
C     OPERATION ON THE INVERSE FILTERED PSDF FOR SPI AND SPL.
C     COMPILER MOSTACK
C     SUBROUTINE AC1(GKCP,GKC3P,M,H,XA)
C     DIMENSION GKCP(101),GKC3P(101)
C     PI=3.14159
C     MR=M+1
C     DO 10 K1=1,MR
C     K=K1-1
C     IF(K.GT.0) GO TO 5
C     GKC3P(K1)=GKC3P(K1)
C     GO TO 10
C     5 IF(SIN(K*PI*XA)/(2*H*M)).LT.1.0E-06) TYPE
C        "THE DENOMINATOR OF SINE FUNCTION BELOW 1.0E-06 ENCOUNTERED IN AC"
C        GKC3P(K1)=GKC3P(K1)*((K*PI*XA)/(2*H*M))/SIN((K*PI*XA)/(2*H*M)))**2
C     CONTINUE
C     TYPE: K
C     GKC(K)    GKC3P(K)
C     DO 2000 J=1,MR
C     IR=J-1
C     WRITE(10,100) IR,GKC3P(J),GKC3P(J)
C     100 FORMAT(1X,I3,8X,E11.4,8X,E11.4)
C     2000 CONTINUE
C     RETURN
C     END
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VOLUME 3

USERS MANUAL
FOR
AUTORADIOGRAPHIC ENHANCEMENT PROCESS
DATA ANALYSIS SOFTWARE
PREFACE

This is the User Manual for the software developed for the evaluation of the Wiener Spectrum and Modulation Transfer Function of the Autoradiographic Enhancement Process.

This report is Volume 3 of the Final Report prepared by ESPEE, INC. under Contract No. NAS8-33405 for the Space Sciences Laboratory of the George C. Marshall Space Flight Center. The NASA COR for this contract is Dr. C. A. Lundquist.
# TABLE OF CONTENTS

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<td>2</td>
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</tr>
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<td>5. OBTAINING A HARD COPY</td>
<td>6</td>
</tr>
<tr>
<td>6. SYSTEM SHUT DOWN PROCEDURE</td>
<td>7</td>
</tr>
<tr>
<td>7. PROGRAM LIMITATIONS</td>
<td>8</td>
</tr>
<tr>
<td>8. EXAMPLE RUN OUTPUTS</td>
<td>9</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

This manual is a description of the use of the Autoradiographic Data Analysis software package with the Data General NOVA 1200 computer system.

In the following description, the symbol \( \) means a carriage return on the tektronix. If at any time a typing mistake is made, the character typed may be deleted by typing the RUBOUT key. Any execution of a program or command may be nullified by pressing the CNTRL and A keys simultaneously.

In case of problems, call the person in charge of the computer system.
2. NOVA POWER-UP PROCEDURE

Before the Autoradiographic Data Analysis software package may be used, the NOVA system must be powered up and the operating system placed into the computer. The procedure for doing this is as follows:

1. Turn power on to the NOVA computer using the front panel key.
2. Turn power on to the disk controller (mounted on the DATA GENERAL rack) using the front panel key.
3. Make sure the pack labelled ESPEE is mounted in the disk drive.
   If it is not, the pack labelled ESPEE may be mounted as follows:
   (a). Remove the pack inside the drive by following these steps:
       (i). Raise the lid of the disk drive.
       (ii). Set the clear plastic cover onto the disk pack.
       (iii). Turn the handle counterclockwise until a pop is heard.
       (iv). Raise the disk pack out and place it on the bottom cover.
       (v). Lock the bottom cover.
   (b). Replace the pack marked ESPEE inside the drive by following these steps:
       (i). Unlock and remove the bottom cover from the disk pack.
       (ii). Place the pack in the drive.
       (iii). Turn the handle clockwise until tight.
       (iv). Remove the clear plastic cover.
       (v). Close the lid of the disk drive.
4. Turn power on to the disk drive by pressing the on button on the drive. Wait for the green light on the disk drive.
to come on before proceeding.

5. Turn power on to the Tektronix graphics display. After the screen brightens, press the CLEAR button. Flip the LINE/LOCAL switch to LOCAL. Press the ESC key. Press the ; key. Flip the LINE/LOCAL switch back to LINE. This sets the character size for the terminal to the smallest. For medium and large character sizes respectively, press 9 and 8 instead of ; in the above procedure.

6. Turn power on to the Hard Copy Unit. The unit requires about 10 minutes to warm up.

7. Set the switches on the NOVA computer panel to octal 00033. (This corresponds to switches 11, 12, 14 and 15 up; all other down). Raise the RESET switch momentarily. Next, raise the switch 0 on the computer panel up. Now raise momentarily the PROGRAM LOAD switch on the computer panel. This series of operations loads the operating system into the computer memory. The word FILENAME? will appear on the Tektronix screen.

8. Type the word SYS32K ). When requested by the computer, enter the date using the format MM/DD/YY ), and the time using the format HH:MM:SS ). Computer types R.

This completes the steps required to get the computer powered-up. The next series of steps are required to prepare for using the Autoradiographic Data Analysis package.
3. **TAPE MOUNTING PROCEDURE**

The source of input data for the Autoradiographic Data Analysis package is the Microdensitometer output tape. The procedure for mounting the tape is as follows:

1. Turn power on to the magnetic tape recorder.
2. Pull out the lever marked OVERRIDE.
3. Mount the tape on the available slot and turn the handle clockwise until tight.
4. Thread the tape as shown in the diagram on the tape recorder unit, and a few feet of tape on the empty reel.
5. Press the LOAD/UNLOAD button on the recorder.
6. Press the FORWARD button on the recorder.
7. When the tape stops winding, press the REMOTE button on the recorder.

The tape recorder is now ready for operation. Type `INIT` on the Tektronix terminal. The system is now ready for program execution.
4. PROGRAM EXECUTION

The program can be executed with four options: (1) Without Filters, (2) With Low Frequency Filter Only, (3) With High Frequency Filter Only, and (4) With Both Filters. For program execution the following steps are followed:

1. **Without Filters**
   1. Type `DIR ESPEE`.
      Computer types `R`.
   2. Type `SPL`.
      The computer will now ask for the user-specified inputs to the program, one at a time. These inputs are:
      ```
      FILE NUMBER, NF=
      DIFFUSE DENSITY FACTOR, DDF=
      MAXIMUM LAG FACTOR, M=
      HEIGHT OF SCANNING SLIT, XL=
      WIDTH OF SCANNING SLIT, XA=
      ```
   3. After typing each value, type `;`. When all values are specified, the computer will halt after program execution is complete.

2. **With Low Frequency Filters Only**
   1. Type `DIR ESPEE`.
      Computer types `R`.
   2. Type `SPL`.
      The computer will now ask for user-specified inputs to the program, one at a time. These inputs are:
      ```
      FILE NUMBER, NF=
      DIFFUSE DENSITY FACTOR, DDF=
      MAXIMUM LAG FACTOR, M=
      HEIGHT OF SCANNING SLIT, XL=
      WIDTH OF SCANNING SLIT, XA=
      LOW FREQUENCY FILTER PARAMETER, P=
      ```
   3. After typing each value, type `;`. When all values are specified, the computer will halt after program execution is complete.
3. With High Frequency Filters Only
   1. Type DIR ESPEE ). Computer types R.
   2. Type SPH ).
      The computer will now ask for user-specified inputs to the program, one at a time. These inputs are:
      FILE NUMBER, NF= 
      DIFFUSE DENSITY FACTOR, DDF= 
      MAXIMUM LAG FACTOR, M= 
      HEIGHT OF SCANNING SLIT, XL= 
      WIDTH OF SCANNING SLIT, XA= 
      HIGH FREQUENCY FILTER PARAMETER, Q= 
   3. After typing each value, type ). When all values are specified, the computer will halt after program execution is complete.

4. With Both Filters
   1. Type DIR ESPEE ). Computer types R.
   2. Type SP2 ).
      The computer will now ask for user-specified inputs to the program, one at a time. These inputs are:
      FILE NUMBER, NF= 
      DIFFUSE DENSITY FACTOR, DDF= 
      MAXIMUM LAG FACTOR, M= 
      HEIGHT OF SCANNING SLIT, XL= 
      WIDTH OF SCANNING SLIT, XA= 
      LOW FREQUENCY FILTER PARAMETER, P= 
      HIGH FREQUENCY FILTER PARAMETER, Q= 
   3. After typing each value, type ). When all values are specified, the computer will halt after program execution is complete.
5. OBTAINING A HARD COPY

The results of the program execution may be recorded by using the Hard Copy Unit. A copy of the Tektronix display may be obtained by pressing the AUTO PRINT/COPY switch on the Tektronix keyboard to COPY.

In case the results take more than one page, automatic copying of the results may be accomplished as follows:
1. Set the AUTO PRINT/COPY switch to AUTO PRINT.
2. Set the MARGIN CONTROL switch on the Tektronix terminal to 2.
6. SYSTEM SHUT DOWN PROCEDURE

The procedure for shutting down the system is as follows:

1. Type RELEASE MTÔ.
2. Type RELEASE DPÔ. This will cause the computer to halt.
3. Turn power off to the hard copy unit.
4. Turn power off to the Tektronix terminal.
5. Turn power off to the disk drive by pushing the ON button.
6. Press the LOAD/UNLOAD button on the tape recorder. Manually rewind the tape and remove it from the tape recorder.
7. (Caution: Before executing this step, make sure that the disk has stopped spinning.) Turn power off to the disk controller.
8. Turn power off to the NOVA computer.

The shut down procedure is now complete.
7. PROGRAM LIMITATIONS

The following are some of the limitations of the program. In actual practice, these limitations are not likely to be violated.

1. The maximum no. of data points on a record on the microdensitometer tape is 1000.
2. The maximum no. of records per file on the microdensitometer tape is 50.
3. The maximum value of the Maximum Lag Factor, M is 100.
4. For comparison with the microdensitometer printout, at most 300 data points will be printed from the first data record.
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<tr>
<th>SPI</th>
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</thead>
<tbody>
<tr>
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<tr>
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</tr>
<tr>
<td>0</td>
<td>0.3133E-3</td>
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</table>

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| 3 | 0.1711E-3 | 0.2490E-0 |
| 4 | 0.1708E-3 | 0.1762E-0 |
| 5 | 0.8411E-4 | 0.1228E-0 |
| 6 | 0.9461E-4 | 0.1319E-0 |
| 7 | 0.1203E-3 | 0.1749E-0 |
| 8 | 0.1556E-3 | 0.2264E-0 |
| 9 | 0.1788E-3 | 0.2721E-0 |
| 10 | 0.1820E-3 | 0.2648E-0 |
| 11 | 0.1519E-3 | 0.2111E-0 |
| 12 | 0.1361E-3 | 0.2811E-0 |
| 13 | 0.1321E-3 | 0.1922E-0 |
| 14 | 0.1263E-3 | 0.1922E-0 |
| 15 | 0.1188E-3 | 0.1718E-0 |
| 16 | 0.1301E-3 | 0.1893E-0 |
| 17 | 0.1292E-3 | 0.2066E-0 |
| 18 | 0.1495E-3 | 0.2044E-0 |
| 19 | 0.1596E-3 | 0.2031E-0 |
| 20 | 0.1395E-3 | 0.2034E-0 |
| 21 | 0.1486E-3 | 0.2049E-0 |
| 22 | 0.1374E-3 | 0.1938E-0 |
| 23 | 0.1172E-3 | 0.1746E-0 |
| 24 | 0.1093E-3 | 0.1507E-0 |
| 25 | 0.9151E-4 | 0.1332E-0 |
| 26 | 0.7795E-4 | 0.1130E-0 |
| 27 | 0.8041E-4 | 0.1166E-0 |
| 28 | 0.9431E-4 | 0.1372E-0 |

| 1.71 | 1.77 |
| 1.78 | 1.80 |
| 1.81 | 1.83 |
| 1.84 | 1.86 |
| 1.87 | 1.89 |
| 1.90 | 1.92 |
| 1.93 | 1.95 |
| 1.96 | 1.98 |
| 1.99 | 2.01 |
| 2.02 | 2.04 |
| 2.05 | 2.07 |
| 2.08 | 2.10 |
| 2.11 | 2.13 |
| 2.14 | 2.16 |
| 2.17 | 2.19 |
| 2.20 | 2.22 |
| 2.23 | 2.25 |
| 2.26 | 2.28 |
| 2.29 | 2.31 |
| 2.32 | 2.34 |
| 2.35 | 2.37 |

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| 0.3133E-3 | 0.1916E-3 |
| 0.1900E-3 | 0.1900E-3 |
| 0.1749E-0 | 0.1749E-0 |
| 0.2264E-0 | 0.2264E-0 |
| 0.2721E-0 | 0.2721E-0 |
| 0.2648E-0 | 0.2648E-0 |
| 0.2111E-0 | 0.2111E-0 |
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| 0.1922E-0 | 0.1922E-0 |
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| 0.1718E-0 | 0.1718E-0 |
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| 0.2049E-0 | 0.2049E-0 |
| 0.1938E-0 | 0.1938E-0 |
| 0.1746E-0 | 0.1746E-0 |
| 0.1507E-0 | 0.1507E-0 |
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| 0.1166E-0 | 0.1166E-0 |
| 0.1372E-0 | 0.1372E-0 |

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| 0.6131E-2 | 0.6131E-2 |
| 0.4388E-2 | 0.4388E-2 |
| 0.2616E-2 | 0.2616E-2 |
| 0.2983E-2 | 0.2983E-2 |
| 0.1973E-2 | 0.1973E-2 |
| 0.2255E-2 | 0.2255E-2 |
| 0.1677E-2 | 0.1677E-2 |
| 0.2262E-2 | 0.2262E-2 |
| 0.2132E-2 | 0.2132E-2 |
| 0.1504E-2 | 0.1504E-2 |
| 0.1903E-2 | 0.1903E-2 |
| 0.1526E-2 | 0.1526E-2 |
| 0.1366E-2 | 0.1366E-2 |
| 0.2262E-2 | 0.2262E-2 |
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| 0.1526E-2 | 0.1526E-2 |
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| 0.2262E-2 | 0.2262E-2 |
| 0.2132E-2 | 0.2132E-2 |
| 0.1504E-2 | 0.1504E-2 |
| 0.1903E-2 | 0.1903E-2 |
| 0.1526E-2 | 0.1526E-2 |
| 0.1366E-2 | 0.1366E-2 |</p>
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**DATA IS BEING FORMATTED**

<table>
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<tr>
<th>DATA FORMATTING COMPLETED</th>
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<tbody>
<tr>
<td>RAW DATA STORED ON DISK</td>
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**HISTOGRAM IS BEING COMPUTED**

**TOTAL NO. OF CLASSES**

**100**

**CLA: S NO.**

**NO. OF DATA POINTS**

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<tbody>
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</table>
**Mean of Normalized Data:** 0.12700e-1

**Data is being filtered for low frequency.**

**Data is being filtered for high frequency.**

**Mean Square Value:** 0.28185e-3

**Root Mean Square Value:** 0.16798e-1

**Auto-correlation is being computed.**

<table>
<thead>
<tr>
<th>X Coordinate (Microns)</th>
<th>Y Coordinate (Microns)</th>
<th>Delta X (Microns)</th>
<th>Delta Y (Microns)</th>
<th>Data Is Being Formatted</th>
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**The denominator of sine function below 1.0e-06 encountered in Inf.**

**Data formatting completed.**

**Raw data stored on disk.**

**Histogram being computed.**

**Total number of classes:** 100

**Class No.**

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**Raw Mean:** 0.145498e-4
APPENDIX

MODIFICATION OF DATA ANALYSIS SOFTWARE FOR AUTORADIOGRAPHIC ENHANCEMENT PROCESS
PREFACE

This is the Description and Program Listings of the modification of Data Analysis Software developed for the evaluation of the Wiener Spectrum and Modulation Transfer Function of the Autoradiographic Enhancement Process.

This report is an addendum to the three-volume report No. 79-01 of Contract No. NAS8-33405 and is the Final Report prepared by ESPEE, INC. under Contract No. P.O. H-30573B for the Space Sciences Laboratory of the George C. Marshall Space Flight Center.

The NASA COR for this Contract is Mr. Ray Hembree.
TABLE OF CONTENTS

1. MODIFICATION OF DATA ANALYSIS SOFTWARE  
   1.1 Individual Record Processing----------------------- 1 
   1.2 Averaging Results of all Records------------------- 1 
   1.3 Computing Standard Deviation and Error------------- 1 
   1.4 Four Cases---------------------------------------- 2 

2. SOFTWARE MODULES AFFECTED 
   3. PROGRAM LISTINGS  
      SPLIST------------------------------------------------ 5 
      SPIA-------------------------------------------------- 6 
      SP2A------------------------------------------------- 6 
      SPLA------------------------------------------------- 6 
      SPHA------------------------------------------------- 6 
      SPL-------------------------------------------------- 7 
      SPL-------------------------------------------------- 10 
      SPH-------------------------------------------------- 13 
      SP2-------------------------------------------------- 16 
      SP26------------------------------------------------- 19 

4. SAMPLE RUNS  
   SP1----------------------------------------------------- 20 
   SPL----------------------------------------------------- 21 
   SPL----------------------------------------------------- 23 
   SPH----------------------------------------------------- 25 
   SP2----------------------------------------------------- 27
1. MODIFICATION OF DATA ANALYSIS SOFTWARE

The following modifications have been done to data analysis software developed under an earlier contract No. NAS8-33405:

1.1 Individual Record Processing

The data from each record in a file on micordensitometer tape is individually processed. All processes, namely compute histogram, compute average, normalize data, calculate zero-mean data, filter data for low frequency, filter data for high frequency, compute standard deviation, compute autocorrelation, compute power spectral density function, apply inverse filter transform, apply aperture compensation and smooth power spectral densities are applied to each record separately. These processes were formerly applied to all records in a file combined into one record.

1.2. Averaging Results of all Records

After the autocorrelation and smoothed power spectral density function arrays are computed for each record, an average of these arrays is computed.

1.3. Computing Standard Deviation and Error

The standard deviation and error are computed for the averaged autocorrelation and smoothed power spectral density arrays. The standard deviation is computed as follows:

\[
\text{Standard Deviation} = \left[ \frac{\sum_{n=1}^{m+1} D_n^2}{M} \right]^{\frac{1}{2}}
\]

where \( M \) is the max lag factor and \( D_n \) is the \( N \)-th data point. The error is computed as follows:

\[
\text{Error} = \frac{\text{Standard Deviation}}{(N)^{\frac{1}{2}}}
\]

where \( N \) is the No. of records.
1.4. Four Cases

The above modifications have been applied to all four cases, namely without filters, with low frequency filter only, with high frequency filter only and with both filters.
2. SOFTWARE MODULES AFFECTED

The following software modules were changed:
- SP1
- SP2
- SPL
- SPH

A new module named LAST has been added to the software. This module computes the standard deviation and error for the averaged autocorrelation and power spectral density functions. This module is the last module called by the main modules SP1, SP2, SPL and SPH.

The modifications have been made in a manner such that the use of the program is unchanged from the way described in the users manual.
3. **PROGRAM LISTINGS**

The program listings for the modified modules and the new module are given in the following pages. Also included are the updated list of modules and code for loading compiled modules.
TYPE SPLIST

FILE SPLIST
SP1A-RLDR/M FOR SP1
SP2A-RLDR/M FOR SP2
SPLA-RLDR/M FOR SPL
SPHA-RLDR/M FOR SPH
SP23A-RLDR/M FOR SP23
SP24A-RLDR/M FOR SP24
SP1-MAIN WITHOUT FILTERS
SP2-MAIN WITH FILTERS
SP1-MAIN WITH LOW FREQ. FILTER
SP2-MAIN WITH HIGH FREQ. FILTER
SP3=PTDT
SP4=SKPFL
SP5=RDFL
SP6=HDR
SP7=CORD
SP8=RFMT
SP9=BYTE
SP10=MEANS
SP11=SIGMA
SP12=AUTOCOR
SP13=(DELETED)
SP14=HIST
SP15=DCLS
SP16=AUG
SP17=NRMLZ
SP18=ZMEAN
SP19=PSDF
SP20=SPDF
SP21=INF
SP22=AC
SP23=LFF
SP24=HFF
SP25=AC1
SP26=LAST
TYPE SP1A
RLDR/M SP1 SP3 SP4 SP5 SP6 SP7 SP8 SP9 SP10 SP11 SP12 SP14 SP15
SP16 SP17 SP18 SP19 SP25 SP20 SP26 FORT.LB
R
TYPE SP2A
RLDR/M SP2 SP3 SP4 SP5 SP6 SP7 SP8 SP9 SP10 SP11 SP12 SP14 SP15
SP16 SP17 SP18 SP19 SP21 SP22 SP20 SP26 FORT.LB
R
TYPE SPLA
RLDR/M SPL SP3 SP4 SP5 SP6 SP7 SP8 SP9 SP10 SP11 SP12 SP14 SP15
SP16 SP17 SP18 SP19 SP21 SP25 SP20 SP26 FORT.LB
R
TYPE SPHA
RLDR/M SPH SP3 SP4 SP5 SP6 SP7 SP8 SP9 SP10 SP11 SP12 SP14 SP15
SP16 SP17 SP18 SP19 SP21 SP22 SP20 SP26 FORT.LB
R
TYPE SP23A
RLDR/M SP23 FORT.LB
R
TYPE SP24A
RLDR/M SP24 FORT.LB
R
TYPE SP1

FILE SP1-MAIN WITHOUT FILTERS
PROGRAMMER NAME: S.P. SINGH
REVISION:3, MULTIPLE RECORDS/FILE
DATE:7/31/79

PURPOSE: THIS MODULE ACCEPTS USER INPUTS AND CALLS ALL
SUBSEQUENT MODULES
RRH IS AUTOCORRELATION VALUES OF DATA
GKC IS POWER SPECTRAL DENSITY FUNCTION
GKH IS SMOOTHED POWER SPECTRAL DENSITY
GKCP IS THE INVERSE FILTER FUNCTION
GKC3P IS THE APERTURE COMPENSATION FUNCTION
ITEMP,XTEMP ARE BUFFERS
NR IS THE NUMBER OF RECORDS IN THE FILE
NW IS THE NUMBER OF WORDS PER RECORD
NP IS THE NUMBER OF POINTS PER RECORD
INTEGER P,Q
DIMENSION RRH(101),ITEMP(1000),
GKC(101),GKH(101)
DIMENSION GKCP(101),GKC3P(101)
DIMENSION NW(50),NP(50)
DIMENSION XTEMP(1000)
DIMENSION RR(101),GH(101)
ACCEPT "FILE NUMBER,NF="NF
ACCEPT "DIFFUSE DENSITY FACTOR,DDF="DDF
ACCEPT "MAXIMUM LAG FACTOR,M="M
ACCEPT "HEIGHT OF SCANNING SLIT,XL="XL
ACCEPT "WIDTH OF SCANNING SLIT,XA="XA
ACCEPT "LOW FREQUENCY FILTER PARAMETER,P="P
ACCEPT "HIGH FREQUENCY FILTER PARAMETER,Q="Q
P=0
Q=0
CALL PTDT (ITEMP,NF,H,NR,NW,NP)
CALL FOPEN(3,"RD",2000)
CALL FOPEN(2,"SRD",2000)
DO 10 I=1,NR
CALL READR(3,I,ITEMP,1,IER)

TRANSFER RAW DATA RECORDS INTO A FILE SRD
CALL WRTR(2,I,ITEMP,1,IER)
CONTINUE
CALL FCL0S(2)
CALL FCL0S(3)
NRK=1
CALL FOPEN("PAR")
WRITE BINARY (4) NP,P,Q,NRK
CALL FCL0S(4)
A=0
B=3200
NC=100
DO 15 J=1,101
RR(J)=0.
GH(J)=0.
15 CONTINUE
DO 20 I=1,NR
20 TYPE * *
TYPE * "RECORD NO.",I
TYPE * *
CALL HIST (ITEMP,A,B,NC,NRK,NP)
CALL MEANS(ITEMP,XTEMP,NP,NRK,DDF)
CALL SWAP(\"SP23.SU\",IER); CALL LFF(\"SP24.SU\",IER); CALL LFF(\"SP23.SU\",IER); CALL LFF(XTEMP,\"SP24.SU\",IER);
CALL SIGMA(XTEMP,NP,NRK)
CALL AUTOCOR(XTEMP,NP,NRK,M,RRH,P,Q)
MP1=M+1
DO 30 J=1,MP1
RR(J)=RRH(J)+RR(J)
30 CONTINUE
CALL PSDF(RRH,M,H,XL,GKC)
CALL INF(GKC,GKCP,Q,M)
CALL AC1(GKC,GKC3P,M,H,XA)
CALL SPDF(M,GKC3P,GKH)
DO 40 J=1,MP1
GH(J)=GH(J)+GKH(J)
40 CONTINUE
CALL DELETE("RD")
CALL DELETE("NRD")
CALL DELETE("ZRD")
CALL DELETE("ZP")
CALL DELETE("TD")
CALL FOPEN(3,"RD",2000)
CALL FOPEN(2,"SRD",2000)
IF (I.GE.NR)GO TO 20
I1=I1+1
CALL READR(2,I1,ITEMP,1,IER)
CALL WRITR(3,1,ITEMP,1,IER)
CALL FCLOS(2)
CALL FCLOS(3)
CONTINUE
20 CALL DELETE("PAR")
DO 50 J=I,MP1
RR(J)=RR(J)/NR
GH(J)=GH(J)/NR
CONTINUE
50 AVERAGE R-HAT
DO 60 J=I,MP1
IR=J-1
WRITE (10,100)IR,RR(J)
CONTINUE
60 FORMAT(1X,I3,8X,E11.4)
CONTINUE
70 AVERAGE GH(K)
DO 70 J=I,MP1
IR=J-1
WRITE(10,100)IR,GH(J)
CONTINUE
70 CALL LAST (RR,GH,MP1,NR)
STOP
END
TYPE SPL
C FILE SPL-MAIN WITH LOW FREQ. FILTER
C PROGRAMMER NAME: S.P. SINGH
C REVISION:3, MULTIPLE RECORDS/FI LE
C DATE: 8/14/79
C PURPOSE: THIS MODULE ACCEPTS USER INPUTS AND CALLS ALL
C SUBSEQUENT MODULES
C RRH IS AUTOCORRELATION VALUES OF DATA
C GKC IS POWER SPECTRAL DENSITY FUNCTION
C GKH IS SMOOTHED POWER SPECTRAL DENSITY
C GKC3P IS THE INVERSE FILTER FUNCTION
C GKC3P IS THE APERTURE COMPENSATION FUNCTION
C ITEMP,XTEMP ARE BUFFERS
C NR IS THE NUMBER OF RECORDS IN THE FI LE
C NW IS THE NUMBER OF WORDS PER RECORD
C NP IS THE NUMBER OF POINTS PER RECORD
C INTEGER P,Q
1 DIMENSION RRH(101),ITEMP(1000),
   GKC(101),GKH(101)
10 DIMENSION GKC3P(101),GKC3P(101)
10 DIMENSION NW(50),NP(50)
10 DIMENSION XTEMP(1000)
10 DIMENSION RR(101),GH(101)
C ACCEPT "FILE NUMBER,NF=" ,NF
C ACCEPT "DIFFUSE DENSITY FACTOR,DDF=" ,DDF
C ACCEPT "MAXIMUM LAG FACTOR,M=" ,M
C ACCEPT "HEIGHT OF SCANNING SLIT,XL=" ,XL
C ACCEPT "WIDTH OF SCANNING SLIT,XA=" ,XA
C ACCEPT "LOW FREQUENCY FILTER PARAMETER,P=" ,P
C ACCEPT "HIGH FREQUENCY FILTER PARAMETER,Q=" ,Q
Q=0
C CALL PTDT (ITEMP,NF,H,NR,NW,NP)
C CALL FOPEN(3,'RD',2000)
C DO 10 I=1,NR
   CALL READR(3,I,ITEMP,1,IER)
CALL WRITR(IS,I,ITEMP,1,IER)

10 CONTINUE
CALL FCLOS(IS)
CALL FCLOS(3)
NRK=1
CALL FOPEN(4,"PAR")
WRITE BINARY (4) NP,P,Q,NRK
CALL FCLOS(4)
A=0
B=3200
NC=100
DO 15 J=1,101
RR(J)=0.
GH(J)=0.
15 CONTINUE
DO 20 I=1,NR
TYPE ' '*
TYPE 'RECORD NO.',I
TYPE ' '*
CALL HIST (ITEMP,A,B,NC,NRK,MP)
CALL MEANS(ITEMP,TEMP,MP,NRK,DDF)
CALL SWAP("SP23.SU",IER); CALL LFF(ITEMP,TEMP2,TEMP3,MP,P,NRK)
C TYPE 'IER=',IER
CALL DELETE ("ZRD")
CALL RENAM("ZP","ZRD",IER)
C CALL SWAP("SP24.SU",IER); CALL HFF(ITEMP,TEMP2,TEMP3,MP,Q,NRK)
CALL SIGMA(ITEMP,NRK,MP)
CALL AUTOCOR(ITEMP,MP,NRK,RRH,P,Q)
MP1=M+1
DO 30 J=1,MP1
RR(J)=RRH(J)+RR(J)
30 CONTINUE
CALL PSDF(RRH,M,H,XL,GKC)
C CALL INF(GKC,GKCP,Q,M)
CALL AC1(GKC,GKC3P,M,H,XA)
CALL SPDF(M,GKC3P,GKH)
DO 40 J=1,MP1
GH(J)=GH(J)+GKH(J)
CONTINUE
CALL DELETE("RD")
CALL DELETE("NRD")
CALL DELETE("ZRD")
CALL DELETE("TP")
CALL DELETE("TD")
CALL FOPEN(3,"RD",2000)
CALL FOPEN(IS,"SRD",2000)
IF (I.GE.NR)GO TO 20
I1=I+1
CALL READR(IS,I1,ITEMP,1,IER)
CALL WTRITR(3,ITEMP,1,IER)
CALL FCLOSP(IS)
CALL FCLOSP(3)
CONTINUE
CALL DELETE("PAR")
DO 50 J=1,MP1
RR(J)=RR(J)/NR
GH(J)=GH(J)/NR
CONTINUE
TYPE* R AVERAGE R-HAT*
DO 60 J=1,MP1
IR=J-1
WRITE (10,100) IR,RR(J)
100 FORMAT(1X,I3,8X,E11.4)
CONTINUE
TYPE* K AVERAGE GH(K)*
DO 70 J=1,MP1
IR=J-1
WRITE(10,100) IR,GH(J)
70 CONTINUE
CALL LAST (RR,GH,MP1,NR)
STOP
END
TYPE SPH

FILE SPH=MAIN WITH HIGH FREQ. FILTER ONLY
PROGRAMMER NAME: S.P. SINGH
REVISION: 3, MULTIPLE RECORDS/FILE
DATE: 8/20/79
PURPOSE: THIS MODULE ACCEPTS USER INPUTS AND CALLS ALL
SUBSEQUENT MODULES
RRH IS AUTOCORRELATION VALUES OF DATA
GKC IS POWER SPECTRAL DENSITY FUNCTION
GKH IS SMOOTHED POWER SPECTRAL DENSITY
GKCP IS THE INVERSE FILTER FUNCTION
GKC3P IS THE APERTURE COMPENSATION FUNCTION
ITEMP, XTEMP ARE BUFFERS
NR IS THE NUMBER OF RECORDS IN THE FILE
NW IS THE NUMBER OF WORDS PER RECORD
NP IS THE NUMBER OF POINTS PER RECORD
INTEGER P, Q
DIMENSION RRH(101), ITEMP(1000),
  GKC(101), GKH(101)
DIMENSION GKCP(101), GKC3P(101)
DIMENSION NU(50), NP(50)
DIMENSION XTEMP(1000)
DIMENSION RR(101), GH(101)
ACCEPT "FILE NUMBER, NF=", NF
ACCEPT "DIFFUSE DENSITY FACTOR, DDF=", DDF
ACCEPT "MAXIMUM LAG FACTOR, M=", M
ACCEPT "HEIGHT OF SCANNING SLIT, XL=", XL
ACCEPT "WIDTH OF SCANNING SLIT, XA=", XA
ACCEPT "LOW FREQUENCY FILTER PARAMETER, P=", P
P=0
ACCEPT "HIGH FREQUENCY FILTER PARAMETER, Q=", Q
CALL PTDT (ITEMP, NF, H, NR, NU, NP)
TRANSFER RAW DATA RECORDS INTO A FILE SRD
CALL FOPEN(3, 'RD', 2000)
IS=1
CALL FOPEN(IS, 'SRD', 2000)
DO 10 I=1, NR
  CALL READR(3, I, ITEMP, 1, IER)
CALL WRITR(IS,I,ITEMP,1,IER)
   CONTINUE
   CALL FCLOS(IS)
   CALL FCLOS(3)
   NRK=1
   CALL FOPEN(4,"PAR")
   WRITE BINARY (4) NP,P,Q,NRK
   CALL FCLOS(4)
   A=0
   B=3200
   NC=100
   DO 15 J=1,101
      RR(J)=0.
      GH(J)=0.
   CONTINUE
   DO 20 I=1,NR
      TYPE = "*
      TYPE = "RECORD NO.",I
      TYPE = "*
      CALL HIST (ITEMP,A,B,NC,NRK,NP)
      CALL MEANS(ITEMP,XTEMP,NP,NRK,DDF)
   CONTINUE
   CALL SWAP("SP23.SV",IER); CALL LFF(XTEMP,TEMP2,TEMP3,NP,F,NRK)
   CALL RENAM ("ZRD","ZP",IER)
   CALL SWAP("SP24.SV",IER); CALL HFF(XTEMP,TEMP2,TEMP3,NP,Q,NRK)
   CALL DELETE ("ZRD");
   CALL RENAM ("ZFP","ZRD",IER)
   CALL SIGMA(XTEMP,NRK,NP)
   CALL AUTOCOR(XTEMP,NP,NRK,M,RRH,P,Q)
   MP1=M+1
   DO 30 J=1,MP1
      RR(J)=RRH(J)+RR(J)
   CONTINUE
   CALL PSDF(RRH,M,H,XL,GKC)
   CALL INF(GKC,GKC3P,Q,M)
   CALL AC(GKC3P,GBK3P,M,H,XA)
   CALL SPDF(M,GKC3P,GKH)
   DO 40 J=1,MP1
      GH(J)=GH(J)+GKH(J)
CONTINUE
CALL DELETE("RD")
CALL DELETE("NRD")
CALL DELETE("2RD")
CALL DELETE("2P")
CALL DELETE("TD")
CALL FOPEN(3,"RD",2000)
CALL FOPEN(IS,"SRD",2000)
IF (I.GE.NR) GO TO 20
I1=I+1
CALL READR(IS,I1,ITEMP,1,IER)
CALL WRITR(3,1,ITEMP,1,IER)
CALL FCLOS(IS)
CALL FCLOS(3)
CONTINUE
CALL DELETE("PAR")
DO 50 J=1,MP1
RR(J)=RR(J)/NR
GH(J)=GH(J)/NR
CONTINUE
TYPE* R AVERAGE R-HAT*
DO 60 J=1,MP1
IR=J-1
WRITE (10,100) IR,RR(J)
100 FORMAT(1X,13,8X,E11.4)
CONTINUE
TYPE* K AVERAGE GH(K)*
DO 70 J=1,MP1
IR=J-1
WRITE(10,100) IR,GH(J)
70 CONTINUE
CALL LAST (RR,GH,MP1,NR)
STOP
END
FILE SP2=MAIN WITH FILTERS

PROGRAM NAME: S.P. SINGH

REVISION:3, MULTIPLE RECORDS/FIELD

DATE:8/24/79

PURPOSE: THIS MODULE ACCEPTS USER INPUTS AND CALLS ALL

SUBSEQUENT MODULES

RRH IS AUTOCORRELATION VALUES OF DATA

GKC IS POWER SPECTRAL DENSITY FUNCTION

GKH IS SMOOTHED POWER SPECTRAL DENSITY

GKCP IS THE INVERSE FILTER FUNCTION

GKC3P IS THE APERTURE COMPENSATION FUNCTION

ITEMP,XTEMP ARE BUFFERS

NR IS THE NUMBER OF RECORDS IN THE FILE

NW IS THE NUMBER OF WORDS PER RECORD

NP IS THE NUMBER OF POINTS PER RECORD

INTEGER P,Q

DIMENSION RRH(101),ITEMP(1000),

GKC(101),GKH(101)

DIMENSION GKCP(101),GKC3P(101)

DIMENSION NU(50),NP(50)

DIMENSION XTEMP(1000)

DIMENSION RR(101),GH(101)

ACCEPT "FILE NUMBER,NF=" ,NF

ACCEPT "DIFFUSE DENSITY FACTOR,DDF=" ,DDF

ACCEPT "MAXIMUM LAG FACTOR, M=" ,M

ACCEPT "HEIGHT OF SCANNING SLIT,XL=" ,XL

ACCEPT "WIDTH OF SCANNING SLIT,XA=" ,XA

ACCEPT "LOW FREQUENCY FILTER PARAMETER,P=" ,P

ACCEPT "HIGH FREQUENCY FILTER PARAMETER,Q=" ,Q

CALL PTDT (ITEMP,NF,NH,NR,NW,NP)

CALL FOPEN(IS,"RD",2000)

CALL FOPEN(IS,"SRD",2000)

DO 10 I=1,NR

CALL READR(3,I,ITEMP,IER)

CALL WRITR(IS,I,ITEMP,IER)
CONTINUE
CALL FCLOS(IS)
CALL FCLOS(3)
NRK=1
CALL FOPEN(4,"PAR")
WRITE BINARY (4) NP,P,Q,NRK
CALL FCLOS(4)
A=0
B=3200
NC=100
DO 15 J=1,101
RR(J)=0.
GH(J)=0.
15 CONTINUE
DO 20 I=1,NR
TYPE *=
TYPE *=
CALL HIST (ITEMP,A,B,NC,NRK,NP)
CALL MEANS(ITEMP,XTEMP,NP,NRK,DDF)
CALL SWAP("SP23.SU",IER);  CALL LFF(XTEMP,TEMP2,TEMP3,NP,P,NRK)
CALL SWAP("SP24.SU",IER);  CALL HFF(XTEMP,TEMP2,TEMP3,NP,Q,NRK)
CALL DELETE("ZRD")
CALL RENAM (*ZPP","ZRD",IER)
CALL SIGMA(XTEMP,NRK,NP)
CALL AUTOCOR(XTEMP,NP,NRK,M,RRH,P,Q)
MP1=M+1
DO 30 J=1,MP1
RR(J)=RRH(J)+RR(J)
30 CONTINUE
CALL PSDF(RRH,M,H,XL,GKC)
CALL INF(GKC,GKCP,Q,M)
CALL AC(GKCP,GKC3P,M,H,XA)
CALL SPDF(M,GKC3P,KH)
DO 40 J=1,MP1
GH(J)=GH(J)+GKH(J)
40 CONTINUE
CALL DELETE("RD")
CALL DELETE("NRE")
CALL DELETE("ZRI")
CALL DELETE("ZP")
CALL DELETE("TD")
CALL FOPEN(3, "RD", 2000)
CALL FOPEN(IS, "SRD", 2000)
IF (I.GE.NR) GO TO 20
II=I+1
CALL READR(IS, I1, ITEMP, 1, IER)
CALL WRITR(3, I, ITEMP, 1, IER)
CALL FCLOS(IS)
CALL FCLOS(3)
CONTINUE

20 CALL DELETE("PAR")
DO 50 J=1, MP1
RR(J)=RR(J)/NR
GH(J)=GH(J)/NR
CONTINUE

50 TYPE* R AVERAGE R-HAT*
DO 60 J=1, MP1
IR=J-1
WRITE (10, 100) IR, RR(J)
60 FORMAT(1X, I3, 8X, E11.4)
CONTINUE

TYPE* K AVERAGE GH(K)*
DO 70 J=1, MP1
IR=J-1
WRITE(10, 100) IR, GH(J)
CONTINUE

70 CALL LAST(RR, GH, MP1, NR)
STOP
END
TYPE SP26
C.
C FILE SP26=LAST
C PROGRAMMER NAME: S.P. SINGH
C REVISION: 0
C DATE: 8/3/79
C PURPOSE: THIS MODULE COMPUTES STANDARD
C DEVIATION AND ERROR FOR THE AVERAGED
C R-HAT AND G-HAT ARRAYS.
C COMPILER: NOSTACK
C SUBROUTINE LAST(RR, GH, MP1, NR)
C DIMENSION RR(101), GH(101)
C RSQ=0.
C GSQ=0.
DO 80 I=1,MP1
RSQ=RSQ+(RR(I)**2)
GSQ=GSQ+GH(I)**2
80 CONTINUE
RSD=SQRT(RSQ/(MP1-1))
GSD=SQRT(GSQ/(MP1-1))
RN=NR
ERH=RSD/SQRT(RN)
EGH=GSD/SQRT(RN)
C TYPE "STANDARD DEVIATION FOR R-HAT", RSD
C TYPE "STANDARD DEVIATION FOR G-HAT", GSD
C TYPE "ERROR FOR R-HAT", ERH
C TYPE "ERROR FOR G-HAT", EGH
STOP
END
4. SAMPLE RUNS

Sample run results are included in the following pages for a file containing 3 records. Same data is used for each of the four cases namely without filters (SP1), with low frequency filter only (SPL), with high frequency filter only (SPH) and with both filters (SP2).
**SP1**

FILE NUMBER: MF=1  
DIFFUSE BURNING FACTOR, DDF=1  
MAXIMUM LAG FACTOR, R=1  
HEIGHT OF SCANNING SLIT, X=1  
WIDTH OF SCANNING SLIT, W=1  
DATA PREPARATION COMMENCED  
FILE IS BEING READ FROM TAPE  
NUMBER OF RECORDS READ: 3  
FILE READ FROM TAPE AND WRITTEN ON DISK  
By k(hkl), ek(hkl)  
NUMBER OF SAMPLES: 101  
X COORDINATE (MICRONS)= -3697  
Y COORDINATE (MICRONS)= 0  
DELTA X (H) (MICRONS)= 12  
DATA IS BEING FORMATTED  

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DATA FORMATTING COMPLETED  
RAW DATA STORED ON DISK.

**RECORD NO. 1**  
HISTOGRAM BEING COMPUTED  

| TOTAL NO. OF CLASSES|= 100  
| CLASS NO. | NO. OF DATA POINTS |  
| 79        | 2                   |  
| 80        | 2                   |  
| 81        | 7                   |  
| 82        | 7                   |  
| 83        | 22                  |  
| 84        | 23                  |  
| 85        | 18                  |  
| 86        | 16                  |  
| 87        | 4                   |  
| 88        | 3                   |  

RAW MEAN = 0.26858E+4  
MEAN OF NORMALIZED DATA= 0.100000E+1  
MEAN SQUARE VALUE = 0.49376E-3  
ROOT MEAN SQUARE VALUE = 0.22331E7  
AUTOCORRELATION IS BEING COMPUTED  

**RECORD NO. 2**  
HISTOGRAM BEING COMPUTED  

| TOTAL NO. OF CLASSES|= 100  
| CLASS NO. | NO. OF DATA POINTS |  
| 79        | 1                   |  
| 80        | 1                   |  
| 81        | 3                   |  
| 82        | 2                   |  
| 83        | 16                  |  
| 84        | 18                  |  
| 85        | 27                  |  
| 86        | 18                  |  
| 87        | 1                   |  

RAW MEAN = 0.26861E+4  
MEAN OF NORMALIZED DATA= 0.100000E+1  
MEAN SQUARE VALUE = 0.13491E-2  
ROOT MEAN SQUARE VALUE = 0.15954E-1  
AUTOCORRELATION IS BEING COMPUTED  

**RECORD NO. 3**  
HISTOGRAM BEING COMPUTED  

| TOTAL NO. OF CLASSES|= 100  
| CLASS NO. | NO. OF DATA POINTS |  
| 79        | 1                   |  
| 80        | 1                   |  
| 81        | 3                   |  
| 82        | 2                   |  
| 83        | 16                  |  
| 84        | 18                  |  
| 85        | 27                  |  
| 86        | 18                  |  
| 87        | 1                   |  

RAW MEAN = 0.26861E+4  
MEAN OF NORMALIZED DATA= 0.100000E+1  
MEAN SQUARE VALUE = 0.0.13491E-2  
ROOT MEAN SQUARE VALUE = 0.15954E-1  
AUTOCORRELATION IS BEING COMPUTED  

**ACKNOWLEDGMENTS**

This research was supported by the National Science Foundation under Grant No. DMR-8923371. The authors would like to thank Dr. J. Smith for his valuable suggestions and Dr. L. Brown for his assistance in the preparation of the manuscript. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the National Science Foundation.
### SPL

**FILE NAME:** HF-1  
**DIFFUSE DENSITY FACTOR:** DF-1  
**MAXIMUM LAG FACTOR:** M-8  
**HEIGHT OF SCANNING SLIT:** H-1  
**WIDTH OF SCANNING SLIT:** W-1  
**LOW FREQUENCY FILTER PARAMETER:** P-10

#### DATA PREPARATION COMPLETED

**FILE:** IS BEING READ FROM TAPE  
**NUMBER OF RECORDS READ:** 3  
**FILE READ FROM TAPE AND WRITTEN ON DISK**  
**ON-HIGH FILE**  
**NUMBER OF SAMPLES:** 101  
**X COORDINATE (MICRONS):** -3292  
**Y COORDINATE (MICRONS):** 0  
**DELTAX (microns):** 12  

#### DATA IS BEING FORMATTED

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<th>DeltaY</th>
<th>DeltaZ</th>
<th>Data Point</th>
<th>Raw Mean</th>
<th>Mean of Normalized Data</th>
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</table>

#### DATA FORMATTING COMPLETED

**RAW DATA STORED ON DISK.**

**RECORD NO.:** 1

#### HISTOGRAM BEING COMPUTED

**TOTAL NO. OF CLASSES:** 100  
**CLASS NO.:** NO. OF DATA POINTS  
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<td>8</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
</tr>
</tbody>
</table>

**RAW MEAN:** 0.285538E-4  
**MEAN OF NORMALIZED DATA:** 0.109800E-1  
**DATA IS BEING FILTERED FOR LOW FREQUENCY**  
**MEAN SQUARE VALUE:** 0.435614E-3  
**ROOT MEAN SQUARE VALUE:** 0.289538E-1  
**AUTOCORRELATION IS BEING COMPUTED**

**R**  
<table>
<thead>
<tr>
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<th><strong>NORM. R-HAT</strong></th>
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</tr>
<tr>
<td>1</td>
<td>0.1777E-4</td>
</tr>
<tr>
<td>2</td>
<td>0.1472E-3</td>
</tr>
<tr>
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<td>0.1395E-1</td>
</tr>
<tr>
<td>4</td>
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**RECORD NO.:** 2

#### HISTOGRAM BEING COMPUTED

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<td>8</td>
<td>16</td>
</tr>
<tr>
<td>9</td>
<td>16</td>
</tr>
</tbody>
</table>

**RAW MEAN:** 0.285538E-4  
**MEAN OF NORMALIZED DATA:** 0.109800E-1  
**DATA IS BEING FILTERED FOR LOW FREQUENCY**  
**MEAN SQUARE VALUE:** 0.125135E-3  
**ROOT MEAN SQUARE VALUE:** 0.111338E-1  
**AUTOCORRELATION IS BEING COMPUTED**

**R**  
<table>
<thead>
<tr>
<th><strong>R-HAT</strong></th>
<th><strong>NORM. R-HAT</strong></th>
</tr>
</thead>
<tbody>
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<td>0</td>
<td>0.1040E-1</td>
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<tr>
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<td>0.1395E-1</td>
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<tr>
<td>4</td>
<td>0.1398E-1</td>
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**RECORD NO.:** 3
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</table>

AVERAGE R-HAT   0.22666E+1

AVERAGE G-HAT   0.16051E+0

ERROR FOR R-HAT 0.22666E+1

ERROR FOR G-HAT 0.99995E+2

STOP
SPH
FILE NUMBER, HP-1
DIFFUSE DENSITY FACTOR, DDF-1
MAXIMUM LAG FACTOR, M-1
HEIGHT OF SCANNING LENS, H-1
WIDTH OF SCANNING LENS, W-1
HIGH FREQUENCY FILTER PARAMETER, G-1
DATA PREPARATION CORRECTED
FILE IS BEING READ FROM TAPE
NUMBER OF RECORDS READ= 3
FILE READ FROM TAPE AND WRITTEN ON DISK
BY hh:mm:ss ddmmyy 10
NUMBER OF SAMPLES= 101
X COORDINATE (MICRONS)= -3607
Y COORDINATE (MICRONS)= 0
DELTA X (Microns)= 12
DATA IS BEING FORMATTED
3.34 3.34 3.28 3.32 3.29 3.31 3.30 3.28 3.28 3.28
3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28
3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28
3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28
3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28
3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28
3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28
3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28
3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28
3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28 3.28
DATA FORMATTING COMPLETED
RAW DATA STORED ON DISK.
RECORD NO. 1
HISTOGRAM BEING COMPUTED
TOTAL NO. OF CLASSES= 100
CLASS NO. NO. OF DATA POINTS
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1 1
2 1
3 1
4 1
5 1
6 1
7 1
8 1
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100 1
RECORD NO. 3
HISTOGRAM BEING COMPUTED
TOTAL NO. OF CLASSES= 100
CLASS NO. NO. OF DATA POINTS
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The denominator of sine function below 1.0E-06 encountered in INF

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STOP
### Record No. 1

#### Histogram Being Computed

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#### Mean of Normalized Data

| 0.100000E+1 |

#### Mean Square Value

| 0.01709E-3 |

#### Root Mean Square Value

| 0.78945E-2 |

#### Histogram Being Computed

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TYPE SP16
C FILE SP16=AUG
C PROGRAMMER NAME: S.P. SINGH
C REVISION: 0
C DATE: 3/6/79
C PURPOSE: THIS MODULE COMPUTES THE RAW MEAN OF THE DATA.
C COMPILER NOSTACK
C SUBROUTINE AVG(ITEMP,ICH,1R,NR,LP,RAWM)
C SP16 is AVG
C REAL ISUM
C DIMENSION ITEMP(1000),NP(50)
C CALL fopen(ICH,R,"RD",2000)
C INP=0
C ISUM=0
C
C SUM ALL THE POINTS IN THE FILE
C
DO 10 I=1,NR
CALL readr(ICH,1,ITEMP,1,IER)
INP=NP(1)
DO 20 J=1,INP
ISUM-ISUM+ITEMP(J)
20 CONTINUE
INP=INP+NP(1)
CONTINUE
RAWM-ISUM/INP
TYPE *"RAW MEAN = ",RAWM
CALL fclos(ICH)
RETURN
END