FINAL REPORT

ON-BOARD DATA MANAGEMENT STUDY FOR EOPAP

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ON-BOARD DATA MANAGEMENT STUDY FOR EOPAP

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# TABLE OF CONTENTS

1. Summary ........................................... 1
2. SEASAT Sensor Data Processing .................. 3
   2.1 Short Pulse Radar .............................. 3
   2.2 Long Pulse Radar ............................... 4
   2.3 Synthetic Aperture Radar ..................... 4
   2.4 Passive Microwave Radiometer Facility ...... 5
   2.5 Very High Resolution Radiometer ............ 5
3. Rate Distortion Theory ........................... 7
4. Short Pulse Radar Data Reduction ............... 13
   4.1 Introduction .................................. 13
   4.2 Simplified Theory of Wave Height and Wave Periodicity Estimation .......... 16
   4.3 Computer Programs Developed for the Analysis ...... 19
      4.3.1 Data Input Program ....................... 19
      4.3.2 Fast Fourier Transform ................... 19
      4.3.3 Analysis Program ......................... 20
5. VHRR Data Compression ............................ 22
6. On-Board Data Management System ............... 27
REFERENCES .......................................... 28
APPENDIX A Data Input Program ..................... 29
APPENDIX B Fast Fourier Transform ................ 32
APPENDIX C Main Analysis Program ................ 34
APPENDIX D Printout of Average Pulse and Spectrum .... 41
APPENDIX E Peak Histogram .......................... 50
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>A Simplified Communication Block Diagram</td>
<td>8</td>
</tr>
<tr>
<td>4.1.1</td>
<td>Typical Signal Return (Jonswop Data)</td>
<td>14</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Short Pulse Radar Geometry</td>
<td>16</td>
</tr>
<tr>
<td>5.1</td>
<td>VHRR Signals</td>
<td>23</td>
</tr>
<tr>
<td>5.1</td>
<td>VHRR Timing</td>
<td>24</td>
</tr>
</tbody>
</table>
1. Summary

A study of the requirements, implementation techniques and mission analysis associated with on-board data management for EOPAP has been performed. SEASAT-A has been used as a baseline with reference [1] used as the primary source of information for the spacecraft configuration. The storage requirements, data rates, and information extraction requirements have been investigated for each of the following proposed SEASAT sensors: a short pulse 13.9 GHz radar, a long pulse 13.9 GHz radar, a synthetic aperture radar, a multispectral passive microwave radiometer facility and an infrared/visible very high resolution radiometer (VHRR). The short pulse radar is used for altimetry and the determination of wave height and wave directional spectra. Primary consideration in this study was given to this sensor based on data provided by the GSFC technical officer. The long pulse radar is used for measuring wind speeds by scatterometry. The synthetic aperture radar provides side-looking coherent imagery. The passive microwave sensors are radiometers at 5, 13.9, 18, 22, 36, and 53 GHz which are used for correcting altimeter measurements, measuring surface roughness and sea ice. The VHRR sensor provides cloud cover maps and sea surface temperature information. Data management principles for the latter were included in the study based upon the results of the earlier study contract NAS5-21940 "ITOS VHRR On-Board Data Compression Study" (reference [2]) and extended to include the other SEASAT sensors.

Rate distortion theory was applied to determine theoretical minimum
data rates and compared with the rates required by practical techniques. It was concluded that practical techniques can be used which approach the theoretically optimum based upon an empirically determined source random process model.

Finally the results of the preceding investigations were used to recommend an on-board data management system. The purpose of the on-board data management system is for (1) data compression through information extraction, optimal noiseless coding, source coding with distortion, data buffering and data selection under command or as a function of data activity, (2) for command handling, (3) for spacecraft operation and control, and (4) for experiment operation and monitoring. It was concluded that an on-board general purpose programmable computer should be used and that the advanced on-board processor (AOP) developed by NASA GSFC is suitable for the tasks required.

Section 2 is a review of the SEASAT sensors studied and their data rate requirements. Section 3 presents rate distortion theoretic considerations. Section 4 is a discussion of the data reduction and estimation techniques applied to aircraft samples of the short pulse radar type and the computer programs developed in this study for the analysis. Section 5 presents results for the VHRR data. Finally section 6 discusses an on-board data management system.
2. SEASAT Sensor Data Processing

2.1 Short Pulse Radar

The short pulse radar is used to measure the mean altitude of the spacecraft and the rms wave height in a nadir-looking mode with a .6 m dish. It also can be used with a 2 m dish in an off-nadir conical scan mode to measure wave directional spectra. The radar uses linear chirp FM transmission to attain the required resolution (≈3 nsec compressed pulse length) in altitude, wave height, and wave directional spectra. On-board processing can be used to estimate and transmit these parameters at a low bit rate relative to the bit rate required for the unprocessed received radar data. The actual bit rate resulting depends on the number of read-outs per second of the processed estimates which can be controlled by the on-board data management system. The control can be through read-out rate selection under ground station control or under data control as a function of data activity. In either case, data compression can be used for further bit rate reduction by sending encoded changes in the parameters rather than the parameters themselves. In this method noiseless coding is used to take advantage of the lowered entropy of the difference sequence.

Further details regarding the processing of the radar data for parameter estimation appears in section 4 based upon samples of aircraft data supplied by the NASA GSFC contract technical officer.
2.2 Long Pulse Radar

The long pulse 13.9 GHz radar is used as a scatterometer to measure wind speed and direction. The scatterometer shares the 2 m dish with the short pulse radar in a conical scan mode and operates on the principle that the radar cross section of the sea surface depends on the wind speed and direction. Atmospheric calibration is provided by the 13.9 GHz passive radiometer. As for the short pulse radar, on-board processing can be used to reduce the received radar data into estimates of wind speed and direction so that arbitrarily low bit transmission rates can be attained depending upon the read out rate desired, and/or the data activity and/or the use of data compression on the sequence of parameter estimates.

2.3 Synthetic Aperture Radar

A synthetic aperture radar is provided for side-looking coherent imaging. Waves on the ocean can be analyzed from the imagery to determine wave spacing and direction (except for a 180° ambiguity). From the wave periodicity the rms wave height can be found through the known deterministic relation between the two parameters. Furthermore information on icebergs, shoals, kelp beds, tides, oil slicks, etc. can be provided. The major drawback in the usage of this technique is the high data rate. This data rate can be reduced by selective coverage through the on-board processor and through prefiltering and buffering operations to 8 Mbps. Because of the high data rate and the inherent redundancy of images, particularly the synthetic aperture type, the signal is an ideal candidate for data compression. Using rate distortion theory (see section 3),
and empirical experience with images, it is estimated that the bit rate could be reduced to 1 Mbps with acceptable quality by using a combination of line-to-line and sample-to-sample compression techniques. If further degradation is allowed so that only the essential information is retained (wave locations, edges of land or iceberg or other significant formations, etc) a reduction to .5 Mbps or less may be possible.

2.4 Passive Microwave Radiometer Facility

The passive microwave radiometers provide atmospheric path length corrections for the short pulse radar altimeter, sea surface temperature measurements, surface wind speed measurements, and rain area and cloud water content determinations. The bit rate requirement for this data is 3.7 kbps. This can be substantially reduced by data compression using the inherent redundancy of the data (see section 3).

2.5 Very High Resolution Radiometer

A two channel very high resolution infrared/visible radiometer (VHRR) provides cloud cover pictures and surface temperature measurements in the 10.5 to 12.5 micrometer infrared band and in the 0.6 to 0.7 micrometer visible band. This instrument is essentially identical to that used for ITOS-D. The scan voltage is a 35 kHz low pass signal which requires on the order of 1 Mbps for full-resolution, uncoded transmission. However, undersampling, line deletion, data formatting, and data compression under control of the on-board processor can be used to substantially reduce the required bit rate. Detailed methods of compression for this source data appear in Systems Analysis report no. 75100, "ITOS VHRR On-
Board Data Compression" prepared under NASA GSFC contract NAS5-21940. A summary of the essential results appears in section 5 of this report.
3. Rate Distortion Theory

The rate-distortion function of a source with a given probability distribution determines the minimum channel capacity required to transmit the source output (or the storage capacity required to store the source output per unit time) as a function of the desired maximum average distortion, where the distortion function (sometimes called fidelity criterion) is a measure of the agreement between the source output and the end user output as specified by the user. The concept originated with Shannon who calculated the rate-distortion function for certain sources including in particular a Gaussian discrete time random process. This was later extended to more complicated sources and applied to performance bounding by other authors.

Figure 3.1 presents a highly simplified communication system block diagram. The system designer is given a source and wishes to encode the source in such a way that the channel capacity (or storage) requirement is minimized. To make this minimum as small as possible, he is willing to tolerate some average distortion (typically average error power) between the source output and the decoder output. The problem addressed by rate distortion theory is the minimization of the channel capacity requirement while holding the average distortion at or below an acceptable level.

To be slightly more specific, in figure 3.1 let the average information transmitted from the source to the decoder output be denoted by the function $I(X,Y)$, more information corresponding to larger values of
FIGURE 3.1. A SIMPLIFIED COMMUNICATION BLOCK DIAGRAM
I(X,Y). Let the analogous average information transmitted from the encoder output to the channel output be denoted I(U,V). The channel capacity C is defined as the maximum of I(U,V) over all possible input devices. It is obvious that in figure 3.1, the intervening nature of U and V implies I(X,Y) ≤ I(U,V) ≤ C if the function I(;,*) is properly defined. Shannon defined the correct function for information and defined the rate distortion function R(D) as the minimum value of I(X,Y) for a given distortion level D. He also showed that R(D) < C issues the possibility of attaining average distortion D by coding at rate C with a sufficiently complicated encoder.

To look at the problem from a different angle, the encoding and decoding can be separated into two parts—source coding and channel coding. The job of the source coder is to remove source redundancy, whereas the job of the channel coder is to insert controlled redundancy to combat noise. How well channel coding can perform is established by Shannon's noisy coding theorem which states that transmission without channel errors is possible if and only if the rate at which messages are presented to the channel coder from the source coder does not exceed channel capacity. With this constraint on the source coder, at a given channel capacity the source coding must result in a loss of quality—i.e. some distortion must result. The rate distortion function R(D) is the minimum source coder rate (minimum required channel capacity) for an average distortion level D.

An analytically convenient source model to use is the Gaussian which frequently is a good model in practice, in particular for the image data found on SEASAT. Consider the problem of encoding a source which
generates a sequence of statistically independent Gaussian random variables with a squared error distortion measure. This source is characterized by a known mean (i.e. dc) value, which does not affect coding rate because it is a simple shift, and a variance (power) \( \sigma^2 \). Let the source output be the \( N \) values \( \{ x_i, i=1,2,...,N \} \) and the decoder output be \( \{ y_i, i=1,2,...,N \} \). The distortion is taken as

\[
d(X,Y) = \sum_{i=1}^{N} (x_i - y_i)^2
\]

so that the average distortion is the average mean square error (error power):

\[
D = \frac{1}{N} \sum_{i=1}^{N} E(x_i - y_i)^2
\]

It can be shown that the rate distortion function is given by

\[
R(D) = \begin{cases} 
4 \log \frac{\sigma^2}{D} & \sigma^2 > D \\
0 & \sigma^2 \leq D 
\end{cases}
\]

That is, the rate distortion function is one-half the logarithm of the signal power-to-distortion (noise) ratio. It is achieved conceptually by encoding in such a way that the output error is Gaussian with variance \( D \) on each sample value and is sample-to-sample independent, but not necessarily signal independent. Actually there are no known practical methods for achieving a Gaussian error distribution or for achieving the rate distortion bound of (3.1). Instead one must be content with quantization methods which can be made to be within approximately .25 of a bit or so of the bound by choosing the quantization levels properly and using variable length coding on the quantized values.
In terms of quantizing schemes the rate distortion function has the following rough intuitive justification. The noise standard deviation as a fraction of the signal amplitude is inversely proportional to the number of quantization levels. Therefore, the number of levels should be proportional to \( \sigma / \sqrt{D} \) and the number of information bits should therefore be the logarithm (base 2) of this quantity. This is what is stated in (3.1). If the allowed distortion is greater than the signal power, i.e. \( D > \sigma^2 \), the minimum transmission rate and hence rate distortion function must be zero since nothing need be transmitted at all to achieve error power equal to signal power. This is also stated in (3.1).

The preceding was for a source of independent values. Suppose now the source contains memory as in most physical sources. In particular, suppose the source output is Markov (which means roughly that the future depends only on present values and not the past) with correlation coefficient \( \rho, |\rho| < 1 \). This is a model which has found good agreement in practice, in particular for video data of the VHRR and synthetic aperture radar type. The value \( \rho \) is the correlation between adjacent values on a scan line. If \( \rho = 1 \), then each value is the same as the last. If \( \rho = 0 \), the values are independent as before. For this model it can be shown that (3.1) for low distortion levels becomes

\[
R(D) = \frac{1}{2} \log \frac{\sigma^2 (1-\rho^2)}{D} \tag{3.2}
\]

The typical range of the parameter \( \rho \) is .95 to .99. Thus the number of bits can be reduced by \( \frac{1}{2} \log(1-\rho^2) \), or something up to 3 bits, for a given mean square error \( D \) over coding for independent values. This performance can be approached through differential coding methods whereby successive sample differences are encoded by a variable length code. For
image data further gains can be made by using line-to-line effects. Assuming the same correlation model between lines, another gain of up to 3 bits can be attained assuming sufficient random access storage is available to store one whole line of data (in addition to the present line).

Rate distortion theory is most useful in practice in providing a bound on the performance of practical data compression methods. This is the primary way it has been used in this study. Consider for example differential variable length coding wherein the successive sample differences are quantized and encoded by a variable length code. Assuming fine quantization, the variance of the difference between the present quantized value and the next sample is approximately

$$2(1-\rho) \approx (1+\rho)(1-\rho) \approx 1-\rho^2$$

(3.3)

Allowing .25 bit for the optimum quantized value code over the best that can be done as shown by (3.1) and (3.2), it is seen that the differential method comes within the .25 bit of the optimum up to the approximation of fine quantization and the approximations of (3.3)
4. Short Pulse Radar Data Reduction

4.1 Introduction

Extensive studies were performed on the extraction of rms wave height and wave periodicity based on off-nadir looking aircraft radar measurements provided by the NASA GSFC contract technical officer on digital 9 track tape. Two aircraft runs were provided, the first being from the JONSWOP experiment with the NRL altimeter used in an off-nadir mode by banking the aircraft. In this experiment a 10 nsec pulse width was used with a $6^\circ$ beamwidth antenna. The aircraft was banked so that the beam center pointed about $10^\circ$ and $15^\circ$ off-nadir on passes in various turning configurations. The aircraft was at an altitude of approximately 11,000 feet. Similar data was provided by an NRL experiment in January 1974, the primary differences being a doubled sampling rate, a fixed bearing rather than a turning course by the aircraft, and less noisy data.

The sampled data provided in each of the experiments consisted of 6 digital tape files corresponding to each of 6 aircraft passes under different conditions. Each pass consisted of 8192 signal traces measured by sampling the pulse returns sequentially 160 times with increasing delay on each pulse across a total sampled time interval of one microsecond for the JONSWOP data and 500 nsec for the NRL data. A typical pulse appears in figure 4.1.1 and is seen to comprise the total returned energy from the sea surface plus noise with noise only preceding and following the return signal.
FIGURE 4.1.1. TYPICAL SIGNAL RETURN (JONSWOP DATA)
Computer programs were developed for the analysis of the sampled data and are included in listed form as a portion of this report. These are in Interdata assembly language and FORTRAN IV. The analysis programs include an Interdata assembly language program for inputting the data from the digital tape under a FORTRAN call and a master program with the ability under input control to print out individual signal traces or averages of signal traces, the ability to print out the Fourier transform amplitude spectra of the signal traces or their averages or the average of the Fourier amplitude spectra of the individual signal traces, using a fast Fourier transform routine written for the Interdata in FORTRAN, the ability to print out correlation functions and cross-correlation functions of the signal traces, and the ability to print out histograms of the signal trace peaks subject to a threshold on the signal level, including the calculated mean and rms values of the histogram. Except for the assembly language digital data input routine, FORTRAN IV was used exclusively so that the programs could be compiled on any machine, except, possibly for some minor modifications to conform with the particular compiler conventions.

Extensive computer program outputs of the various types were provided to NASA GSFC during the course of the contract for the purposes of analyzing the various approaches to determining the wave heights and/or wave periodicities from off-nadir short pulse radar data. The results to date appear promising but inconclusive, partly due to the limited amount of data, the noisiness of the data, the lack of resolution of the data, the necessity to construct one pulse from 160 sampled pulses, and the lack of ground truth values.
4.2 Simplified Theory of Wave Height and Wave Periodicity Estimation

Many papers have been written on the theory of wave height and wave period estimation from radar sea scatter measurements. Some of these are listed in the references. In this section a brief review of the pertinent theory to off-nadir short pulse radar measurements is given in highly simplified form.

Consider a radar illuminating a periodic sea surface at an angle $\alpha$ from nadir as shown below:

![Figure 4.2.1. Short Pulse Radar Geometry](image)

The returned signal power is the radar cross section as a function of propagation path length across the illuminated surface. If one assumes that the returns move linearly across the surface in time, the returned signal power contains an amplitude modulation component of frequency $c/(2L\sin\alpha)$. This conceptually can be extracted either directly from the returned power as a function of time or from the Fourier transform (spectrum) of the returned power by peak determination. Complicating the task, of course, is the non-pure periodicity of the sea surface, the nonlinearity of the range-time scale across the sea surface and the receiver noise. In the time domain the estimate could be extracted by a bank of
matched filters, incorporating the range-time base correction as a function of the off-nadir angle, $\alpha$. Alternately the data could be sampled non-uniformly or interpolated to correct the time base followed by a Fourier transform of the squared envelope. The peak of the spectrum (away from D.C.) represents the estimated amplitude modulation frequency.

Given the wave period estimate, the rms wave height estimate can be determined from the deterministic relation between the two. Alternately the wave height can be estimated and used to estimate the wave period through the same relationship. The average power return over a number of pulses is just the convolution of the transmitted pulse with the probability density function of the wave height integrated over range. The spectrum is the product of the transform of these factors. Thus the rms wave height can be extracted from the returned signal by finding the rms value of the probability density imbedded in the averaged returns. Reference [1] proposes doing this from the leading edge of the return which should be more or less spread out depending on wave height (actually [1] proposes using nadir measurements although the same analysis can be applied to small off-nadir observations). Levine [3,4] shows that the spectrum should be approximately proportional to

$$I(v) \exp \left[ -2 \left( \frac{2\pi \sigma_z}{c} \cos \alpha \right)^2 \right] \frac{1}{\sin \alpha}$$

where:

- $v =$ frequency
- $I(v) =$ Fourier transform of the transmitted pulse squared
- $\sigma_z =$ rms wave height
\( \alpha \) = off-nadir angle

\( \ell \) = illuminated surface length.

This is just the product of the transforms of the above referred to factors assuming the wave height distribution is Gaussian. Thus \( \sigma_z \) can be estimated by the rate of exponential decay of the spectrum.

Alternately, Levine [3] has shown that \( \sigma_z \) can be estimated from a histogram of the locations of peaks in the returned signal. In particular, he found that

\[
\sigma_z^2 = \sec \alpha \left( \left( \frac{c}{2} \right)^2 \frac{\ell^2}{T_n^2} - \frac{(\ell \sin \alpha)^2}{12} \right)
\]

where \( T_n^2 \) is the rms peak arrival time. Thus \( \sigma_z \) could be extracted from a peak histogram over several pulses.

Both of the preceding methods of extracting \( \sigma_z \) are theoretical results from a 2 dimensional model and involve approximations. Thus experimental results are needed to confirm the theory or point to needed modifications.
4.3 Computer Programs Developed for the Analysis

4.3.1 Data Input Program

The data as supplied by the NASA GSFC technical officer is formatted on digital tape in 6 files of 257 records. The first record is a short header record for the file. Each succeeding record consists of 32 signal traces, formatted with 14 header bytes followed by 160 2-byte signal sample values. Thus one record consists of $32 \times 167 = 5344$ 2-byte (halfword) values. Each file of 256 data records comprises one aircraft pass.

The program written to read these values into a FORTRAN array is written in Interdata assembly language and appears as appendix A. The program is called by:

```
CALL ECKERM(INP)
```

where INP(N) is a (2-byte) integer array of dimension not less than 5344. All 5344 values from the next record on tape are unpacked sequentially in the array INP, including the header values.

4.3.2 Fast Fourier Transform

A fast Fourier transform was used extensively for data analysis and is listed in Appendix B. It was written in Interdata FORTRAN IV and is a subroutine called by:

```
CALL FOURLT(DATA,N,S,ISIGN)
```

where:

- `DATA(I) = complex array of N values`
- `S = table of sines of dimension not less than N/2 + 1`
ISIGN is used as follows:

\[ \text{sign(ISIGN)} = \text{sign of the exponent in the Fourier transform} \]

If \(|\text{ISIGN}| \neq 1\), the sine tables are set up in S

If \(\text{ISIGN} = 0\), tables are set up only.

The quantity calculated is:

\[
\sum_{k=1}^{N} \text{DATA}(k) \exp \left( i \frac{2\pi}{N} (k-1)(n-1) \right) \text{sign(ISIGN)}) \quad n=1,2,\ldots,N
\]

The results appear in DATA(n) in place of the original data. Note that no normalization by N occurs.

4.3.3 Analysis Program

The listing of the main analysis program appears in Appendix C as it is currently configured. Many modifications were made to the program as the contract progressed to conform to the various analytical approaches and data requests by NASA GSFC. Certain classes of outputs can be generated by an appropriate input to the program from the teletype keyboard as the program now stands. Others can be generated by simple program modifications and re-compilation. The following outputs have been generated to date:

1. A printout of individual signal traces squared (i.e. power) or the average of a number of signal traces squared, with the number under input control, and the centroid of the printed quantity. An example of this printout appears in Appendix D.

2. A printout of the log of the spectrum of the average in (1). An example appears in Appendix D where a 1024 point spectrum
appears, generated by setting all values to zero outside the return signal range. Fourier transform amplitude spectra can also be generated without the appended zeroes, in which case the values are windowed prior to transforming.

(3). The average of the Fourier transform amplitude spectra of individual pulses.

(4). Correlation functions of the signal traces and cross correlation functions between signal traces.

(5). Numbers (2)-(4) with the range-time base corrected by interpolation to be linear.

(6). Signal-to-noise ratio estimates.

(7). Histograms of peaks exceeding an input threshold, including the mean and rms values of the histograms. An example of this printout appears in Appendix E.

To date the efficacy of the various estimation techniques remains unproven, although the results are promising. Upon the attainment of further data, the programs developed under this contract will be available for the analysis and the development of an optimal technique.
5. VHRR Data Compression

The VHRR signal appears as in figure 5.1 with the timing as indicated in table 5.1. The voltage range is 6 volts which is contained within a lowpass bandwidth of 35 kHz nominal. Using a sampling rate on the order of 100 kHz (1.43 times the Nyquist rate) and something like 8 bit sample quantization results in a bit rate on the order of 1 MHz for a straightforward PCM transmission system. However, an examination of table 5.1 reveals that 40% of the data can be essentially eliminated by transmitting the temperature and calibration values as single digital values rather than as long repetitive steps and by synchronizing on and selecting out the earth scan data only. It is shown in the results of an earlier study [2] that another 3 bits can be removed from the 8 bit quantized values in the earth scan data by using variable length coding on the sample differences as described in section 3 of this report. Thus the compressed-buffered bit stream requires a channel capacity on the order of (8-5) bits x 60% x 100kHz \(\approx 300\) kHz. Further details can be found in the reference [2].

As indicated in section 3, a further reduction in bit rate can be achieved by using line-to-line effects, perhaps to as low as 100 kHz if enough storage is allocated to hold the last line. Still further reduction in the average rate can be attained by selecting out only the intervals of time of particular interest or by deleting samples and/or lines on a regular basis. In this case digital filtering should be used to prevent aliasing on reconstruction.
FIGURE 5.1. VHRR Signals
<table>
<thead>
<tr>
<th>Function</th>
<th>After Start of IR Precursor Time (msec)</th>
<th>Duration Time (msec)</th>
<th>Signal Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Counts*</td>
<td>Counts</td>
<td></td>
</tr>
<tr>
<td>Precursor IR</td>
<td>0</td>
<td>5.2</td>
<td>18.75 kHz square wave, 0 to 100% amplitude starts 72 ± 1° before nadir</td>
</tr>
<tr>
<td>Pre-earth Synchronization signal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front Porch</td>
<td>521</td>
<td>256</td>
<td>Amplitude 0%</td>
</tr>
<tr>
<td>Sync Pulse</td>
<td>768</td>
<td>512</td>
<td>Amplitude 100%. Starts 65.8 ±1° before the nadir</td>
</tr>
<tr>
<td>Back Porch</td>
<td>1280</td>
<td>256</td>
<td>Amplitude 0%</td>
</tr>
<tr>
<td>Space scan</td>
<td>1536†</td>
<td>Not clock controlled</td>
<td>Amplitude 100% period varies with spacecraft altitude &amp; attitude</td>
</tr>
<tr>
<td>Earth scan</td>
<td>7.20†</td>
<td>Not clock controlled</td>
<td>Amplitude varies over range 0% to 100% (0% Hot, 100% Cold). Period, varies from 43.68 msec @900 n.mi. to 48.64 msec @800 n.mi.</td>
</tr>
<tr>
<td>1st Sub-Sync marker</td>
<td>4864</td>
<td>16</td>
<td>Two level signal starting at 0% amplitude for ¾ the period when switching to 100% for the remainder of the period</td>
</tr>
<tr>
<td>2nd Sub-Sync marker</td>
<td>13056</td>
<td>16</td>
<td>Same as 1st Sub-Sync marker</td>
</tr>
<tr>
<td>Space scan (post earth)</td>
<td>Not clock controlled</td>
<td>32.52</td>
<td>Amplitude is undefined as signal may be influenced by the visible channel calibration target</td>
</tr>
<tr>
<td>Voltage Calibration</td>
<td>17152</td>
<td>1792</td>
<td>Seven levels increasing in amplitude from 0 to 100%. Zero level following 7th step.</td>
</tr>
<tr>
<td>Visible calibration</td>
<td>18944</td>
<td>256</td>
<td>Normal range when target is illuminated by sun is about 20% amplitude</td>
</tr>
<tr>
<td>Radiance calibration 300K target</td>
<td>19200</td>
<td>256</td>
<td>Amplitude about 20%. Varies with target's actual temperature</td>
</tr>
</tbody>
</table>

TABLE 75.1 VHRR TIMING
<table>
<thead>
<tr>
<th>Function</th>
<th>After Start of IR Precursor Time (msec)</th>
<th>Duration Counts</th>
<th>Time (msec)</th>
<th>Signal Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Sensor 300K target (expanded range +20 to +34°C)</td>
<td>19456 64.85</td>
<td>256 0.85</td>
<td>For normal temperature range amplitude will be between 0 and 80%. (If the temperature is out of this range, the signal will either be 0 or between 85% and 100%)</td>
<td></td>
</tr>
<tr>
<td>Temperature Sensor (expanded) range +7 to +21°C</td>
<td>19712 65.70</td>
<td>256 0.85</td>
<td>Same as above</td>
<td></td>
</tr>
<tr>
<td>Temperature Sensor (expanded range -6 to +8°C)</td>
<td>19968 66.55</td>
<td>256 0.85</td>
<td>Same as above</td>
<td></td>
</tr>
<tr>
<td>Post-earth Synchronization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front Porch</td>
<td>20224 67.41</td>
<td>1024 3.41</td>
<td>Amplitude 0%</td>
<td></td>
</tr>
<tr>
<td>Sync Pulse</td>
<td>21248 70.82</td>
<td>256 0.85</td>
<td>Amplitude 100%</td>
<td></td>
</tr>
<tr>
<td>Back Porch</td>
<td>21504 71.67</td>
<td>256 0.85</td>
<td>Amplitude 0%</td>
<td></td>
</tr>
<tr>
<td>End of IR scan</td>
<td>21760 72.53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precursor Vis</td>
<td>225238 75.00±1.00</td>
<td>512 1.71</td>
<td>12.5kHz square wave, 0 to 100% amplitude. Starts 72±10 before nadir</td>
<td></td>
</tr>
<tr>
<td>Pre-earth Synchronization Signal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front Porch</td>
<td>23035 76.78</td>
<td>256 0.85</td>
<td>Same as IR signal</td>
<td></td>
</tr>
<tr>
<td>Sync Pulse</td>
<td>23291 77.63</td>
<td>512 1.71</td>
<td>Same as IR signal</td>
<td></td>
</tr>
<tr>
<td>Back Porch</td>
<td>23803 79.34</td>
<td>256 0.85</td>
<td>Same as IR signal</td>
<td></td>
</tr>
<tr>
<td>Space scan (pre-earth)</td>
<td>24059 80.19</td>
<td>Not clock controlled</td>
<td>3.08†</td>
<td>Amplitude 0%. Period varies identically with IR signal</td>
</tr>
</tbody>
</table>

*TABLE 5.1 (cont)*
<table>
<thead>
<tr>
<th>Function</th>
<th>After Start of IR Precursor</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth scan</td>
<td>Not clock controlled</td>
<td>82.27+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not clock controlled</td>
</tr>
<tr>
<td>1st Sub-Sync marker</td>
<td>27387</td>
<td>91.28</td>
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<tr>
<td></td>
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<td>16</td>
</tr>
<tr>
<td>2nd Sub-Sync marker</td>
<td>35579</td>
<td>118.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>Space scan (post earth)</td>
<td>Not clock controlled</td>
<td>127.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not clock controlled</td>
</tr>
<tr>
<td>Voltage calibration</td>
<td>39675</td>
<td>132.24</td>
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<tr>
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<td></td>
<td>1792</td>
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<tr>
<td>Visible calib. target</td>
<td>41467</td>
<td>138.22</td>
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<tr>
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<td>256</td>
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<tr>
<td>Radiance calibration</td>
<td>41723</td>
<td>139.00</td>
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<tr>
<td>300°K target</td>
<td></td>
<td>256</td>
</tr>
<tr>
<td>Temperature sensor (+20 to 34°C)</td>
<td>41979</td>
<td>139.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>256</td>
</tr>
<tr>
<td>Temperature sensor (+7 to +21°C)</td>
<td>42235</td>
<td>140.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td>256</td>
</tr>
<tr>
<td>Temperature sensor (+6 to +8°C)</td>
<td>42491</td>
<td>141.64</td>
</tr>
<tr>
<td></td>
<td></td>
<td>256</td>
</tr>
<tr>
<td>Post-earth Synchronization Signal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front Porch</td>
<td>42747</td>
<td>142.49</td>
</tr>
<tr>
<td>Sync Pulse</td>
<td>43771</td>
<td>145.90</td>
</tr>
<tr>
<td>Back Porch</td>
<td>44027</td>
<td>146.76</td>
</tr>
<tr>
<td>Multiplex tolerance safety zone</td>
<td>44283</td>
<td>147.61</td>
</tr>
<tr>
<td>End of Scan</td>
<td></td>
<td>150.00</td>
</tr>
</tbody>
</table>

* A count is one cycle of 300-kHz square wave.
+ Spacecraft at 790 n.mi., 0° roll error, and nominal position for start of precursor.
$ Nominal value for switchover from IR to Visible Scan. All following times assume that this switchover is nominal.
6. On-Board Data Management System

It is clear from the preceding that the on-board processing requires a great deal of flexibility and computation which can be best performed by an on-board programmable computer, the programs for which can be loaded under ground station control. Such programs can be used to select and multiplex the sensors, to reduce the data to the desired parameter estimates, select sampling rates, encode the data and buffer it for transmission and/or storage at a constant rate from variable rate input values.

The primary considerations in the selection of an on-board processor are the computation speed, instruction repertoire and storage capacity. Also important, of course, are the power consumption, weight and volume. An investigation of the NASA GSFC-developed advanced on-board processor (AOP) indicates that it is suitable for SEASAT. It is a 1 microsecond cycle time machine with 16K 2 microsecond cycle time memory banks. There are 11 load/store and 9 arithmetic instructions plus various I/O, interrupt, branching, and test instructions.
REFERENCES


APPENDIX A

Data Input Program

READ ECKERMAN TAPE INTO FORTRAN 5/74

ENTRY ECKERM

EXTRN .0

* CALL IS:
* CALL ECKERM(INP)
* INP(N) IS A FIX PT ARRAY
* N.GE. 5344
* LDD 5/74
* MOD FOR 2 BYTE 10/74

0000R D0A0 ECKERM STL 10,REG SAVE USER REGS
0004R 48AF LH 10,0(15) CK NUMB ARG
0008R 0000 SIS 10,4 SEND ERR MESS
000AR 2337 BZS OK & STOP
000CR C8B0 LHI 11,0'33' GET A(INP)
0010R 3333 BAL 15,0 SAVE FOR LATER
0014R E130 SVC 3,0 SET UP SVC
0018R 41F0 OK LH 10,2(15) GET A(INP)
001CR 08DA LHR 13,10 SAVE FOR LATER
001ER 40A0 STH 10,INPUT+4 END ADDR
0020R 009F AHI 10,10687 END ADDR
0024R 29BF STH 10,INPUT+6 END ADDR
0028R 009E AHI 10,10687 END ADDR
002CR C9FD LHI 15,10688(13) LAST ADDR
0030R E110 GO SVC 1,INPUT READ TAPE IN
0034R 4800 LH 0,INPUT+2 CK STAT
0038R 0098 BNZ NOGO GET MSP
003CR D3BD LOOP LB 11,0(13) GET MSP
0040R 07B0 XHI 11,X'10' MAKE ALL +
0044R 0610 NHI 11,X'1F' MASK OUT INS BIT
0048R D3AD LB 10,1(13) GET LSP
004CR C4A0 NHI 10,X'1F' MASK OUT INS BIT
0050R 91B5 SLLS 11,5 LINE UP
0052R 06BA OHR 11,10 PACK
0054R 40BD STH 11,0(13) STORE AWAY
0058R C1D0 BXLE 13,LOOP GET NEXT
NO ERRORS

* .0 0012R
* ECKERM 0000R
  GO 0030R
  INPUT 0086R
  LIST 0078R
  LOOP 003CR
  MESS 0084R
  NOGO 0064R
  OK 0018R
  PAUSE 0094R
  REG 0088R
  UNPAK 0074R
APPENDIX B

Fast Fourier Transform

SUBROUTINE FOURIT(DATA, NN, S, ISIGN)
  DATA = COMPLEX ARRAY
  NN = NUMB COMPLEX VALS
  S = SIN TBL, DIM = DIM(DATA)/2 + 1
  ISIGN = SIGN IN FOURIER
  IF ABS(ISIGN).NE.1, TABLES SETUP
  IF EQ. 0, TABLES ONLY
  NO NN NORMALIZATION
  DIMENSION DATA(1), S(1)
  N = NN + NN
  NN2 = NN/2
  NN2+1 = NN2 + 1
  NN2+2 = NN2 + 2
  NNP2 = NN + 2
  XN = NN
  IF(ABS(ISIGN).EQ.1) GO TO 1
  DO 4 I = 1, NN21
   THETA = 3.1415926535*FLOAT(I-1)/XN
   S(I) = SIN(THETA)
   IF(ISIGN.EQ.0) RETURN
  1: J = 1
  DO 5 I = 1, N, 2
   IF(I.GE.J) GO TO 2
   TEMPR = DATA(J)
   TEMPI = DATA(J+1)
   DATA(J) = DATA(I)
   DATA(J+1) = DATA(I+1)
   DATA(I) = TEMPR
   DATA(I+1) = TEMPI
   2: M = N/2
   3: IF(J.LE.M) GO TO 5
   J = J - M
   M = M/2
   IF(M.GE.2) GO TO 3
   5: J = J + M
   MMAX = 2
   6: ISTEP = MMAX+MMAX
   NMAX = M/MMAX
   DO 8 M = 1, MMAX, 2
   IND = (M-1)*NMAX/2 + 1
   IF(IND.GT.NN21) GO TO 7
   WI = S(IND)
   IND = NN22 - IND
   WR = S(IND)
   7: CONTINUE
   IF(ISIGN.LE.0) WI = -WI
   DO 8 I = M, N, ISTEP
\[ J = I + M_{\text{MAX}} \]
\[ TEMPR = U_{\text{MAX}} \cdot (\text{DATA}(J) - \text{WIDATA}(J+1)) \]
\[ TEMPI = U_{\text{MAX}} \cdot (\text{DATA}(J+1) + \text{WIDATA}(J)) \]
\[ \text{DATA}(J) = \text{DATA}(I) - TEMPR \]
\[ \text{DATA}(J+1) = \text{DATA}(I) - TEMPI \]
\[ \text{DATA}(I) = \text{DATA}(I) + TEMPR \]
\[ \text{DATA}(I+1) = \text{DATA}(I) + TEMPI \]
\[ M_{\text{MAX}} = I_{\text{STEP}} \]
\[ \text{IF}(M_{\text{MAX}} < N) \text{ GO TO 6 } \]
\[ \text{RETURN} \]
\[ \text{END} \]

FOUR1T 0024R \text{FUNC/SUB}
FOUR1T 0574R \text{FUNC VAR}
Q 0000R \text{EXT FUNC}
PP 0000R \text{EXT FUNC}
DATA 002CR \text{FORM PAR}
NN 002CR \text{FORM PAR}
S 002CR \text{FORM PAR}
SIGN 003CR \text{FORM PAR}
N 057CR \text{INT4 VAR}
NN2 058CR \text{INT4 VAR}
NN21 058CR \text{INT4 VAR}
NN22 058CR \text{INT4 VAR}
nNNP2 059CR \text{INT4 VAR}
KN 058CR \text{REAL VAR}
U 0000R \text{EXT FUNC}
IABS 0000R \text{EXT FUNC}
L 012CR \text{LABEL}
4 00E4R \text{LABEL}
I 059CR \text{INT4 VAR}
THETA 05A0R \text{REAL VAR}
FLOAT 0000R \text{EXT FUNC}
SIN 0000R \text{EXT FUNC}
J 058CR \text{INT4 VAR}
S 027CR \text{LABEL}
2 022CR \text{LABEL}
TEMPR 058CR \text{REAL VAR}
TEMPI 058CR \text{REAL VAR}
M 058CR \text{INT4 VAR}
3 023AR \text{LABEL}
M_{\text{MAX}} 054CR \text{INT4 VAR}
6 024AR \text{LABEL}
I_{\text{STEP}} 058CR \text{INT4 VAR}
M_{\text{MAX}} 054CR \text{INT4 VAR}
8 04E4R \text{LABEL}
IND 0500R \text{INT4 VAR}
7 033CR \text{LABEL}
W1 054CR \text{REAL VAR}
UR 058CR \text{REAL VAR}
9 038CR \text{LABEL}

0000 \text{ERRORS}
APPENDIX C

Main Analysis Program

0001 C THIS PROGRAM IS TO ANALYZE AND DISPLAY EOPAP SEASAT
0002 C SHORT PULSE RADAR DATA. DEPENDING ON THE PROGRAM
0003 C MODE SELECTED, PULSES, PULSE SPECTRA OR PEAK
0004 C HISTOGRAMS CAN BE DISPLAYED. EITHER THE AVERAGE
0005 C SPECTRA OR THE AVERAGE OF THE SPECTRA CAN BE
0006 C SELECTED. MEANS AND RMS VALUES CAN BE EVALUATED.
0007 C DATA ARE ADJUSTED FOR POWER.
0008 C
0009 0004R IMPLICIT INTEGER*2 (I-N)
0010 0004R DIMENSION IPR(168)
0011 0004R DIMENSION INP'(5344), TBL'(1024), DAT'SO), PULSE(256)
0012 0004R DIMENSION PLA(5), PLOT(101), PAV(256), WIND(256)
0013 0004R COMPLEX Z(1024), CMPLX
0014 0004R EQUIVALENCE (Z(1), INP(I))
0015 0004R DATA PI, N, NTUP, L0, IH/3, 1415027, 128; 1024, 23, 150/
0016 0014R DATA DOT, STAR, BLANK, SLASH, ES, AA, PEE/1H, 1H*, 1H, 1H/1HS, 1HA, 1
0017 0014R CALL FOURIT(Z, NTUP, TBL, 0)
0018 C READ IN MODE DESIRED
0019 003ER 101 WRITE (0,100)
0020 0055R 100 FORMAT(11H ENTER MODE):
0021 006ER 102 READ(0,2) MODE
0022 008ER N2=N/2
0023 009CR N21=N2+1
0024 00A3R NTUP2=NTUP/2+1
0025 00BER N1=N+1
0026 00CAR XN=N
0027 00DSR XM=PI/XN
0028 C CALCULATE WINDOW WEIGHTS
0029 004ER DO 42 I=1,N
0030 00ECR 42 WIND(I)=1.-.83636364*COS(FLOAT(I-1)*XN)
0031 C GET LABEL FOR SPECTRA
0032 013ER DO 23 K=1,6
0033 016R 23 XLAB(K)=FLOAT(K-1)
0034 C NOW GET INPUT PARAMETERS
0035 017CR WRITE(0,4)
0036 0194R 4 FORMAT(6H LABEL):
0037 01A2R READ(0,5) DAT
0038 01C4R 5 FORMAT(5A1)
0039 01CER URITE(0,30)
0040 01E6R 30 FORMAT(13H ANGLE, MICSEC)
0041 01FCR READ(0,31) ANGLE, DUR
0042 0224R 31 FORMAT(SF5.1)
0043 0230R URITE(3,5) DAT
0044 0252R 6 FORMAT(1H1, 5A1)
0045 0260R ANG=ANGLE*PI/180.
0046 0270R DELTA=60./(DUR*FLOAT(NTUP))
0047 0288R WRITE(0,1)
0048 02A0R 1 FORMAT(7H FILE=?, 7H THRESH)
0049 02BAR READ (0,2) IFILE, ITHRSH
0050 02E2R 2 FORMAT(8I5)
0051 02EER 3 WRITE(3,3) IFILE, ANGLE, DUR
0052 031CR 3 FORMAT(6H FILE ,13.5X, F6.1, 8H DEGREES, 5X, F6.2, 7H MICSEC)
WRITE(3, 99) ITHRSH
FORMAT(15H THRESHOLD = , I5)
WRITE(0, ?)
FORMAT(12H BLOCKS, SIZE)
READ(0, 2) IBLKS, ISIZE
SIZE = ISIZE
WRITE(3, 99) THRSH
FORMAT(1H, IS, 32H AVG SQUARED PULSES, LOG SPECTRUM)
FORMAT(3H SPECTRA OF AVG=S, AVG SPECTRA=A )
DO56. C BLOCKS ARE INPUT IN 32 TRACE BLOCKS
KOUNT = 33
DO 9 IIII = 1, IBLKS
WRITE(3, 10) IIII
FORMAT(7H BLOCK )
DO 5 K = LO, IHI
WRITE(3, 22) XLAB
FOR ALL BKS(1)
CALL ECKERM(INP): DO 12 I = 1, ISIZE
KOUNT = KOUT + 1
IF(KOUT.LE.32, GO TO 13
MIN = 2
CALL ECKERM(IP)
DO 11 I = 1, 32
I = (III - 1)*167
DO 1 K = LO, IHI
MIN = MIN0(MIN, INP(J))
KOUNT = 1
LOG = (KOUNT - 1)*167
IPR(K) = IPR(K) + I
IF(MODE .NE. 1) GO TO 12
POW = CMPLX(X*X, 0.)
Z(KL) = CMPLX(XX, 0.)*WIND(KL)
PULSE(K) = PULSE(K) + XX
PULSE(K) = PULSE(K) + XX
IF(INP(J), LT, ITHRSH) GO TO 70
IF(INP(J), GT, INP(J-1), AND, INP(J), GT, INP(J+1)) IPR(K) = IPR(K) + 1
CONTINUE
CONTINUE
GO TO 12
C GET PULSE FOURIER TRANSFORM
CALL FOUR1T(Z, N, TBL, 1)
DO 40 K = 1, N21
CR 40 PAV(K) = PAV(K) + ABS(Z(K))

CONTINUE
DO 62 I = 1, 101

DO 62 PLOT(I) = BLAHK

IF (MODE .NE. 1) GO TO 72

WRITE(3,74) I SIZE

FORMAT(1H15, 15H PEAK HISTOGRAM )

CALCULATE MEAN, RMS FOR HISTOGRAM

SUMMRM = 0.
CNR0D = 0.
SUMSQ = 0.
MIN = 5000.
TMAX = 0.
DO 97 J = 0, IHI
XK = I
IF (IPR(I) .GT. 0) TIN = AHIXK(TMIN, XK)
IF (IPR(I) .GT. 0) TMAX = AMAX1(TMAX, XK)
X = IPR(I)
SUMMRM = SUMMRM + X
CNR0D = CNR0D + X
SUMSQ = SUMSQ + X**2
CONTINUE

RMS = SQRT(SUMSQ - CNR0D**2)

WRITE(3,98) CNR0D, RMS

FORMAT(3H CENTROID = ,FE.0, 7H RMS = ,FS50)

GO TO 102

SIGZ = DUR*150.XSQRT(ABS(SIG2))/160.*COS(ANG)

WRITE(3,96) SIGZP

FORMAT(15H SIGMA Z = ,F12.5)

IF(SIGZ.LT.RLTT) WRITE(3,95)

CONTINUE

DO 64 K = LO, IHI
IX = FLOAIPR(K)/SIZE*100. + 5
PLOT(IX) = PEE
WRITE(3, 75) K, IPR(K), PLOT

CONTINUE

GO TO 76

NOW PLOT PULSE AVG, SPECTRUM

XMAX = 0.
CNR0D = 0.
SUMMRM = 0.
DO 64 K = LO, IHI
CNR0D = CNR0D + PULSE(K)*FLOAT(K)
SUMMRM = SUMMRM + PULSE(K)
XMAX = AMAX1(XMAX, PULSE(K))
CNR0D = CNR0D/SUMMRM

ORIGINAL PAGE IS OF POOR QUALITY
0157 0BBER ICNTR=CNTROD+.5
0158 0BDOR WRITE(3,8) ISIZE
0159 0BF0R WRITE(3,65) ICNTR
0160 0C1OR 65 FORMAT(13H CENTROID = ,IS)
0161 0C2AR XNORM=100./XMAX
0162 0C3AR DO 16 K=1,N
0163 0C4AR IJ=LO+K-1
0164 0C4AR IX=PULSE(IJ)*XNORM+.5
0165 0C7OR PLOT(IX)=PEE
0166 0C8OR WRITE(3,61)IJ,PLOT
0167 0CAER 61 FORMAT(1H,13,101A1)
0168 0C0AR PLOT(IX)=BLANK
0169 0CD4R 16 Z(K)=CMPLX(PULSE(IJ)/SIZE,0.)
0170 0C1CR DO 60 K=H1,NTUP
0171 0C2CR Z(K)=CMPLX(0.,0.)
0172 0C3CR CALL FOURIT(Z,NTUP,TBL,1)
0173 0C4R C WRITE(2,200) (Z(K),KK=1,N)
0174 0D2ER 200 FORMAT(4E20.9)
0175 0D6ER WRITE(3,22) XLAB
0176 0D9OR 22 FORMAT(10H FREQUENCY ,4X,1HS,3X,5(F4.1,15X),F4.1)
0177 0DBER DO 18 K=1,NTUP21;
0178 0DC6R C PAV(K)=PAV(K)/SIZE
0179 0D2OR D=FLOAT(K-1)*DELTA
0180 0D2ER X=CABS(Z(K))/XN
0181 0E0SP X=ALOG10(X)
0182 0E1SR IX=20.KX+.5
0183 0E2SR IX=MIN0(MAX0(1,IX+1),101)
0184 0E4R C Y=ALOG10(PAV(K))
0185 0E5R C IV=20.KY+SIGN(.5,Y)
0186 0E6R C IV=MIN0(MAX0(1,IV+1),101)
0187 0E5SP C PLOT(I)=SLASH
0188 0E6SR DO 19 I=2,101
0189 0E6SR PLOT(I)=BLANK
0190 0E7CR IF(((I-1)/4)*4.EQ.I-1)PLOT(I)=DOT
0191 0EBER 19 CONTINUE
0192 0EBR C PLOT(IV)=AA
0193 0EC8R PLOT(IX)=ES
0194 0EDCR WRITE(3,20) D.X,PLOT
0195 0F0ER 20 FORMAT(1H ,F6.2,4X,F7.4,2X,101A1)
0196 0F2ER 18 CONTINUE
0197 0F4SR 76 WRITE(3,21)
0198 0F6SR 21 FORMAT(1H1)
0199 0F8SR 9 CONTINUE
0200 0F6R C NOW GET NEXT INPUT
0201 0F74R GO TO 101
0202 0F78R END:

ORIGINAL PAGE IS OF POOR QUALITY
PULSE 4854R REAL VAR
XLAB 4F54R REAL VAR
PLOT 4F5CR REAL VAR
PAY 5100R REAL VAR
WIND 5500R REAL VAR
CMPLX 0000R EXT FUNC
PI 0008R REAL VAR
N 0000R INT2 VAR
NTUP 0000R INT2 VAR
LO 0019R INT2 VAR
HI 0012R INT2 VAR
DOT 0014R REAL VAR
STAR 0013R REAL VAR
BLANK 001CR REAL VAR
SLASH 002R REAL VAR
ES 002R REAL VAR
AAA 002CR REAL VAR
FOUR1T 0000R EXT FUNC
101 003ER LABEL
100 005ER LABEL
@H 0000R EXT FUNC
2 02E2R LABEL
MODE 5904R INT2 VAR
N2 5906R INT2 VAR
N21 590CR INT2 VAR
NTUP21 5912R INT2 VAR
N1 5914R INT2 VAR
XN 5916R REAL VAR
U 0000R EXT FUNC
XM 591AR REAL VAR
42 00ECR LABEL
I 591ER INT2 VAR
COS 0000R EXT FUNC
FLOAT 0000R EXT FUNC
23 0146R LABEL
K 5938R INT2 VAR
4 0194R LABEL
5 0104R LABEL
30 01E6R LABEL
31 02E4R LABEL
ANGLE 593AR REAL VAR
DUR 593ER REAL VAR
6 0252R LABEL
ANG 5942R REAL VAR
DELTA 594AR REAL VAR
1 02AOR LABEL
IFILE 5952R INT2 VAR
ITHRSH 5954R INT2 VAR
3 031CR LABEL
99 032CR LABEL
7 034CR LABEL

ORIGINAL PAGE IS OF POOR QUALITY
IBLKS  5956R INT2 VAR
ISIZE  5958R INT2 VAR
SIZE   595AR REAL VAR
3      03F2R LABEL
41     0422R LABEL
KOUNT  595ER INT2 VAR
9      0F62R LABEL
III    5964R INT2 VAR
10     0A7AR LABEL
15     04CAR LABEL
IL     5966R INT2 VAR
BKS    0000R EXT FUNC
ECKERM 0000R EXT FUNC
12     076AR LABEL
13     05B2R LABEL
MIN    5970R INT2 VAR
.I     0000R EXT FUNC
11     066ER LABEL
III    5976R INT2 VAR
IJ     597SR INT2 VAR
.MIN0  0000R EXT FUNC
14     0608R LABEL
X      5980R REAL VAR
XX     5984R REAL VAR
70     06F4R LABEL
40     0712R LABEL
CABS   0000R EXT FUNC
62     07B4R LABEL
74     07D2R LABEL
SUMNRM 5986R REAL VAR
CNTROD 5988R REAL VAR
SUMSQ  5990R REAL VAR
TMIN   5994R REAL VAR
TMAX   5998R REAL VAR
97     08CER LABEL
XX     59A0R REAL VAR
AMIN1  0000R EXT FUNC
AMAX1  0000R EXT FUNC
RMS    59A4R REAL VAR
SORT   0000R EXT FUNC
98     09A2R LABEL
102    0A52R LABEL
SIGZ   59A8R REAL VAR
.P     0000R EXT FUNC
SIGZP  59B0R REAL VAR
ABS    0000R EXT FUNC
96     09FER LABEL
95     0A42R LABEL
73     0B10R LABEL
IX     59C0R INT2 VAR
NRL DATA OF 1/74 BY SYSTEMS ANALYSIS 1/75
FILE 1 10.0 DEGREES 0.50 MICSEC
THRESHOLD = 512
BLOCK 1
64 AVG. SQUARED PULSES, LOG SPECTRUM
CENTROID = 89
APPENDIX E

NRL DATA OF 1/74 BY SYSTEMS ANALYSIS 1/75
FILE 1 : 10.0 DEGREES 0.50 MICSEC
THRESHOLD = 512
BLOCK 1
32 PEAK HISTOGRAM
CENTROID = 90. RMS = 26.