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**DEVELOPMENT OF A GROUND SIGNAL PROCESSOR FOR  
DIGITAL SYNTHETIC ARRAY RADAR DATA**

Final Report under Contract NAS9-16104

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## TABLE OF CONTENTS

	<u>Page</u>
LIST OF FIGURES	v
LIST OF TABLES	vii
I. INTRODUCTION	1
II. RADAR AND DIGITAL SAMPLING SYSTEM	3
A. Characteristics	3
B. Parameter Options Available	6
III. RECORDED DATA	11
A. Formatting and Track Assignment	11
B. Decoding and Reformatting Requirements	11
C. DRIE - Functions and Characteristics	13
IV. PROCESSING REQUIREMENTS	15
A. Physical Limitations on Parameter Selection	15
B. Processor Organization	16
C. Image Formation	21
D. Synthetic Array Coverage	26
IV. POSTPROCESSING AND DISPLAY	33
A. Display Parameter Options	33
B. Image Quality Considerations	34
1. Radar/DDRS Parameter Selection Options	34
2. Processing Options	34
C. Algorithm Details	35
REFERENCES	39
ATTACHMENTS	41

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## LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	APQ-102 Antenna Installation, RB-57 Aircraft	4
2	Instrumentation Pallet, RB-57	5
3	Data Recording and Display System	7
4	Digital Data Transformer	12
5	Ground Signal Processor	17
6	Functional Flow of Program GSP	27
7	Synthetic Array Coverage Geometry	29
8	Display Image Photographs, Processor Development	35
9	Display Image Photographs, Variation in Gray Shade Assignments	36

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LIST OF TABLES

<u>Table</u>		<u>Page</u>
I	System Selectable Parameters	10
II	Programs and Subroutines Included in the Ground Signal Processor	18
III	Variables and Constants Used by Program GSP	22

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## I. INTRODUCTION

The optically processed images from a SLAR are useful to investigators in the field of remote sensing to the degree that the wavelength and polarization response of terrain and water areas can be quantitatively determined. Since the radar video is recorded on photographic film with its inherent limitation in dynamic range, it is desirable to consider converting the video to digitally recorded data on magnetic tape, for subsequent correlation to radar maps and analysis of the resolution cell contents. The video data collected by the radar are thus preserved intact and the subsequent operations to recover the images may be closely controlled on a high speed digital computer and high resolution electronic display system with controllable dynamic range. The photographic processing, through an analog recording system and an analog optical film processor, suffers from the aforementioned limitation in film dynamic range (on the order of 23 dB) and correlation errors, which result in loss of precision in the photographic images produced. In addition to these errors, which may occur during the correlation process or film exposure, tight controls are required on film processing to generate a satisfactory photograph.

With properly digitized data, the precision of the operations can be controlled to the level represented by the digital equipment used in recovering the data, and the characteristics of the electronic display system used. Additionally, the data may be made available on magnetic tape records for analysis by users in the field of earth resources. Photographs of the display may be used qualitatively to identify areas of interest for detailed evaluation of magnetic tape data.

The NASA Lyndon B. Johnson Space Center (NASA/JSC) operates an APQ-102 modified SLAR radar on an RB-57 aircraft test bed, normally flying at about 60,000 ft, to simulate orbiting vehicle geometries and to

gather wide coverage camera data. The work described in this report involved the design, fabrication, and installation of a video sampling and recording system on board the aircraft, and the processor development to generate digital radar imagery. The work was performed by ARL:UT under contracts with NASA/JSC.

## II. RADAR AND DIGITAL SAMPLING SYSTEMS

The modified APQ-102 generates two pulse compressed video signals, one from a co-polarized antenna with nominal 3 dB beamwidth of  $1.3^\circ$ , and one from a cross-polarized antenna. The radar uses a linear frequency modulated pulse with 15 MHz bandwidth at an X-band operating wavelength of 3.125 cm. The compressed 3 dB pulse width is about 60 nsec. The radar prf is locked to the aircraft ground speed with a sample rate of two per foot. The transmitter can be switched to either the horizontally or vertically polarized antenna, both of which are gimbaled to provide motion compensation and to keep the boresite direction normal to the velocity vector at nadir angles of  $33^\circ$  or  $54^\circ$ . Figure 1 illustrates the antenna installation.

The digital data recording system (DDRS) was designed to digitize the raw (pulse compressed) video signals from the radar and various parameters from the radar operating environment, such as the inertial platform signals and aircraft operating parameters. These are necessary in reconstituting the radar video into synthetic aperture maps and, subsequently, in analyzing the recorded data.

The DDRS is installed in the instrumentation pallet which is carried in the center section of the RB-57 aircraft test bed. Figure 2 is a photograph of the electronics pallet which houses the APQ-102 photographic data recorder as well as the DDRS.

### A. Characteristics

The DDRS receives the analog video signals generated by the APQ-102 and normally used to modulate the two axes of two cathode ray tubes in the photographic recording system. Buffer amplifiers supply both horizontally and vertically polarized, synchronously detected, and range pulse compressed signals to the DDRS. The operator can adjust the gain of these signals to the DDRS and the photo recorder. In addition,



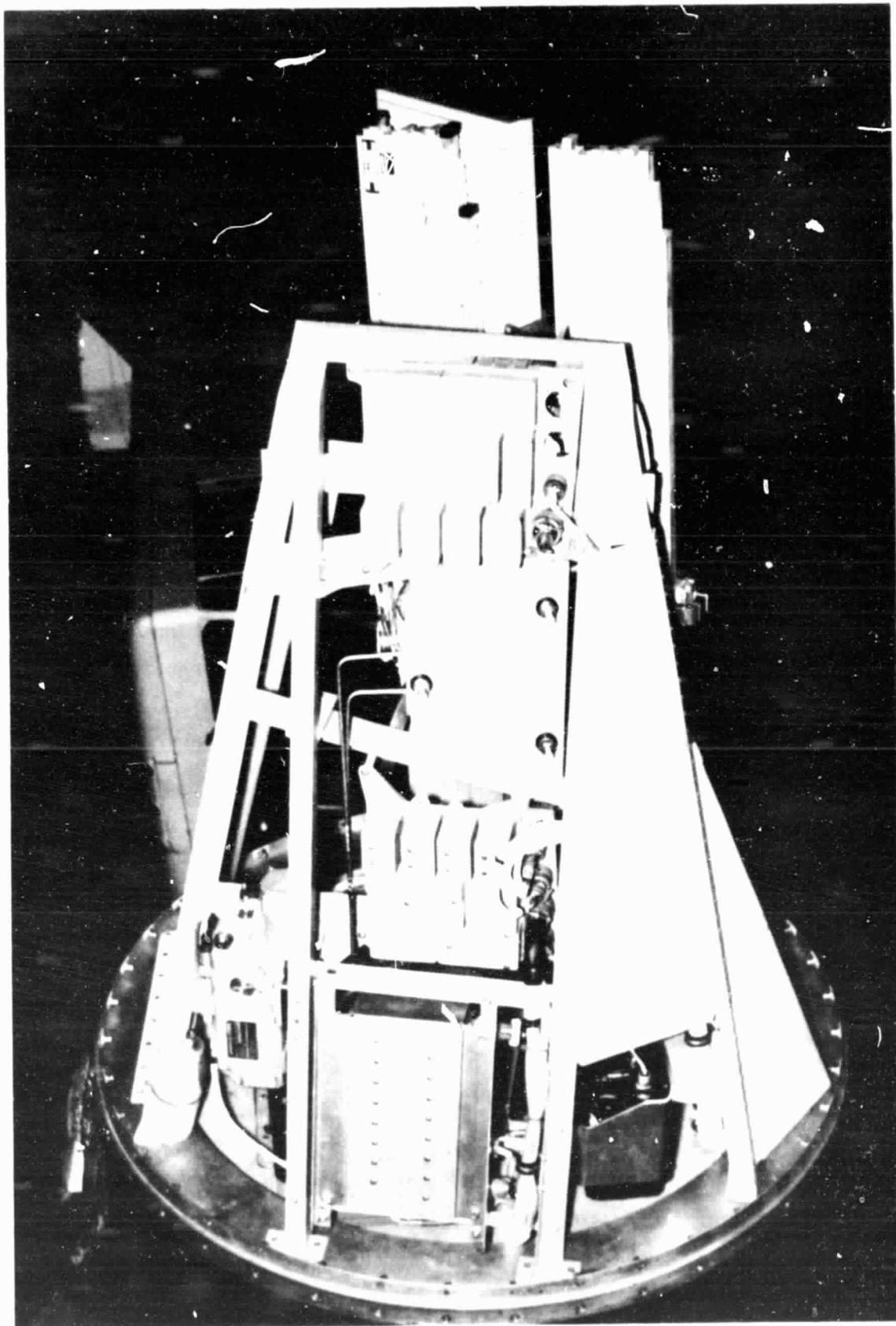


FIGURE 1  
APO-102 ANTENNA INSTALLATION RB-47 AIRCRAFT

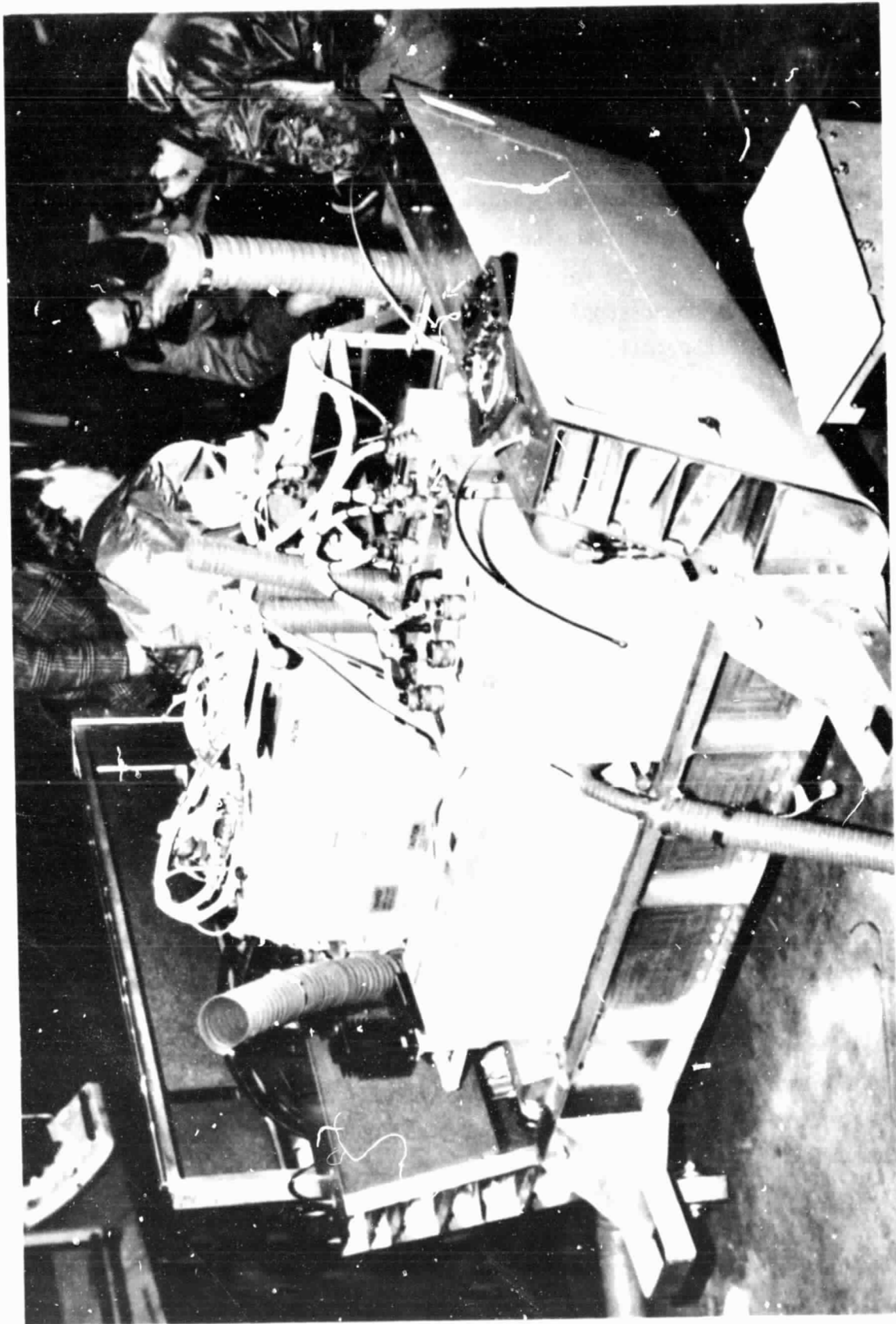


FIGURE 2  
INSTRUMENTATION PALLET

the operator can select the radar mode, which essentially selects the depression angle of the antenna system (or the nadir angle) to change the swath of terrain imaged for a nominal operating altitude of 55,000 to 60,000 ft MSL. The system also digitizes and records various operating parameters of the radar and its platform, the power supply status for various power supply voltages, and operating environment temperatures. This permits evaluation of the digitizing and recording subsystem in conjunction with each data gathering exercise.

The details of the DDRS subsystem and its interface with the APQ-102 radar are documented in ARL-TM-80-14,<sup>1</sup> an operating and maintenance manual produced under NASA Contract NAS9-15217. Figure 3 illustrates the relationships among the various components.

#### B. Parameter Options Available

The principal option available to the system operator is the sampling rate of the DDRS which permits selection of sampling intervals by the high speed analog-to-digital (A/D) converters of 40-150 nsec in 10 nsec steps. The system operation at the 40 nsec interval is critical and requires careful setup of the timing pulses for satisfactory performance. Coupled with the selection of sampling rate is the precision of the data recorded, i.e., 1-, 2-, 4-, or 7-bit levels of digital data for each sample, which may also be selected by the operator. Certain combinations of mode (there are two modes or operating geometries), sample interval (SI), and data precision (DP) are invalid and are so identified in the recorded data. Finally, the start of sampling is set by the delay selected, 2-99  $\mu$ sec.

The prf of the radar system is determined by the ground speed, so that two pulses per foot of travel along its velocity vector are generated by the radar. This parameter is not adjustable, nor is the range resolution, which is set by the analog pulse compression system

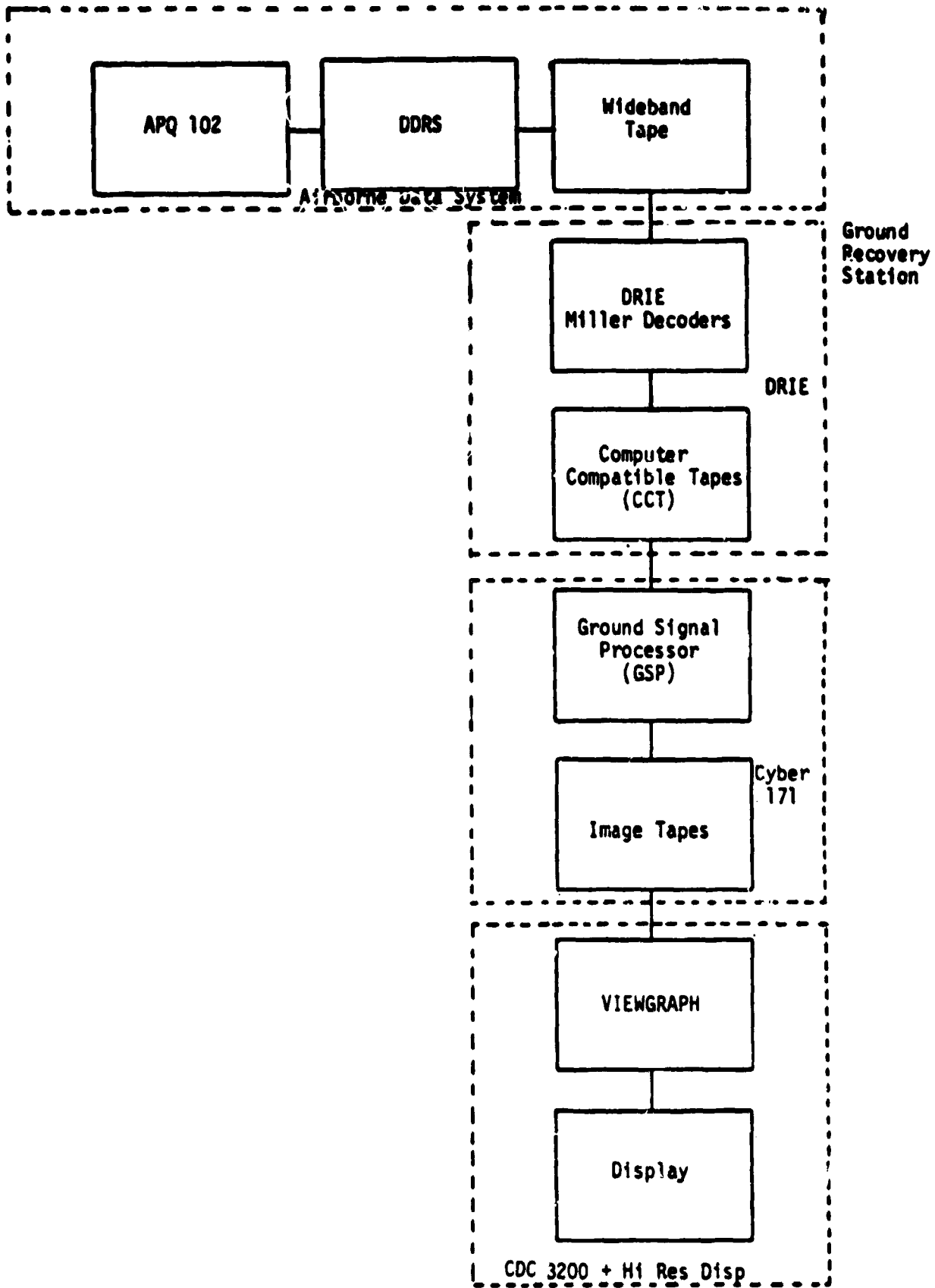


FIGURE 3

of the APQ-102. It has a time bandwidth product of  $(1.2 \mu\text{sec})(15 \text{ MHz})$ , or a compression ratio of 18:1, with a compressed pulse width of about 60 nsec or 30 ft in slant range. The DDRS can thus oversample at the 40 and 50 nsec SI selections, or undersample at the higher rates with respect to the nominal 3 dB range resolution of the radar.

The azimuth resolution of a sidelooking SAR is limited theoretically to half the antenna dimension for the focused processing situation; for the APQ-102 it is the antenna azimuth plane dimension of 120 cm/2, or 60 cm, roughly 2 ft.

Practically speaking, the resolution in azimuth is limited to about 30 ft by errors introduced in motion compensation of the video. The antenna is designed to minimize Doppler ambiguities, i.e., act as a spatial filter to eliminate echoes from scatterers with modulo  $2\pi$  radian phase shifts identical to phase shifts from other (different) scatterers in the main beam. This real beamwidth, coupled with the prf, determines the number of time samples that can be obtained from any given scatterer for processing in a synthetic aperture. The real beamwidth therefore sets the maximum length of a synthetic aperture and the resolution or main lobe width of the synthetic aperture.

The main lobe width of the APQ-102 in azimuth is a nominal  $1.3^\circ$  (22.7 mrad) at the 3 dB points. At the nominal slant ranges for operation in modes 1 and 2 at the center of an imaged swath, the alongtrack ground coverages are 1710 and 2478 ft, respectively, so at 2 samples/ft, a large number can be processed. To keep the sample grid spacing approximately the same in azimuth and range, a much smaller number of pulses should be processed in a synthetic array. The choice of array length will determine the need for applying a quadratic phase correction or focus correction to the recorded data prior to processing the synthetic array.

An additional option for the processor is the selection of a weighting function, or window, to optimize the tradeoff between width of the main lobe in the Doppler spectrum and the suppression of sidelobes. The processor developed by ARL:UT provides either Taylor, cosine<sup>2</sup> on a pedestal (Hamming), or Hanning weights for the pulses in the arrays. Other weighting routines, such as Kaiser, Chebyshev, etc., may be employed by providing the additional algorithms to the software.

Finally, the choice of display parameters must be made in the postprocessor, based on the statistics of the image calculated by the program from the overlaid outputs of the Doppler filters or pixel values. The operator must also choose the threshold of the displayed data, dynamic range, and logarithmic or linear data options, as well as the size of the displayed coverage. The latter is fixed in the ARL:UT processor at 360 azimuth lines by 384 range sample intervals.

In essence, therefore, one set of parameters is chosen at the equipment, and another set in processing the raw data. Table I provides a breakdown of these choices.

TABLE I  
SYSTEM SELECTABLE PARAMETERS

Operator Selectable Parameters

<u>DDRS</u>	<u>Radar</u>
DRMIN - Delay time to start of sampling	Mode (1 or 2)
SI - Sampling interval for A/D	Gain (H or V video)
DP - Data Precision (1,2,4,7 bit)	Transmitted Polarization

Note: The DDRS design incorporates logic to flag incompatible or invalid combinations of the above parameters. Valid settings are listed in Table C-1 of ARL-TM-80-14 for various combinations of mode, delay, SI, and DP. Nevertheless, data can still be recorded, despite invalid control settings.

Processor Selectable Parameters

Co-polarized or Cross-polarized Data

Area to be Imaged: Starting Range Sample + 384 Range Bins

Starting Frame Number + 360 Azimuth Elements

Azimuth Resolution - Fixed by the Software to be the Same as  
Range Resolution at the Map Center

Array Weighting and Beam Broadening Factor

Range Bin Used as the Map Center

Range Bin Used as the First Range Bin on the Image

Postprocessor/Display Parameters

Log or Linear Data

dB/Gray Shade or Number of Filter Magnitudes/Gray Shade Assignment

Brightness, Contrast Settings

### III. RECORDED DATA

The DDRS was designed to record the digital data, video, and radar parameters on a 14-track wideband tape recorder in Miller code. The format was designed to be compatible with the DRIE equipment used at ARL:UT.

#### A. Formatting and Track Assignments

Details of the data formats and the track assignments on the Mincom (in-flight) tape recorder may be found in ARL-TM-80-14.<sup>1</sup> Unfortunately, the track assignment utilized by the NASA/JSC contractor does not agree with that prescribed, requiring some cabling adjustments in the ARL:UT playback equipment for compatibility with the reformatting hardware.

#### B. Decoding and Reformatting Requirements

The video data and the radar parameter environment (RPE) data are recorded on the wideband tape after being Miller encoded. The Miller code has certain advantages over the NRZ (non-return-to-zero) code in recording efficiency and S/N ratio. Miller decoders are required for the 8 tracks of video (4 horizontal and 4 vertical polarization) and 1 track of RPE data. So-called NERDAS (NASA Earth Resources Data Acquisition System) data and time codes are recorded directly in NRZ code. The digital video and RPE data, after decoding, are processed through the DRIE to an IBM computer-compatible format and rerecorded on a Hewlett-Packard 7970B tape drive unit. Figure 4 illustrates the process. The DRIE reformats the data as described in the technical report ARL-TR-76-42.<sup>2</sup> The wideband tape formats are described in the technical manual ARL-TM-80-14.<sup>1</sup>



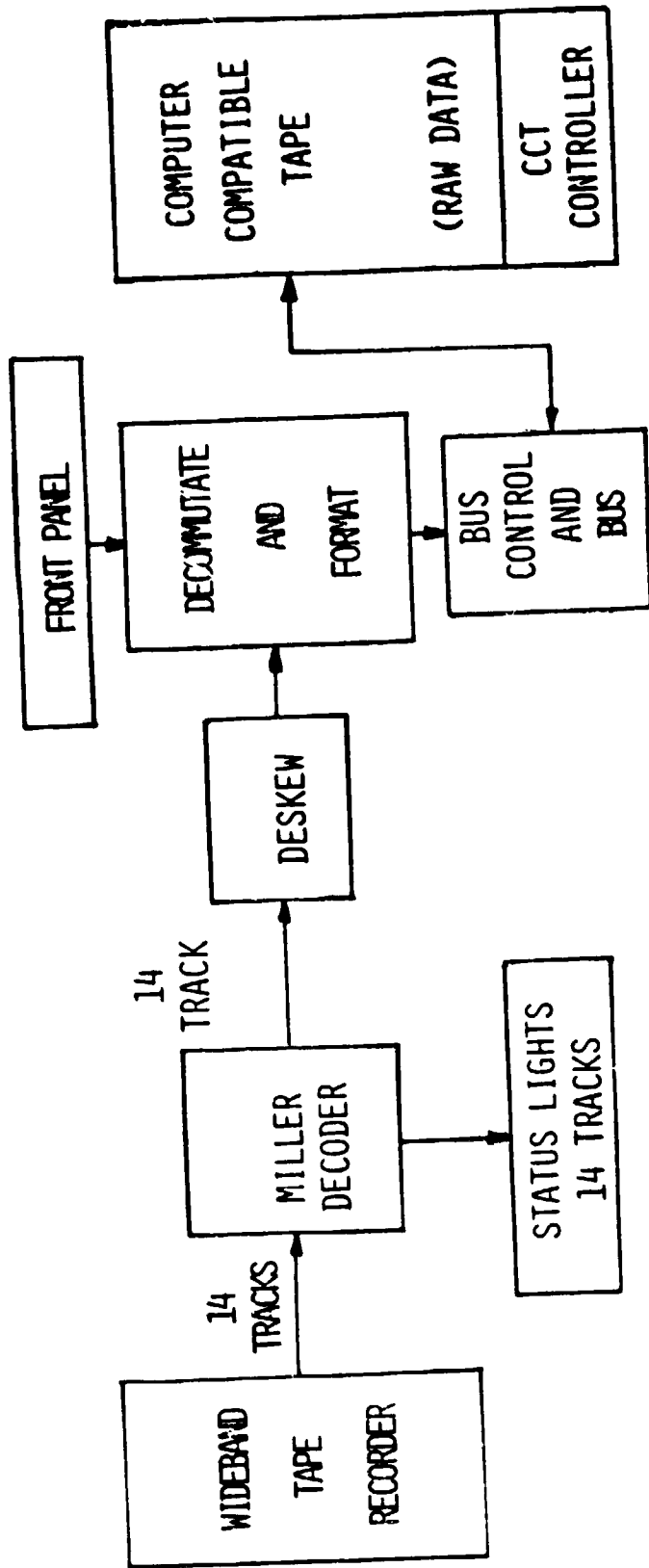


FIGURE 4  
DIGITAL DATA TRANSFORMER

### C. DRIE - Functions and Characteristics

The DRIE equipment was designed for the FLAMR radar system, and hence its application to the APQ-102/DDRS is not very efficient. It duplicates a realtime airborne processor, and the function of converting the data, illustrated in Fig. 4, is not implemented adequately for this purpose. Depending on the bit precision of the data recorded, a maximum of 128 range bin samples may be reduced at one pass through the selected frame numbers (FN) on the wideband tape. This is true for the 4-, 2-, and 1-bit data. With 7-bit data, however, only 16 range samples can be processed at a time; consequently, 24 passes are required through the wideband tape records to convert 384 range samples of data. Usually, 8-12 9-track, 800 bpi computer tapes are required for a full image set of raw data.

The DRIE contains bit parity error detecting circuitry which permits monitoring the source and rate of bit error generation, a feature of considerable value in evaluating the performance of the DDRS and wideband tape recording equipment. It also indicates error sources in the re-encoding process, such as the Hewlett-Packard tape drive buffer memory and tape recorder operation. Various addresses for the RPE data may also be displayed, with their bit contents, to evaluate the data as decoded from the instrumentation (wideband) tape.

#### IV. PROCESSING REQUIREMENTS

The video data are recorded in continuous strips. The range swath beginning and width are determined by the DRMIN variable (the selected delay following the STC trigger in the APQ-102), the sampling interval, bit precision, and mode (see Performance Specifications, pp. 20-21, ARL-TM-80-14<sup>1</sup>). The range coverage is thus determined by the number of samples to be displayed and the sample interval. Likewise, the displayed azimuth coverage is determined by the Doppler filter separation or spatial frequency corresponding to spectral frequency, and the number of unique filters, after overlay. The ground signal processor (GSP), in its delivered configuration, makes the azimuth interval equal the range interval at the center of the image.

##### A. Physical Limitation on Parameter Selection

The GSP options are limited by the previously selected values of the DDRS and APQ-102 parameters, and by certain design parameters of the radar system. The most important of the latter is the fixed relationship between the platform ground speed and the radar prf of 2 pulses/ft, which sets the maximum synthetic beamwidth of the system and the fixed slant range resolution capability of the radar (about 30 ft). Sampling in range can be varied from a 1.5 oversampling ratio at the 40 nsec rate to 0.4 undersampling at the 150 nsec rate. Once the DDRS parameters are set by the airborne operator, the GSP characteristics are fixed, except those that determine the azimuth resolution and at the same time, the sampling ratio, since the sampling rate is fixed by the platform velocity. Second, the GSP operator must select the portion of the sampled radar data to be processed, depending on the number of display elements available.

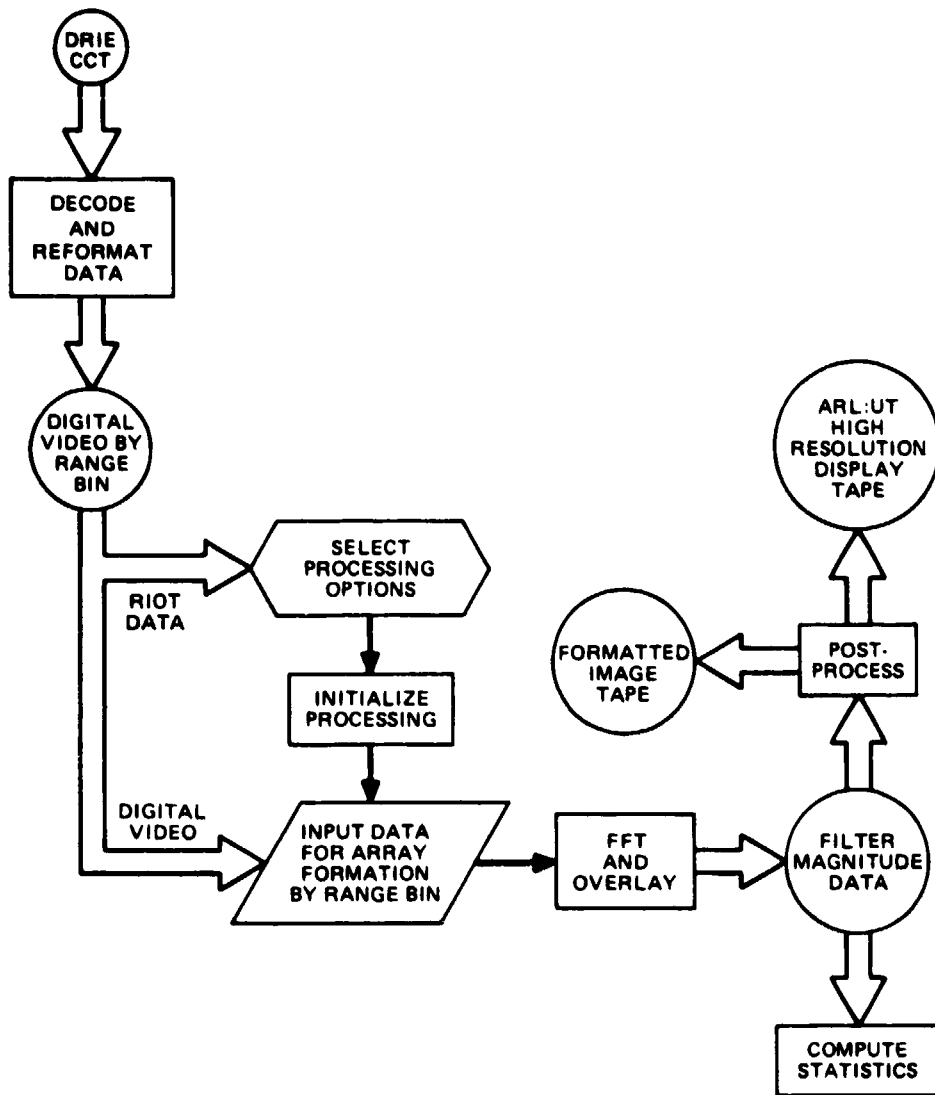
The smallest number of range samples recorded (at 7-bit precision) is 512, and this is larger than, for example, the number of display elements (pixels) on the ARL:UT High Resolution Display System. The number of azimuth elements is usually of the same order as the range elements on most CRT displays. Thus, the displayed area should be small enough to accept (digitally) a legend containing a description of the scene, its dimensions, and data concerning the flight parameters.

Finally, the GSP operator must select the postprocessing display parameters such as the dynamic range represented, number of bits, intensity resolution, etc. This selection can be made after examining the statistics of the linear data for the radar image, i.e., the mean, standard deviation, and maximum and minimum values generated after array processing and overlaying. The characteristics of a display will determine this selection, i.e., number of gray shades, availability of color, etc. The ARL:UT display is limited to 16 gray shades, and the dynamic range is determined by the assignment of dB/gray shade. Usually, 2 dB/gray shade is used, with a dynamic range of 32 dB.

#### B. Processor Organization

Figure 5 is a flow diagram of the processor, which is organized into a Doppler processor and a postprocessor. Table II lists the routines included in the GSP.

The first step is to reformat the DRIE data records. Program REFORMP reads the DRIE records, decodes them, and then outputs them to a scratch disk file. REFORMP also has the option of checking the DRIE records for errors; each DRIE record contains parameters which alert the operator to possible errors in the radar, DDRS, and DRIE hardware and its tape output unit. The first file generated by REFORMP contains recorded radar parameters. The rest of the generated files contain



**FIGURE 5  
GROUND SIGNAL PROCESSOR**

TABLE II  
PROGRAMS AND SUBROUTINES INCLUDED IN THE GROUND SIGNAL PROCESSOR

GSP	Main program, performs Doppler processing and filter overlay
REFORMP	Program, decodes DRIE records and formats them into range bin records
REFORMD	Program, uses output of REFORMP and creates files of samples by range bin
RDECOD	Subroutine used by REFORMP to decode the RIOT parameters from DRIE formatted records
RSCALE	Subroutine used by REFORMP to interpret the decoded RIOT parameters from part of the output of RDECOD
HVDECOD	Subroutine which recovers the video data samples from DRIE formatted records
IBCDTD	Function, converts BCD to binary format, used by RSCALE
APWT	Subroutine used to calculate an array of weights for different aperture weighting functions
TAYLOR	Subroutine used by APWT to calculate an array of weighting coefficients for the Taylor weighting function
PULSES	Subroutine, it skips and recovers video pulses from the input data file into an array for use by GSP
LIGHTF	Function which checks the status of pseudo-sense switches set by the operator before program execution
LUNPOS	Subroutine that positions data files
FFTCC	Subroutine, computes fast Fourier transform of a complex sequence; from the International Mathematical and Statistical Library
MAPSTAT	Program which reads all or part of GSP output files of filter magnitude values and compiles statistics on the data
DSTATR	Subroutine which compiles and computes statistics, used by MAPSTAT
PIMAGE	Program, performs the postprocessing on filter magnitude data in files generated by GSP, then outputs the data in records formatted for input to the ARL:UT high resolution display software
DRTA	Subroutine, reformats azimuth lines of 384 range samples into records compatible with the ARL:UT high resolution display software, used by PIMAGE

1024-word records of sampled video data at different range bins. Program REFORMD is run next to reorganize the records into files containing the sampled video at individual range bins. At the start of the reformatting process, the operator must choose to decode either the co-polarized or the cross-polarized data.

The output file from REFORMD is used as input to the main program, GSP. GSP requires the operator to select parameters such as the aperture weighting function, shading factor and, in particular, the range bin of the map center, an important parameter in the processor algorithms.

Certain default values are provided in the programs. For example, the Taylor aperture weighting function with 30 dB peak sidelobes is the default for the window function, and 1.27 (BBF) is the 3 dB width of the resulting Doppler filters. If a different weighting function is chosen, the BBF must be calculated or obtained, and entered into the program as a change.

The selection of synthetic array length is governed by the range sampling interval originally selected and the operating mode and patch center, which determine the nadir angle to the patch center. Referring to the GSP program listing, the Doppler spectrum line spacing is set equal to the projection of the slant range sample spacing on the horizontal or image plane. This is fixed in the software, but could be changed by making FILTSPC equal any arbitrary spacing.

In using digital SAR data to provide radar images for remote sensing applications, achieving maximum resolution in azimuth was not considered important. In addition, by keeping the array length shorter, focusing requirements are less stringent, although focusing (quadratic phase) corrections are included.

Following establishment of the window weights, the focus weights are obtained and placed in a complex array FOC. The correction to the  $i$ th pulse in the array is

$$DPHI = \frac{4 * PI}{WL} \left( \sqrt{RANGE^2 + D^2} - RANGE \right) ,$$

where  $D$  is the distance from the  $i$ th pulse to the center pulse in the synthetic array. The phase angles are converted to in-phase and quadrature components and combined with the aperture weights.

Since the ground coverage of the synthetic arrays is a function of range, the corresponding filters from arrays at different range bins may not represent the same azimuth components. To maintain the integrity of the image, the difference in the azimuth coverage at the current range bin versus the coverage at an initial reference range bin is computed. This reference range bin is input as parameter IRBFMAP. If processing is to begin with range bin one, then IRBFMAP=1. The azimuth component represented by the first filter from the first available synthetic array of range bin IRBFMAP is then the azimuth coordinate of the start of the map. To have the first filter of following range bins represent the same azimuth coordinate, the difference in the coverage is converted into pulses and these pulses (data samples) are skipped before Doppler processing begins.

Subroutine PULSES skips data samples in a file and recovers data into array VIDATA. The data for one array are then weighted with the proper weight from array FOC and placed in a complex array HV. The array is processed by a complex FFT and the resultant filters are obtained by summing the square of the real and imaginary components out of the FFT. The corresponding filters from consecutive arrays are summed (overlaid), and the number of overlays at each azimuth coordinate is kept in array RNORM so that the filters may be normalized for the number of summations they contain.



### C. Image Formation

Referring to Attachment I for the algorithms, Attachment II for numerical values associated with the images shown in Section V, Table III for a list of GSP variables, and Fig. 6 for the flowchart,

$$\text{RESR} = \frac{\text{CL} * \text{SISR}}{2 * \text{SIN}(\text{XNAPC})} = \frac{(0.2998 \times 10^9)(1.006 \times 10^{-7})}{2 \sin(0.70973 \frac{180}{\pi})}$$

RESR = 23.14 m and FILTSPC is set to this value.

Each input file into GSP contains the samples from one range bin. The coverage and filter spacing of the synthetic arrays are a function of range. Based on a desired filter spacing on the ground of FILTSPC, the size of the synthetic arrays is calculated,

$$\text{NP (at range R)} = \frac{\text{WL} * \text{R}}{\text{FILTSPC}} + 1$$

Since NP is an integer, the filter spacing out of the synthetic arrays is actually given by FILTSP,

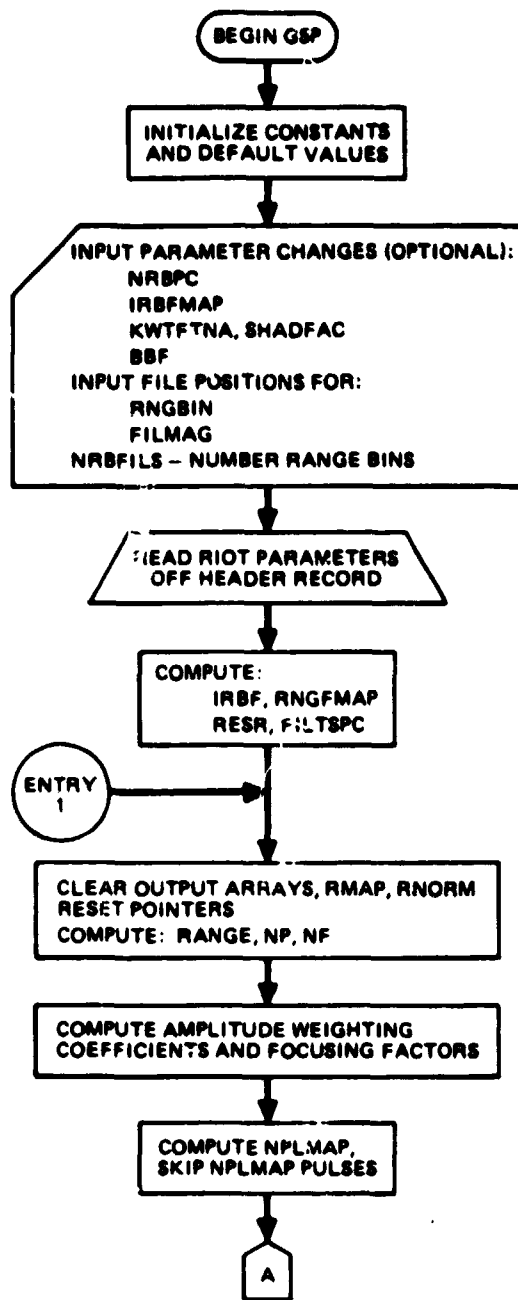
$$\text{FILTSP} = \frac{\text{WL} * \text{R}}{\text{NP} - 1}$$

This number is calculated and printed for reference; however, for the parameters encountered in this system, FILTSP and FILTSPC are nearly equal and FILTSPC is assumed to be the filter spacing.

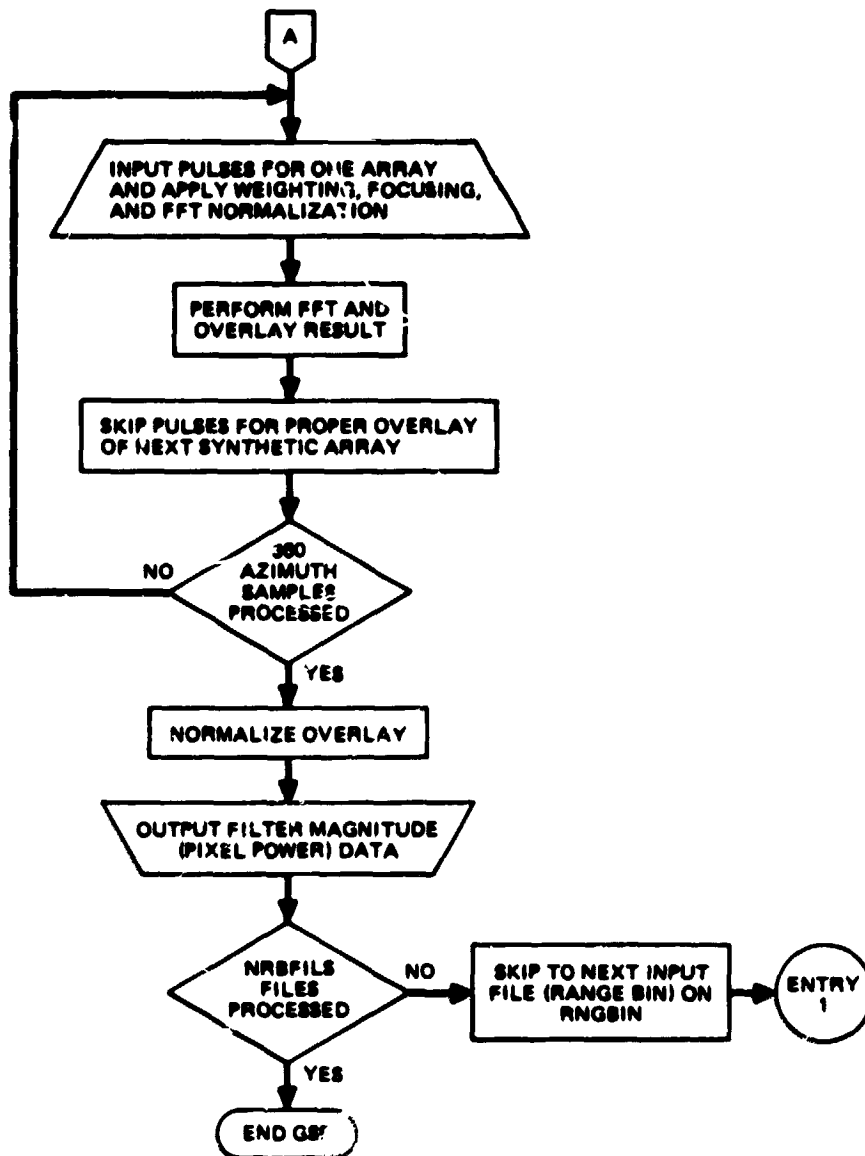
The 3 dB resolution of the synthetic filters is also calculated and given for reference,

$$\text{RESA} = \frac{0.4429 * \text{BBF} * \text{WL} * \text{RAIIGE}}{(\text{NP}-1) * 0.5 \text{ ft}}$$

Next, the pulse weights for the input aperture weighting function are calculated in APWT.



**FIGURE 6**  
**FUNCTIONAL FLOW OF PROGRAM GSP**



**FIGURE 6 (Cont'd)  
FUNCTIONAL FLOW OF PROGRAM GSP**

TABLE III  
 VARIABLES AND CONSTANTS USED BY PROGRAM GSP

PI	The value of $\pi$
TPI	Twice the value of $\pi$
PIH	Half the value of $\pi$
RTD	Degrees/radian, conversion factor
DTR	Radians/degree, conversion factor
FPM	Feet/meter, conversion factor
CL	Velocity of light, 2.997925E8
WL	Operating wavelength of radar, 0.031228 m
BBF	Beam broadening factor, default=1.27
KWTFTNA	Name of weighting function in H format, default="TAYLOR"
SHADFAC	Scale factor for the weighting function; for Taylor weighting, it is the peak sidelobe ratio (in dB), default=30
NRBPC	Number of range bins to be used as the map center, default=1/2 of the number of range samples per pulse taken by the DDRS
IRBFMAP	Number of range bins to be used to set the azimuth coordinate of the start of the image, default=range bin of the first file processed
DRMIN	Delay (sec) from the STC trigger to the start of sampling by the DDRS
SISR	Slant range sample interval of DDRS
NBIT	Bit precision of the sampled video data
NRB	Number of digitized samples or range bins, per pulse
RMIN	Slant range distance (m) from the radar to start of DDRS sampling
RPC	Range to the map center, m
XNAPC	Nadir angle to the map center
IRBF	Range bin of first data file processed

TABLE III (Cont'd)  
 VARIABLES AND CONSTANTS USED BY PROGRAM GSP

RNGFMAP	Slant range distance, m, from radar to the range bin IRBFMAP
RESR	Ground spacing, m, between range samples at the map center
FILTSPC	Desired spacing (ft) of output azimuth filters
NPT	Counter to keep track of total number of pulses used during processing of each range bin file
IAZLINE	Counter pointing to the azimuth line with which the first filter out of the current array is overlaid
NRBPROC	Range bin currently being processed
RANGE	Slant range (m) to the range bin currently being processed
XNP	Number of pulses to process per array, real variable
NP	Round of XNP
NF	Number of filters recovered per synthetic array
FILTSP	Actual filter spacing (ft) of the current arrays
RESA	The 3 dB resolution of the Doppler filters of the current arrays
WT	Array containing the amplitude weight for each pulse in a synthetic array
GI	Inverse gain factor of the weighting array, from APWT
DPHI	Quadratic phase correction angle
FOC	Array containing the focusing corrections and amplitude weights for each pulse
NPLMAP	Number of pulses to skip on the current range bin file so the first filter out of the first synthetic array represents the azimuth coordinate of the left edge of the map
VIDATA	Array containing the video data samples of one synthetic array
HV	Complex array used for input and output to the FFT routine
IWK	Integer scratch array for FFTCC

TABLE III (Cont'd)  
VARIABLES AND CONSTANTS USED BY PROGRAM GSP

WK	Scratch array for FFTCC
RMAP	Array containing the processed overlaid filter magnitude values for a range bin
RNORM	Array containing the number of overlays at each azimuth line
DFLOWN	Distance (ft) the radar has moved since the start of azimuth processing
NPSKIP	Number of pulses to skip before forming the next synthetic array

Based on the principle of keeping the Doppler filters aligned from one array to the next, it is necessary to discard some of the pulse samples. The distance flown (in feet) is computed as equal to half the total number of pulses, NPT, reached at the last pulse of the last array processed, based on two pulses/ft. Next, the residual fraction of a filter spacing in azimuth is calculated by dividing DFLOWN by FILTSPC and discarding the integer part of the quotient. The fractional part, FLEFT, is subtracted from a filter spacing and the remainder is converted to an integer number of pulses to be skipped by doubling, adding 0.5, and truncating.

$$NPSKIP = 2(RESAEF - FLEFT) + 0.5$$

The next pulse (after skipping) becomes the first in the next array. Finally, the overlaid filter magnitude values in RMAP are normalized, using RNORM, the number of overlays. These data are buffered out onto tape or disc file.

The user must control the processing by interacting with the processor to provide various parameter or data selections.

The principal operations consist of the following.

1. Select the desired frame numbers (octal) to start and stop the map. The start FN is usually the first one on the file.
2. Indicate the tape number and select the file to be processed, which usually contains a strip of 16 or 32 range samples.
3. Select the polarization you wish to process.
4. Select the aperture weighting function and shading factor. Default is Taylor weighting, 30 dB PSLR.
5. Select patch (map) center range bin.
6. Select beam broadening factor. For Taylor 30 dB weighting, it is 1.27.  $\text{Cosine}^2$  and Hanning must be determined after establishing shading factor.

The main processor program GSP, listed in Table II, is supported by a number of subroutines and library functions. The most important ones are HVDECOD, which decodes the horizontal or vertically polarized video signals; RDECOD, which decodes and makes available necessary radar system operating parameters; and a complex Fourier transform routine FFTCC from International Mathematical and Statistical Library. Others include APWT, the calculation of synthetic aperture pulse weighting values; PULSES and RECOVERY, used in organizing and obtaining the data from tape and disc; and LIGHTF, a means for checking a pseudo-sense switch. Program MAPSTAT compiles statistics, i.e., minimum and maximum values, mean and standard deviation. MAPSTAT may be run on the entire map or any desired section. Figure 6 is a flow diagram of GSP.

#### D. Synthetic Array Coverage

Consider a digital time series of  $N_p$  samples of video data in a synthetic array. The sample rate is the PRF of the radar so that  $PRF/2$  is the highest recoverable frequency in the series and  $\Delta f = PRF/(N_p - 1)$  is the spacing between resultant filters of a Fourier transform performed on the series.

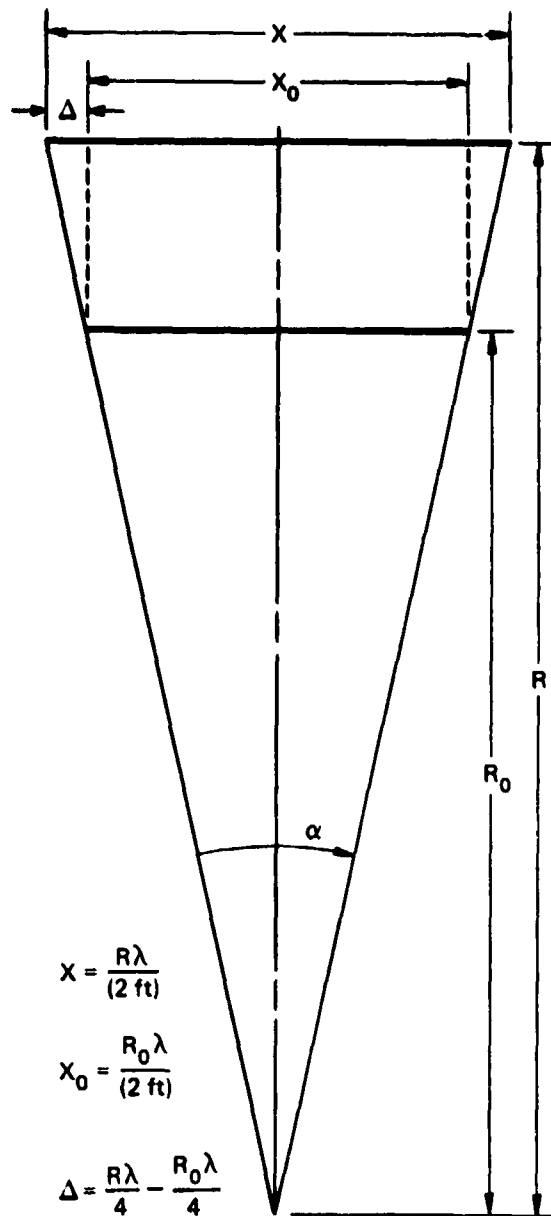
The two-way Doppler shift associated with a target is given by

$$\Delta f_d = \frac{2V_r}{\lambda} = \frac{2V \sin \theta}{\lambda} ,$$

where  $V_r$  is the radial velocity,  $\lambda$  is the operating wavelength of the radar, and  $\theta$  is the angle from the normal to the target. Figure 7 illustrates the geometry of the ground coverage of a synthetic array; for typical values of  $R$ , i.e., slant range from radar to ground,  $\alpha \approx 3^\circ$  so that  $\sin \alpha \approx \alpha \approx \chi/R$ . As stated above, the maximum recoverable frequency is  $PRF/2$  so that

$$\Delta f_d = \frac{PRF}{2} = \frac{2V \sin \alpha}{\lambda} = \frac{2V \chi}{R \lambda} .$$





**FIGURE 7**  
**SYNTHETIC ARRAY COVERAGE GEOMETRY**

Now, two pulses per foot are emitted by the radar, so  $PRF=2V$  if PRF is in hertz and V in ft/sec, and  $x=R\lambda/2$  if R,  $\lambda$  are in feet.

Thus the coverage for any synthetic array formed is a function of the range represented by the data samples of the array. The radar is mounted on the left side of the plane so the image is made from left to right as the synthetic arrays are formed. To start the coverage of the arrays at the same azimuth coordinate, the difference in coverage,  $\Delta$ , at R and  $R_0$  (RNGFMAP in program GSP) is computed. Then  $\Delta$  ft  $\times$  2 pulses/ft is the number of pulses to skip before processing the range bin at R.

The spacing between the resultant FFT filters,  $d_f$ , represented on the ground is

$$d_f = \frac{\lambda R}{(N_p - 1)} \quad , \quad R \text{ in ft} \quad .$$

Thus, once a value for the filter spacing is obtained (in GSP it is arbitrarily taken to be the spacing between range samples at the patch center), the number of pulses,  $N_p$ , necessary to obtain that spacing is fixed. In this way the spacing between azimuth filters remains the same at different ranges. Since  $N_p$  must be an integer, one can only get close to the desired spacing; however, with the parameters and geometry encountered in this system, actual spacings within 1% of the desired spacing are realized.

Finally, the 3 dB resolution of the formed synthetic beams (filters) is given by

$$\rho_a = \frac{0.4429\lambda K_a R}{(N_p - 1)0.5 \text{ ft/pulse}} \quad ,$$

where  $K_a$  is the beam broadening factor resulting from nonuniform weighting of the synthetic arrays. Note that  $\rho_a = 0.886 K_a d_f$ ; thus for Taylor weighting ( $K_a=1.27$ ) the 3 dB resolution of the synthetic beams is approximately  $1.12 d_f$ . The only variables which affect the accuracy of the calculation for filter spacing are  $\lambda$ ,  $R$ , and the accuracy of PRF versus ground speed, i.e., how accurate is the assumption of two pulses per foot emitted by the radar. Inaccurate determination of  $d_f$  results in improper overlay, which has the effect of degrading the azimuth resolution of the image.

## V. POSTPROCESSING AND DISPLAY

Attachment III is a listing of the short program which generates the image display tape. In generating the tape, the operator should refer to the (optional) printout of statistics of the filter magnitude values. This will provide insight to the gray shade resolution, noise threshold, and dynamic range of data to be displayed.

### A. Display Parameter Options

There are three display parameter options:

(1) Logarithmic or linear data. Logarithmic data are most representative since the human eye functions in a logarithmic manner, and dynamic range is compressed on the display.

(2) Gray shade level assignments. The gray shade resolution may be adjusted by selection of the levels per gray shade, DBGS assignment. A default value of 2 is provided in the software.

Note: Dynamic range is set by (2) above. The ARL:UT high resolution display has 16 gray shade levels, so DBGS x 15 is the dynamic range.

(3) Threshold. A noise cutoff threshold is set by the assignment of a selected level to the top gray shade (number 15 out of 0-15), and then subtracting the dynamic range.

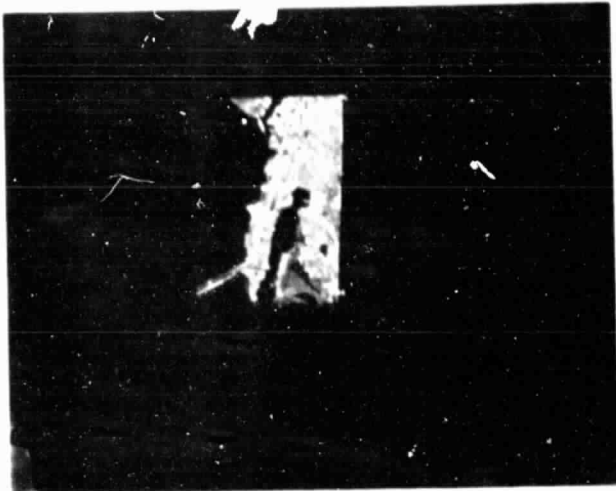
Once the data are displayed, the characteristics of the display itself must be considered. In particular, the brightness and contrast controls will affect the quality of the displayed radar image.

## B. Image Quality Considerations

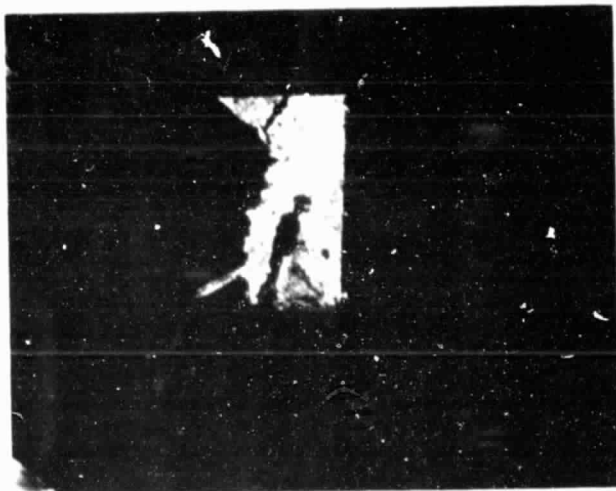
In providing maximum image quality, a most important consideration is resolution. In this case, the sampling rate of the DDRS sets the resolution of the image. Comparisons of digitally and photographically processed images reveal the effects of undersampling. Figures 8 and 9 illustrate the evolution of high quality digital imagery.

1. Radar/DDRS Parameter Selection Options - Selection of the longer SI (sampling intervals) on the DDRS increases the range swath recorded, but results in undersampling in both range and azimuth (although the latter could be changed in the GSP). The choice of bit precision also affects the quality of the image, since the lower bit precision values result in decreased data resolution compared with 7-bit data. Mode selection affects ground resolution versus slant range resolution, since in mode 2 the cosecant of the nadir angle is less than in mode 1.

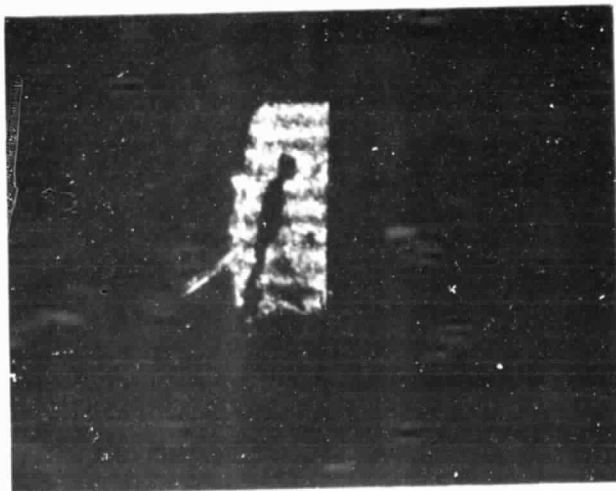
2. Processing Options - Since the factors above are set, once the data are recorded, only the selection of polarization channel to be processed and those factors discussed previously (such as the weighting function), can be adjusted. In particular, the display options in Section V.A become effective. Figures 8 and 9 illustrate, to some degree, variations in gray shade assignment, focusing of the data in a relatively short array, and overlaying of arrays. These variations affect the displayed image quality in varying degrees. Although the processor does not generate images with maximum azimuth resolution, the saving in processing time was considered the overriding factor. If maximum length arrays were processed, then the focus function would become very important, whereas improvement over the unfocused image for the relatively short arrays is almost indiscernible.



(c) 100% Overlay of Patches  
48 Arrays Processed  
6 Arrays in Map, 76 ft  
Azimuth Resolution

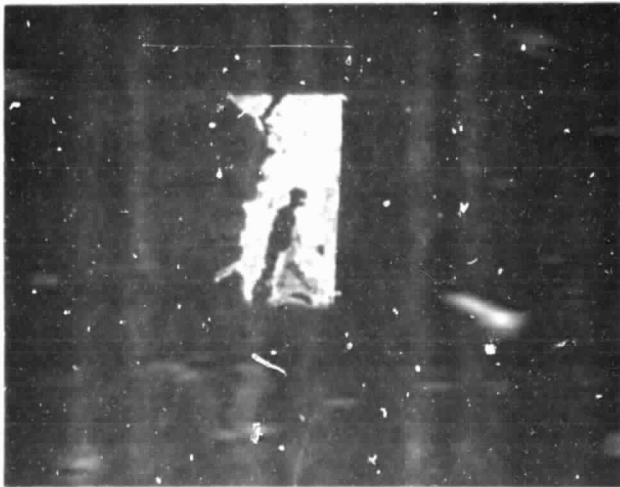


(b) 75% Overlay of Patches  
24 Arrays Processed  
6 Arrays in Map, 76 ft  
Azimuth Resolution

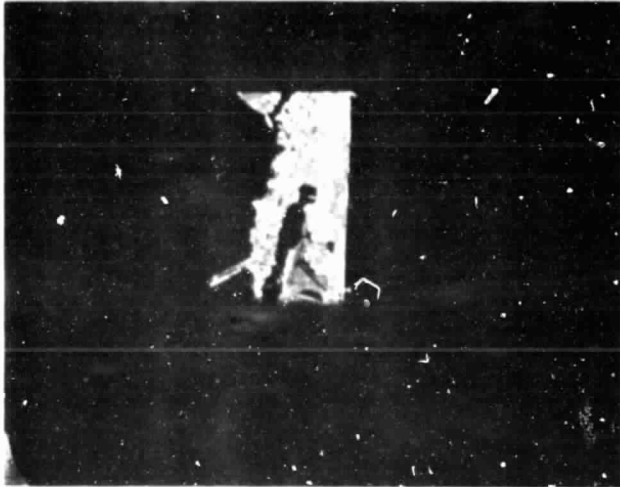


(a) 50% Overlay of Patches  
12 Arrays Processed  
6 Arrays in Map, 50 ft  
Azimuth Resolution

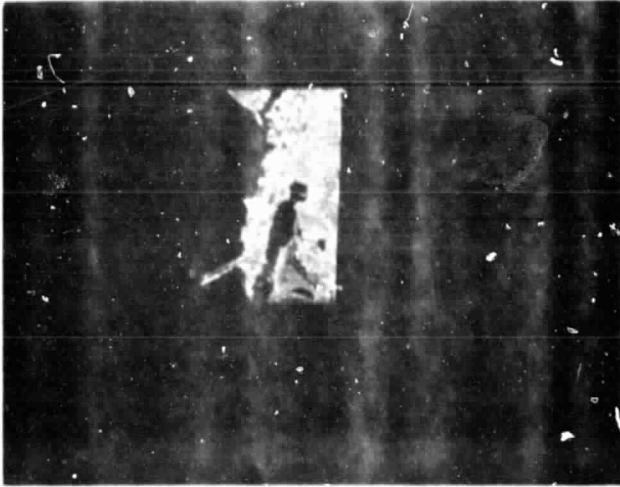
FIGURE 8  
DISPLAY IMAGE PHOTOGRAPHS, PROCESSOR DEVELOPMENT



(a) 1 1/2 dB/Gray Shade



(b) 2 dB/Gray Shade



(c) 2 1/2 dB/Gray Shade

### FIGURE 9

#### DISPLAY IMAGE PHOTOGRAPHS, VARIATION IN GRAY SHADE ASSIGNMENT

All images were processed with the GSP in its final form. Azimuth filter spacing is 76 ft with 85 ft azimuth resolution.

### C. Algorithm Details

Program PIMAGE is the postprocessing program which requires the inputs listed in Section V.A. After entry of DBGS and T15, (power level assigned to the top gray shade) a threshold is set, THOLD =  $10 \log(T15) - 16$  DBGS. Then an integer value from 0-15(IGS) is assigned to each pixel power level ( $P_i$ ) output from GSP,

$$IGS = (10 \log(P_i) - THOLD) / DBGS \quad .$$

If  $IGS < 0$ , then  $IGS = 0$ ; or if  $IGS > 15$ , then  $IGS = 15$ .

Next, subroutine DRTA is called to output the display values IGS in a format compatible with the ARL:UT high resolution display software. Following the same procedure, values could be assigned based on any number of gray shades and output in formats compatible with other displays.



ATTACHMENT I  
LISTING OF PROGRAM GSP

```

1 PROGRAM GSP (RNGBIN=0,INPUT,IMPUI,FILMAG=0)
C
C
C
5 ----- INITIALIZE -----
COMMON/CON/ PI,TPI,PI,MID,UM,CL
COMMON/HJOT/ I11,E,DATE,XLAT,ALONG,ALT,HOG,DRIFT,ROLL,PITCH,GSMU,
IVACC,XIPP,KFN,DRMIN,SISH,NB11,NRB,RMIN,RPC,XNAPC,MODE,IMV,AUX(16)
DIMENSION WT(512),WK(322),IWK(322),MNORM(J60),KATCH(Y)
1 RMAP(360),VUATA(1024)
C
10 COMPLEX FOC(512),MV(512)
EQUIVALENCE (WK(1),IWK(1))
C
C
15 C----- GROUND SIGNAL PROCESSOR. INPUT DATA (FROM FILE- RNGB(IN)
C----- IS FORMATTED BY RANGE BIN AND INPUT TO THE MAIN PROGRAM VIA
C----- SUBROUTINE- PULSES. THE FIRST FILE ON FILE RNGBIN, HOWEVER,
C----- CONTAINS RIOT DATA AND 'I' IS INPUT IN THE PROGRAM. AZIMUTH
C----- COVERAGE IS SET AT 360 LINES! RANGE COVERAGE IS VARIABLE UP TO
C----- THE EXTENT OF AVAILABLE DATA. BECAUSE OF STORAGE CONSIDERATIONS
C----- NPMAX IS THE MAXIMUM NUMBER OF PULSES THAT CAN BE PROCESSED
C----- IN ONE SYNTHETIC ARRAY.
C
20 NPMAX=512
CALL RECOVERY
PI=3.1415926535898
TPI=2.*PI
PIH=PI/2.
RTD=180./PI
DIR=1./RTD
CL=.2997925E+09
FPM=3.2808399
BBF=1.27288
WL=.031228
KWTFNA=#TAYLOR#
SHADFAC=#30.
NRPBC=0
IRBFMAP=#0
C
25
30
35

```

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40 C ----- KBRANCH -----

```

20 PRINT *, # INPUT NBRANCH#
   READ *, KBRANCH
   IF (EOF(5LINPUT),NE.0.0) STJP
   IF (KBRANCH.EQ.#CHGRBPC#) GO TO 70
   IF (KBRANCH.EQ.#CHGRBMP#) GO TO 80
   IF (KBRANCH.EQ.#CHGAPWT#) GO TO 100
   IF (KBRANCH.EQ.#CHGRBF#) GO TO 110
   IF (KBRANCH.EQ.#PHCESS#) GO TO 120
   GO TO 20

```

```

C ***** CHGRBPC - CHANGE RANGE BIN USED TO COMPUTE THE DISTANCE TO THE
C ***** PATCH CENTER TO BE PROCESSED. DEFAULT IS 0.
C ***** USE CENTER RANGE BIN OF THE ENTIRE SAMPLED PULSE IF
C ***** NRBPC=0 (IE. 256 FOR 7-BIT DATA, 512 FOR 4-BIT DATA,
C ***** 1024 FOR 2-BIT DATA, AND 2048 FOR 1-BIT)

```

```

70 CONTINUE
   PRINT *, # INPUT NRBPC#
   READ *, NRBPC
   PRINT *, #PATCH CENTER RANGE BIN CHANGED TO #NRBPC
   GO TO 20

```

```

C ***** CHGRBMP - CHANGE RANGE BIN USED FOR ALIGNMENT OF LEFT EDGE OF
C ***** MAP. DEFAULT IS VALUE OF FIRST RANGE BIN DESIGNATED
C ***** IN RIOT HEADER.

```

```

80 CONTINUE
   PRINT *,#INPUT IRBFMAP#
   READ *,IRBFMAP
   PRINT *,#FIRST RANGE BIN USED AS LEFT EDGE OF IMAGE - #,IRBFMAP
   GOTO 20

```

```

C ***** CHGAPWT - CHANGE APERTURE WEIGHT FUNCTION, DEFAULT IS TAYLOR
C ***** AT 30 DB.
C ***** KWIFINA= APERTURE WEIGHT FUNCTION (BCD), EITHER -
C ***** HANNING, LOSINE**2, OR TAYLOR.
C ***** SHADFAC= SHADING FACTOR -

```

```

C****
C****
C****
C****
C
80
      HANNING - PERCENT OF APERTURE WITH COSINE TAPEM
      COSINE=0.2 - VALUE OF ARGUMENT AT APERTURE END-
      POINT, DEGREES.
      TAYLUM - PEAK SIDELOBE RATIO (DB).

C 100 CONTINUE
      PRINT *, # INPUT KWITNA,SHAUFAC#
      READ *, KWITNA,SHADFAC
      PRINT *, #APERTURE SHADING CHANGED TO #,KWITNA,#, FACTOR #,SHAUFAC
      IC
      GO TO 20

C
C**** CHGBBF - CHANGE BEAM BROADENING FACTOR, DEFAULT IS 1.27.
C****
C
90
      BRF= BEAM BROADENING FACTOR.

C 110 CONTINUE
      PRINT *, # INPUT BRF#
      READ *, BRF
      PRINT *, #BEAM BROADENING FACTOR CHANGED TO #,BRF#
      GO TO 2

C
C**** PROCESS - PROCESS INPUT DOPPLER VIDEO INTO DISPLAY VIDEO.
C****
C****
C****
C****
C
100
      IFIL= INPUT FILE NO.
      IFILO= OUTPUT FILE NO.
      NRBFILES= NUMBER OF INPUT FILES (RANGE BINS) TO PROCESS

C 120 CONTINUE
      LUNI=6LRNGBIN
      LUNO=6LFLMAG
      PRINT *, # INPUT IFIL,IFILO, NRBFILES#
      READ *, IFIL,IFILO,NRBFILES
      PRINT *,#INPUT FILE, OUTPUT FILE, NUMBER FILES (RANGE BINS) TO
      IPROCESS #,IFIL,IFILO,NRBFILES
      CALL LUNPOS (LUNI,IFIL)
      CALL LUNPOS (LUNO,IFILO)

C
C ---- READ RIOT RECORD FROM FIRST FILE OF LUNI, -----
C
      BUFFER IN (LUNI,1) (ITIME,AUX(16))

```

```

120 IF (UNIT(LUNI))150,140,130
130 PRINT *,P.E. ON LUNI - HEADEN #
STOP #P.E. ON LUNI#
140 PRINT *,EOF ON LUNI - HEADEN #
STOP #EOF ON LUNI#
150 BUFFER IN (LUNI,1) (KATCH(1),KATCH(9))
IF (UNIT(LUNI)) 100,140,130
160 CONTINUE
C
C ---- INITIALIZE VARIABLES COMMON TO ALL RANGE BINS. -----
C
IF (NRBPC.NE.0) RVC=KMIN*NRBPC*SIGR*CL/2.
IF (NRBPC.NE.0) ANAPC=ACUS(ALI/FRM/MP)
IRBF=KATCH(7)
IF (NBIT.EQ.4) IRBF=IRBF*2
IF (NBIT.EQ.2) IRBF=IRBF*4
IF (NBIT.EQ.1) IRBF=IRBF*8
IF (IRBFMAP.EQ.0) IRBFMAP=IMBF
PRINT *,RANGE BIN=#,IRBFMAP,# USED TO LINE UP LEFT EDGE OF IMAGE#
PRINT, # #
RNGFMAP=RMIN+IMBFMAP*SIGR*CL/2.
RESR=CL*SIGR/2./SIN(ANAPC)
FILTSPC=RESR*FRM
C
C ---- PROCESS= NRBFILES RANGE BINS. -----
C
C DO 380 IRBFIL=1,NRBFILS
C
C ---- INITIALIZE VARIABLES FOR STAIR OF PHUCESSING OF ONE RANGE BIN.
CALL SKIPER(LUNI,1,0,9LIMBUFFER)
CALL SETO(RMAP(1),RMAP(360),0.)
CALL SET(RNORM(1),RNORM(360),0.)
MPT=0
IAZLINE=1
IFIRST=1
NRBPROC=IRBF*IMBFIL-1
RANGE=RMIN+NRBPHOL*SIGR*CL/2.

```

```

160 XNP=WL*FPM* RANGE*PM/FILISPC*1.0
    NP=XNP*.5
    NF=NP/2-1
    FILTSP=WL*FPM*HANGE*FPM/(NP-1)
    RESA=.4429*BF*WL*FPM*HANGE*FPM/(.5*(NP-1))
    CALL APWT (WT, NP, KWTPINA, SHAUPAC, UI)
    DO 260 IP=1, NP
260 WT(IP)=WT(IP)*UI/NP
    PRINT *, NBRPHUC, NP, RESA, FILISPC, FILISP, #, NBRPHUC, NP, RESA,
1    FILTSP, FILISP
    IF (NP.LE.NPMAX) GOTU 265
    PRINT *, #, NUMBER OF PULSES NECESSARY FOR SYNTHETIC ALWAYS GREATER
    I THAN NPMAX #
    STOP
265 CONTINUE
C
C**** COMPUTE ARRAY OF VALUES FOR FOCUSING THE SYNTHETIC ARRAYS.
C
    DO 270 J=1, NP
270 D=(ABS(FLOAT(J)-FLOAT(NP)/2.)*.5+.25)/FPM
    DPHI=.4*PI/WL*(SQRT(HANGE*HANGE*D*D)-RANGE)
    FOC(J)=CMPLX(COS(UPHI), -SIN(DPHI))
    FOC(J)=FOC(J)*WT(J)
    CONTINUE
C
C**** SKIP PULSES SO THAT THE START OF THE MAP COINCIDES WITH THE
C**** START OF THE MAP AT RANGE BIN - IMB*MAP.
C
    NPLMAP=WL*(HANGE*HANGE*MAP)/2.*FPM*FPM*.5
    CALL PULSES(LUNI,VIDATA,NPLMAP,0,IFIRST)
    IFIRST=0
C
C**** RECOVER NP PULSES.
C
280 CONTINUE
    CALL PULSES(LUNI,VIDATA,0,NP,y)
    NPT=NPT+NP
C
C**** APPLY FOCUSING AND WEIGHING, FOURIER PROCESS, OVERLAY.

```

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```

C
200 DO 310 IP=1,NP
      HV(IP)=VIDATA(IP)*FUC(IP)
      CALL FFTC(HV,MP,IMK,WK)
      JEND=IAZLINE*NP-1
      IF(JEND.GT.360)JEND=360
      K1=3
205 DO 330 J=IAZLINE,JEND
      RMAP(J)=(REAL(HV(K1)))**2.+(AIMAG(HV(K1)))**2.)*RMAP(J)
      K1=K1+1
      330 CONTINUE
C
210 DO 350 J=IAZLINE,JEND
      RNORM(J)=RNORM(J)*1
      350 CONTINUE
C
220 C***** DETERMINE VALUES FOR PROPER ARRAY POSITIONING AND FILTER OVERLAY.
      DFLOW=NPT*.5-.5
      IAZLINE=DFLOW/FILTSPC*1
      FLEFT=AMOD(DFLOW,FILTSPC)
      NPSKIP=(FILTSPC-FLEFT)*2.+.5
      IF (NPSKIP.LT.NP) IAZLINE=IAZLINE+1
      IF (NPSKIP.GE.NP) NPSKIP=0
      CALL PULSES(LUNI,VIDATA,NPSKIP*0.0)
      NPT=NPT+NPSKIP
      IF (IAZLINE.LT.360)GOTO 280
C
225 C***** NORMALIZE SUMS OF FILTER MAGNITUDES.
      DO 360 J=1,360
      RMAP(J)=RMAP(J)/RNORM(J)
      360 CONTINUE
C
230 C***** OUTPUT AMPLITUDE UATA.
      BUFFER OUT (LUNO,1) (RMAP(1),RMAP(360))
      IF (UNIT(LUNO).GT.0.) GOTO 390
      ENDFILE LUNO

```

PROGRAM GSP 73/171 OPT=1 FIN 4.8.528 81/05/27. 10.35.55

```
235 C 380 CONTINUE
      C
      C
240 C 390 PRINT *,#PARITY ERROR ON OUTPUT#
      C STOP
      C PRINT #P.E. ON LUNU#
      C END
```



ATTACHMENT II  
PRINTOUT OF DRIE DATA FOR GALVESTON ISLAND

~~Page 48~~ 48

ATTACHMENT II

```

INPUT KRBRANCH
INPUT NRMPC
PATCH CENTER RANGE BIN CHANGED TO 344
INPUT KRBRANCH
INPUT IFN,IFN
PROCESS FRAMES 144510 THRU 146400
INPUT KRBRANCH
INPUT IFILI,IFILO
INPUT HORIZONTAL VIDEO DATA READ FROM DRIE
OUTPUT IMAGE WRITTEN ON IMAGE * FILE 12
0000000000000000171 00000000000010610410 00000000000000000200 000000000000040200424 00000000000000000221 00.01
0000000000000000132 000000000000070112106 00000000000000000175 00000000000005402540 00000000000000000170 00001
0000000000000000125 00000000000001720043 00000000000000000130 00000000000002140005 00000000000000000127 00001
0000000000000000172 00000000000002352025 00000000000000000123 000000000000000415011 00000000000000000020 00001
0000000000000000177 000000000000077144507 00000000000000000101 00000000000007770007 00000000000000000102 00001
0000000000000000103 000000000000077777777 00000000000000000201 000000000000077772542 00000000000000000202 00001
0000000000000000203 000000000000077774227 00000000000000000204 000000000000077770265 00000000000000000205 00001
0000000000000000206 000000000000077774605 00000000000000000207 000000000000077774014 00000000000000000210 00001
0000000000000000211 000000000000077774030 00000000000000000212 000000000000077775731 00000000000000000213 00001
0000000000000000214 00000000000007777206 00000000000000000215 000000000000077771562 00000000000000000216 00001
0000000000000000217 000000000000077775777 00000000000000000220 000000000000077771562 00000000000000000217 00001
0000000000000000200 000000000000040200424 00000000000000000221 000000000000050510210 00000000000000000218 00001
0000000000000000175 00000000000005402540 00000000000000000170 000000000000010402431 00000000000000000219 00001
0000000000000000130 00000000000002160005 00000000000000000127 00000000000000000320010 00000000000000000172 00001
0000000000000000123 00000000000000415011 00000000000000000020 000000000000077772724 00000000000000000177 00001
0000000000000000101 000000000000077770007 00000000000000000102 000000000000055313777 00000000000000000103 00001
0000000000000000201 000000000000077772727 00000000000000000202 000000000000077774035 00000000000000000203 00001
0000000000000000207 000000000000077774021 00000000000000000205 000000000000077774322 00000000000000000204 00001
0000000000000000212 000000000000077775731 00000000000000000210 000000000000077771607 00000000000000000211 00001
0000000000000000215 000000000000077770000 00000000000000000213 000000000000077773777 00000000000000000214 00001
0000000000000000220 000000000000077770000 00000000000000000216 000000000000077772314 00000000000000000217 00001
KFN,TIME,DATE,LAT,LONG*** 51528 211108 810114 29088 -9446
ALT,HDG,CRFT,ROLL,PITCH*** 60560, 51.9 2.3 -.5 .A
GSPD,VACC,XTRP,DRMIN,SISR*** 415, 10.09 .00072054648 .00000193176 1.00613E-7
NRB,NRTI,MODE,RMIN,RPC*** 512 7 0 19146.5118299 24334.55175193
XNAPC,ICT***.7097293950706 1
TEMP1,TEMP2,TEMP3,TEMP4*** 23.3487382183 27.11888111888 -34.02432350258 28.85193067802
NV5,7,PV5,NV2,PV5,NV15*** -5.697669 5.044795 -2.161782 5.013036 -15.122538
PV10,ALT,AGCMAN,GAINSTC*** 10.005736 9.07946 0. 3.001232
PV15,PRES*** 15.026403 .323076
DRIE RECOVERY MODE --

```

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50

21 00 00

32 PULSES, 1A RANGE	RIMS PER RECORD, START	RANGE	RIN	320
2214400000040212000	07400032240201004132	02-00000776000007760	000077600007760000000	77400000776000027760
000077600000077601000	07400000776000007760	0000776000077600007760	000077600007760000000	000077600007760000000
77600000776000007760	0000776000007760000000	0000776000007760000000	774000077600000000000	774000077600000000000
42252517501226602740	074024467360402412220	76203450126150312037	77044435761045550131	17260047000410305270
13100467406756032174	5447720123370703206	3712335074517106273	64501611644435442323	75174401710056243500
17444722402402030321	37602145001432314237	0603535064965200000	0000000000000000000	00000000033333757171
02010443400120014031	06104412113221512340	37260005054740310122	15251072000726002740	02053410500125720535
20112464442000810321	75377577217447742020	376077641371745732503	437777774026133657770	10247617760345774377
4132760770772767617	76064137477416006370	777041477477776110617	43774255477377705777	75777614415273774320
036077077775177617	77775774407136377674	44100422060005000601	44304220504551064516	01753000246736014405
1065243500025300134	00102560424005275025	65004523022150020415	23657767751062376101	01770377205776275524
1777777760165772777	40416770777016317617	76045757037741351370	77703111763776070437	43774210376377704404
7617761266357774277	7767770620377577615	00170377435863647770	77777677762036571777	36204021103000240030
06214211024226443224	70076540012131700420	24432522164001254005	70004127021200253641	27240225141106401020
6452777376437117704	04077417750277713665	2077777777006247537	76020517437740736370	77705330767776137777
37774310137677706400	74177616601723774377	77737771016274777617	77775774407176377771	01607477762034171777
4377773777101670477	75322011234237220006	15474025012211251052	00010457167076743766	06170344777543777037
44110155640575202765	03164011061762677715	37711217503076245771	05773017000077637637	1414762434764571657
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47427636136565774750	741567606317306337637	63666737325272721771	05173022754104037320	27050076340361373377

ORIGINAL PAGE IS OF POOR QUALITY

PULSE NO.	RANGE RINS 320 THRU 395										7-RIT* HORIZONTAL									
1	9	-36	-13	12	-14	-20	-16	4	-18	-6	-6	-12	12	-37	-21	20				
2	12	37	11	7	7	-4	6	20	-23	-41	-15	-33	-12	5	-2	1				
3	20	55	11	-3	9	8	19	16	14	32	-20	11	2	26	46	-18				
4	3	7	17	-1	22	13	-4	10	41	29	13	23	3	22	32	8				
5	-17	-47	12	-13	10	-6	-22	-13	26	1	8	23	1	-1	8	15				
6	-2	-19	-32	4	-28	-16	-11	-6	-19	-17	1	-7	13	19	-15	2				
7	8	31	-3	5	5	-3	20	4	-1	-7	-23	-15	-14	-38	-15	-9				
8	-20	-14	-11	9	11	14	19	10	28	16	-5	10	3	-5	7	7				
9	-2	-35	4	34	-3	30	0	11	-13	20	34	9	34	36	16	21				
10	44	32	5	-15	7	-21	-5	-7	-30	-24	-14	-6	-4	12	0	-19				
11	-9	16	13	-42	12	-26	-7	20	3	-12	-18	-9	-15	-14	-18	-25				
12	-17	-20	4	-26	-27	18	4	-5	23	23	-16	17	13	-22	17	33				
13	29	-20	28	3	-23	17	12	-18	-15	21	-13	-2	30	12	6	51				
14	-9	-27	3	0	-3	-28	-1	3	-9	19	32	-27	33	6	-6	-9				
15	-7	-6	-4	-13	9	-13	-20	-20	19	8	43	2	6	2	0	-40				
16	-21	10	-34	18	-1	21	-6	-13	19	-16	7	13	-17	4	-7	3				
17	-28	-28	-34	9	-17	3	3	16	-19	-13	-48	-18	-16	-23	-41	24				
18	23	1	27	0	13	-31	12	-2	13	21	18	-22	33	29	37	11				
19	35	44	5	10	36	-3	-4	26	0	3	43	45	17	43	40	5				
20	-59	-39	-27	-16	-13	20	-39	12	-17	-13	-12	0	-9	-32	-34	-5				
21	-14	-27	15	-5	-24	-3	-3	-28	10	-33	-12	-54	-46	-32	-19	-5				
22	50	44	49	25	1	3	5	-34	41	11	-14	10	28	21	6	12				
23	6	22	1	27	23	5	12	-8	-14	52	-2	30	53	38	16	19				
24	20	-22	-40	27	37	10	34	24	-32	22	27	-10	23	30	16	-1				
25	23	15	-13	19	36	16	37	28	9	-15	48	-10	-7	35	-7	7				
26	-31	-7	8	-16	-29	-6	-7	-27	-4	-23	-3	-21	-17	-27	12	6				
27	-8	-15	-14	-22	-31	-20	-14	1	-13	-8	-11	11	-17	-6	22	-30				
28	30	36	20	44	39	-4	-5	42	48	23	33	30	15	10	0	-18				
29	5	-4	-2	28	-12	8	-15	-43	21	-15	-15	-21	-12	-18	-26	25				
30	-2	-18	-43	-47	10	9	8	-10	-30	-13	-30	-1	-22	2	4	13				
31	-7	-7	10	-21	15	-15	24	25	-8	10	-7	16	20	15	13	-15				
32	-17	-17	38	30	-3	-15	-4	-13	20	7	2	-25	18	-17	-14	-28				

PARITY ERROR SENSED AT PULSE 3, RAN GE BIN 6  
 PARITY ERROR SENSED AT PULSE 4, RAN GE BIN 14  
 PARITY ERROR SENSED AT PULSE 5, RAN GE BIN 6

ATTACHMENT III  
LISTING OF PROGRAM PIMAGE

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1      PROGRAM PIMAGE(FILMAG=0,IMAGE=0,IMPUI,OUTPUT)
C.....
C     PIMAGE -- PERFORMS POST PROCESSING OF DATA FROM THE GSP. EACH
C     INPUT FILE IN FILE FILMAG CONTAINS 360 VALUES (ONE
C     RANGE BIN). BECAUSE OF STORAGE CONSIDERATIONS ONLY
C     48 FILES MAY BE PROCESSED AT A TIME.
C.....
10     REAL RMAP(360,48)
        INTEGER IAZ(384)
        LUNI=6LFIIMAG
        LUNO=5LIMAGE
C
15     C 10 PRINT '#NO OF FILES #,
        READ '#NFILES
        IF (NFILES.EQ.0) STOP
        PRINT '#ENTER DB/GRAY SHADE, TID#,
        READ '#DBGS,TID#
C
20     C THOLD=10,ALOG10(115)-15,0DBGS
C
        DO 20 K=1,NFILES
        BUFFER IN (LUNI,K) (RMAP(1,K),RMAP(360,K))
        IF (UNIT(LUNI)) 20,30,40
30     PRINT '#EOF ON LUNI#
        STOP
40     PRINT '#PARITY ERROR ON LUNI#
        STOP
20     CALL SKIPER(LUNI,1,0,9LBINBUFF,CR)
C
C     --- PROCESS INTO 4-BIT IMAGE DATA AND OUTPUT TO SUBROUTINE
C     --- DATA IN AZIMUTH LINES.
C
35     CALL SETO (IAZ(1),IAZ(384),0)
        DO 60 IF=1,360
        DO 50 IRB=1,NFILES
        SS=RMAP(IF,IRB)
        IF (SS.LE.V.0) SS=1.0E-100

```

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PROGRAM PIMAGE 73/171 OPT=1

```
40 IGS=(10.*ALOG10(SS)-1*HOLU)/DDBGS  
   IF (IGS.LE.0) IGS=0  
   IF (IGS.GT.15) IGS=15  
50 IAZ(IRB)=IGS  
   CALL DRTA (IT,IAZ,I*LUNO)  
45 60 CONTINUE  
   END FILE LUNO  
   GOTO 10  
C  
   END
```

## REFERENCES

1. C. R. Griffin and J. I. Jones, "Digital Data Recording System (DDRS) Operating and Maintenance Manual," Applied Research Laboratories Technical Manual No. 80-14 (ARL-TM-80-14), Applied Research Laboratories, The University of Texas at Austin, 29 August 1980.
2. F. A. Collins and K. E. Graf, "FLAMR/FLAP Data: A Discussion of Origin and Formats," Applied Research Laboratories Technical Report No. 76-42 (ARL-TR-76-42), Applied Research Laboratories, The University of Texas at Austin, September 1976.