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APQ-102 IMAGING RADAR DIGITAL IMAGE QUALITY STUDY

Final Technical Report under Contract NAS9-16497

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A modified APQ-102 sidelooking radar flown in an RB-57 by National Aeronautics and Space Administration, Lyndon B. Johnson Space Center (NASA/JSC) collected synthetic aperture radar (SAR) data which was digitized and recorded on wideband magnetic tape. These tapes were then ground processed by NASA/JSC into computer compatible tapes (CCT's). The CCT's may then be processed into high resolution radar images by software on the CYBER computer at Applied Research Laboratories, The University of Texas at Austin (ARL:UT).

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The purpose of this study was to analyze and quantitively characterize the images created. An analysis was made of the radar, the digitizing and recording equipment, and the computer software. A set of "image quality" parameters have been derived which characterize the created image data.

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PREFACE

Remote sensing of the earth's characteristics, as well as of other planets, is being effected by radar, infrared and optical sensors, and radio probes. The National Aeronautics and Space Administration (NASA) Jet Propulsion Lab (JPL) and Johnson Spacecraft Center (JSC) have been operating synthetic aperture radars (SAR's) gathering data for various scientific purposes. For several years JSC has been operating an X-band radar, a modified APQ-102 reconnaissance system, on an RB-57 testbed aircraft. This radar originally used optical data processing to produce the radar image; it was modified, however, to digitize and record radar video signals using the digital data recording system (DDRS). These data are processed into digital images for use in scene analysis. The study described herein was undertaken to quantitatively characterize the radar system performance, and to provide information relevant to the data gathered. Such information is vital to a valid analysis of the digital data provided by the radar sensor.

Due to funding cutbacks, the XSAR (X-band SAR) system has been decommissioned; nevertheless a substantial body of data is available. The value of this study is in the analysis of images created from the existing data. This work was performed under the cognizance of Mr. G. Fels of NASA/JSC.

I. BACKGROUND

A. Radar System

Compressed pulse radar video data are normally recorded on photographic film in the APQ-102 X-band radar system. The recording film is pulled past a cathode ray tube (CRT) display at a rate proportional to the aircraft velocity; it can later be processed in an optical Fourier transform processor to produce a high resolution radar image of the object scene.

Alternatively, by digitizing samples of the compressed pulse video, and recording these samples on a wideband magnetic tape recorder, a radar image may be created by processing the samples in a digital computer, using Fourier transform computer routines.

The system that gathers the digital data is the combination of the RB-57 testbed aircraft, APQ-102 radar (modified), and the DDRS, described in Ref. 1. The data pulses are compressed in time by analog circuits in the radar system, and other circuits compensate for the roll and yaw of the aircraft to keep the antenna axis stabilized in the broadside direction off the left side of the aircraft's velocity vector.

The digitized data must also be compressed in azimuth, i.e., separated into Doppler filters which correspond to azimuth "lines" on the surface being illuminated by the moving radar.

B. Digitizing and Processing System

The DDRS system was built by ARL:UT to enhance the usefulness of the remotely sensed radar data to various investigators. The presumption was that the contents of the individual resolution cells could provide more detailed information than a photographically processed radar image of a portion of the earth's surface.

The DDRS proved to be effective in digitizing the video data. Subsequently, the software was developed at ARL:UT for the ground signal processor (GSP), which converts the video data into image data. At this point, it became desirable to evaluate the entire process of data gathering and image generation, to determine the quality of the radar images produced by the system. An image quality study was done to extract and evaluate specified image quality parameters.

C. Data Base

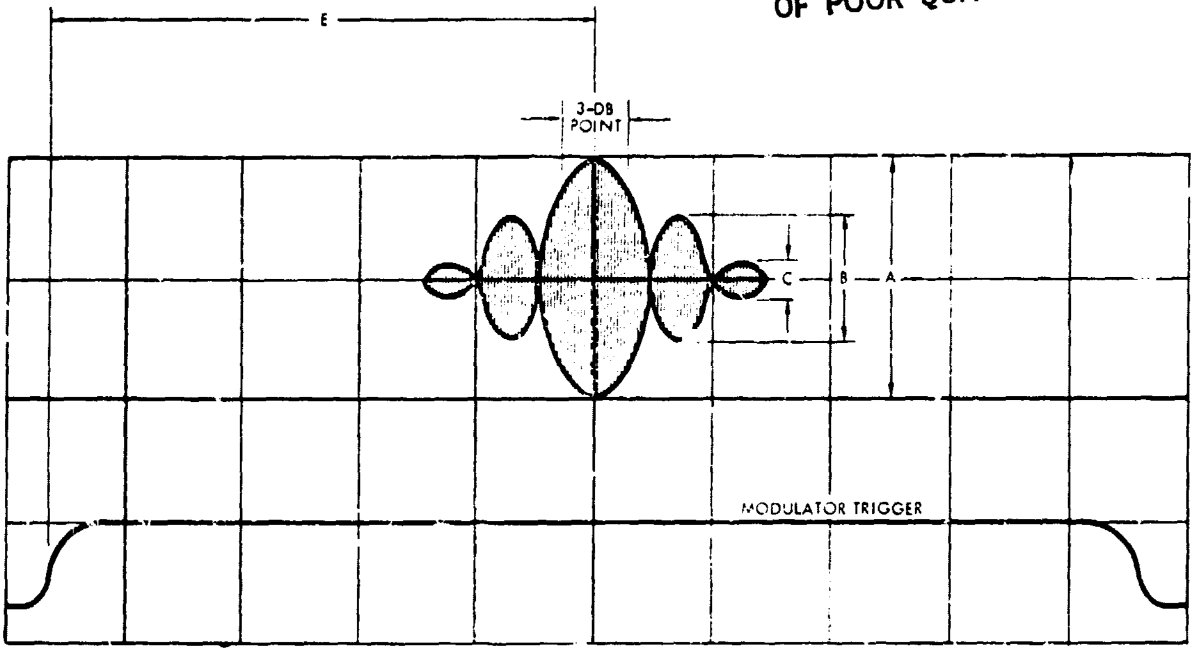
A matrix of data desired for the study was given to NASA/JSC for acquisition by the radar-DDRS. These data were the noise data from the radar system, and data obtained on imaging flights against a corner reflector array at Wilcox Playa in Arizona. Various combinations of sampling rates, radar modes, etc., were requested. These matrices and the data actually obtained are described in Section IV of this report.

II. RADAR SYSTEM DESCRIPTION

The APQ-102 radar system was modified by Goodyear Aerospace Corporation for installation in the RB-57 testbed aircraft. It generates two pulse compressed video signals, one from a co-polarized antenna with nominal 3 dB beamwidth of 1.3^{0}, and one from a cross-polarized antenna. The radar uses a linear frequency modulated pulse with a 15 MHz bandwidth operating at 9600 MHz, or a wavelength of 3.125 cm. The compressed 3 dB pulse width is about 60 nsec. Figure 1 illustrates the sinx/x pulse shape after compression, taken from the radar technical manual.[22] The radar pulse repetition frequency (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^{0} or 54^{0}. These angles are selected by the mode of operation selected. That is, the operator selects the mode, which essentially selects the antenna depression angle, to change the swath size of terrain imaged for a nominal operating altitude of 55,000-60,000 ft msl.

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 signals which have been synchronously detected and range pulse compressed. The operator can adjust the gain of these signals to the DDRS and the photographic recorder.

The principal option available to the system operator is the sampling rate of the DDRS, which permits selection of sampling intervals



PARAMETER	MEASURED VALUE
AMPLITUDE A*	30.9 ±5.4 MVRMS
AMPLITUDE B*	AT LEAST 13.5 DB LESS THAN A
AMPLITUDE C*	AT LEAST 13.5 DB LESS THAN A
DELAY E	0.53 ±0.05 μSEC
PULSE WIDTH	0.055 ±0.005 μSEC AT 3 DB

*MEASURED WITH 6-DB ATTENUATION

FIGURE 1
RANGE COMPRESSED PULSE CHARACTERISTICS
[Reproduced from Ref. 2]

by the high speed analog-to-ditital (A/D) converters of 40-150 nsec in 10 nsec steps. System operation at the 40 nsec interval is critical and careful setup of the timing pulses is required for satisfactory performance. The operator may select the sampling rate and the precision of the data recorded, i.e., the number of bits, 1, 2, 4, or 7, of digital data for each sample.

The radar has an analog chirp-type FM pulse compression system, with a time-bandwidth product of 1.2 sec x 15 MHz, or a compression ratio of 18:1. The 3 dB compressed pulse width of about 60 nsec results in a slant range resolution of approximately 30 ft. The ground resolution is less, by the cosecant of the nadir angle.

In focused Doppler processing, the azimuth resolution of a side-looking SAR is limited in theory to one-half the antenna dimension; for the APQ-102, it is the antenna azimuth plane dimension of 120/2 cm, or roughly 2 ft. In practice, it is desirable to set the azimuth resolution approximately equal to the range resolution and, in any case, errors in the antenna motion compensation limit the practical azimuth resolution to about 30 ft.

Two modes are available, illustrated by Figs. 2 and 3, with mode selection setting the antenna nadir angle and the swath width associated with it.

The delay to the start of video sampling is labeled DRMIN and is usually set at 2 μsec. The operator can select the linear polarization of the transmitted wave, and also the video gain in the receiver. This last setting is evidently chosen from experience, depending on the operator's perception of the reflectivity levels of the area to be imaged.

The maximum number of range samples recorded depends on the interpulse period (IPP); therefore the range swath coverage depends on the

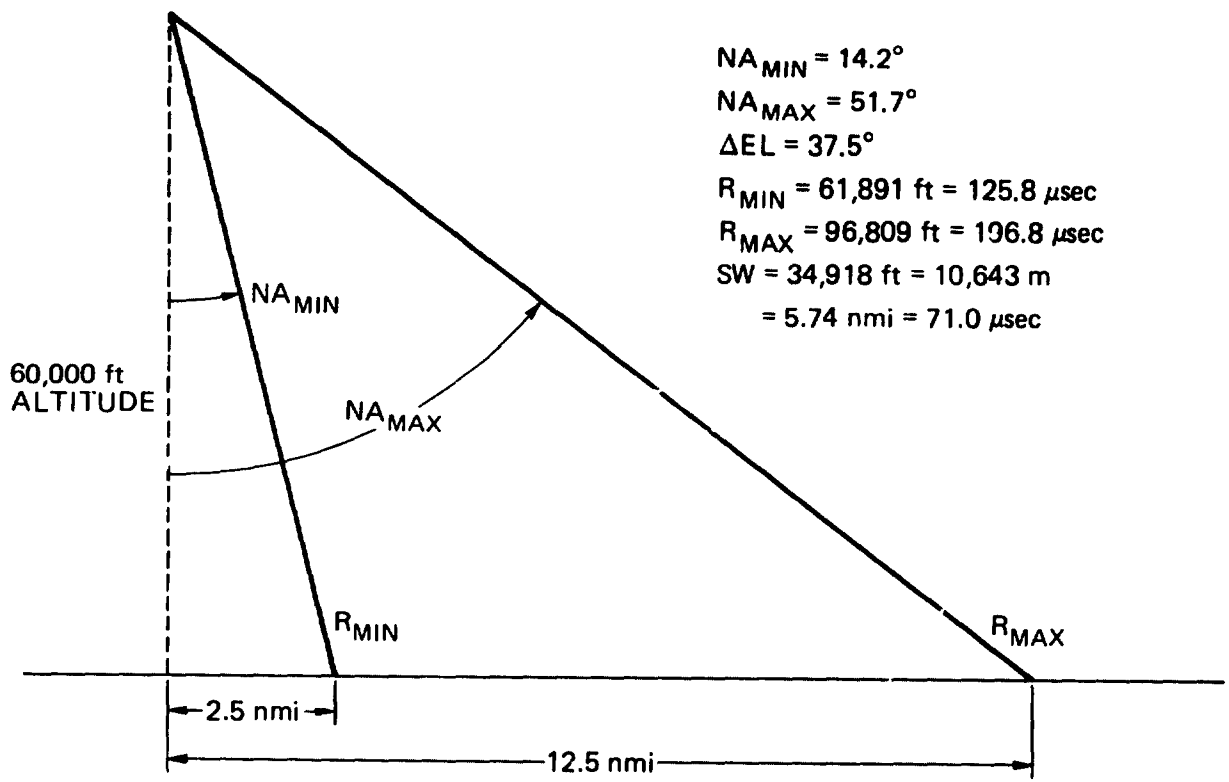


FIGURE 2
MODE 1 GEOMETRY

ARL:UT
AE-80-91
CRG-GA
9-11-80

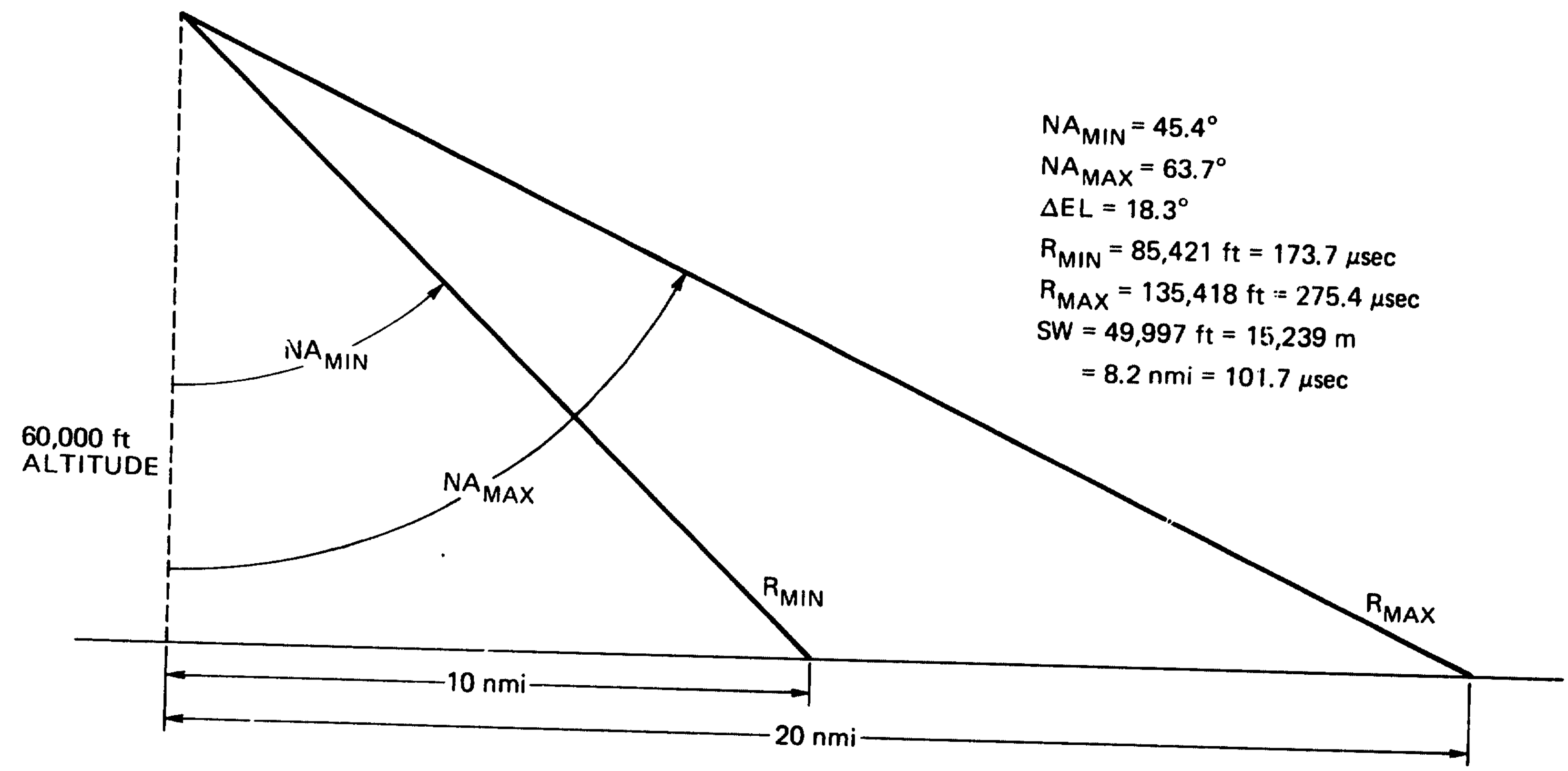


FIGURE 3
MODE 2 GEOMETRY

ARL:UT
AE-80-92
CRG-GA
9-11-80

sampling rate, and the bit precision per sample. For example, with 7-bit data, at the 50 nsec sampling interval, 512 range samples are recorded. With 4-bit data, however, twice as many samples (1024) can be recorded. These samples are Miller-encoded and recorded on wide band instrumentation tape for later ground processing.

Ground processing involves playback of the wideband tape through Miller decoders, reformatting, and recording in computer-compatible tape format. In addition to the digitized video samples, radar parameter environment (RPE) data are recorded. These are data concerning the aircraft platform dynamics, radar operation, and DDRS settings.

The reformatted video is now available for azimuth compression and image processing. The processor is described in Section III, following.

Table I is a list of the system selectable parameters. Operator selectable parameters can be set by the flight crew of the XSAR testbed aircraft. Processor selectable parameters are chosen by the programmer to be compatible with the RPE data from the flight. The programmer also chooses the postprocessor/display parameters based on the principal investigator's desires or specifications, and the general type of scene and scene content.

TABLE I

SYSTEM SELECTABLE PARAMETERS

Operator Selectable Parameters

DDRS	Radar
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

Processor Selectable Parameters

Co-polarized or Crosspolarized Data

Area To Be Imaged: - Starting Range Sample
Starting Radar Pulse

Azimuth Resolution - Normally Chosen 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/Grade Shade Assignment

Brightness, Contrast Settings

III. PROCESSOR DESCRIPTION

A. Overview

The GSP developed for correlation of DDRS data on a Control Data Corporation (CDC) CYBER computing system was documented in Refs. 3 and 4. Since the completion of these reports, many changes have been incorporated in the GSP to bring it up to the version used during the current image quality study. The wideband tapes created by the DDRS for the current study were reduced to computer compatible tapes (CCT's) on a minicomputer, with attached Miller decoders, at NASA/JSC. The format and composition of these tapes is different from the CCT's created by the digital recording interface equipment (DRIE) at ARL:UT so that the GSP's DDRS data and format routines had to be changed. In general, the data handling process was simplified. The main processing program, also referred to as GSP, has been modified to increase its versatility, additional shading windows are available, and several programs to print and plot the filter magnitude output data of GSP have been written. Table II is a list of the programs which make up the current GSP, with a short description of each. The results of actual slant range sample interval measurements on the DDRS presented in Ref. 1 (pp. 126-139), are slightly different from the design objectives so these results were incorporated in Program RPESCAL instead of the previously used values for slant range sample intervals.

B. Program GSP

The main driver program, GSP, has been significantly modified from its original version. Appendix IV contains a listing of the current version. Table III is a list of the processing options (entered interactively) available in the current configuration. Since the raw video

TABLE II

PROGRAMS AND SUBROUTINES IN THE CURRENT GROUND SIGNAL PROCESSOR

GSP	Main program, performs Doppler processing and filter overlay.	
NPULSES	Subroutine, recovers video data from the indexed disk file into an array for use by program GSP.	
WINDOW	Subroutine, calculates array of aperture weighting coefficients for program GSP; windows and the needed parameters are:	
	RECT	Rectangular window, all weights set to 1.
	HANNING	Hanning or extended cosine, specify total percent of cosine taper.
	COSINE**2	Cosine squared, specify argument maximum in degrees.
	KAISER	Kaiser weighting, specify sidelobe level in dB relative to the main lobe.
	TAYLOR	Taylor weighting, specify peak sidelobe ratio in dB and number of sidelobes of near level.
TAYLOR	Subroutine, used by subroutine WINDOW to calculate the Taylor weighting function.	
RPEPNT	Subroutine, prints a formatted list of the RPE data stores in common block RIOT, used by program GSP.	
RPEDCOD	Program, reads the RPE data record off the NASA/JSC formatted tape, decodes the data, scales the data, and then generates the RIOT common block used by program GSP.	
RPESCAL	Subroutine, used by program RPECOD to apply units to the values decoded off the RPE header record of the NASA/JSC formatted DDRS data tape.	

TABLE II (Cont'd)

PROGRAMS AND SUBROUTINES IN THE CURRENT
GROUND SIGNAL PROCESSOR

CNTURN7	Program, reads the 7-bit DDRS sampled data off the NASA/JSC formatted DDRS data tape.
CNTURN4	Program, same as CNTURN7 but for 4-bit DDRS sampled video data.
DEMPLEX	Subroutine, used by the CNTURN programs to demultiplex the range sample by pulse video data samples to pulse by range sample data.
IBCDTD	Subroutine, decodes binary coded decimal data.
LUNPOS	Subroutine, positions multifile files.
NMPSTAT	Program, collects statistics on the GSP output filter magnitude data.
STATPLT	Program, compiles statistics on specified pulse/range bin raw video data and then creates a histogram plot of the probability mass function.
PLTPIX2	Program, compiles statistics on specified azimuth lines and range bins of processed pixels and creates a histogram plot of the probability distribution function for the specified pixels.
DSTATR	Subroutine, performs the actual compilation and calculation of statistics; it is used by all the programs which calculate statistics on processed pixels or raw pulse data.
NPIMAGE	Program, creates tape of image data in a format suitable for use on the ARL:UT high resolution display.
DRTA	Subroutine, reorders one azimuth line of pixels for proper input to the high resolution display software, used by program NPIMAGE.

TABLE II (Cont'd)

PROGRAMS AND SUBROUTINES IN THE CURRENT GROUND SIGNAL PROCESSOR

PRTPIX	Program, prints azimuth filter values across the page, up to 120 values per line (RB). Each value is a hex character (0-f) representing one of 16 logarithmic gray scales assigned to each filter magnitude. Statistics on the printed area are optionally compiled and printed.
PRTPIX2	Program, prints the value of filter magnitudes to one decimal place. Up to 26 values per line (RB) are printed with optional statistics on the printed area.
PLTPIX	Program, plots histogram of filter magnitudes of specified azimuth lines of one range bin on a dB scale.
PARITY	Program, checks the parity of the 7-bit DDRS data and prints each data byte with a parity error.
PARITY2	Program, accumulates and then prints parity errors as a function of RB over a specified number of pulses.

TABLE III

PROGRAM GSP SELECTABLE OPTIONS AND THEIR DEFAULTS

OPTION	DEFAULT
1. Select range bin (RB) to be used as the patch center (PC) RB of the image. Used in the default selection of the azimuth filter spacing.	256 for 7-bit data 512 for 4-bit data 1024 for 2-bit data 2048 for 1-bit data
2. Select "QUICK LOOK," on/off; one-look (no filter magnitude overlay) image is produced to check data or determine ground position within the data without costly full overlay processing.	OFF
3. Select RB to be used to line up the left edge of the image, pulses are skipped before processing of the RB's above the selected RB so that the beginning of the first synthetic array at each RB line up.	IRBFMAP = 1
4. Select azimuth filter 3 dB width RESA, in meters, for each or all of the range bins.	RESA = RESR, the 3 dB range resolution on the ground at each range bin. RESR = 8.25 m/sin (nadir angle to RB)
5. Select azimuth filter spacing FILTSPC, in meters, for each or all of the range bins.	The range sample spacing projected onto the ground at the patch center is used as the filter spacing for all the range bins, FILTSPC = where C = speed of light SISR = sample interval in slant range (i.e., selected DRS sample interval)

TABLE III (Cont'd)

PROGRAM GSP SELECTABLE OPTIONS AND THEIR DEFAULT

6. Select azimuth sample ratio, SRA, to adjust azimuth filter spacing, FILTSPC = FILTSPC/SRA.	SRA = 1
7. Select aperture weighting function, KWTFTNA, and function parameters (if needed): SHADFAC, main lobe to sidelobe ratio in dB and NBAR, number of sidelobes of near level (only used with Taylor weighting.)	KWTFTNA = "TAYLOR" SHADFAC = 30 NBAR = 5
8. Select beam broadening factor, BBF, to match selected aperture weighting function. BBF equals the ratio of the 3 dB main beam width of the Fourier transform of the selected weighting function to the 3 dB main beam width of the Fourier transform of a rectangular window.	BBF = 1.27188
9. Select the number of azimuth lines, TAZLNS, to be generated at each range bin in the image.	tazlns = 360
10. Enter: Output IFILO, number of the output file to receive the filter magnitude data. IRBF, number of first RB to process. NRBPROC, number of RB's to process starting with IRBF. IPSKIP, number of pulses to skip before the start of processing (used to select the images' starting azimuth location within a run).	No defaults - these parameters must be entered to begin processing.

data are placed in an indexed random access disk file, GSP can efficiently pick out selected pulse/range bin data for processing. This new storage scheme has little effect on the computer resources required to sequentially process an image. However, when selective and repetitive processing of specific sections of the data from an entire run is desired, such as was needed for the image quality study, the computer time and "wall clock" time are substantially reduced from the original version. The current version of GSP also produces a more detailed printout; a list of the selected processing options (with the entered values) is printed first, followed by a printout of the RPE data; then the calculated data independent of range bin is printed (see Fig. 20 for a sample of this output) followed by a paragraph of data for each processed range bin containing the calculated variables unique to that range bin (or possibly unique, depending upon the processing options selected; see Fig. 34). Table IV contains a sample paragraph of output with a description of the variables. A complete, compiled listing of the programs making up the current version of the GSP was sent to NASA/JSC under separate cover.

C. Parity Checking

Two programs were written to check the parity of the 7-bit sampled video data (the 4-bit, 2-bit, and 1-bit data do not contain parity bits to check). Data from Run 1 on Line 1 and Run 1 on Line 2 were tested for parity errors. The frequency of errors was observed to be independent of run and relative pulse position in the run; however, accumulation of parity errors as a function of range bin over many thousands of pulses showed a general trend of alternating sets of one to four range bins containing parity errors followed by a range bin containing no (or just a few) parity errors. Averaging the parity errors from over 5 million video samples showed that 0.31% of the data contained parity errors. Assuming one-half of the "bad" video data samples showed a parity error, then 0.62% of the video data samples are invalid. This percentage implies that the overall integrity of the data is good and makes little contribution to error in the image quality

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TABLE IV

DEFINITION OF VARIABLES PRINTED BY GSP FOR EACH RANGE BIN

A sample paragraph of range bin dependent data printed by GSP is shown below. The data were generated using the default values of the GSP options, except the total number of azimuth lines generated per range bin was 150.

```
RB- 230   RESR- 12.9   RESA- 12.9   FILTSP- 16.9   RANGE- 22103.5   RNGNADR- 14095.2
          NP- 198   NPFFT- 268   IFBEAM- 19   NFBEAM- 31   NPLMAP- 424   IFILOUT- 2   GI- 1.5600
     1   1   2   2   3   3   4   4   5   5   6   6   7   7   8   8   9   9  10  10  11  11  12  12  13
    13  14  14  15  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15
    16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16
    15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15
    16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16
    15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15  16  15
```

VARIABLE DEFINITIONS

RB - Range bin (in the example the current RB is 230).

RESR - The 3 dB range resolution projected on the ground, in meters.

RESA - The 3 dB azimuth filter resolution desired, in meters.

FILTSP - The actual azimuth filter spacing of the synthetic arrays at the current RB, in meters.

RANGE - Slant range from the radar to the RB, in meters.

RNGNADR - The ground range from the nadir to the RB, in meters.

NP - Number of pulses, video data samples, in each synthetic array formed for processing the RB. NP is calculated to yield filters of 3 dB width, RESA.

TABLE IV (Cont'd)

DEFINITION OF VARIABLES PRINTED BY GSP
FOR EACH RANGE BIN

NPFFT - Number of points in the FFT's computed for the current RB. The first NP points in the FFT contains the synthetic array data with the rest of the points set to zero for interpolation. NPFFT is calculated to yield azimuth filter spacings as close as possible to the desired spacing.

IFBEAM - Location of first filter out of the FFT to be used in constructing the image.

NFBEAM - Number of filters from each FFT used in constructing the image. Starting with the IFBEAMth filter, the next NFBEAM filters in the FFT represent the ground coverage of the 3 dB width of the real beam antenna pattern.

NPLMAP - Number of pulses skipped before processing of the current range bin (in addition to any skipped when the GSP execution was begun) to force the first azimuth line created to line up with first azimuth lines created from the data at the other RB's in the image.

IFILOUT - Every IFILOUTth filter out of the FFT is used in the image. Each FFT must be at least NP pulses in length, if the minimum length FFT produces filter spacing less than the desired spacing, then zeroes are added to the FFT length until the filter spacing is 1/FILOUT of the desired spacing and every IFILOUTth filter out of the FFT is used in image formation.

GI - Inverse gain factor of the array. The effect of aperture weighting is to reduce the amplitude of the filters out of the FFT; the filters are multiplied by GI to compensate for the effect of aperture weighting.

The list of numbers following the above defined parameters show the number of overlays for each azimuth line. The numbers are read left to right, top to bottom, one number for each azimuth line in the output image (150 azimuth lines were processed in the example).

parameters extracted. Possible sources of errors include the DDRS, Miller encoding and recording to wideband tape, Miller decoding from the wideband tape, transfer to CCT's, and input to the CYBER.

IV. DATA BASE DESCRIPTION

To evaluate SAR image quality, calibrated reflectors and homogeneous terrain backgrounds are required. The data used in this study were obtained by flying the system against a corner reflector array set out on Wilcox Playa, a dry lake bed, near Wilcox, Arizona. Figure 4 is a map of Wilcox Playa, and Fig. 5 illustrates the geometry of the corner reflector array, which was emplaced by personnel from Ft. Huachuca, Arizona. Figure 6 is a simplified layout diagram, showing the area with the largest reflectors at the four corners, three arrays of large (100 cm) reflectors with different separations, and several smaller reflectors varying from 9.5 cm to 40 cm on the inside joined edges of the reflectors.

Table V provides data on the calculated (theoretical) radar cross section values for the different sized corner reflectors in the array. Values are provided in units of square meters, and in decibels referenced to a 1 m^2 target. Figure 7, taken from Ref. 5, illustrates the pattern of the response in azimuth and elevation of a trihedral corner reflector. The axes of these corner reflectors were oriented north in azimuth, or normal (within 2-3^{o}) to the flight paths used, and elevated "about 45^{o}". The elevation aspect, referring to Figs. 1 and 2, varied considerably with the mode and nadir angle (NA), and response could be reduced by as much as 15 dB due to off-axis illumination in elevation.

Two data gathering flights were made, the first on 30 September 1981 and the second on 20 October 1981. Five runs were made in the first flight, three on Line 1, used for the Mode 1 geometry, and two on Line 2 for Mode 2. Table VI is a listing of the CCT's furnished for this study.

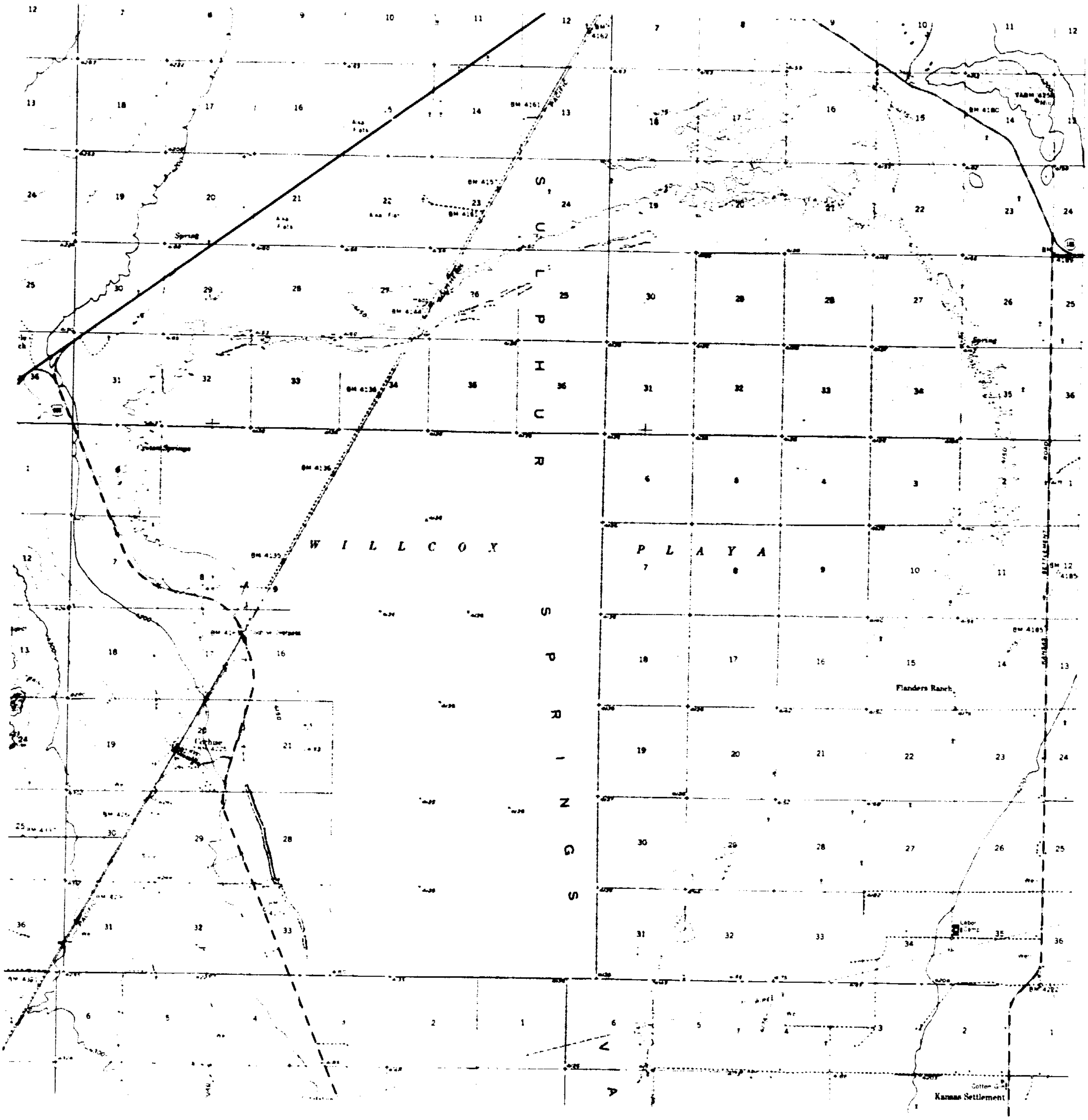
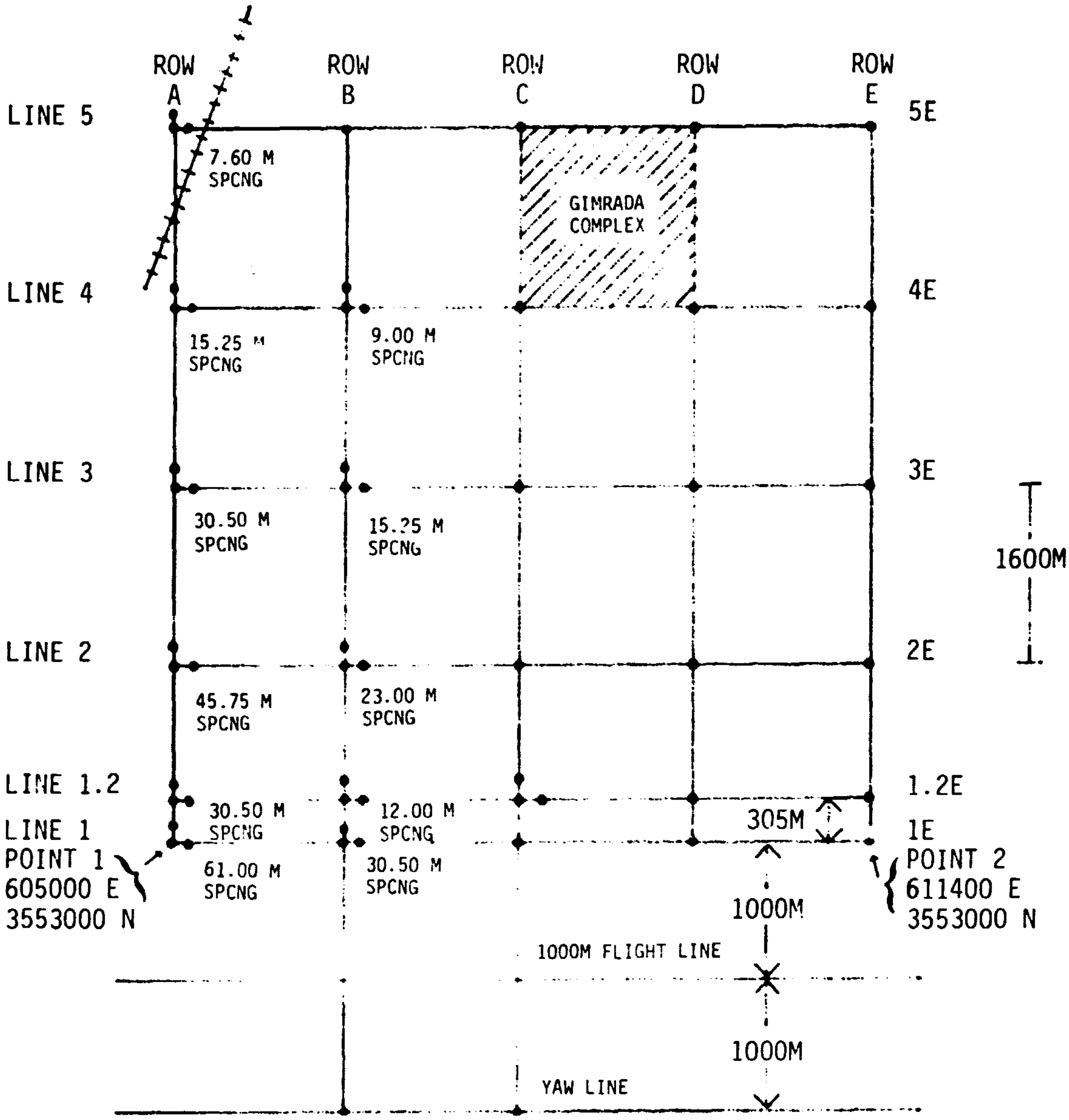


FIGURE 4
MAP OF WILCOX PLAYA



COMPLEX WILL ACCOMMODATE ANY TETRAHEDRON TARGET UP TO 100 cm. TARGETS MAY BE RAISED IN HEIGHT TO 6 ft ABOVE PEDESTALS IN 6 in. INCREMENTS. PEDESTALS ARE ARE 4140 ft ABOVE MSL. TARGETS MAY BE ELEVATED IN ANGLE. AZIMUTHS IN 200 mil INCREMENTS.

FIGURE 5

RADAR GEOMETRIC FIDELITY COMPLEX
WILCOX DRY LAKE, WILCOX, ARIZONA

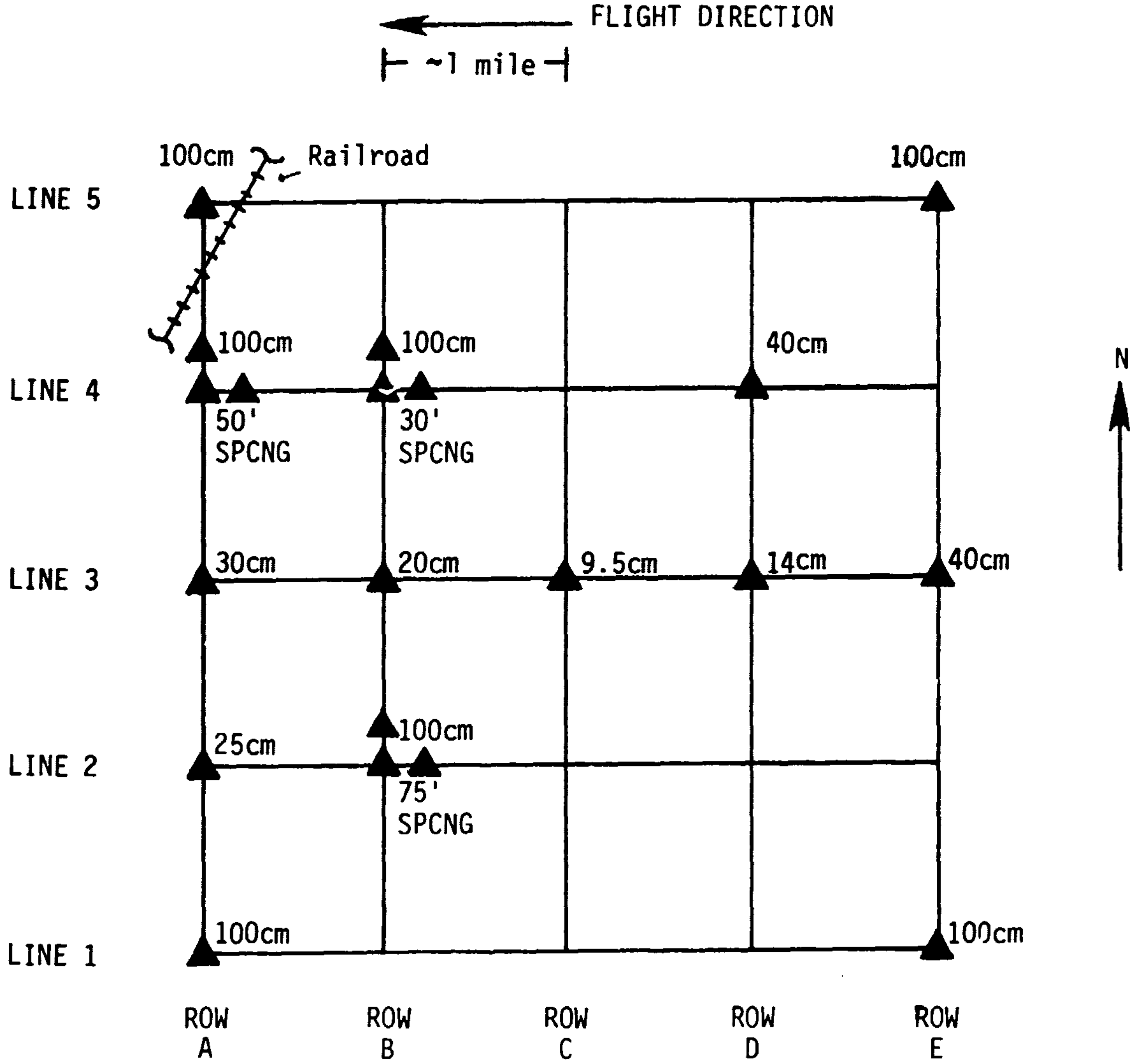


FIGURE 6

WILCOX PLAYA CORNER REFLECTOR
LAYOUT FLOWN FOR THE STUDY
PSP T-034

TABLE V

CORNER REFLECTOR CROSS SECTIONS

$\lambda = 3.125$

$$\sigma = \frac{4\pi}{3}\left(\frac{\ell^2}{\lambda}\right)^2$$

$$= \frac{4\pi}{3\lambda^2} \ \ell^4$$

$$= 4289.32 \ \ell^4 \ (m)^2$$

ℓ(cm)	σm^2	σ dBm^2
100	4289.3	36.3
40	109.8	20.4
30	34.7	15.4
30	34.7	15.4
25	16.8	12.2
20	6.9	8.3
14	1.6	2.1
9.5	0.35	-4.5

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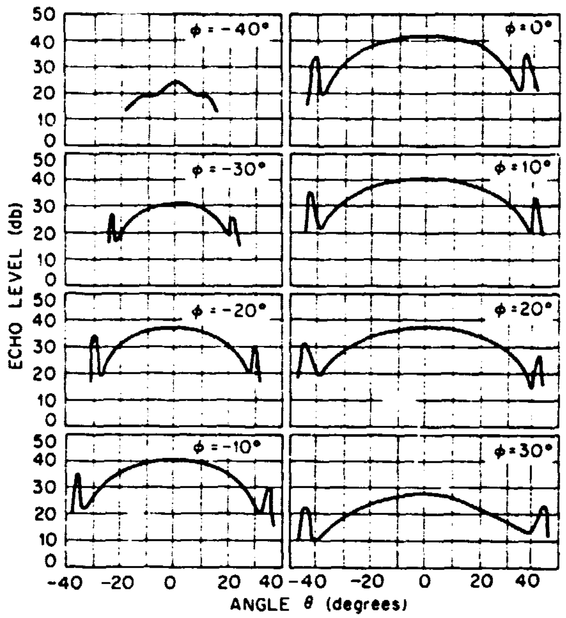


Fig. 12 Echo-response patterns of a triangular trihedral reflector. Edge of aperture = 24 in.; λ = 1.25 cm. (*Courtesy of American Telephone and Telegraph Co.*[29])

and azimuth are shown in Fig. 12, based on the angular coordinates defined by Fig. 13. The maximum radar cross section obtained on the symmetry axis is given by the modified flat-plate formula

$$\sigma = 4\pi \frac{(0.289l^2)^2}{\lambda^2} \tag{10}$$

where l is the length of each side of the reflector. The factor 0.289 is obtained by considering the fraction of the trihedral projected area that participates fully in the triple-reflection process.[29] An interesting and informative discussion of the effects of small errors in construction upon the radar cross section of a corner reflector is given by Robertson.[29]

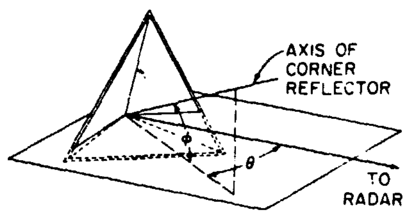


Fig. 13 Coordinate system for describing the radar cross section of a triangular trihedral corner reflector. (*Courtesy of American Telephone and Telegraph Co.*[29])

High-resolution Measurements The use of range resolution capable of isolating individual scattering centers on a target generally yields much more information for each target aspect than the relatively narrowband measurement which has been represented in the previous data. One experimental evidence of this is shown in Fig. 14, where a fiber-glass model of an F-102 fighter aircraft is shown as seen by a radar with resolution of approximately 6 in.[30] Several scattering sources at different locations are evident. These may be identified generally with specific features within the model for which one can predict scattering as seen here.

High-resolution studies place emphasis upon the ability to examine separately the

FIGURE 7

ECHO RESPONSE PATTERNS OF TRIHEDRAL CORNER REFLECTOR
(from Radar Handbook, edited by M. I. Skolnik)

TABLE VI

CORNER REFLECTOR DATA RUNS

(a)

DDRS Computer-Compatible Tape Data

A/C Flight No. 6, 10/20/81, Mission No. 450

Analog Tape No. 3309

CCT #	Line	Run	Polarization	Start Time	Stop Time
002199	1	3	Linear-HH	17:55:15	17:56:05
002200	1	3	Cross-HV	17:55:15	17:56:05
002201	1	3	Linear-HH	18:05:10	18:06:00
002202	2	3	CrossOHV	18:05:10	18:06:00
002203	1	4	Linear-HH	18:13:22	18:14:12
002204	1	4	Cross-HV	18:13:11	18:14:12
002205	2	4	Linear-HH	18:23:58	18:24:48
002206	2	4	Cross-HV	18:23:58	18:24:48
002207	1	5	Linear-HH	18:32:17	18:33:07
002208	2	5	Linear-HH	18:42:05	18:42:55
002209	1	6	Linear-HH	18:50:04	18:50:54
002210	2	6	Linear-HH	18:59:45	19:00:35

(b)

DDRS Computer-Compatible Tape Data

A/C Flight No. 8, 9/30/81, Mission No. 448

Analog Tape No. 3302

CCT #	Line	Run	Polirization	Start Time	Stop Time
002121	1	1	Linear-HH	17:25:43	17:26:43
002132	2	1	Linear-HH	17:33:27	17:34:28
002133	1	2	Linear-HH	17:43:47	17:44:48
002134	2	2	Linear-HH	17:51:50	17:52:50
	1	3	Linear-HH	18:01:29	18:02:29

In addition to the radar data tapes, a tape was furnished with video noise data in digital form, obtained from the radar receiver with a dummy load in place of the antenna. The purpose was to establish the noise level of the system. The radar was operating in the aircraft in the "standby" mode (transmitter off). A reference signal was input to the radar in place of the velocity signal so that a PRF could be generated. Data were recorded with the rest of the radar fully operational, and should be indicative of receiver noise levels.

Some data, derived from the FLAMR (forward looking advance multimode radar) flight test program are furnished for comparison purposes (Ref. 6). That system operated at Ku band, was a digital SAR, and was designed as such from its inception.

To obtain a rough calibration (within 4 dB) of the observed radar return signals, data from other research efforts on the reflectivity of background terrain similar to the Wilcox Playa were used. Some of these data were obtained by the FLAMR system, and others from measurements using scattermeters and airborne radars. Ground truth information is very sketchy; however, it was learned from NASA/JSC personnel that the playa was quite moist as a result of rains subsequent to placement of the corner reflectors. This condition accounts for variations in the reflectivity of the background. References for the reflectivity of desert terrain are given in Refs. 7 and 8. From the data available, it is estimated that the playa reflectivity (σ^0) is -22 dB in dry areas and -15 dB in wet areas.

As a reference for the digitally processed radar image, a pair of photographically processed images are included. Figure 8 is an image with horizontal-horizontal (HH) polarization, Mode 1 and 50 nsec sampling interval; Fig. 9 is the same as 8, except that the DDRS was set for 70 nsec sampling interval (SI). (These are nominal value for the SI.)

FIGURE 8
OPTICALLY PROCESSED IMAGE
LINE 1, RUN 1, HH, MODE 1

4058-1

FIGURE 9
OPTICALLY PROCESSED IMAGE
LINE 1, RUN 2, HH, MODE 1

4058-2

V. IMAGE QUALITY PARAMETERS

A. Resolution - xdB Resolvable Distance

To estimate this parameter, a number of individual measurements are averaged. The data base consists of video samples from three triangular arrays of 100 cm corner reflectors with spacings of 23 m, 15.25 m, and 9 m. With a continuously sampled system, resolution in range is determined by the impulse response, or compressed pulse shape (see Fig. 1). For a finitely sampled system, however, the sampling ratio is a factor. The 9 m array spacing could potentially be resolved in range in the optically processed image if it were not for dynamic range limitations. In fact, referring to Figs. 8 and 9, none of the arrays are resolved in range, due to saturation by the high level returns, in the radar receiver, or in the processing.

In azimuth, a similar effect occurs for the optically processed image and, additionally, aliasing or grating lobe generation is observable. The digitally processed data can be compressed in azimuth resolution by taking larger arrays to get narrower filters, up to a limit. The limit is the inaccuracy of the sample values due to noise, motion compensation errors, and sampling errors. In addition, the filter (sample) spacing is variable. For the purposes of the study, the synthetic array size processed will be that which sets the azimuth resolution equal to the ground range resolution, which varies with the secant of the grazing angle. The grazing angle not only varies with the range of the corner reflector array, but also with the mode, or antenna position, in elevation. For Mode 1, the resolution will not be as good as for Mode 2 since the grazing angle for the antenna is greater (thus, the nadir angle is smaller) than for Mode 2, and resolution should be worse for the targets closer to the nadir of the system. The azimuth sample spacing is also adjustable, but is selected in the GSP to be the same as the range sample spacing at the patch center (default processing). This results in undersampling, but is at least a consistent criterion.

The standard digital processing failed to resolve the 9 or 15.25 m spaced corner reflector. Figure 10(a) is a plot of the 23 m spacing corner reflector response, with filter values plotted for the range bin containing the two 100 cm corners. The reflectors are not resolved in the main response, due to the previously mentioned dynamic range limitations of the system. They are resolved in the grating lobe structure, however, with 3 dB resolvable distance of two azimuth filters, or 24.2 m. By processing in azimuth with higher resolution and closer sample spacing than standard, it is possible to resolve the corner reflectors in the main lobe. Figure 10(b) illustrates the result with azimuth line spacing decreased by a factor of 4 (3.04 m) and azimuth resolution remaining at 12.2 m.

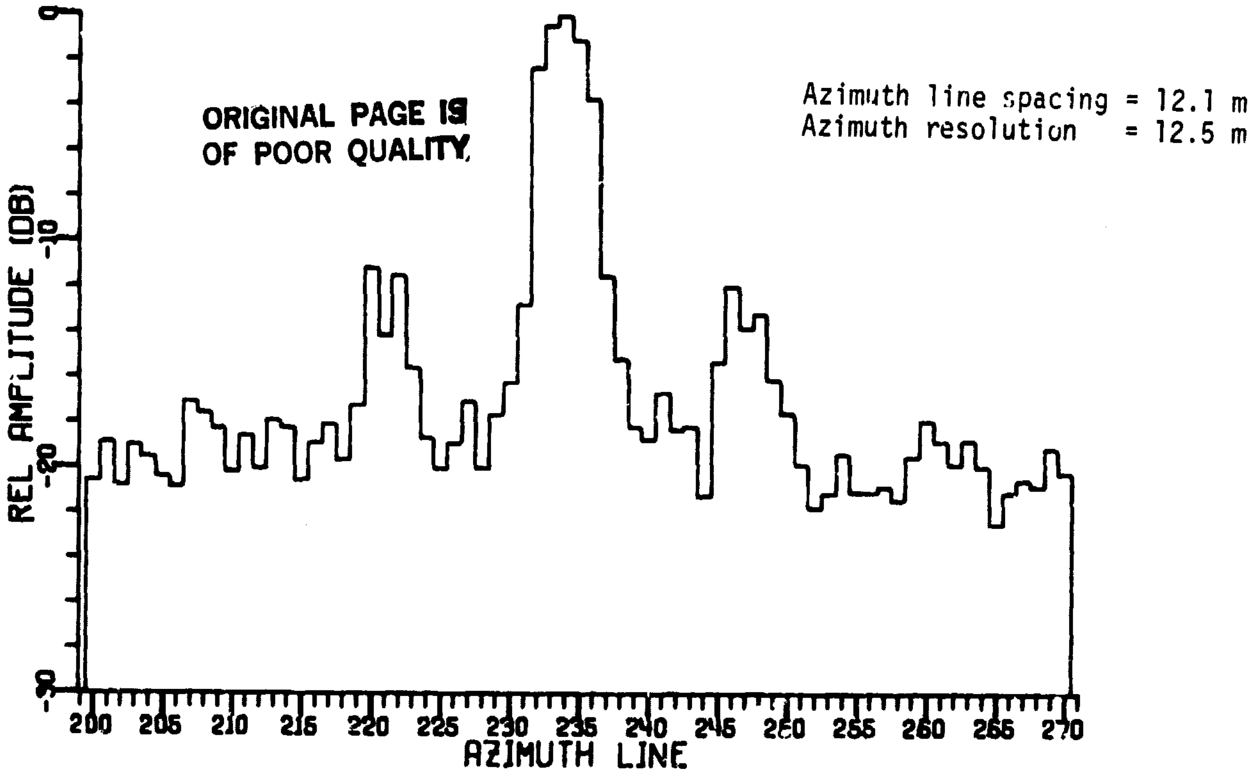
Here the 2 dB resolvable distance is 21.28 m (7 lines x 3.04 m spacing).

The problem with the dynamic range limitation is discussed in Section VII, "System Design Parameters".

The resolution of the system, with the standard Doppler (azimuth) processing, is a nominal 3 dB resolvable distance of 24 m, for radar targets of equal cross section not in the saturation range of the radar system.

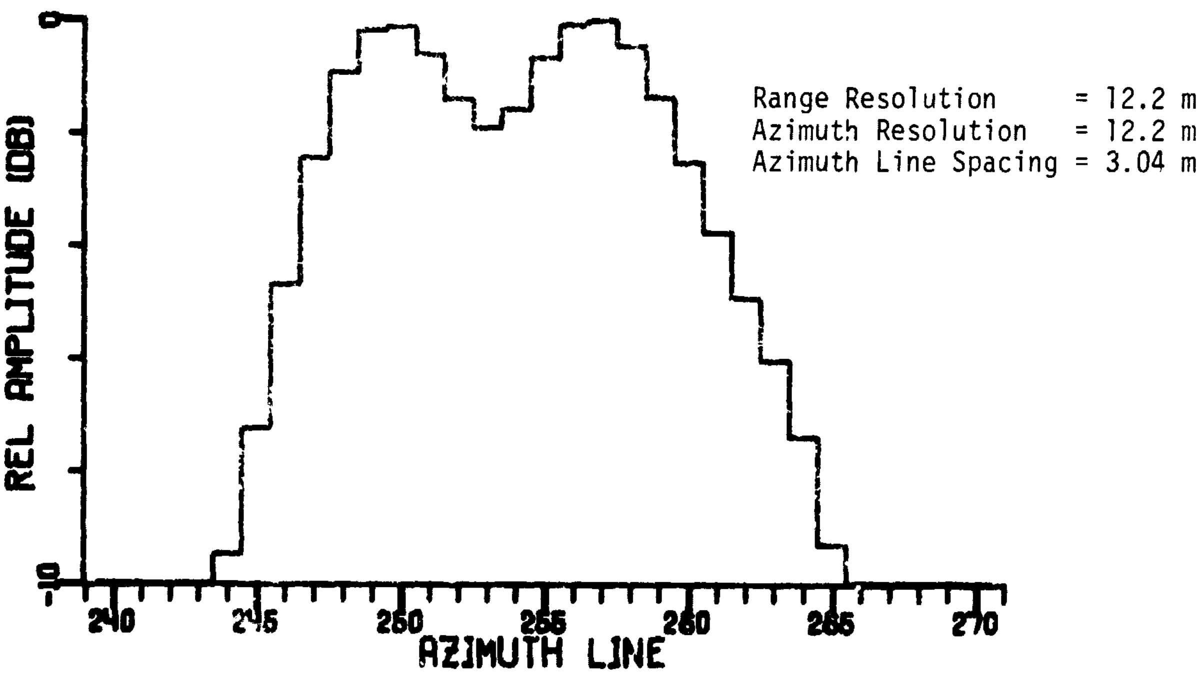
B. Background Roughness (Speckle)

Figure 11 is a set of photos of the area imaged on Line 1, Run 1, Table VI(a). The upper photo, Fig. 11(a), is a portion of the photographically processed image, and Fig. 11(b) is a digitally processed image. Figure 12 is a sketch of the area of uniform background



(a)

Normally Processed Corner Reflector Array, 23 m Separation



(b)

23 m Corner Reflector Array APQ-102 SAR Imagery

FIGURE 10

AZIMUTH LINE PLOTS CONTAINING 23 m SEPARATED CORNER REFLECTORS

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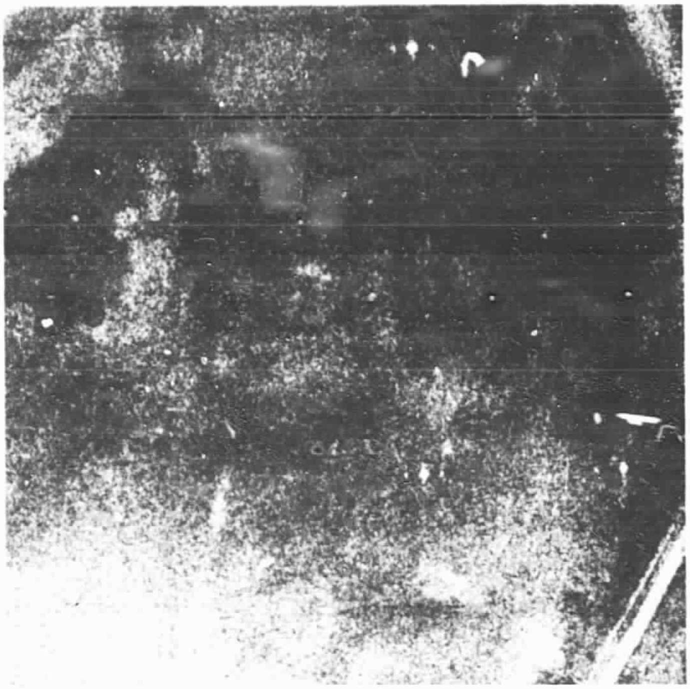
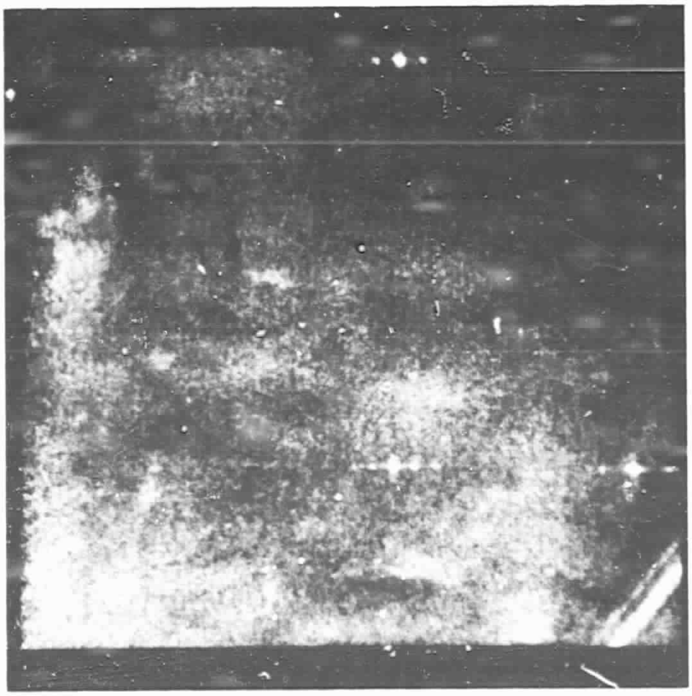


(a) Photographically Processed Image



(b) Digitally Processed Image

FIGURE 11
APQ-102 SAR IMAGERY

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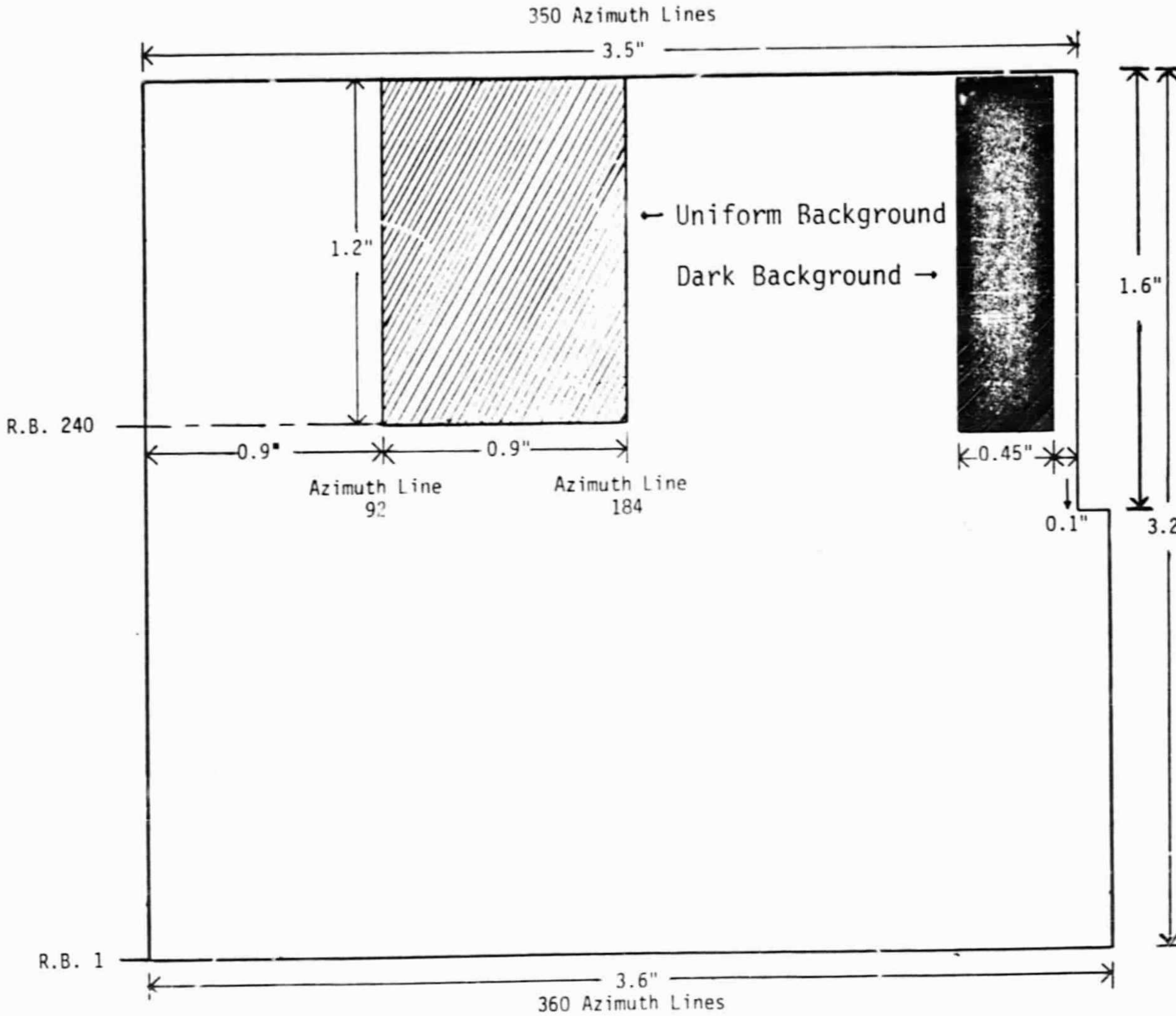

FIGURE 12

SKETCH OF UNIFORM BACKGROUND
AND DARK BACKGROUND AREA LOCATIONS

used to derive background roughness, consisting of 93 azimuth lines by 145 range bins, 13340 samples (pixels). The overlay ratio for these azimuth lines, or coherent integration ratio, was 14:1 and 15:1. The mean value was 0.671, with a standard deviation of 0.201, yielding a background roughness of about 0.3. This is low, which is due to the large amount of overlay, which effectively suppresses coherent speckle. Appendix II contains the pixel values in hexadecimal form for 16 gray shades, 1.5 dB per gray shade. One-look images of the dark area around the SE corner reflector (mean return at the noise level) and one look images from higher reflectance (mean = 0.9) homogeneous areas yield values for the background roughness from 0.9 to 1.1.

C. Dark Target Contrast

This is the ratio of the mean level of an area of low reflectance (see Fig. 12) such as a radar shadow, to the mean level of the entire image. The minimum level is limited by sidelobes and by the signal-to-noise ratio (S/N). This ratio gives an indication of the dynamic range, minimum to mean, in response to extended targets. Appendix III provides the gray levels (16) in hexadecimal values, for the dark background area of 7130 pixels.

The dark target contrast is the ratio of the mean from the dark area, 0.483, to the mean of the entire scene, 0.946. The value is 0.511, or -3 dB. This value is not particularly representative, because of the nature of the scene. Reference 5 provides data reduced from FLAMR digital images, for comparison purposes. The FLAMR system had much lower sidelobes, in general, than does the APQ-102, and the maximum dark target contrast of -25 dB is about 632 times that of the APQ-102 system.

D. Maximum Contrast (Dynamic Range)

The dynamic range of the system, for a particular image, is the ratio of the maximum filter value to the minimum (nonzero) linear value.

The scene should contain a large corner reflector or large scatterers, such as an urban area, and shadow regions. From the Line 1, Run 1 scene (Fig. 13), the maximum return is 169.74. The minimum from the statistics is not a representative value, however, because there is no overlay and the samples are not integrated at the edge of the scene. The minimum value from the portion of the image with full overlay was 0.08, giving a ratio of 2122 or 33 dB.

Figure 14 is a printout of the right side of the image, which was processed with azimuth sample spacing of one half the normal value, i.e., 12.14 m spacing. The maximum-to-minimum ratio in this image is 540 or 27 dB. It is reasonable to assume that the noise level mean value, after processing, represents the minimum, for purposes of determining dynamic range.

E. Adjacent Sample Contrast (Crispness)

This is the ratio of maximum response of a corner reflector (point scatterer) to the average of the responses in the adjacent samples. Two of the corner reflectors on the corners of the array were examined. For Line 1, Run 1 (Mode 1), with 50 nsec range sampling, the data on the SW corner reflector were:

<u>4.9</u>	<u>33.8</u>	<u>15.9</u>	Peak
<u>31.8</u>	50.0	<u>7.9</u>	Average of Adjacent Samples (underlined) = 12.64
<u>2.3</u>	<u>2.8</u>	<u>1.7</u>	

Adjacent Sample Contrast = 3.96

For Line 1, Run 2, 70 nsec range sample spacing, the data on the NE 100 cm corner reflector were:

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```
        ARRAY STATISTICS FOR 134400 POINTS.
MAXIMUM 169.7401997373,  MINIMUM .00385497698538 6
MEAN .9459447211714.  SIGMA 1.142683516601

ENTER NUMBER OF RECORDS, NO AZIMUTH LINES/RECORD
```

FIGURE 13

STATISTICS OF WILCOX PLAYA IMAGE

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Flight No. 8 (9/30/81) Mode 1, Horizontal Polarization, 50 nsec Sampling, Line 1, Run 1
Range Sample Interval: 52.5 nsec Azimuth Spacing: 12.14 m

PIXEL VALUES FOR RANGE BINS 1 TO 384
AZIMUTH LINES 351 TO 376

S 1

25 cm C.R.

351									360										370					375		
.6	.5	.6	.8	.9	.9	.7	.4	.6	.6	.6	.5	.4	.4	.4	.7	.4	.8	.9	.4	.6	.9	.8	.8	1.1	1.2	
.5	.6	.5	.7	.4	.9	.8	.4	.6	.8	.9	.7	.2	.3	.7	.5	.5	.7	.8	.5	.5	.9	1.1	.8	1.2	.8	
.3	.6	.5	.9	.4	.8	.6	.8	.8	.7	.4	.4	.4	.4	.2	.4	.6	.8	1.0	.7	.7	.5	.7	.4	.7	1.4	
.5	.4	.4	.6	.7	.8	.7	.9	1.0	.5	.5	.4	.2	.4	.4	.4	.5	.5	.6	.7	.5	.9	.7	.8	.8	1.0	450
.5	.4	.7	.9	.5	.7	.7	.8	.5	.6	.8	.3	.4	.4	.3	.4	.5	.3	.5	.6	.5	.6	.8	.8	.7	.7	
.6	.5	.5	.6	.6	.3	.3	.7	.7	.4	.6	.5	.3	.3	.4	.7	.4	.6	.3	.6	.7	.6	.7	.7	.6	.9	
.4	.5	.4	.4	.8	.3	.5	.5	.3	.8	.4	.5	.4	.4	.4	.4	.8	.5	.4	.8	.8	.9	.9	1.0	1.0	1.1	
.5	.5	.3	.5	.8	.4	.5	.8	.7	1.0	.7	.6	.8	.5	.4	.5	.4	.5	.5	.5	.6	.6	.8	.8	.7	1.0	
.3	.4	.4	.5	.9	.6	.5	.5	.4	.8	.8	.5	.5	.4	.3	.6	.5	.3	.4	.6	.5	.5	.5	.8	.4	.8	
.3	.6	.6	.8	.6	.6	.6	.6	.4	.9	.8	.6	.6	.5	.6	.3	.9	.5	.6	.9	.5	1.0	1.1	.6	.5	1.0	
.3	.3	.8	.8	.6	.4	.4	.5	.6	.8	.8	.7	1.3	.6	.4	1.0	$\boxed{2.0}$	.8	.3	.8	.8	.9	.7	.5	.7	.8	
.7	.5	.5	.4	.6	.7	.5	.4	.6	.6	.7	.5	.6	.6	.6	.7	.8	.7	.6	.6	.5	.7	.6	.8	.5	.7	
.5	.4	.3	.5	.5	.5	.8	.5	.6	.4	.6	.5	.6	.6	.4	.3	.4	.7	.7	.7	.9	.7	.9	1.0	.6	.5	
.7	.5	.4	.4	.4	.5	.6	.7	.5	.5	.5	.4	.4	.7	.4	.4	.5	.6	.5	.5	.7	.4	.7	.6	.9	.6	440
.7	.7	.4	.4	.4	.5	.5	.5	.6	.5	.5	.4	.4	.4	.6	1.0	1.4	.5	.5	.5	.7	.3	.5	.4	1.0	.4	
.5	.7	.7	.5	.4	.5	.9	.6	.5	.6	.5	.5	.2	.5	.5	.4	.4	.5	.5	.6	.7	.6	.6	.6	.5	.7	
.4	.4	.7	.6	.6	.4	.5	.6	.4	.4	.6	.6	.5	.7	.3	.3	.4	.4	.6	.5	.5	.7	.7	.6	.9	.8	
.7	.2	.5	.4	.5	.6	.4	.4	.3	.4	.6	.5	.3	.4	.4	.3	.5	.3	.3	.4	.4	.6	.7	.9	.7	.6	
.5	.6	.3	.5	.5	.4	.3	.3	.4	.4	.6	.4	.6	.5	.6	.2	.4	.3	.3	.3	.3	.6	.9	.9	.5	.4	
.6	.6	.6	.4	.4	.5	.3	.4	.4	.6	.9	.8	.7	.6	.4	.4	.3	.2	.2	.2	.3	.4	.6	.5	.3	.2	
.3	.4	.3	.3	.4	.4	.4	.3	.4	.3	.7	.9	.4	.5	.4	.3	.3	.4	.2	.3	.3	.4	.4	.4	.5	.6	
.4	.4	.5	.4	.3	.5	.6	.3	.6	.6	.4	.3	.5	.8	.6	.3	.4	.3	.3	.4	.2	.3	.5	.4	.3	.7	
.4	.2	.5	.6	.5	.6	.7	.4	.4	.3	.5	.5	.7	.8	.8	.4	.6	.3	.4	.4	.3	.3	.6	.4	.4	.7	
.4	.6	.5	.8	.5	.4	.5	.5	.4	.4	.7	.5	.5	.7	.8	.6	.7	.3	.4	.4	.6	.4	.3	.2	.6	.8	430
.7	.7	.5	.5	.4	.4	.5	.4	.7	.5	.4	.5	.6	.5	.5	.3	.5	.3	.3	.2	.4	.4	.4	.2	.4	.6	
.4	.4	.4	.5	.3	.3	.3	.4	.7	.4	.4	.5	.4	.6	.5	.5	.4	.4	.4	.3	.5	.3	.5	.4	.7	.7	
.7	.4	.5	.3	.4	.3	.3	.4	.3	.3	.6	.5	.3	.5	.8	.6	.6	.5	.3	.2	.3	.3	.4	.3	.6	.6	
.7	.3	.6	.4	.3	.5	.4	.3	.3	.6	.5	.4	.4	.5	.6	.6	.7	.7	.4	.6	.4	.4	.3	.4	.5	.4	
.5	.5	.4	.4	.4	.5	.4	.4	.3	.4	.4	.4	.3	.2	.4	.5	.6	.5	.5	.4	.5	.4	.3	.4	.6	.3	
1.0	.5	.5	.6	.4	.8	.5	.4	.3	.2	.4	.5	.5	.5	.4	.7	.4	.8	.4	.4	.4	.6	.5	.5	.4	.2	
.4	.4	.5	.6	.4	.4	.5	.4	.3	.4	.4	.4	.3	.5	.5	.5	.6	.7	.5	.3	.4	.5	.3	.5	.3	.4	
.5	.4	.4	.6	.6	.6	.3	.4	.4	.5	.4	.4	.7	.3	.4	.4	.5	.6	.3	.5	.4	.3	.3	.6	.5	.3	
.7	.3	.5	.4	.7	.5	.4	.5	.4	.6	.4	.5	.4	.4	.6	.6	.7	.5	.6	.6	.5	.4	.5	.5	.3	.3	
.7	.5	.4	.5	.5	.5	.5	.5	.3	.4	.3	.4	.4	.7	.7	.5	.4	.5	.9	.7	.4	.4	.4	.3	.3	.4	420
.6	.5	.4	.6	.4	.4	.3	.2	.4	.3	.3	.4	.6	.6	.6	.4	.3	.7	.3	.4	.5	.3	.4	.3	.5	.3	
.5	.5	.6	.7	.5	.6	.5	.5	.3	.2	.3	.7	.6	.4	.2	.4	.4	.4	.4	.9	.5	.3	.7	.4	.5	.4	
.7	.5	.5	.5	.4	.4	.4	.5	.4	.3	.3	.3	.3	.4	.4	.6	.7	.5	.7	.4	.5	.5	.6	.5	.3	.5	

W

FIGURE 14

FILTER MAGNITUDE VALUES FROM THE LINE 1, RUN 1, PROCESSED IMAGE

AS-82-1770

.8	.6	.6	.5	.5	.3	.4	.7	.5	.5	.5	.4	.5	.5	.4	.7	.5	.5	.7	.4	.4	.6	.4	.5	.5	.3	
.6	.3	.3	.6	.5	.8	.4	.6	.6	.5	.5	.4	.6	.4	.2	.3	.5	.4	.6	.7	.6	.5	.4	.6	.4	.3	
.9	.4	.5	.6	.8	.4	.5	.6	.5	.5	.3	.5	1.0	.6	.3	.4	.5	.3	.3	.4	.6	.5	.3	.4	.6	.4	
.8	.6	.4	.4	.5	.5	.5	.5	.6	.4	.4	.8	.7	.4	.5	.3	.4	.5	.4	.4	.3	.4	.3	.2	.3	.3	
.3	.5	.4	.5	.4	.8	.6	.4	.5	.5	.4	.5	.4	.3	.3	.6	.6	.8	.5	.5	.5	.3	.3	.4	.3	.6	
.5	.5	.3	.6	.5	1.0	.6	.5	.4	.6	.4	.5	.6	.8	.4	.3	.3	.4	.4	.4	.5	.5	.6	.4	.4	.3	
.3	.4	.3	.4	.4	.4	.4	.4	.9	.8	.8	.4	.5	.3	.4	.6	.6	.4	.4	.4	.4	.5	.4	.3	.3	.4	410
.4	.4	.3	.4	.6	.5	.5	.5	.5	.5	.9	.5	.4	.3	.2	.2	.6	.4	.6	.6	.4	.5	.3	.2	.4	.5	
.4	.4	.3	.4	.4	.4	.5	.5	.6	.7	.5	.3	.6	.3	.5	.5	.4	.3	.3	.4	.4	.4	.4	.3	.5	.4	
.7	.4	.4	.3	.3	.4	.7	.6	.6	.9	.5	.4	.4	.5	.3	.3	.5	.4	.3	.4	.6	.4	.7	.6	.6	.2	
.5	.4	.4	.2	.3	.4	.6	.4	.6	.8	.5	.5	.4	.5	.6	.6	.6	.4	.3	.5	.3	.3	.4	.3	.4	.3	
.5	.4	.4	.2	.5	.4	.5	.3	.6	.6	.6	.5	.4	.5	.3	.9	.5	.3	.4	.4	.3	.4	.3	.3	.4	.4	
.5	.5	.2	.4	.2	.5	.6	.5	.5	.4	.5	.4	.4	.3	.3	.3	.4	.4	.5	.3	.5	.6	.5	.5	.4	.3	
.6	.6	.4	.4	.5	.5	.6	.3	.3	.5	.6	.5	.3	.6	.6	.5	.5	.4	.5	.5	.6	.5	.6	.4	.4	.3	
.5	.5	.6	.6	.6	.5	.3	.2	.5	.5	.6	.4	.4	.4	.3	.5	.3	.4	.5	.3	.5	.5	.3	.4	.3	.4	
.8	.6	.7	.3	.5	.7	.4	.3	.4	.5	.4	.7	.5	.6	.4	.5	.4	.3	.4	.4	.5	.4	.3	.6	.7	.4	
.7	.5	.6	.5	.5	.5	.3	.4	.8	.5	.6	.7	.8	.3	.3	.4	.4	.3	.5	.3	.5	.5	.4	.6	.5	.4	400
.4	.5	.7	.5	.5	.4	.4	.7	.4	.7	.5	.3	.4	.8	.7	.5	.4	.4	.5	.3	.3	.2	.4	.5	.5	.3	
.5	.6	.5	.5	.7	.5	.4	.7	.6	.6	.5	.5	.5	.6	.4	.5	.6	.4	.4	.4	.6	.3	.4	.6	.4	.4	
.3	.3	.7	.6	.9	.8	.4	.6	.3	.4	.6	.4	.6	.6	.6	.7	.4	.4	.4	.3	.3	.5	.3	.5	.4	.5	
.5	.5	.5	.4	.8	.5	.4	.4	.5	.7	.6	.5	.6	.7	.5	.7	.3	.3	.6	.3	.4	.6	.3	.6	.5	.5	
.5	.5	.6	.5	.7	.4	.7	.8	.7	.4	.5	.3	.5	.6	.5	.7	.4	.3	.4	.6	.6	.4	.4	.4	.6	.5	
.6	.5	.4	.4	.5	.7	.9	.5	.6	.8	.3	.5	.6	.6	.6	1.0	.7	.5	.3	.6	.5	.2	.5	.3	.4	.6	
.6	.9	.6	.7	.6	.6	.6	.6	.5	.6	.4	.6	.7	.4	.4	.5	.7	.5	.4	.4	.4	.4	.5	.5	.6	.5	
.3	.7	.6	1.1	.7	.4	.6	.8	.4	.6	.6	.5	.7	.4	.4	.6	.5	.5	.4	.2	.5	.7	.4	.4	.3	.3	
.3	.5	.4	.3	.6	.7	.6	.4	.5	.7	.7	.6	1.0	.5	.5	.7	.4	.6	.7	.4	.4	.6	.3	.4	.3	.3	
.4	.6	.7	.3	.5	.5	.5	.6	.5	.6	.6	.4	.4	.8	.8	.6	.5	.4	.6	.2	.5	.7	.6	.3	.2	.7	390
.7	.5	.6	.4	.6	.5	.4	.9	.6	.6	.6	.5	.7	.8	.4	.5	.5	.8	.8	.3	.4	.6	.6	.3	.4	.6	
.6	.3	.7	.7	.4	.2	.3	.8	.5	.3	.7	.5	.6	.7	.6	.8	.4	.4	.6	.4	.5	.4	.2	.4	.4	.3	
.6	.4	.9	1.0	.6	.5	.5	.5	.7	.5	.5	.5	.9	1.0	.9	.9	.4	.4	.8	.5	.7	.4	.3	.2	.4	.5	
.6	.3	.5	.8	.6	.6	.6	.6	.5	.6	.6	.6	.5	.7	.5	.4	.3	.5	.4	.7	.6	.5	.3	.2	.4	.4	
.3	.3	.5	.6	.5	.7	.6	.5	.7	.8	.6	.5	.6	.6	.3	.4	.3	.6	.3	.3	.4	.6	.2	.4	.2	.4	
.9	.6	.4	.8	.4	.4	.4	.6	.5	.5	.5	.5	.6	.4	.3	.5	.8	.7	.7	.6	.8	.6	.4	.5	.5	.6	
.7	.7	.6	.6	.5	.3	.6	.7	.4	.7	.4	.8	.4	.4	.5	.8	.7	.5	.5	.4	.5	.5	.4	.4	.5	.4	
.4	.5	.5	.7	.5	.8	.9	.8	.6	.4	.4	.6	.5	.4	.5	.5	.4	.3	.5	.5	.7	.8	.5	.4	.2	.3	
.6	.6	.7	.7	.8	.8	.6	.5	.4	.4	.6	.6	.6	.5	.6	.6	.6	.5	.5	.9	.4	.4	.4	.6	.3	.3	
.6	.5	.4	.7	.7	.6	.6	.3	.7	.4	.6	.6	.6	.5	.5	.7	.6	.9	.6	.7	.5	.6	.5	.5	.5	.4	380
.7	.6	.5	.7	.5	.4	.5	.5	.6	.7	1.3	.5	.3	.3	.4	.7	.6	.5	.8	.6	.5	.5	.4	.3	.4	.4	
.5	.5	.6	.7	.6	.4	.4	.5	.6	.6	.5	.6	.4	.4	.4	.6	.5	.9	.6	.5	.4	.5	.6	.4	.2	.4	
.6	.8	.4	.5	.3	.5	.5	.5	.5	.7	.7	.5	.4	.4	.5	.5	.6	.7	.3	.4	.4	.4	.8	.6	.5	.4	
.6	.6	.6	.2	.4	.8	.7	.5	.8	.5	.5	.3	.5	.4	.5	.7	.9	1.0	.6	.7	.5	.3	.8	.4	.6	.3	
.4	.5	.4	.5	.4	.4	.6	.5	.3	.4	.5	.4	.6	.7	.5	.5	.8	.5	.5	.8	.5	.8	.7	.5	.5	.3	
.6	.5	.7	.6	.6	.5	.6	.6	.5	.6	.5	.5	.6	.5	.6	.4	.8	.5	.5	.5	.5	.5	.7	.6	.4	.2	

FIGURE 14 (Cont'd)

.6	.4	.3	.6	.6	.5	.7	.6	.6	.6	.9	.6	.4	.5	.4	.8	.5	.6	.4	.4	.6	.3	.4	.5	.4	.3	
.6	.5	.4	.5	.9	.4	.4	.5	.8	.6	.4	.5	.5	.6	.5	.8	.6	.9	.8	.5	.9	.7	.9	.5	.5	.3	
.4	.3	.4	.4	.6	.3	.6	.2	.5	.4	.5	.3	.3	.4	.6	.8	1.0	.8	.5	.7	.6	.6	.4	.5	.8	.4	
.3	.4	.5	.4	.5	.5	.7	.3	.6	.6	.4	.5	.6	.9	.7	.6	.6	.7	.4	.4	.2	.4	.5	.8	.8	.6	370
.4	.6	.6	.6	.7	.5	.5	.7	.4	.3	.5	.4	.9	.6	.4	.4	.4	.7	.7	.4	.4	.4	.5	.5	.4	.4	
.6	.5	.7	.7	.4	.4	.2	.5	.6	.8	.5	.3	.8	.5	.4	.2	.4	1.0	.6	.5	.5	.3	.5	.5	.6	.5	
.3	.5	.6	.7	.4	.3	.5	.7	.9	.8	.4	.4	.4	.6	.5	.4	.6	.6	.5	.7	.7	.5	.4	.3	.3	.3	
.6	.5	.4	.3	.4	.6	.5	.5	.9	.7	.4	.6	.6	.5	.7	.7	.6	.6	.7	.4	.4	.3	.4	.5	.8	.6	
.7	.8	.7	.6	.4	.5	.8	.9	.4	.5	.6	.7	.9	.5	.7	1.0	.4	.6	.5	.6	.9	.4	.4	.6	.5	.8	
.5	.4	.5	.6	.3	.4	1.0	1.1	.7	.6	.8	.9	.7	.7	.8	.7	.4	.5	.6	.6	.7	.4	.5	.5	.4	.5	
.5	.6	.6	.5	.6	.7	.5	.7	.6	.9	.7	.6	.7	.4	.5	.6	.6	.5	.6	.3	.8	.7	.4	.7	.8	.5	
.4	.5	.5	.7	.6	.8	.7	.9	.6	.6	.5	.3	.6	.4	.6	.6	.7	.6	.7	.3	.7	.6	.5	.6	.8	.3	
.4	.6	.7	.4	.5	.8	.7	.4	.5	.9	.4	.4	.6	.6	.5	.5	.8	.6	.6	.5	.5	.6	.5	.4	.8	.5	
.4	.5	.6	.6	.4	.8	.5	.5	.8	.4	.7	.6	.4	.6	.6	.5	.6	.4	.8	.4	.5	.4	.5	.4	.5	.5	360
.4	.4	.4	.4	.5	.4	.4	.6	.4	.6	.9	.6	.5	.5	.5	.6	.5	.6	.3	.6	.5	.2	.4	.5	.6	.5	
.3	.4	.5	.6	.5	.5	.5	.5	.4	.7	.5	.5	.8	.9	.7	.4	.6	.9	.5	.7	.4	.5	.5	.4	.6	.4	
.3	.3	.2	.4	.5	.3	.5	.6	.7	1.0	.8	.5	.3	.7	.5	.4	.6	.7	.6	.7	.6	.5	.5	.6	.6	.5	
.4	.2	.4	.4	.4	.5	.5	.4	.4	.6	.5	.4	.5	.6	.3	.4	.4	.6	.5	.5	.4	.4	.5	.5	.8	.5	
.5	.4	.4	.6	.6	.7	.4	.6	.4	.5	.4	.5	.5	.9	.5	.6	.5	.4	.3	.3	.6	.3	.5	.4	.2	.5	
.3	.7	.6	.6	.6	.6	.5	.8	.5	.4	.6	.4	.4	.5	.8	.5	.7	.7	.8	1.1	.5	.3	.8	.5	.4	.6	
.4	.5	.3	.4	.4	.5	.4	.7	.7	.4	.4	.3	.7	.4	.3	.2	.5	.7	.5	.6	.6	.5	.8	.6	.4	.5	
.7	.4	.5	.4	.3	.7	.5	.3	.6	.4	.4	.4	.7	.7	.3	.5	.7	.7	.5	.6	.6	.4	.5	.2	.6	.8	
.4	.5	.4	.4	.2	.3	.5	.5	.3	.6	.5	.4	.6	.6	.5	.4	.5	.7	.6	.7	.6	.6	.6	.6	.5	.4	
.4	.4	.3	.5	.5	.5	.4	.3	.5	.6	.3	.6	.5	.7	.8	.3	.7	.5	.4	.5	.7	.5	.4	.4	.4	.5	350
.4	.2	.3	.4	.3	.2	.5	.4	.5	.4	.3	.6	.4	.6	.6	.6	.7	.8	.4	.6	.4	.5	.6	.7	.6	.5	
.5	.5	.4	.5	.2	.3	.3	.3	.5	.3	.5	.4	.4	.5	.7	.7	.5	.5	.7	.6	.6	.5	.4	.6	.5	.6	
.4	.3	.4	.4	.3	.3	.5	.5	.6	.4	.2	.4	.6	.8	.8	.4	.9	1.0	.5	.6	.8	.6	.6	.7	.8	.8	
.5	.4	.5	.3	.3	.3	.7	.5	.6	.8	.7	.8	.6	.3	.9	.8	.8	.9	.4	.4	.6	.8	.6	.4	.8	.4	
.6	.4	.3	.4	.4	.5	.4	.4	.6	.4	.5	.4	.8	.4	.5	.5	.8	.9	.5	.6	.7	.6	.5	.8	.5	.4	
.4	.3	.3	.4	.3	.5	.4	.3	.5	.7	.5	.3	.6	.4	.5	.5	.7	.6	.6	.7	.6	.5	.6	.4	.7	.7	
.5	.4	.5	.5	.5	.3	.3	.3	.6	.4	.3	.5	.5	.6	.4	.4	.5	.5	.5	.6	.5	.4	.6	.7	.6	.6	
.4	.4	.4	.2	.5	.6	.6	.4	.3	.5	.5	.4	.8	.6	.4	.6	.5	.7	.5	.6	.9	.5	.4	1.0	.5	.5	
.4	.3	.4	.3	.4	.5	.3	.4	.3	.6	.6	.4	.6	.8	.6	.8	.4	.7	.9	.7	.8	.5	.4	.7	.7	.4	
.4	.3	.4	.5	.4	.6	.3	.6	.6	.5	.4	.4	.6	.9	.6	.6	.4	.5	.5	.6	.7	.2	.4	.4	.7	.5	340
.2	.3	.5	.4	.5	.6	.5	.7	.5	.7	.5	.4	.5	.8	.5	.4	.3	.4	.6	.5	1.1	.5	.5	.6	.5	.5	
.3	.4	.7	.4	.5	.4	.4	.4	.6	.5	.4	.4	.8	.6	.5	.7	.8	.8	.7	.7	.5	.2	.5	.7	.5	.6	
.4	.6	.5	.3	.6	.6	.4	.5	.7	.4	.3	.2	.5	.4	.6	.7	.8	.7	.7	.6	.3	.6	.8	.7	.5	.4	
.3	.4	.3	.4	.4	.6	.8	.4	.5	.8	.5	.4	.5	.7	.4	.5	1.0	.4	.6	.8	.3	.6	.6	.6	.4	.8	
.5	.4	.4	.4	.4	.5	.4	.4	.4	.4	.5	.5	.5	.6	.4	.5	1.0	.7	.5	.4	.4	.5	.8	.8	.5	.7	
.3	.3	.3	.3	.4	.3	.5	.6	.2	.4	.5	.5	.4	.2	.5	.6	.9	.6	.3	.4	.7	.6	1.0	.7	.5	.7	
.3	.3	.3	.5	.3	.6	.5	.8	.4	.8	.6	.6	.6	.3	.4	.5	.4	.5	.6	.6	.3	.2	.5	.5	.5	.7	
.3	.4	.5	.5	.6	.8	.4	.8	.5	.9	.4	.6	.6	.4	.5	.3	.8	.5	.5	.6	.5	.4	.3	.6	.6	.9	
.6	.5	.2	.3	.4	.6	.4	.3	.3	.6	.5	.6	.6	.6	.7	.5	.5	.7	.5	.6	.6	.6	.3	.5	.6	1.0	

FIGURE 14 (Cont'd)

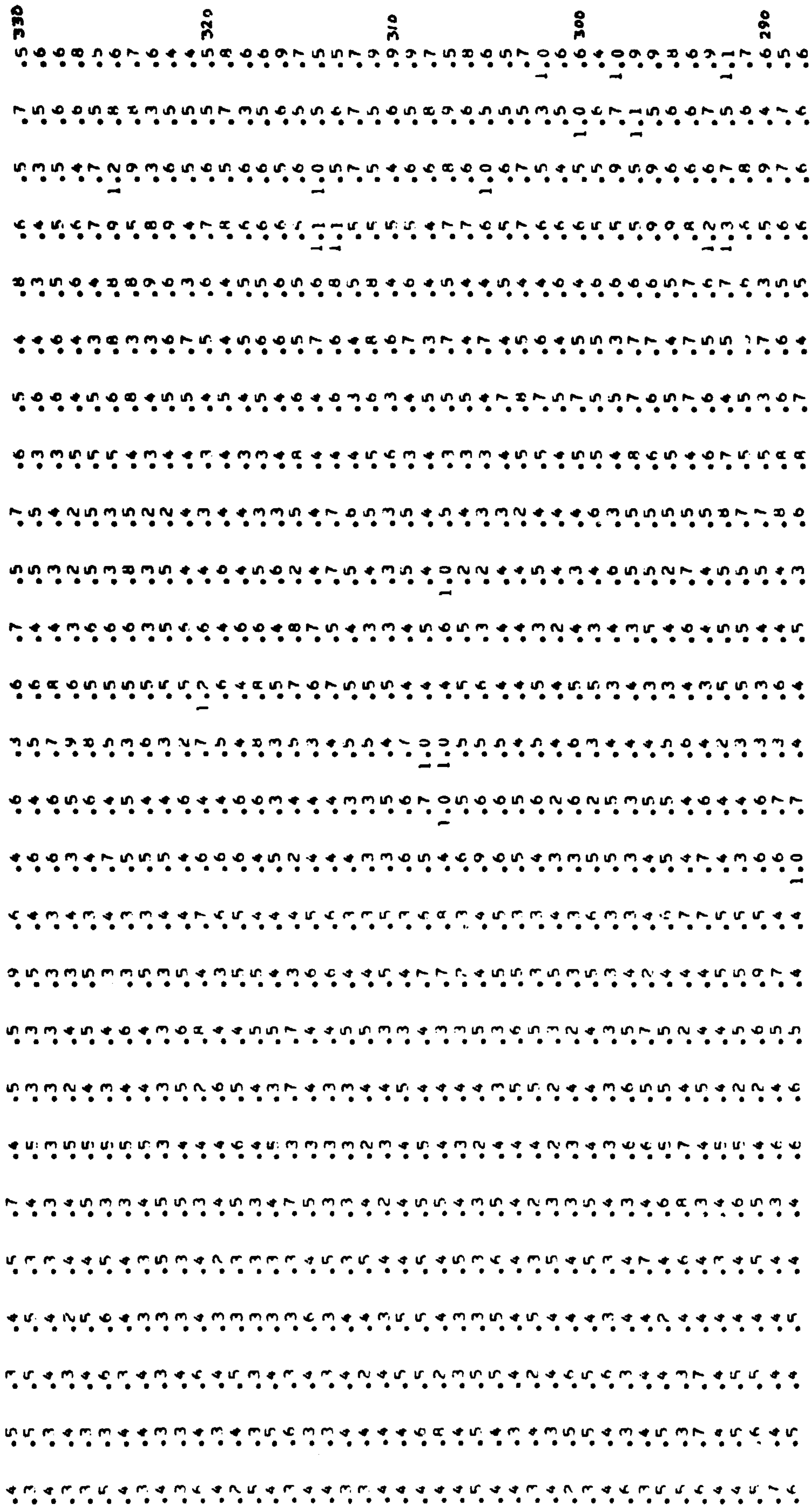

FIGURE 14 (Cont'd)

.5	.4	.3	.5	.6	.5	.4	.6	.6	.6	.5	.5	.7	.7	.6	.6	.5	.4	.5	.8	.6	.5	1.1	1.1	.7	1.0	
.4	.3	.4	.5	.8	.5	.6	.7	.5	.5	.3	.4	.6	.4	.5	.5	.7	.6	.8	.4	.5	.6	1.2	1.0	1.1	.8	
.6	.5	.6	.5	.9	.7	.5	.5	.8	.5	.5	.3	.4	.5	.6	.6	.4	.6	.6	.5	.5	.8	.5	.8	.9	1.3	
.7	.5	.4	.6	.5	.5	.7	.8	.7	.5	.4	.5	.5	.6	.3	.6	.7	.8	.6	.8	.7	.5	.7	1.2	.7	.9	
.4	.5	.6	.6	.4	.6	.4	.3	.9	.8	.6	.4	.3	.8	.6	.6	.7	.5	.4	.4	1.0	.7	.3	.4	.3	.5	
.5	.8	.6	.9	.8	.6	.5	.7	.8	.5	.8	.4	.6	.8	.5	.7	.6	.6	.4	.9	1.0	.9	.8	.4	.8	.8	
.6	.9	.5	.8	.8	.8	.7	.8	.8	.5	.6	.4	.5	.6	.5	.6	.6	.6	.4	.8	.9	.5	.3	.8	1.1	.6	
.4	.4	.7	.7	.3	.6	.3	.6	.8	.5	.5	.6	.5	.6	.6	.7	.8	.6	.7	.6	.7	.4	.6	.5	.9	.7	280
.4	.4	.8	.7	.6	.8	.6	1.0	.6	.7	.7	.6	.7	.5	.5	.7	1.0	.7	.7	.7	.5	.5	.6	.7	.7	1.2	
.6	.9	.7	.4	.5	.7	.5	.9	.4	.5	.8	.6	.4	.8	.5	.4	.8	.8	1.4	.7	.6	.9	.6	.9	.8	.8	
.8	.7	.9	1.2	.7	.8	.7	.6	.4	.5	.5	.4	.4	.8	.5	.5	.6	1.0	1.3	.8	.9	.5	.7	1.0	1.2	.7	
.7	.8	.5	.5	.5	.9	.8	.4	.5	.4	.6	.5	.5	.8	.6	.6	.5	.8	1.0	.8	.5	.5	.8	1.0	.9	.6	Min.
.7	.7	.8	.8	.5	.7	.6	.5	.5	.5	.5	.7	.5	.8	.7	.9	.3	.5	.8	.8	.8	.5	1.3	1.3	.9	0.0	Value
.5	.4	.8	.5	.6	.7	.9	.8	.8	.5	.8	.6	.6	.8	.6	.8	.5	.8	1.0	.9	.7	.7	1.2	.8	.9	.4	
.9	.8	.8	.5	.8	.5	.7	.6	.7	.4	.6	.6	.4	.8	.7	1.0	.8	.6	1.1	1.1	.6	.7	.8	1.0	1.3	1.1	
.6	.9	.6	.7	.9	.9	1.0	.5	.5	.6	.5	.4	1.1	.8	.6	.9	1.1	.9	.4	.9	.6	.6	1.1	.6	.8	1.0	
.7	.9	1.0	1.0	.6	.6	.9	.7	.6	.6	.5	.6	.6	.9	1.0	.5	.4	.7	.6	.8	1.0	1.5	1.1	1.0	.4	.9	
.5	.4	.5	1.2	.8	.5	.9	.7	.5	.3	.4	.7	.8	.5	.9	.8	.6	.5	.8	.7	.9	1.2	1.4	1.3	.9	1.0	270
.4	.8	.8	.7	.8	1.0	.4	.8	.5	1.0	.7	.4	.6	.4	1.0	.5	.3	.6	.7	1.2	.7	.5	1.1	1.1	.9	1.2	
.4	.8	1.1	.8	1.0	1.5	1.0	.6	.8	.9	.5	.6	.9	.5	.8	.8	.8	.8	.5	.9	.9	.6	1.2	.9	.9	1.5	
1.0	.8	.9	1.3	.7	.8	.7	.7	.6	.6	.6	.7	1.3	.8	.7	.5	.7	.6	.7	.9	.9	.8	1.3	.7	.7	1.2	
.8	.6	.7	.5	.6	.4	.4	.6	1.0	.7	.9	.5	.7	.7	.5	.8	.4	.9	.8	.5	.9	.8	1.0	.3	.5	.8	
.6	.7	.5	.6	.6	.4	.9	.7	.4	.8	.7	.6	.6	.5	.5	.5	.4	.9	.7	.6	.7	.9	1.1	1.0	.7	.6	
.5	.5	.5	.8	.8	.5	.6	.4	.6	.7	.7	.7	.7	.5	.5	.5	.6	1.0	.6	.5	1.2	1.4	.8	.9	.6	.6	
1.1	.5	.5	.7	.7	.5	.6	.5	.5	.7	.7	.5	.8	.6	.5	.6	1.0	.8	.5	.8	1.1	.9	.9	1.2	.8	1.3	
.8	.3	.5	.8	1.1	.9	.5	.5	.4	.6	.6	.6	.9	1.1	.6	.7	1.0	1.2	.5	.4	.6	1.7	1.2	.8	.9	.9	
.8	.7	.5	.7	1.0	1.3	.4	.3	.5	.6	.7	.6	.6	.6	.6	.4	.6	.8	.8	.9	.8	1.2	1.2	1.1	.8	1.3	
.7	1.1	.9	.5	.4	.5	.8	.6	.6	.8	.4	.6	.8	.6	.6	.5	.5	.7	.4	.9	.5	1.0	1.6	.8	1.0	1.2	260
.4	.6	.6	.8	.6	.5	.4	.5	.6	.9	1.0	.7	.6	.7	.6	.3	.3	.7	.7	1.0	.5	1.2	1.8	1.0	1.4	.6	
.8	.5	.5	.7	.5	.5	.6	.6	.7	.7	1.1	.8	.6	.4	.7	.4	.5	.4	.6	.7	.8	.7	.5	.9	1.2	.7	
.5	.4	.5	.4	.5	.6	.6	.5	.7	.7	1.0	1.1	.8	.6	.6	.8	.6	.9	.7	.8	1.1	.8	1.4	1.1	1.2	.9	
.9	1.0	.7	.4	.6	.4	.6	.8	.7	.7	.4	.6	.9	.5	.3	.4	.4	.8	.6	1.0	1.0	.6	.7	1.2	1.0	1.3	
1.1	.9	.6	.8	1.3	.7	.8	.9	.6	.9	.5	.7	.9	.7	.3	.6	1.0	.7	.7	1.2	1.5	.6	.9	.9	.7	.8	
.7	.5	.6	.5	.5	.7	1.1	.8	.8	.9	.7	.6	.6	.6	.6	.5	.6	.6	.6	.8	.5	.7	.9	1.0	.8	.9	
.7	.9	.8	.7	.6	.8	.7	.6	.8	.5	.7	.6	.7	.6	.4	.4	.4	.4	.5	.7	.7	.6	.8	1.4	1.0	.8	
1.1	.7	.6	.6	.6	.7	.9	.7	.6	.4	.6	.7	.5	.5	.5	.7	.4	.3	.5	.6	.4	.6	.9	.7	.7	1.1	
.4	.5	.3	.5	.8	.9	1.2	1.0	.5	.6	.4	.9	.6	.5	.7	1.1	.6	.4	.5	.5	.6	.6	.7	.5	.9	1.1	
.8	1.0	.4	.6	.8	.6	.9	1.2	.4	.5	.7	.6	.6	.6	.5	.6	.3	.6	.3	.7	.8	.9	.6	1.0	1.0	1.3	250
.8	.6	.6	.7	.7	.5	.7	1.4	1.2	.7	.6	.4	.6	.4	.6	.7	.4	.5	.4	.5	.5	.8	.6	.5	.7	.9	
.6	.9	.7	.6	.7	.6	.6	.8	.7	.6	.6	.5	.6	.4	.7	.4	.5	.6	.5	.9	1.0	.6	1.0	1.0	.6	1.0	
.5	.8	.4	.7	.4	.5	.2	.5	.5	.7	.5	.6	.4	.4	.5	.4	1.1	.9	.8	.6	.5	.4	1.0	.8	.6	.7	
.0	.4	.6	.4	.7	.5	.4	.5	.9	1.0	.6	.7	.5	.5	.4	.6	.9	.6	.3	.8	.7	.9	.8	.9	.8	.8	
.7	.5	1.0	.5	.6	.4	.4	.7	.4	.5	.7	.4	.7	.6	.5	.2	.6	.4	.6	.6	.5	.6	1.1	.9	.7	.9	

FIGURE 14 (Cont'd)

ORIGINAL PAGE IS OF POOR QUALITY

1.0	.8	1.3	.8	.6	.5	.6	.8	.9	1.1	.6	.7	.4	.5	.4	.6	.4	.3	.6	.7	.6	.7	.7	.6	.9	.5	
.7	.6	.9	.5	.5	.8	.6	.7	.7	1.0	.9	.8	.7	.5	.6	.4	.3	.6	.7	.7	.7	.8	.5	.8	.7	.6	
.6	.5	.5	.5	.4	.8	.8	.5	.5	.8	.6	.9	.7	.6	.4	.6	.7	.8	.6	.6	.6	.8	.5	.7	.8	.6	
1.1	.5	.3	.7	.8	.5	.8	.4	.6	.5	.6	.9	.9	.4	.6	.6	.6	.7	.6	1.0	.9	.4	.6	.6	.6	.3	
.6	.4	.6	.8	.9	.5	.4	.4	.4	.4	.5	.9	.6	.8	.7	.7	.7	.5	.4	.6	.5	.6	.6	.7	.6	.5	240
.6	.6	.4	.7	.7	.7	.5	.4	.4	.5	.5	.7	.8	.5	.8	.6	.5	.7	.8	.9	.4	.4	.9	.4	.9	.8	
.8	.6	.8	.8	.8	.6	.6	.5	.5	.7	.7	.8	.6	.9	.9	.6	.5	.4	.3	.7	.6	.5	.9	.5	.6	.7	
1.2	.7	.9	.8	.6	.8	.5	.5	.6	.6	.8	.6	.4	.6	.7	.9	.3	.5	.5	.5	.5	.7	.6	.8	.7	.5	
.9	.5	.5	.8	.4	.6	.5	.5	1.0	.9	.9	.7	.3	.5	.5	.9	.7	.9	.6	.4	.9	.6	.5	.7	.4	.6	
.5	.4	.6	.7	.8	.6	.3	.3	1.1	.9	.7	.7	.9	.9	.5	.6	.7	.9	.7	.6	.5	.5	.7	.8	.8	.5	
.4	.4	.6	.3	.4	.5	.4	.7	1.3	.7	.3	.7	.6	.6	.4	1.0	.8	.5	.7	.8	.9	.9	.5	.5	.8	.7	
.6	.7	.6	.9	.6	.6	.5	.5	.9	.5	.7	.8	.7	1.1	.8	.5	.5	.7	.8	1.0	1.0	.5	.6	.8	.6	.4	
.5	.7	.4	.6	.4	.6	.8	.9	.9	.7	1.0	.7	.5	.4	.7	.9	.8	.5	.6	.7	1.0	.9	.7	.6	.6	.8	
.5	.6	.5	.5	.6	.4	1.0	1.0	.8	.7	.8	.9	.4	.4	.5	.9	.9	.8	1.0	.6	.8	.6	.7	.8	.8	.7	
.7	.7	.4	.5	.7	.4	.6	.9	.7	.5	.9	[illegible]	.7	.5	.6	.8	.6	.4	.9	.9	.6	.4	.4	.6	1.3	.4	230
.6	.7	.4	.3	.4	.5	.4	.8	.6	1.1	1.0	.7	.9	.6	.5	.6	.6	.3	.7	.5	1.1	.6	.7	.4	.6	.4	
.5	.6	.6	.8	.4	.6	.9	1.0	.8	.7	1.0	.6	.6	.5	.6	.8	.9	1.0	1.2	1.2	.7	.5	.7	.5	.8	.5	
.3	.4	.7	.4	.7	.6	.7	.7	.9	.9	.7	.8	1.0	.6	.5	.7	.7	.6	.7	.8	.5	.5	.4	.5	.6	.9	
.5	.5	.8	.6	.5	.5	.7	.8	1.0	.6	.6	.8	.5	.7	.7	.6	1.0	1.0	1.1	1.0	.8	.6	.4	.7	.9	.8	
.4	.5	.6	.5	.9	.7	.7	.7	.8	.5	.5	.4	.7	.6	.7	.7	1.0	.9	.6	.8	.9	.4	.9	.9	.6	.4	
.8	.7	1.0	.8	.3	.5	.4	.5	.8	.8	1.0	.8	.8	1.0	.8	.5	.8	.5	.6	.6	.5	.6	1.1	.9	.6	.7	
.5	.2	.4	.8	.6	.7	.5	1.0	.8	.6	.8	1.0	.9	1.2	1.0	.6	.9	.4	.6	.8	.8	.6	.5	.6	.8	.6	
.5	.5	.5	.8	.8	.8	.8	1.0	.8	.7	.4	1.2	1.0	.8	1.0	.6	.7	.4	.8	.9	.7	.7	.8	.9	1.0	.8	
.6	.6	.4	.8	.8	.5	[illegible]	.5	.3	.5	1.0	1.6	.8	.9	.6	.9	.5	.5	.8	1.2	.6	.8	.6	1.1	.9	1.2	
.6	.9	.7	.6	.6	.6	.5	.6	.6	.7	1.0	.9	.6	.8	.7	.6	.5	.7	.6	1.0	.8	.7	.7	.8	.6	1.0	220
.6	.6	.6	.7	.7	[illegible]	.6	.4	.4	1.1	.5	.6	.7	.8	.6	.4	.5	.7	.8	.5	1.1	1.2	.6	1.0	.8	.7	
1.0	.7	.6	.8	.8	1.1	1.0	.5	.4	.6	.6	.7	.7	.7	.7	.6	.7	.6	1.2	.9	.3	.8	.7	.6	.3	.9	
.7	.8	.7	.5	.6	.8	.7	.5	.6	.5	.4	.6	.9	.6	.5	.7	.9	.7	1.4	.7	.6	.5	1.2	.8	.4	.9	
.5	.4	.4	.5	.8	.5	.7	.6	1.0	.7	.4	.5	.7	.9	.6	.7	.8	.9	.9	.7	.7	1.0	.5	.5	.6	.6	
.8	.8	1.0	.5	.7	.5	.9	.5	.9	.8	.5	.7	.2	.5	.6	1.5	1.0	1.0	.7	.6	.8	1.1	.7	.6	.7	.6	
.4	.9	.7	.7	.6	.5	.5	1.1	.5	.9	.6	.4	.6	.7	.9	.7	.6	.5	.8	1.1	.5	.6	1.0	1.1	.9	.9	
.4	.6	.7	.7	.5	.6	1.1	.5	.6	.4	.9	.6	.6	.7	.8	.8	.9	1.0	1.3	.9	.4	.9	1.0	.9	1.0	.8	
.5	.4	.4	.6	.9	.5	.5	.7	1.2	1.1	.6	1.1	.6	.6	.7	.9	1.0	1.1	.7	.6	1.1	1.2	.8	.6	.8	.7	
.7	.6	.6	.6	.4	.5	.6	.7	.9	.8	.8	1.0	.5	1.0	1.0	.8	.9	1.0	.7	1.2	1.0	.8	.5	.9	.6	.6	
.8	1.0	.9	.7	.5	.6	1.2	.7	.8	.6	.5	.4	.4	.7	.8	.5	.9	1.2	.9	.7	1.2	1.4	1.0	.9	.6	.6	210
.7	.6	.5	.7	.7	.7	1.3	.7	.7	.8	.9	.4	.8	.9	1.0	.7	1.0	1.2	1.0	1.2	1.6	1.8	.7	.8	.6	.7	
.8	.8	.5	.7	.6	1.1	1.0	.6	1.0	.9	1.1	.7	.6	1.1	1.3	.9	.5	.9	.6	1.0	1.0	.8	.4	.6	.6	1.4	
.8	.5	.8	.6	.4	.6	.9	1.2	1.3	1.1	.6	.8	1.0	1.1	.9	1.1	1.1	.9	.6	.7	1.3	.7	.8	.8	1.0	.6	
.6	1.0	.8	.5	.9	.7	.9	1.0	.8	.8	.5	.5	.6	.6	.6	.5	.8	.7	.7	1.1	.8	.3	1.1	1.1	1.2	.8	
.6	.8	.6	.7	1.4	1.1	.8	.5	.5	.6	.6	.5	.4	.6	.6	.7	.8	.9	.6	.7	.8	.9	1.2	.7	.4	.6	
.6	.8	.7	1.0	.8	.5	.7	.4	.7	.6	.5	.4	.9	1.0	.9	.7	1.3	.9	1.0	.8	1.0	.8	.7	.9	.8	1.1	
.8	.7	.3	.6	.9	1.3	.8	.6	.7	.9	.7	.5	.7	.6	1.1	.9	.5	.9	.6	.5	.5	.8	.6	.5	.8	.6	
.8	.9	.7	.7	.5	.9	.8	.6	.9	.6	.7	.7	.4	.7	.8	1.1	.9	.9	.9	.7	.8	.8	.7	.6	.6	.9	

FIGURE 14 (Cont'd)

Array of 3 C.R (100 cm, 36.3 dB m²)

.6	.9	.6	.8	1.5	.9	.7	.8	1.2	.8	.8	.7	.8	1.0	.5	.8	1.1	1.4	1.2	.8	1.1	.6	.8	.9	.9	1.1	
.7	.7	.6	.6	.3	.4	1.0	.9	1.1	.8	1.1	.7	.6	1.2	1.3	1.3	.9	.7	.5	.5	.7	.8	.6	.5	.8	.8	200
1.3	.7	.8	.9	.5	.6	.6	1.1	.8	.7	1.0	.5	.9	1.3	.7	1.1	.8	.6	1.1	.9	.8	.8	.6	.7	1.0	1.1	
.5	.6	.5	.6	.5	.9	.7	.7	1.0	1.2	1.0	.8	.6	.9	1.2	.8	.5	.6	1.3	.8	.6	.6	.7	1.1	.5	.7	
1.1	1.1	.7	.6	.8	.7	.7	.8	1.2	1.2	.5	.8	.5	.8	.7	1.0	.5	.9	.9	1.4	.8	1.1	1.0	1.0	.8	.6	
.6	.5	.6	.7	.6	.8	.7	1.0	.6	.6	1.3	1.0	.6	.6	1.4	1.6	1.3	.6	.8	1.0	.6	.8	1.1	.7	.6	1.1	
.5	.5	.5	.6	.9	1.0	.6	.7	.7	.6	.6	.7	.8	1.2	.7	1.0	.9	.6	.4	.5	1.1	1.0	.6	1.0	.8	.9	
1.1	.9	.4	.5	.4	1.0	.3	.3	.7	1.1	.9	.5	.5	1.4	.7	.8	.9	.6	.8	1.2	.7	.7	1.0	1.1	.6	.8	
.8	.4	.9	.7	.3	1.2	.7	.6	.5	.3	1.0	1.3	1.0	.7	.5	.6	.5	.5	1.0	.8	.8	.6	.6	.8	.6	.8	
.8	.8	.5	.7	.9	1.0	1.1	.9	.9	1.4	.8	1.3	.6	.4	.8	1.1	.9	.4	.6	.6	.7	1.0	.8	.9	.6	.7	
.9	.6	.9	.8	.9	.3	.8	1.4	1.7	1.4	.8	.6	.9	.5	1.0	1.2	.7	.8	.7	.7	.7	.7	.7	.7	.5	1.0	
.4	.7	.8	1.0	.7	.7	.9	1.3	1.4	1.1	1.1	.8	1.0	1.1	.8	.7	.6	1.0	.9	.6	.5	.8	.5	.7	.8	.8	190
.5	.8	.6	1.3	1.0	.7	1.5	2.1	1.4	1.5	1.4	1.5	1.0	.9	.6	.9	1.1	1.7	.8	.8	.6	.5	.6	.6	.7	.7	
1.0	.7	.5	1.0	1.1	.9	1.2	1.2	1.1	1.1	1.1	1.4	.9	.5	.6	.8	.8	.9	1.1	.8	.7	.6	.3	1.0	1.2	.7	
1.6	.8	.7	1.1	2.0	1.2	.8	.9	1.3	1.0	.9	.6	.5	.9	.8	1.0	1.1	1.0	1.4	1.5	1.1	.9	.9	.6	.6	.7	
1.0	.6	.7	1.0	1.1	.8	.9	.6	2.1	1.4	1.3	.7	.9	.6	.9	.8	.8	.7	1.6	1.0	.9	.9	.7	.5	.5	.7	
.8	.8	.8	1.2	.7	.8	1.0	.9	1.0	1.9	1.4	.8	1.0	.6	.5	.8	1.0	.6	.9	1.0	1.0	.7	.9	1.0	.6	.6	
1.0	1.1	1.9	1.0	1.1	.7	1.5	1.7	2.6	3.9	3.6	.9	1.0	.9	.6	.7	.8	.7	1.0	.9	.7	.9	.9	1.2	1.7	1.0	
1.0	1.3	2.2	1.0	.7	.8	.5	1.1	5.9	5.7	2.0	.8	.9	1.3	.8	1.2	.7	1.0	1.2	.9	.7	1.0	1.1	.7	.7	.5	
1.0	.8	1.4	.9	1.5	2.6	2.6	14.5	58.4	58.4	55.[illegible]	3.4	3.2	3.1	1.2	1.2	1.3	1.4	.8	1.4	1.6	.9	.5	1.0	.9	1.4	
1.4	1.5	1.1	1.0	1.5	2.8	4.9	30.0	55.7	108.0	89.[illegible]	7.6	4.6	2.4	1.9	1.5	1.5	1.0	1.3	1.6	1.4	1.0	1.1	1.7	1.9	2.6	
1.2	.9	.7	1.3	1.3	1.1	2.2	3.6	13.6	46.2	31.2	3.2	1.6	1.4	1.4	1.5	1.1	1.4	1.0	.7	1.0	.9	.6	.9	1.4	.8	180
.9	.5	.7	1.1	.7	.8	.8	1.5	2.7	1.8	[illegible]	.8	1.0	.4	.8	1.1	1.0	1.3	1.0	.3	.9	.9	.6	.8	.9	.6	
1.2	.7	.8	1.2	.9	1.2	.7	1.4	1.8	1.8	1.3	.5	.6	.8	.9	.6	.7	.5	.5	.4	.6	.6	.4	.5	.6	.6	
1.1	.5	.7	.9	.9	1.0	.6	1.6	2.4	2.4	1.3	1.2	1.0	.8	.9	1.0	1.0	.6	.6	.8	.7	.5	.6	.5	.8	.8	
.7	.9	.9	.7	.8	.7	.7	1.5	1.3	1.6	1.8	.8	1.0	1.4	1.3	.8	.5	.6	.7	.8	.9	.8	.8	.6	.8	.8	
.5	.8	.8	.9	1.1	1.1	.6	.7	.7	.6	.6	.9	.6	1.3	.9	.3	.6	.8	.8	1.2	.5	.6	.6	.6	.3	.6	
.7	.5	.8	.6	1.4	.8	1.5	.7	1.7	1.4	1.2	1.5	1.3	1.0	.8	.8	.6	.7	.8	.7	.7	.8	.5	.6	.5	1.0	
.8	.8	.8	.9	1.1	1.0	.9	.7	1.0	1.6	1.2	.7	.7	.5	.5	.4	.4	.6	1.1	.7	.8	.6	.6	.8	.6	.7	
.5	.8	.9	1.1	1.1	.9	.9	1.3	1.4	2.3	1.6	1.5	.7	1.0	.6	.8	.7	.6	.7	.7	.8	.9	.6	.7	.5	.8	
.9	1.2	.9	.9	1.2	1.0	1.1	1.6	.7	1.6	1.6	1.2	1.0	.9	.7	.8	.5	.7	.7	.5	.4	.5	.4	1.1	.8	.5	
.7	1.3	1.1	1.1	1.4	.8	.8	1.1	1.0	1.0	1.4	1.1	1.0	.9	.8	.6	.6	.8	.5	.5	.6	.7	.6	.8	.4	.6	170
1.2	1.3	.7	.7	.9	.9	.7	1.0	1.1	.6	.7	1.2	.8	1.1	.7	.8	.5	.5	.7	.5	.4	.3	.4	.4	.4	.5	
.9	.9	.6	1.2	1.7	1.7	1.0	1.1	.9	1.5	1.3	1.5	.8	.6	.7	.8	.5	.9	.6	1.0	.6	.5	.3	.9	.7	.7	
.9	.6	.7	1.1	1.7	.8	1.1	1.1	1.2	1.4	1.0	.8	.5	.8	1.1	1.4	.7	.5	.6	.8	.8	.8	.7	.6	.6	[illegible]	
1.1	.7	.8	.7	1.3	1.0	.5	1.0	.7	.4	1.0	.7	.7	1.1	.8	1.3	1.1	.6	.5	.5	.9	.8	.8	.9	.8	.7	
.8	1.4	.5	1.0	1.3	1.1	1.5	2.5	1.3	.6	1.2	1.0	.4	.7	.6	.6	.6	.6	.7	.4	.7	.7	.7	.9	.7	.7	
.9	.7	.5	.7	1.0	1.3	1.9	1.7	1.3	.7	.6	.8	1.2	.6	.6	.8	.5	.7	.8	.7	.6	1.0	.7	1.1	.8	.9	
.7	1.2	.9	.6	1.2	1.7	1.9	.8	1.0	.9	.9	.9	.8	.8	.4	.5	.5	.4	.7	.5	.5	.6	.7	1.0	.9	.6	
1.2	1.4	1.3	1.1	1.1	1.3	1.7	1.5	1.2	1.3	1.3	.7	.3	.8	.7	.6	.7	.7	.8	.8	.7	.5	.8	.9	.7	.8	
1.1	1.7	1.3	.8	.9	.8	1.5	1.4	.9	1.4	.8	.5	.5	.6	.4	.7	.6	1.1	1.0	.6	.5	.6	.5	.8	.6	.5	
1.1	1.4	.6	.7	.8	.8	1.1	.8	1.0	1.1	.8	.5	.4	.4	.7	.9	.9	1.0	.6	.6	.7	1.0	.6	.8	.5	.7	160
.7	.7	.9	.6	.6	.7	.6	.6	.9	.7	.6	.9	.4	1.2	.7	.6	.5	.9	.8	1.0	1.2	.7	.8	.8	.8	.5	

FIGURE 14 (Cont'd)

ORIGINAL PAGE IS
OF POOR QUALITY

.4	.6	1.0	1.0	1.0	.8	1.0	1.1	1.2	.8	.7	.7	.7	.5	.7	.6	.9	1.0	.8	.9	.9	.9	1.0	.7	1.0	.8	
.4	1.1	1.5	.9	.8	.7	.8	.7	.8	.8	.5	.5	.5	.6	.8	.5	.5	1.0	.8	.6	.5	.6	.8	.7	.6	.7	
.8	.9	.9	1.1	1.1	.8	.8	.5	.6	.8	.3	.7	.7	.7	.9	1.1	1.0	.6	.4	.6	.6	.9	1.2	.7	.6	.5	
1.3	.8	.7	.8	1.1	.8	.6	.6	.6	.6	.4	.6	.6	.5	.9	.7	.7	.9	.6	.4	.7	.9	1.0	1.2	.6	.6	
.7	.9	.8	.4	.6	.5	.9	.7	.7	.5	.5	.9	.8	.3	.4	.5	.5	1.0	.6	.7	.7	.6	.7	.9	.6	.5	
.9	.5	1.2	.7	.5	.8	.8	.4	.7	.7	.7	.6	.6	.7	.9	1.0	1.1	.7	1.0	.7	.8	.9	.5	.8	.8	.7	
.4	.8	.8	.7	.8	.8	.4	.6	.5	.3	.7	.8	.9	.8	.9	.4	.7	.8	.3	.8	.9	1.0	.8	.6	.7	.4	
1.0	.8	.6	.9	1.0	1.1	.8	.9	1.2	1.3	.9	1.0	.8	.8	.7	.7	.5	.6	.4	1.1	.9	1.0	.8	.4	.5	.5	
1.4	.9	1.0	.7	1.0	.5	.9	1.0	1.4	.9	.9	.8	1.5	.8	1.0	1.0	1.0	.7	.8	1.1	.9	.9	1.1	.7	.6	.5	150
1.2	.8	1.2	1.3	1.0	.9	.9	1.2	.9	.7	.8	1.1	1.2	.6	.7	.7	.5	.8	.6	1.2	.9	.8	.6	.6	.8	.4	
.8	.9	.8	1.1	.8	.5	.7	1.2	.7	.5	.5	.6	1.1	.6	.9	.6	1.0	.4	.4	.5	.7	.7	.4	.4	.3	.4	
.4	.8	.4	1.2	1.2	.9	.8	.8	.8	.6	.7	.8	.9	.7	.8	.4	.4	.3	.7	.5	.8	.8	.5	.5	.6	.5	
1.1	.8	.5	1.1	.8	.4	.5	1.2	1.0	.9	.9	.6	.5	.4	.5	.5	.9	.5	.7	.5	.5	.8	.4	.6	.4	.4	
1.1	.6	.6	.6	1.2	.8	.7	.4	.4	.6	.6	.7	.4	.9	.7	.6	.9	1.0	1.0	.5	.7	.5	.5	.7	.6	.8	
.7	.7	1.1	.8	1.0	.8	1.2	.8	.6	.3	.4	.5	.5	.8	.5	.8	.8	.5	.7	1.0	.8	.8	.7	.6	.6	.6	
1.2	1.1	1.0	1.1	.9	.8	.6	1.1	1.2	.5	1.1	.7	.6	1.1	1.0	.6	.7	.5	.8	.5	1.0	.8	.7	.6	.9	.7	
.5	.8	1.2	1.2	1.0	.6	.7	1.1	1.1	1.0	.8	.8	.8	.6	.6	.6	1.1	.6	.6	.6	1.1	.8	.5	.6	.8	.8	
1.2	.5	1.4	1.4	1.5	1.0	1.1	.8	.6	.7	1.0	1.0	1.0	.4	.8	.6	.6	.6	.5	.7	.9	.8	.6	.5	.8	.8	
.6	.6	1.5	1.6	1.3	.8	.9	.6	.5	.7	1.0	.8	.8	.6	.4	.7	.6	.6	.9	.9	.9	.7	.6	.5	1.2	.7	140
.6	.5	.7	.8	.8	.7	.7	.4	.6	.6	1.0	.6	.6	.7	.7	.4	.6	.6	.3	.8	.7	.6	.6	.8	1.0	.5	
.9	.7	.5	.8	.6	.8	1.0	.7	.8	1.1	.7	.7	.6	.5	.6	.9	1.1	.8	.5	.5	.5	.7	.9	.6	.6	1.1	
.5	.4	.8	1.1	.8	.9	.7	.7	.5	.7	.4	.5	.7	.7	.6	.9	.8	.6	.5	.3	.8	.8	1.6	.5	.7	.8	
1.1	.8	.9	1.1	.6	.5	.6	.9	.4	.4	.6	.5	.5	.9	.9	.6	.8	.5	.4	.9	1.1	.6	.6	.5	.6	.6	
1.3	1.1	1.0	1.2	.9	.6	.8	.5	.3	.7	.8	.4	.5	.7	.7	.4	.6	.6	.6	1.0	1.0	.6	.6	.6	.8	.6	
.6	.7	1.2	.7	.7	.7	.7	1.1	.3	.4	.6	.8	.9	.8	.7	.5	1.3	1.2	.7	1.0	.5	.6	.6	.6	.6	.7	
1.1	.6	.9	1.3	1.4	.7	.6	.5	.6	.5	.5	.6	1.0	.5	.4	.4	1.5	1.1	.9	.7	.7	.7	.9	1.1	.5	.5	
.8	.8	1.0	1.2	1.2	.7	.9	.8	.6	.7	.8	.7	.8	.4	.3	.3	.8	.7	.9	1.0	.4	.5	1.1	1.0	.6	1.0	
1.1	.7	1.0	1.1	1.0	.7	.8	.5	.6	.5	.8	.6	.6	.6	1.0	.6	.9	.5	.7	.9	.6	.5	.8	.6	.6	.6	
1.3	.8	.5	.4	.7	.8	.6	.5	.6	.7	.8	.4	.6	.4	.3	.6	.7	.5	.8	.6	.5	.8	1.2	1.0	.8	.6	130
1.3	.9	.7	.6	.7	.7	.7	.5	.8	1.1	.6	.7	.8	.5	1.0	1.0	.8	.4	.9	.9	.6	.6	.8	1.2	.9	.8	
.8	.8	.6	.5	.9	.8	.4	.5	.6	.5	.7	.7	.7	.5	1.0	1.1	.6	.7	.8	.5	.8	.9	.5	.6	1.0	2.1	
.6	.9	.7	1.2	.8	.7	.5	.4	.6	.7	.6	.6	.7	.8	.7	.8	1.0	.6	.9	1.2	1.0	.5	.5	.8	2.4	2.1	
1.3	.9	1.1	.8	.6	.4	.5	.9	.8	.5	.4	.6	.6	.9	.6	1.0	.7	.7	.8	1.2	.7	.8	.7	1.4	2.1	1.1	
.9	.6	.6	.8	.9	.4	.6	.6	.4	.7	.9	.5	.9	.8	.9	.6	.5	1.0	1.2	1.1	.4	.8	.9	2.0	2.2	3.6	
.9	.6	.7	.5	.6	.8	1.0	.8	.7	.9	.7	.5	.5	.7	.7	.5	.7	1.1	.6	.5	1.0	.8	1.3	.9	1.7	2.2	
.5	.3	.7	.5	.6	.7	.8	.6	.5	.7	1.0	.7	1.2	.8	.9	.8	.9	.6	.6	.9	.8	.8	1.4	1.7	2.4	1.3	
1.4	.9	1.0	.7	.5	1.0	1.2	.7	.9	.6	.7	.7	.9	.7	1.4	.9	.8	.7	.9	.9	1.8	1.9	1.3	2.6	1.9	.9	
1.5	.9	.6	1.1	.9	.7	.7	.5	.5	.8	1.2	.9	.8	1.0	1.2	.9	.6	.8	.8	.8	1.6	1.6	2.2	1.2	.5	1.0	
.8	.5	.7	.7	.5	.7	.6	.5	.3	.5	.8	.7	.9	.7	.9	.6	.5	.8	.5	1.2	1.1	1.1	2.4	1.0	1.4	1.2	120
1.3	.4	.6	.7	.5	.5	.5	.9	.7	.7	.8	.8	.6	.9	.7	.7	.5	.8	1.5	1.4	1.6	1.3	1.0	.6	.5	.3	
1.0	.8	.8	.4	.6	1.4	.4	.6	.6	.4	.5	1.0	1.4	.9	1.2	.8	.8	1.7	2.3	2.1	1.8	1.3	.6	.8	1.5	1.0	
.7	.8	1.1	.5	.8	.6	.5	.6	.9	.9	1.0	.6	1.4	.8	.5	.8	1.0	2.2	1.9	1.8	1.1	1.0	1.0	1.1	1.2	1.6	
1.2	1.1	1.0	.7	.6	.7	.8	.7	.9	.6	.5	.5	.3	[illegible]	.9	.9	2.0	3.7	2.6	1.3	.7	.7	.9	1.1	.9	.9	

FIGURE 14 (Cont'd)

.8	1.3	1.7	.6	.7	.6	.8	1.2	.7	.7	.8	.5	.9	.9	.8	1.3	1.4	1.8	2.0	.8	.8	.6	1.2	1.7	1.1	1.4	
.5	1.1	.7	.5	.9	.7	.8	1.2	.9	.8	1.3	.7	.9	.7	.9	1.1	1.4	2.0	2.0	.5	.6	.5	1.1	1.1	.9	2.4	
.9	.7	.4	.8	.9	.8	.7	.9	1.2	.8	1.4	1.3	1.1	.8	1.1	1.7	2.3	1.1	1.1	.6	.8	1.2	1.5	1.3	2.0	2.7	
.5	.7	.7	.3	.6	.7	.7	.4	1.0	.8	.5	.6	.7	.8	1.5	2.0	1.8	.7	.9	.9	1.3	1.0	.5	1.8	3.9	2.1	
.5	.7	1.3	.7	.5	1.0	1.4	.9	.8	.9	1.1	1.3	1.2	1.5	1.4	2.5	1.3	.8	1.0	1.8	1.0	1.0	1.6	3.0	3.6	3.9	
1.2	1.0	1.0	.8	.6	.7	.7	.7	1.0	1.0	1.1	1.1	2.1	1.4	2.5	1.4	1.0	1.2	1.3	1.6	1.4	1.0	1.9	3.6	3.4	2.6	110
.5	.8	.8	.5	.6	.7	.9	1.3	.8	.6	.7	1.4	1.3	.8	1.3	.7	1.0	.9	1.6	.9	.9	1.3	2.7	3.6	3.2	7.4	
.7	.9	.7	.6	.8	1.3	1.3	.8	.7	.8	1.1	2.0	1.6	.8	.7	.8	1.2	1.3	1.3	1.2	1.4	2.5	2.6	2.8	7.6	6.9	
.6	.7	1.0	1.0	.8	1.3	1.0	.9	.9	1.1	1.1	1.5	3.6	1.8	1.4	1.5	1.8	1.3	1.4	1.0	1.6	3.5	2.2	4.8	9.6	4.8	
.5	.5	.8	.7	.8	.8	1.2	.6	.6	1.1	1.6	1.5	1.9	.8	.7	1.1	1.1	.9	.7	1.1	1.9	2.8	4.2	5.2	6.2	2.9	
1.0	.6	.6	1.4	.7	.9	.5	.6	.9	2.4	4.2	3.0	1.1	.7	1.1	.8	.8	.9	.8	4.1	3.9	4.2	7.9	5.6	3.2	2.4	
1.1	.7	.7	.9	1.5	1.1	.7	1.0	2.5	1.7	2.7	1.3	.7	.9	1.0	.8	1.3	1.3	2.2	3.8	3.3	7.0	7.2	5.7	4.3	4.1	
.7	.6	.8	.9	.9	.8	.4	1.2	2.4	3.3	1.7	.8	1.0	.7	1.1	.7	.9	2.7	2.1	3.3	3.6	7.2	5.0	2.3	3.0	3.0	
.8	1.0	.9	.9	.8	1.2	.8	1.1	2.0	1.9	1.0	1.3	1.0	1.0	1.1	.7	1.5	5.1	3.1	3.5	7.8	9.3	4.2	2.3	2.8	2.8	
1.2	.8	.9	.8	1.0	1.2	1.1	1.9	2.5	.7	1.3	1.6	1.3	1.0	.6	.6	1.7	2.8	4.3	8.1	5.9	4.3	3.7	3.3	1.4	1.4	
1.0	1.1	.7	.7	.6	1.0	1.3	2.6	1.7	1.1	1.1	1.1	.9	.7	.6	1.4	4.5	2.8	4.0	9.3	6.7	2.2	4.0	4.4	4.9	1.3	100
1.1	1.5	.8	.5	.8	.8	1.4	1.6	.9	1.4	1.2	1.0	1.0	.9	1.8	2.4	2.8	3.4	3.9	5.3	4.7	3.8	2.4	2.6	2.0	1.2	
.7	1.0	.7	.6	1.3	1.7	1.7	.9	.9	1.2	1.0	1.0	[illegible]	1.0	2.8	1.6	2.9	5.0	7.3	3.1	2.7	4.8	3.6	3.1	1.4	.7	
.9	.8	.8	1.1	2.4	1.7	.9	1.0	1.1	1.2	.9	.8	[illegible]	1.5	3.1	2.8	6.1	10.2	3.2	2.5	3.6	4.5	[illegible]	1.6	1.8	1.3	
.5	.7	1.1	1.7	1.6	.9	.8	1.0	1.4	1.2	.6	.8	1.7	2.0	2.5	3.1	7.7	5.3	2.2	2.9	[illegible]	5.6	3.0	1.1	.7	.6	
.8	.6	1.4	2.3	1.5	1.0	1.4	1.1	.8	.8	1.2	1.4	2.2	2.9	3.9	5.1	6.4	3.8	2.6	3.7	3.0	3.2	1.7	1.0	.5	.6	
1.1	1.3	3.2	2.4	.9	1.0	1.2	1.1	.9	1.4	.7	2.7	2.5	4.0	8.4	12.7	4.5	2.6	4.1	3.3	2.9	1.0	1.1	.9	.7	.7	
.9	1.4	2.4	1.8	.7	1.0	1.2	.6	.7	.8	1.1	3.2	3.4	3.4	7.2	5.3	1.1	3.9	6.2	2.5	1.4	1.1	.8	.7	1.1	1.3	
1.9	2.0	1.7	1.0	.7	1.1	1.0	.9	.6	1.1	1.4	2.4	2.7	6.8	7.0	4.6	3.2	1.7	3.6	3.0	.6	.6	1.1	1.1	1.5	1.8	
2.2	1.5	1.7	.6	1.2	1.2	1.2	1.1	1.3	1.4	2.4	2.0	4.5	6.7	3.6	3.5	3.1	2.8	3.3	2.2	1.0	1.0	.7	1.1	1.7	1.6	
2.6	1.3	.4	.9	1.7	1.5	.9	1.0	4.1	3.4	2.5	3.2	7.8	3.6	4.1	3.9	3.5	3.5	2.5	1.2	1.5	1.3	1.0	1.3	1.4	1.0	90
1.3	.6	.6	.9	1.2	1.0	1.2	[illegible]	4.7	4.2	3.4	7.4	9.4	4.7	4.0	2.9	4.2	2.3	.7	1.1	.7	1.0	1.0	.8	1.0	1.3	
1.1	.8	.7	1.5	1.0	1.1	1.6	2.7	4.2	5.3	7.1	8.5	3.2	3.6	3.3	2.6	2.2	1.9	1.3	.9	1.1	1.7	1.6	1.4	2.8	1.5	
.9	.7	1.2	1.2	.8	1.8	4.4	4.5	4.8	8.3	8.9	4.1	3.7	4.2	4.5	4.6	1.7	1.1	1.3	1.1	1.1	1.1	1.9	2.2	1.8	1.4	
1.2	.8	.9	.9	1.5	2.0	3.2	2.8	3.9	6.9	6.9	2.1	3.4	2.7	3.4	1.3	1.0	.7	1.1	1.4	1.3	2.0	1.3	.9	1.3	.4	
1.2	1.3	1.2	1.6	1.5	2.2	2.0	4.6	6.5	4.4	4.2	4.4	4.0	3.2	2.7	1.8	1.5	1.1	2.4	1.4	2.0	1.4	1.8	2.2	.9	1.7	
1.2	1.0	.5	1.3	1.8	2.5	2.7	8.8	9.8	3.6	2.1	3.9	5.0	4.6	1.6	.8	1.2	1.0	1.5	1.2	1.9	1.0	2.1	2.4	1.6	2.4	
.7	.7	1.8	3.2	3.7	6.0	8.2	9.1	4.3	3.6	3.9	2.3	4.5	2.0	1.0	1.1	.8	1.3	1.2	1.1	.8	1.2	2.1	2.5	1.7	1.7	
2.0	1.9	2.4	3.6	2.7	5.5	9.5	6.4	3.7	2.8	3.2	4.7	3.6	1.5	1.1	1.6	1.5	.8	1.2	1.7	1.6	2.0	1.8	2.1	1.8	1.1	
2.3	2.3	7.2	4.8	4.6	8.0	8.7	4.6	2.7	2.8	2.9	2.7	2.0	1.7	1.2	.7	.9	1.1	1.0	1.4	1.5	1.2	1.6	1.5	1.3	1.4	
1.5	4.1	4.0	3.3	3.5	8.7	4.9	3.3	2.9	2.0	1.9	1.2	1.3	.8	.8	.9	1.4	1.1	1.0	1.9	3.1	2.8	1.7	2.0	1.7	1.1	80
4.6	4.7	2.5	5.3	5.3	4.2	4.3	7.8	5.3	3.7	1.8	.8	1.2	1.2	1.3	1.4	1.6	1.6	1.7	1.5	2.2	1.8	1.9	2.7	2.2	1.5	
3.3	4.1	4.1	5.0	3.4	1.5	4.4	5.1	4.5	2.5	1.0	1.2	1.7	1.6	.6	1.0	1.8	1.2	1.8	1.8	.4	1.0	1.2	1.3	1.5	2.1	
3.6	4.0	7.9	6.9	4.7	5.0	5.3	4.9	2.2	1.1	.9	1.0	2.0	1.9	1.7	1.8	1.7	1.6	1.9	1.6	.8	1.6	1.7	2.2	1.6	1.9	
2.7	4.9	4.5	3.4	2.9	2.8	2.8	3.1	2.6	1.6	1.0	.7	1.4	1.4	1.4	1.3	1.4	1.2	1.7	1.1	1.3	1.1	1.0	1.5	1.5	1.3	
3.8	6.9	5.7	3.7	4.8	2.2	4.0	3.5	1.4	1.7	1.7	2.1	2.0	2.8	2.4	1.9	1.6	1.7	1.2	1.1	2.0	1.1	1.1	1.3	2.6	1.6	
12.9	13.9	5.2	3.2	2.2	1.7	2.0	1.0	1.1	1.3	1.4	2.1	1.9	2.4	2.6	2.1	.9	1.8	1.6	1.9	2.3	1.2	1.4	1.6	1.4	2.5	
12.7	7.9	3.5	2.3	3.8	4.3	1.8	2.6	2.3	1.4	2.5	2.1	2.0	1.5	1.1	1.5	1.9	1.6	1.8	2.6	2.1	1.5	2.1	2.4	1.8	2.0	

Railroad Embankment

FIGURE 14 (Cont'd)

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5.4	5.1	3.3	3.1	2.8	3.3	1.6	1.8	2.5	2.4	1.1	1.5	1.8	1.6	1.8	2.0	2.1	1.5	1.7	2.9	2.5	1.1	.8	1.9	2.0	1.8	
3.8	4.8	2.0	2.5	2.5	1.2	1.1	1.3	2.2	2.0	1.3	1.2	1.4	1.3	2.7	2.5	1.8	1.6	2.1	2.3	2.4	1.4	1.3	1.5	1.8	1.1	
3.3	3.1	2.7	2.1	1.8	1.5	1.3	2.6	2.4	1.8	1.6	1.6	1.7	1.5	1.7	2.2	2.6	2.0	.9	1.3	1.6	1.5	1.8	1.1	1.1	1.0	70

R.B.

N

STATISTICS ON PRINTED PIXELS
MAX = .10798E+03 MIN =0.2
MEAN= .88186E+00 SIGMA= .20811E+01

FIGURE 14 (Cont'd)

3.0	2.1	4.5	Peak
3.1	60.5	17.3	Average of Adjacent Samples (underlined) = 6.075
2.3	9.3	7.0	

Adjacent Sample Contrast = 9.95

For finitely sampled systems the highest recoverable spatial frequency is determined by the spatial sampling interval, and the correspondence between this highest recoverable frequency and the highest spatial frequency in the system spatial passband is what determines the value for adjacent sample contrast. For one extreme, with sampling ratios much greater than one, the adjacent sample contrast will be close to the integrated sidelobe ratio (ISLR). For the other extreme, with sampling ratios much less than one, adjacent sample contrast will approach infinity.

F. Mean Level (Brightness)

The average level of linear image data is determined by radar system gain settings, noise sources, and S/N enhancement during signal processing. For the image of Fig. 11(b) (statistics in Fig. 13), the mean level is 0.946. It may be noted that the standard deviation (SIGMA) is 1.14, due to the presence of the large point reflectors in the scene.

G. Noise Level

The noise data tape supplied by NASA/JSC was analyzed and Figs. 15 and 16 are histograms of the bipolar video samples in two different range swaths. Figure 17 gives the radar parameters for the noise recording operation. Figure 18 is a histogram of the processed (Fourier analyzed) noise data, a Rayleigh distribution, as is expected, versus the Gaussian distributions of Figs. 15 and 16. The mean value of the

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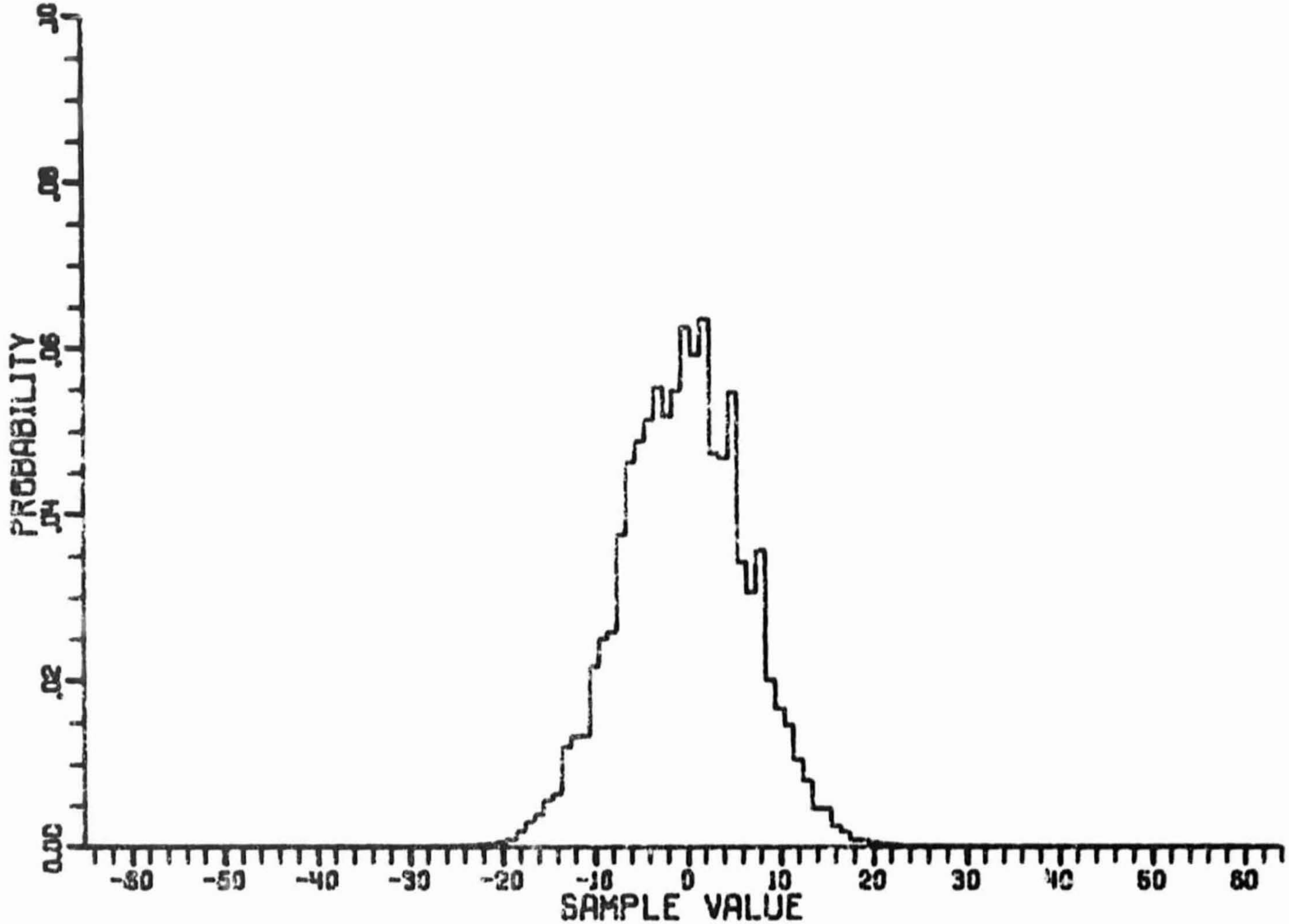

FIGURE 15

NOISE SAMPLE AMPLITUDE DISTRIBUTION, RANGE BINS 50-99

Amplitude Statistics for Pulses 1-3000 — Range Bins 50-99

150000 Points — Maximum: 56.000 — Minimum: -42.000

Mean: -.33565 — Sigma: 6.6063

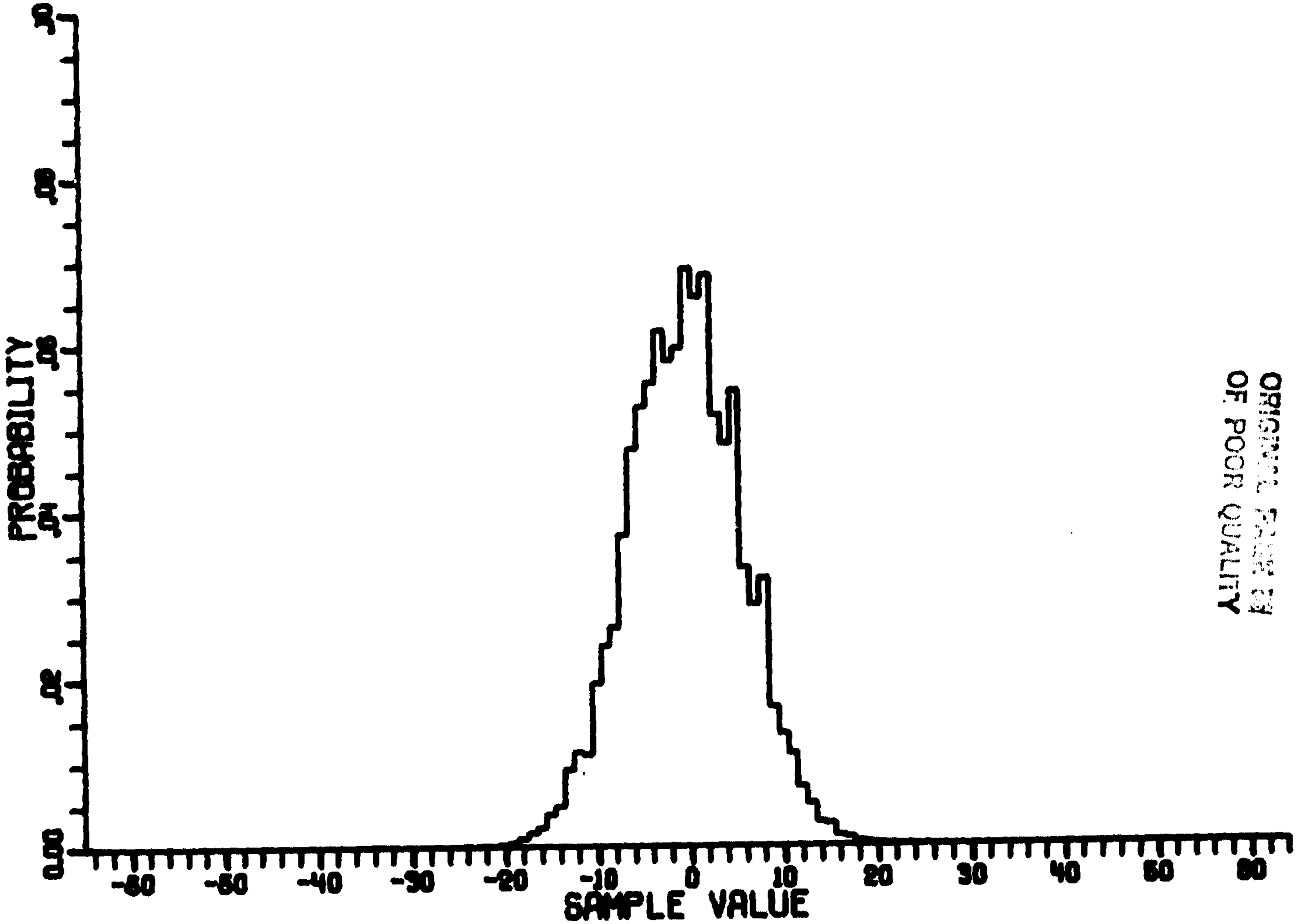

FIGURE 16

NOISE SAMPLE AMPLITUDE DISTRIBUTION, RANGE BINS 180-350

Amplitude Statistics for Pulses 1-3000 Range Bins 180-350

513000 Points

Maximum:	63.000	Minimum:	-29.000
Mean:	-.44974	Sigma:	5.9759

```
                    RADAR  PARAMETER  ENVIRONMENT  DATA
                    -----  ---------  -----------  ----

DATE (YR:MO:DAY) - 81:06:18                 TIME (HR:MIN:SEC) - 08:02:10
LATITUDE (DEG:MIN) -  29:36.7               LONGITUDE (DEG:MIN) - -095:10
RADAR ALTITUDE (FT) - 04930
HEADING (DEG) -  43.9                       DRIFT (DEG) -    0.0
ROLL (DEG) -   -.3                          PITCH (DEG) -   -1.2
GROUND SPEED (KNOTS) - 000                  VERTICAL ACCELERATION (G) - 10.09
INNER PULSE PERIOD (SEC) - .1477639300E-2   FRAME NUMBER - 002870   0054668

STATUS WORD:    VIDEO DATA VALID - YES    RPE DATA VALID - YES    CLOCK IN SYNC - YES
                VIDEO OVERRANGES IN 100 MSEC PERIOD - 0000     PARITY ERRORS IN 10 MSEC PERIOD - 00

MODE WORD:     DRMIN (SEC) - .1738584E-4     SAMPLE INTERVAL (SEC) - .10061300E-6
               DATA PRECISION - 7 BIT    RADAR MODE (1 OR 2)- 2     MODE SETTINGS VALID - YES

AUXILIARY DATA:    TEMP1, DDRS (DEG C) - 29.     TEMP2, DDRS (DEG C) - 34.     TEMP4, AGC/STC (DEG C) - 26.
                   DDRS VOLT, -5.7(V) - -5.67    DDRS VOLT, 5.(V) - 5.39       DDRS VOLT, -2.(V) - -2.45
                   AUX VOLT, 5.(V) - 5.47        AUX VOLT, -15.(V) - -15.10    REF VOLT, 10.(V) - 10.01
                   DC ALTITUDE (V) - .86468720E+1
                   AGC/MAN (V) - .0              GAIN (V) - 1.50,  SETTING (1-4) - 2
                   AUX VOLT, 15.(V) - 15.01      PRESSURE (PSIA) -  0.000
```

FIGURE 17

RADAR PARAMETER ENVIRONMENT DATA, NOISE RECORDING

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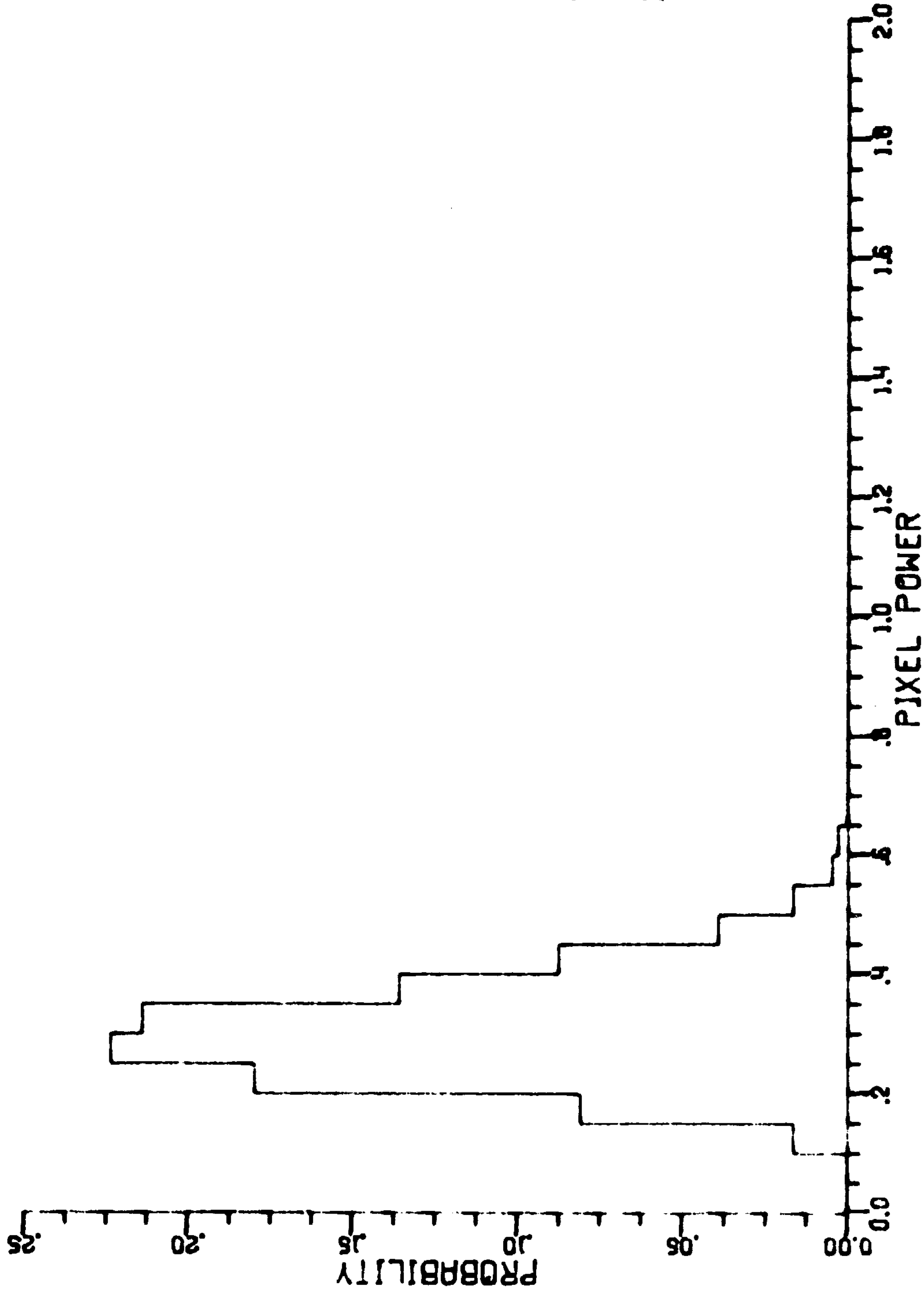

FIGURE 18
GSP PROCESSED NOISE DATA

noise is 0.21, which represents the dark background level in a radar shadow.

One of the "dark" areas in the Wilcox Playa scene was processed; it is also Rayleigh distributed and has a mean of 0.42 (see Fig. 19), and demonstrates the influence of the system noise level.

H. Geometric Fidelity (Distortion)

Due to the effects of the slant range geometry, the sample spacing in ground range decreases with increasing grazing angle. But the azimuth processor maintains a constant azimuth sample spacing equal to the range sample spacing at the patch center, therefore the pixel dimensions are greater at greater ranges. Based on the corner reflector spacings of 1600 m, and the sample spacings, a test was made of the range fidelity, using Fig. 14. From range bin 182, where two 100 cm corner reflectors were located, to range bin 443, where a 25 cm corner reflector was located, should be 3200 m. Radar altitude was 17,306.5 m; the slant range to start of sampling was 20149.8 m. The 30 cm corner reflector was at range bin 307 or an additional slant range increment of 307 X 52.5 nsec, which, when converted to range, is 2416.2 m. The slant range to the 30 cm corner reflector midway between the 100 cm and 25 cm targets was 22,566 m. The nadir angle corresponding to this is 39.92°. Calculating the ground range from the nadir, RNGNADR, to each of the range bins gives the following results: RNGNADR to RB 182 = 12895 m, RNGNADR to RB 307 = 14481 m, and RNGNADR to RB 443 = 16098 m. The ground range from RB 182 to RB 443 and RB 307 shows excellent range fidelity: RB 182 to RB 443 = 3203 m, and RB 182 to RB 307 = 1586 m.

In azimuth, a similar test was performed using the two 3-corner reflector arrays separated by 1600 m and at the same range. The more easterly array was in range bin 183, azimuth line 229, and the westerly array was in range bin 181, azimuth line 361. This difference of 131 azimuth lines, times the filter spacing of 12.6 m, gave a separation of

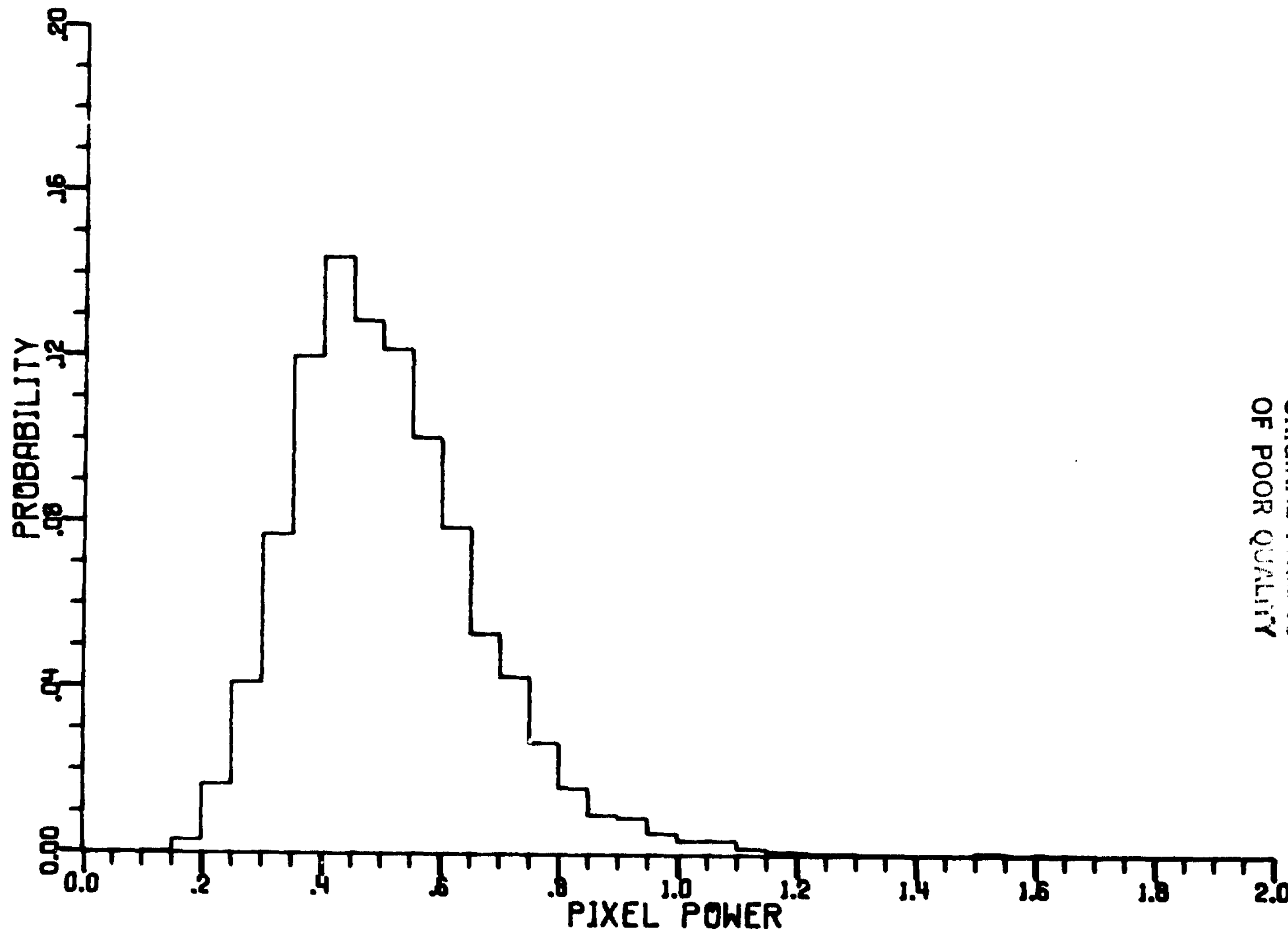

FIGURE 19
PROCESSED PIXELS FROM A "DARK" AREA OF THE WILCOX PLAYA IMAGES

1650 m. Geometric fidelity is therefore satisfactory. Appendix I provides the data used for this result.

I. Coverage

Coverage for the GSP developed by ARL:UT is 360 azimuth lines by 384 range bins, or 138,240 pixels. The SI can be varied from 50 nsec to 100 nsec in range; therefore the coverage will be governed by the pixel size, set by the 25-50 ft slant range interval, and the nadir angle, determined by the mode and the range at start of sampling (DRMIN setting). Typically, the coverage is 4500 m in azimuth x 4800 m in range, using 50 nsec SI.

VI. SYSTEM DESIGN PARAMETERS

A. Main Lobe Width

This is the spatial coverage of the -3 dB main lobe width of the impulse response, and establishes nominal system resolution. It corresponds to the distance between two scatterers of the same cross section at which mutual interference will not prevent their being resolved in the SAR image. Main lobe width is measured by observing the response to a large single corner reflector. The nominal value is that of the compressed pulse main lobe given in Fig. 1.

The image response was obtained for the SE corner reflector of the array by examining the pixel response for Line 1, Run 2. The radar parameters are given in Fig. 20. The SI was 73.5 nsec. Figures 21-28 are plots of amplitude versus azimuth line for range bins on either side of the peak response. Examination of the data indicates that the dynamic range of the radar is limiting the peak response. The plot of Fig. 33 matches the sidelobe structure of a sinx/x pulse (see Fig. 1) to the observed amplitude distribution for azimuth line 265. The background level was used to scale the data, based on data from Refs. 4 and 5.

From this plot, the combined effects of undersampling and dynamic range limitation result in a main lobe width of 85 ft, or 26 m in range. In azimuth, the 3 dB main lobe width (see Fig. 30) is one azimuth line or 17 m for the NE corner reflector. Figure 31 is the printout of data from which Fig. 30 was plotted. For this example, in which the sampling grid seems to have fallen almost precisely on the corner reflector, the 3 dB range response is also about 16 m. On the average, the width of the main lobe in azimuth and in range is 23 m. Here the ratio of the

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RADAR PARAMETER ENVIRONMENT DATA

```
DATE (YR:MO:DAY) - 81:09:30                     TIME (HR:MIN:SEC) - 17:44:01
LATITUDE (DEG:MIN) -  32:15.5                   LONGITUDE (DEG:MIN) - -109:47
RADAR ALTITUDE (FT) - 55860
HEADING (DEG) - 268.2                           DRIFT (DEG) -    1.0
ROLL (DEG) -    -.5                             PITCH (DEG) -    1.3
GROUND SPEED (KNOTS) - 418                      VERTICAL ACCELERATION (G) - 10.06
INNER PULSE PERIOD (SEC) - .6954336000E-3       FRAME NUMBER - 038561   112565H

STATUS WORD:    VIDEO DATA VALID - YES    PPE DATA VALID - YES    CLOCK IN SYNC - YES
                VIDEO OVERRANGES IN 100 MSEC PERIOD - 0000     PARITY ERRORS IN 10 MSEC PERIOD - 00

MODE WORD:    DRMIN (SEC) - .7727040E-5     SAMPLE INTERVAL (SEC) - .73500000E-7
              DATA PRECISION - 7 BIT    RADAR MODE (1 OR 2)- 1    MODE SETTINGS VALID - YES

AUXILIARY DATA:  TEMP1, DDRS (DEG C) - 33.      TEMP2, DDRS (DEG C) - 38.     TEMP4, AGC/STC (DEG C) - 43.
                 DDRS VOLT, -5.7(V) - -5.69     DDRS VOLT, 5.(V) - 5.01       DDRS VOLT, -2.(V) - -2.13
                 AUX VOLT, 5.(V) - 5.00         AUX VOLT, -15.(V) -   0.00    REF VOLT, 10.(V) -  0.00
                 DC ALTITUDE (V) - .0
                 AGC/MAN (V) - .0               GAIN (V) - 0.00,  SETTING (1-4) - 1
                 AUX VOLT, 15.(V) -  0.00       PRESSURE (PSIA) -  0.000
```

VARIABLES COMMON TO ALL RANGE BINS

```
NUMBER OF RANGE BINS SAMPLED -  512             RADAR ALTITUDE (M) - 17026.1

DELAY TO START OF STC (SEC) -  .122900E-03      SLANT RANGE TO START SAMPLING (M)- 19580.5

SLANT RANGE TO PATCH CENTER (M) - 22401.0       SLANT RANGE TO MAP START (M) - 19580.5

ANGLE FROM NADIR TO PC (DEG) - 40.53            FILTER SPACING, AZIMUTH (M) -  3.00
```

FIGURE 20

RPE DATE FOR RUN 1, LINE 1

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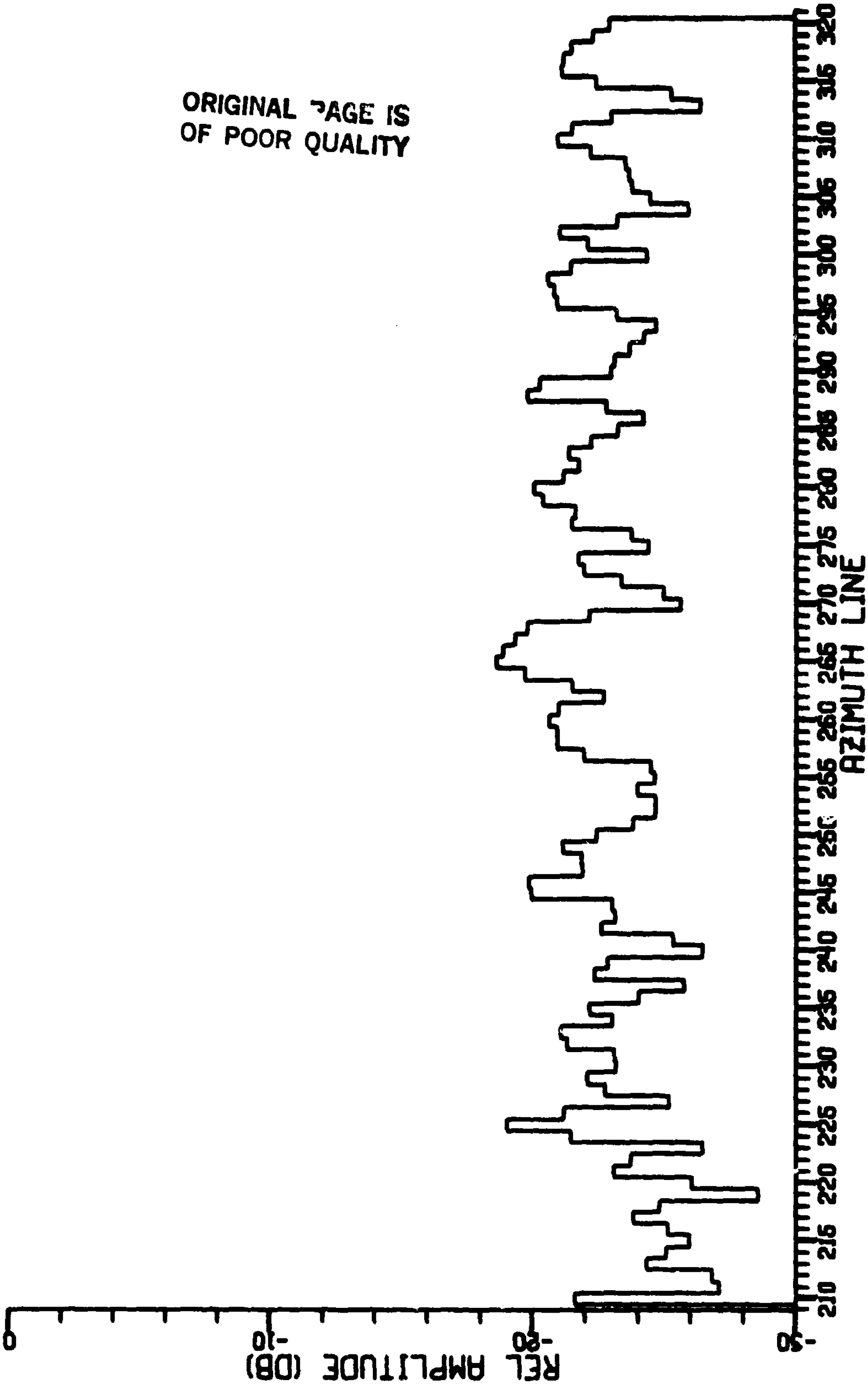

FIGURE 21

RANGE BIN 1, AZIMUTH LINE, AMPLITUDE PLOTS

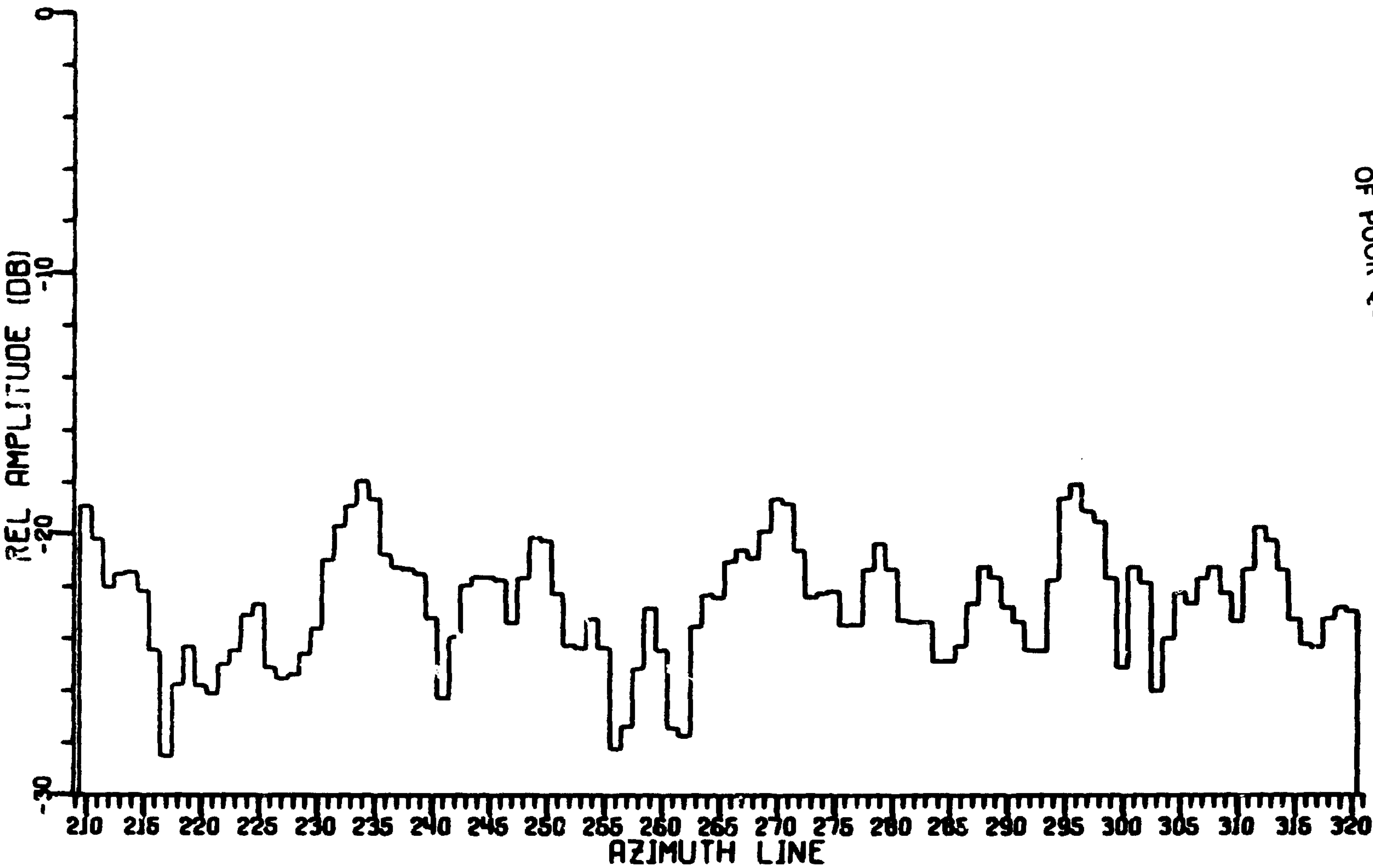

FIGURE 22

RANGE BIN 2, AZIMUTH LINE, AMPLITUDE PLOTS

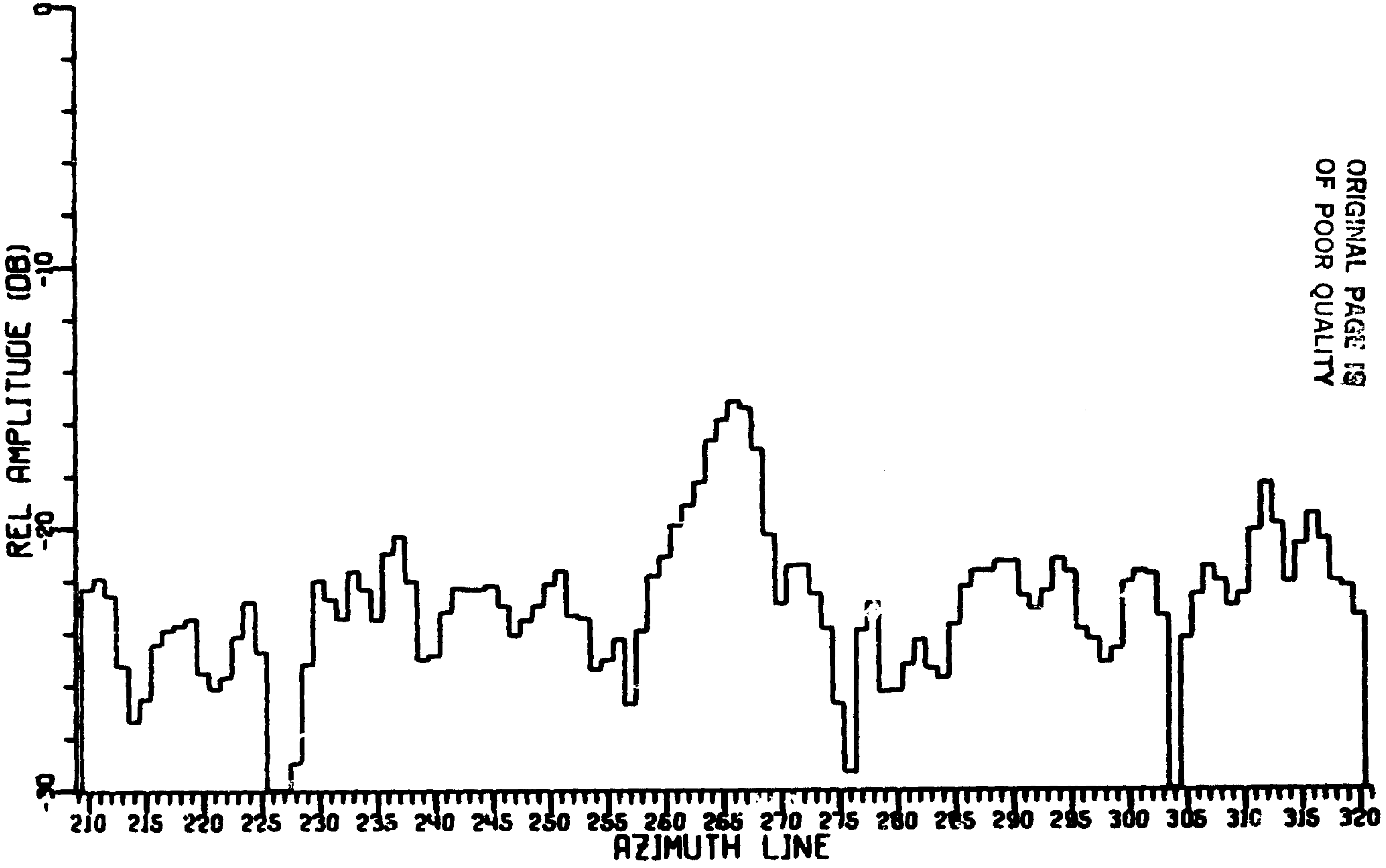

FIGURE 23

RANGE BIN 3, AZIMUTH LINE, AMPLITUDE PLOTS

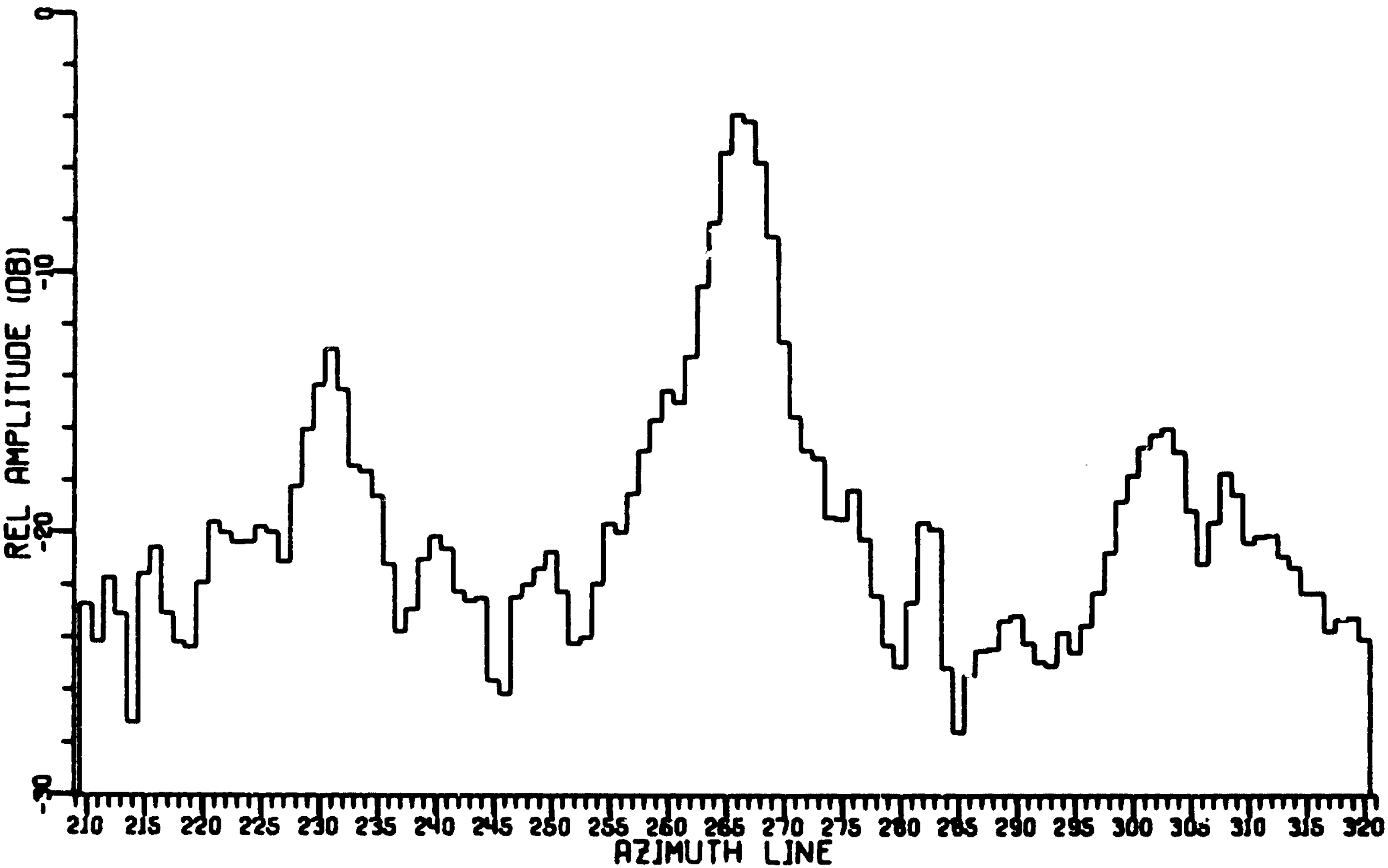

FIGURE 24

RANGE BIN 4, AZIMUTH LINE, AMPLITUDE PLOTS

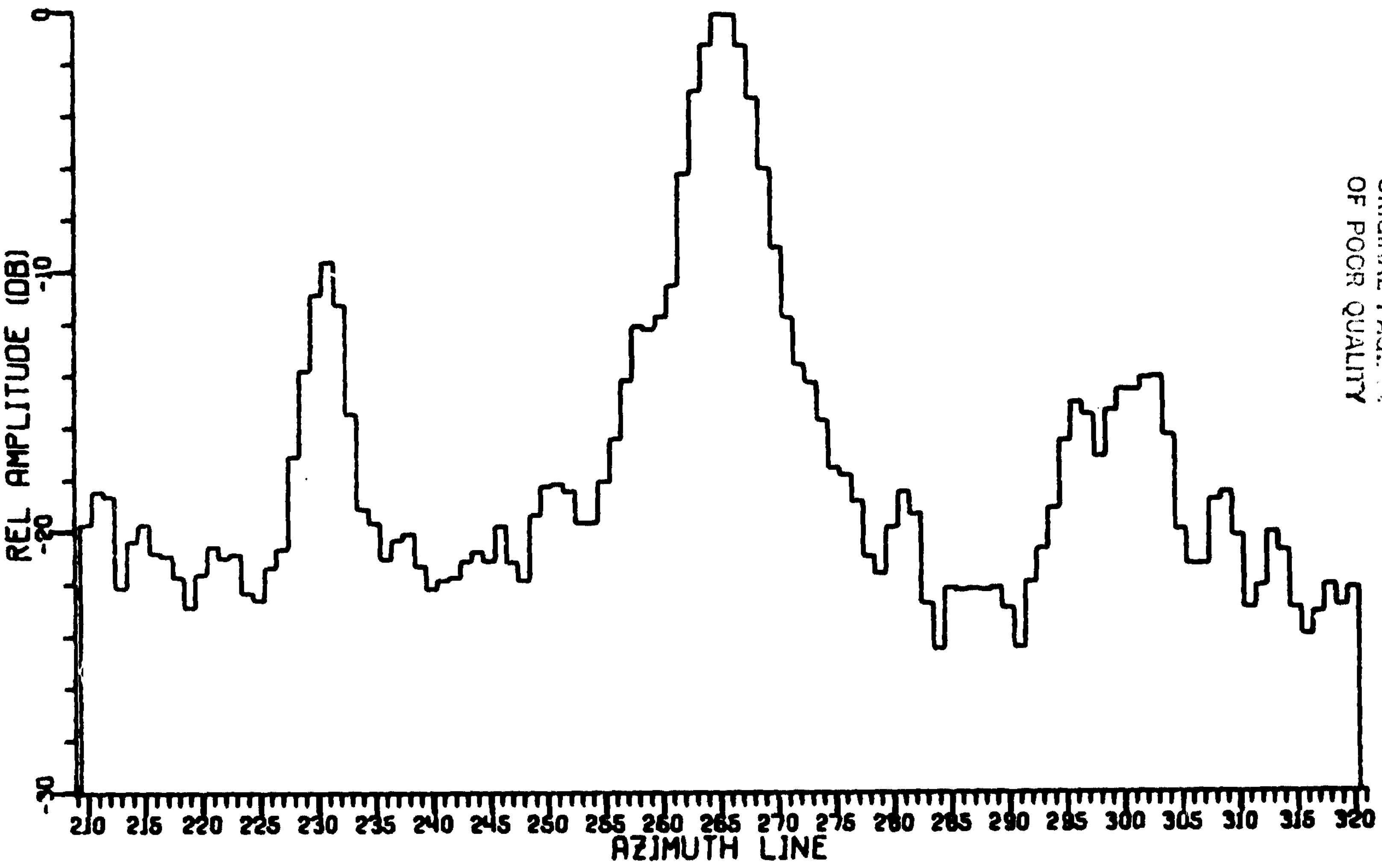

FIGURE 25

RANGE BIN 5, AZIMUTH LINE, AMPLITUDE PLOTS

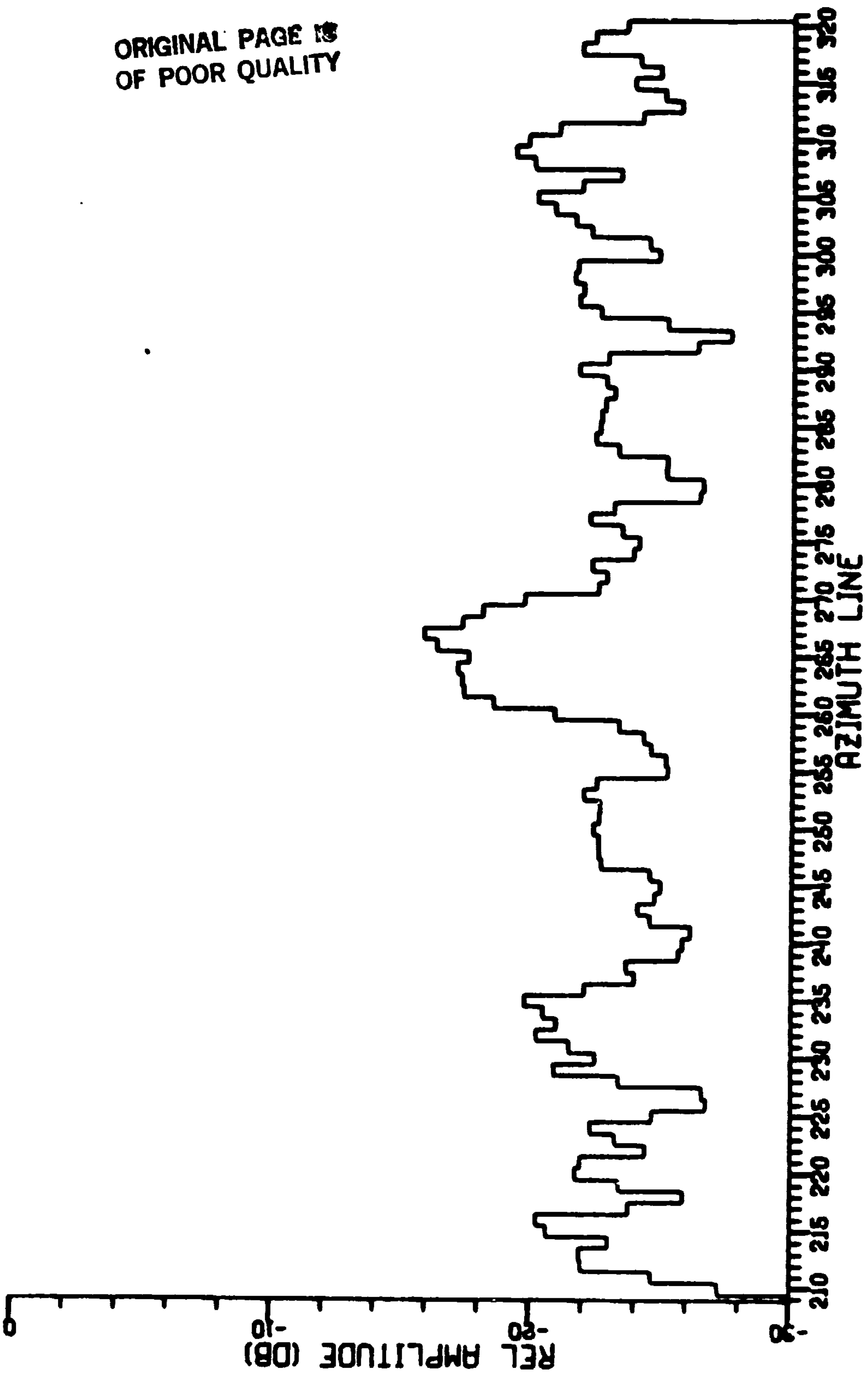

FIGURE 26

RANGE BIN 6, AZIMUTH LINE, AMPLITUDE PLOTS

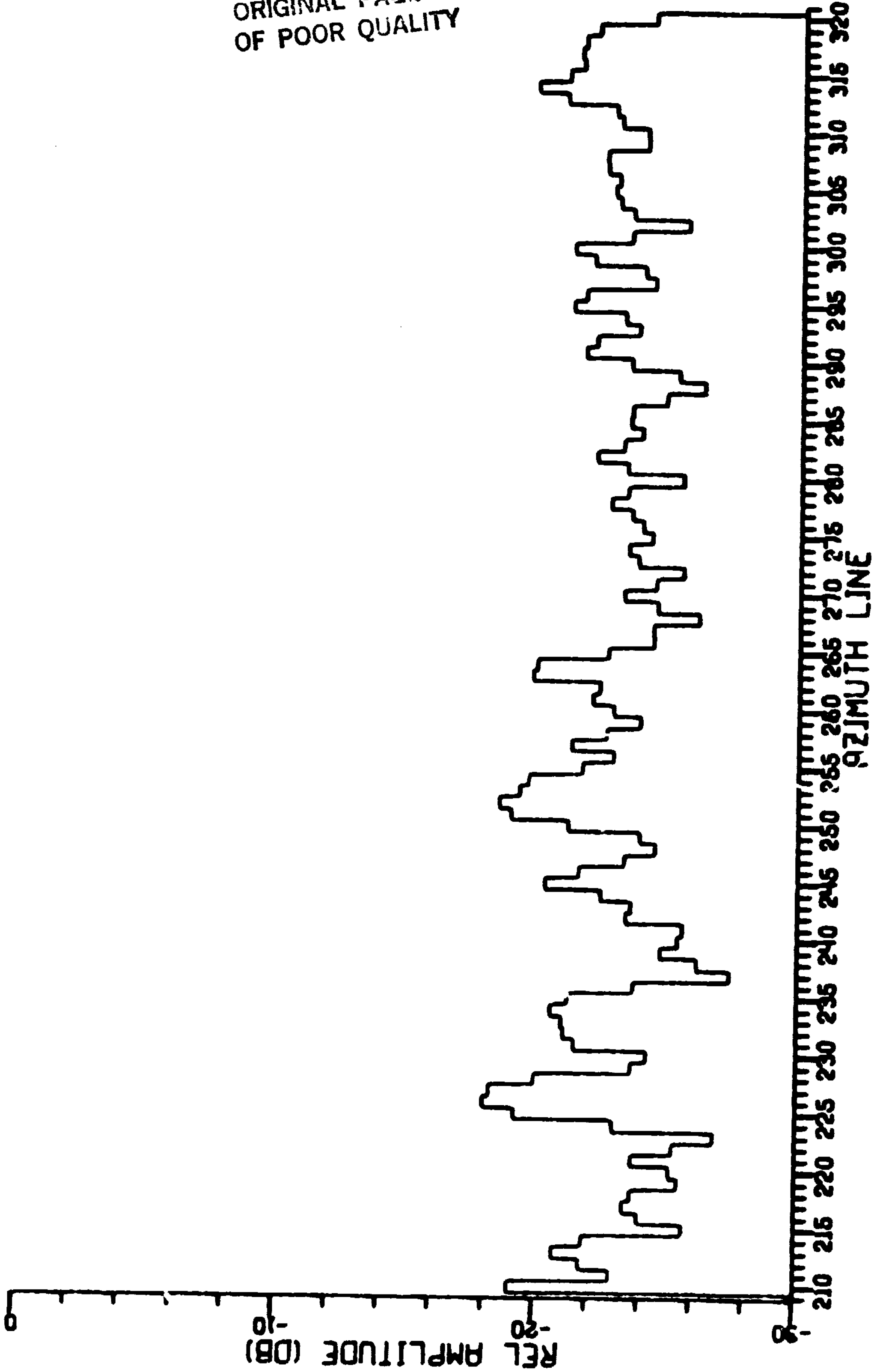

FIGURE 27

RANGE BIN 7, AZIMUTH LINE, AMPLITUDE PLOTS

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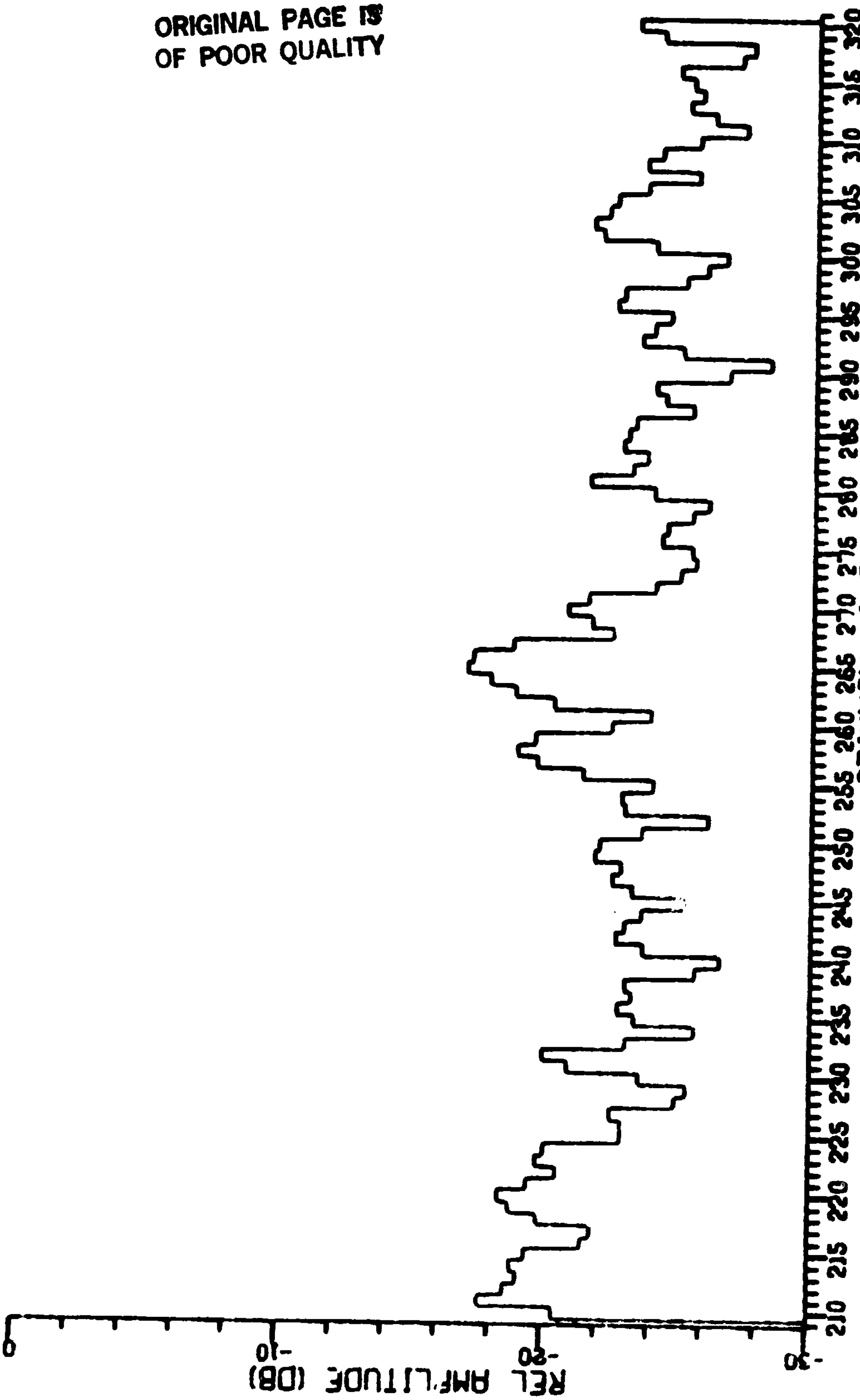

FIGURE 28

RANGE BIN 8, AZIMUTH LINE, AMPLITUDE PLOTS

AS-82-1784

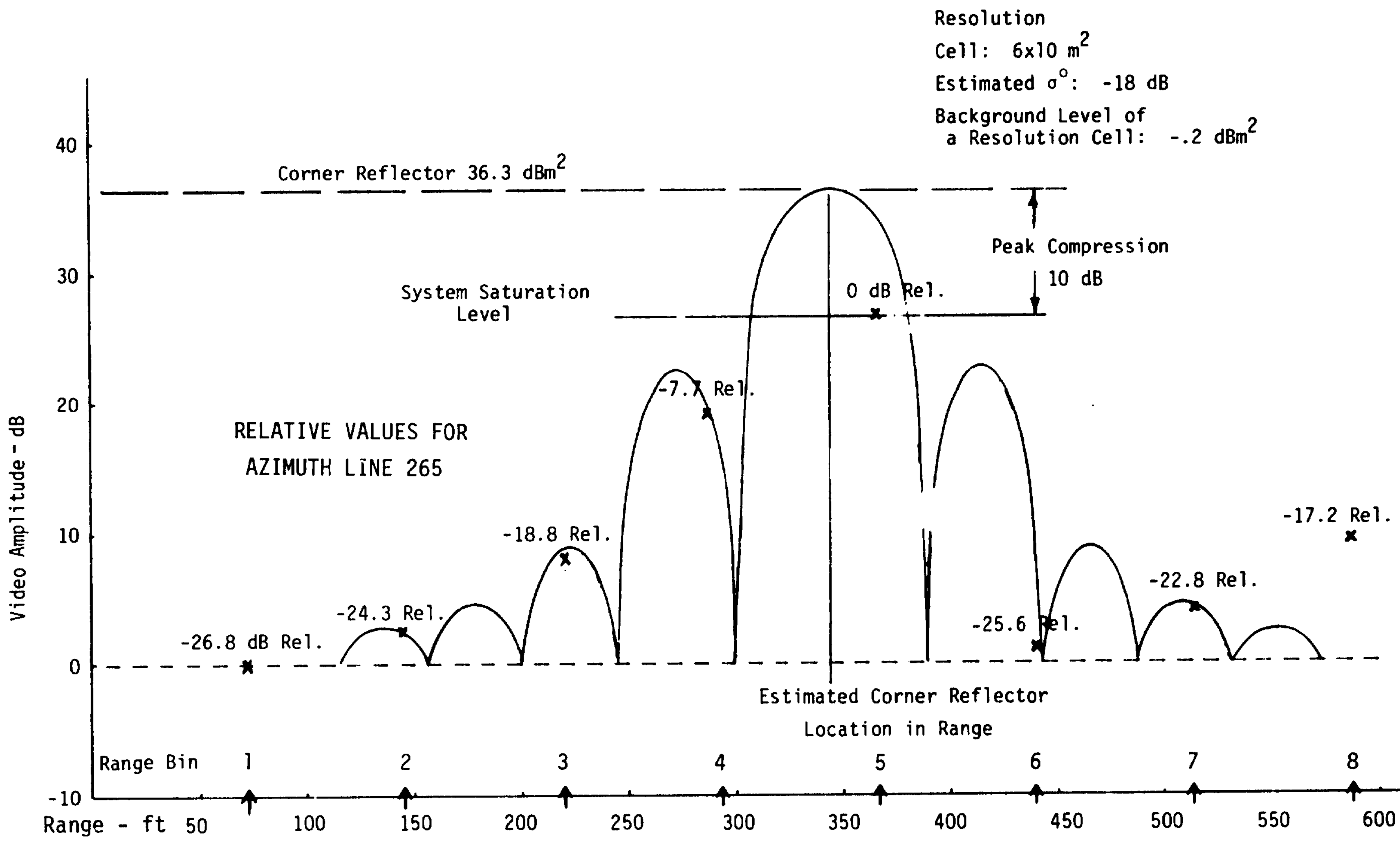

FIGURE 29
SIDELOBE DISTRIBUTION PLOT

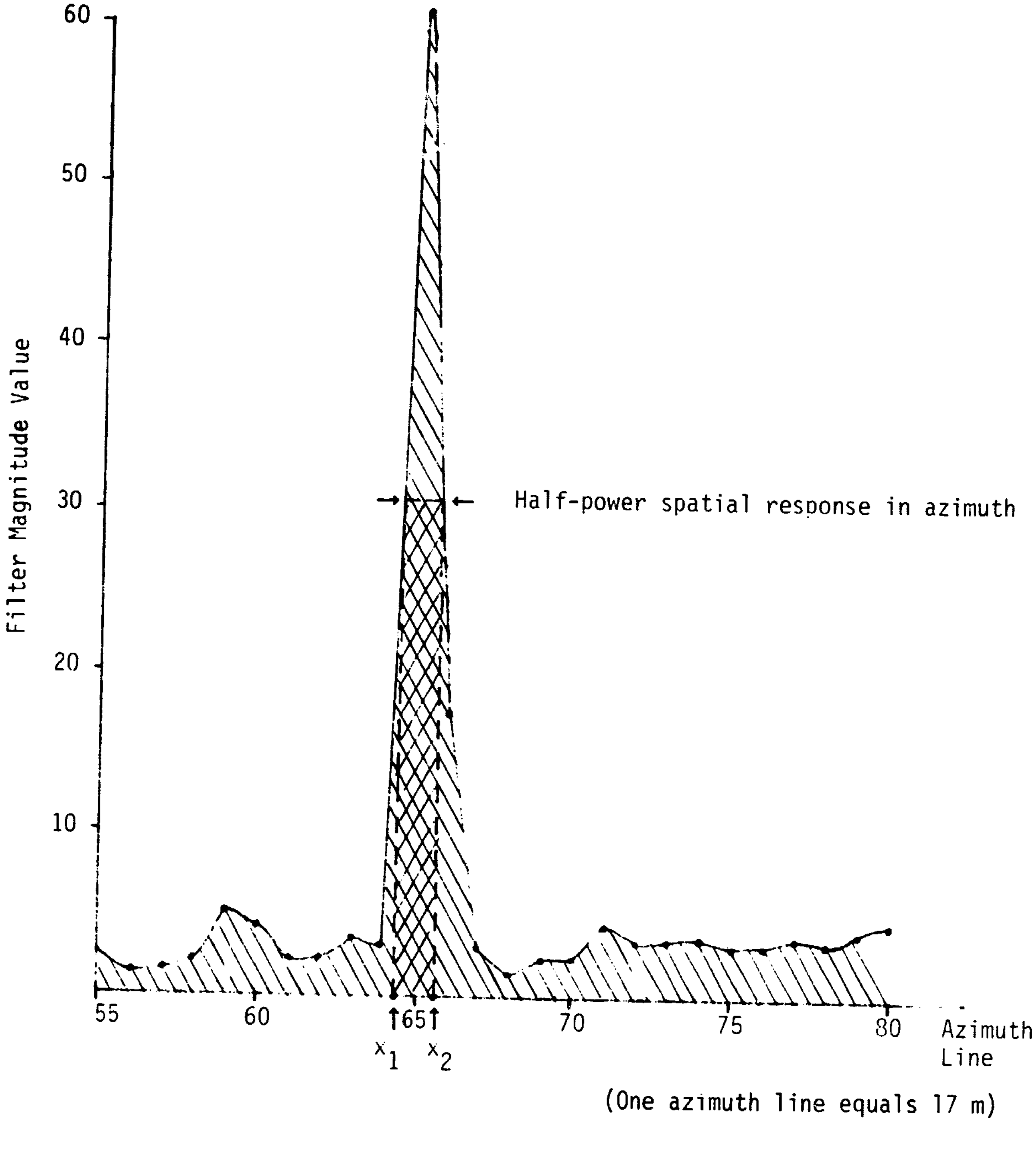

FIGURE 30
CORNER REFLECTOR AZIMUTH RESPONSE

PIXEL VALUES FOR RANGE BINS 1 TO 11
AZIMUTH LINES 55 TO 79

2.6	1.8	1.7	.9	1.5	.9	1.2	2.1	1.9	1.5	2.3	2.0	2.7	2.0	2.0	2.0	1.7	1.4	2.6	2.[illegible]	1.5	2.7	2.6	2.1	2.2
1.5	1.5	1.9	1.7	2.6	2.4	1.7	2.2	2.4	3.6	2.5	1.4	2.2	2.4	3.2	2.1	1.8	2.8	2.7	1.[illegible]	1.3	3.4	2.5	2.2	3.3
2.0	1.5	2.5	1.5	2.1	2.6	1.8	2.0	2.4	2.8	3.9	3.0	3.0	2.4	3.2	2.3	3.2	2.3	2.2	2.7	2.0	2.4	2.5	3.3	1.9
1.8	2.4	2.0	1.8	1.7	2.2	1.2	2.0	2.7	2.2	2.6	2.3	1.8	2.4	4.1	3.7	2.0	1.4	1.1	3.6	2.[illegible]	1.5	3.5	2.7	2.0
1.7	1.6	1.3	1.3	1.6	3.0	2.1	2.0	1.7	1.7	2.2	3.0	2.0	3.[illegible]	3.1	3.5	2.7	2.3	2.3	3.8	3.6	3.7	3.8	3.2	3.5
2.1	1.9	1.6	1.8	2.2	2.4	2.1	1.0	3.4	3.1	2.5	1.7	2.3	2.[illegible]	3.[illegible]	2.[illegible]	2.5	4.[illegible]	2.[illegible]	2.[illegible]	2.[illegible]	1.4	2.6	3.1	2.8
2.1	2.7	1.3	1.9	1.3	2.1	2.4	2.1	3.2	3.7	2.7	1.8	2.2	2.[illegible]	3.7	2.7	2.0	2.5	1.0	2.2	2.[illegible]	2.7	2.3	2.4	6.1
1.4	1.9	1.5	2.4	2.9	2.7	1.3	1.8	1.4	3.0	2.1	4.5	2.3	1.[illegible]	2.5	2.7	2.0	2.0	2.1	1.[illegible]	3.[illegible]	4.3	3.2	3.7	2.6
2.5	1.1	1.6	2.0	5.2	4.1	2.0	2.2	3.6	3.1	60.5	17.3	2.8	1.0	2.3	2.3	4.5	3.[illegible]	3.4	[illegible].4	3.1	3.2	3.8	3.3	4.0
1.6	1.8	1.5	2.8	3.4	3.7	2.0	4.9	1.7	2.3	9.3	7.0	2.7	1.6	4.8	3.5	3.0	3.2	2.5	2.[illegible]	1.[illegible]	2.4	2.4	4.0	5.1
2.1	1.7	2.2	2.7	4.1	3.4	2.2	3.9	5.6	2.5	2.9	2.8	1.3	3.8	4.[illegible]	1.9	1.2	3.[illegible]	3.[illegible]	[illegible]	2.[illegible]	2.2	3.4	4.2	2.2

STATISTICS ON PRINTED PIXELS
MAX = .60469E+02 MIN = .86595E+00
MEAN= .26333E+01 SIGMA= .37328E+01

FIGURE 31

FILTER MAGNITUDES FOR NE CORNER REFLECTOR maximum to the mean is 13.3 dB. The background is estimated to have a cross section σ^o of -12 dB. Applying this to pixel area of 231 m^2 (15.2 m in range x 15.2 m in azimuth), we obtain a cross section of 14.6 m^2 or 11.6 dBm^2. The difference in the radar cross section of the 100 cm corner reflector (36.3 dBm^2) and the background should therefore be about 25 dB, instead of 13.3; either the sampling point not being on the peak of the response or the radar's dynamic range limitation (or both) causes the difference of about 12 dB.

Figures 32 and 33 are plots of the SE corner reflector response. The azimuth resolution is equal to range resolution and azimuth sample spacing is equal to range sample spacing at the patch center for Fig. 33, i.e., 16.95 m. Sample spacing was reduced to 4.24 m for the same data in Fig. 32. The peak value in Fig. 33 was 107.5 and, for Fig. 32, it was 69.7, so it is evident that sample spacing can have an effect of about 3 dB on the peak response observed.

B. Flare Ratio

This parameter is related to the average brightness of flare that surrounds the image of an isolated point scatterer. It is the ratio of the average level of the impulse response function outside the main (3 dB) lobe to the average level of the entire response.

The integrated main lobe response w_t of an impulse response $R(x)$ is

$$w_t = \int_{x_1}^{x_2} R(x)\, dx \quad , \tag{1}$$

where x_1, x_2 = spatial projection 3 dB from peak response (cross-hatched area of Fig. 30). A measure of total clutter w_c is the area of the entire response function (shaded area of Fig. 30):

$$w_c = \int_{-\infty}^{\infty} R(x)\, dx \quad .$$

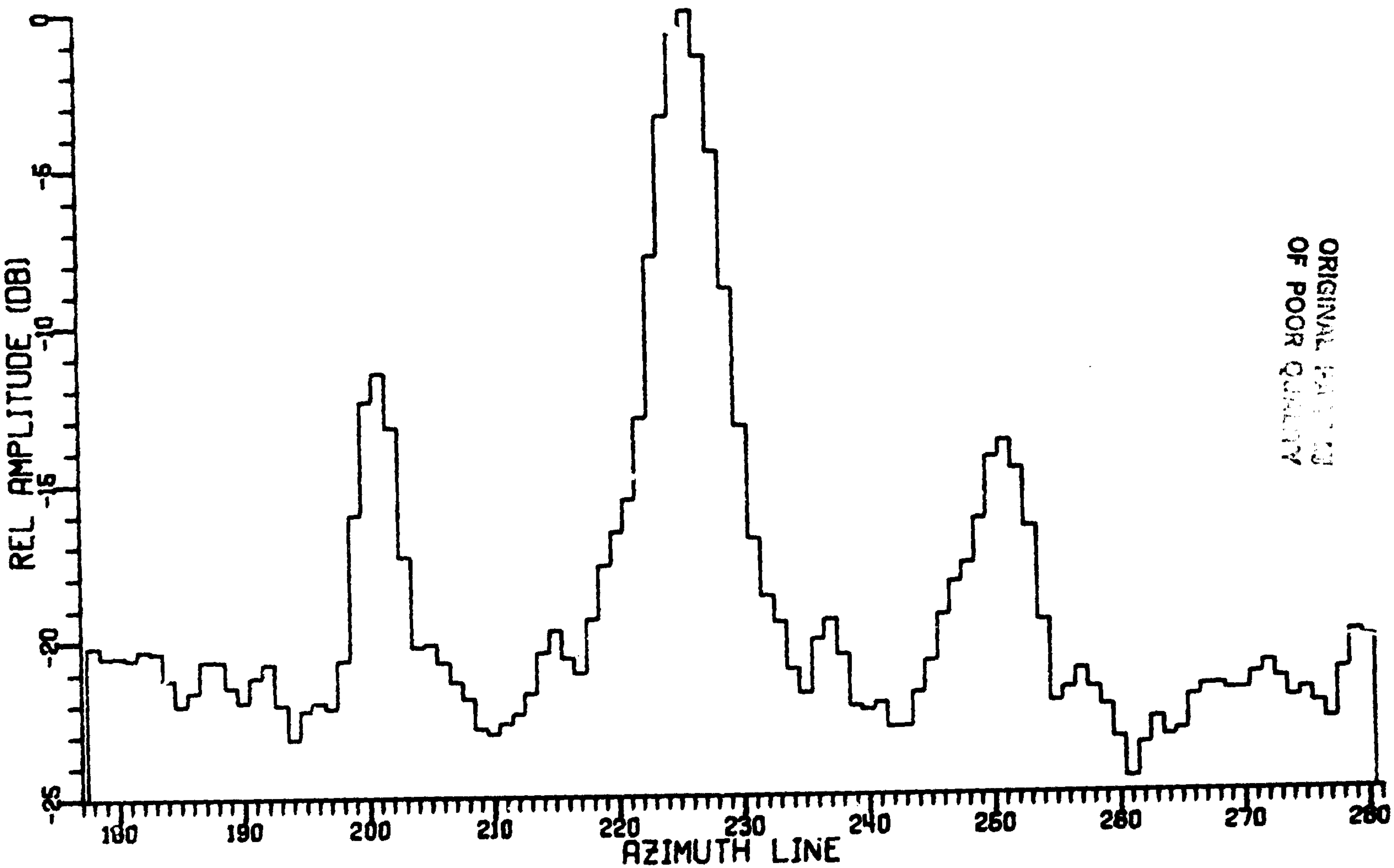

FIGURE 32

SE CORNER REFLECTOR AZIMUTH LINE SPACING, 4.24 m

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OF POOR QUALITY

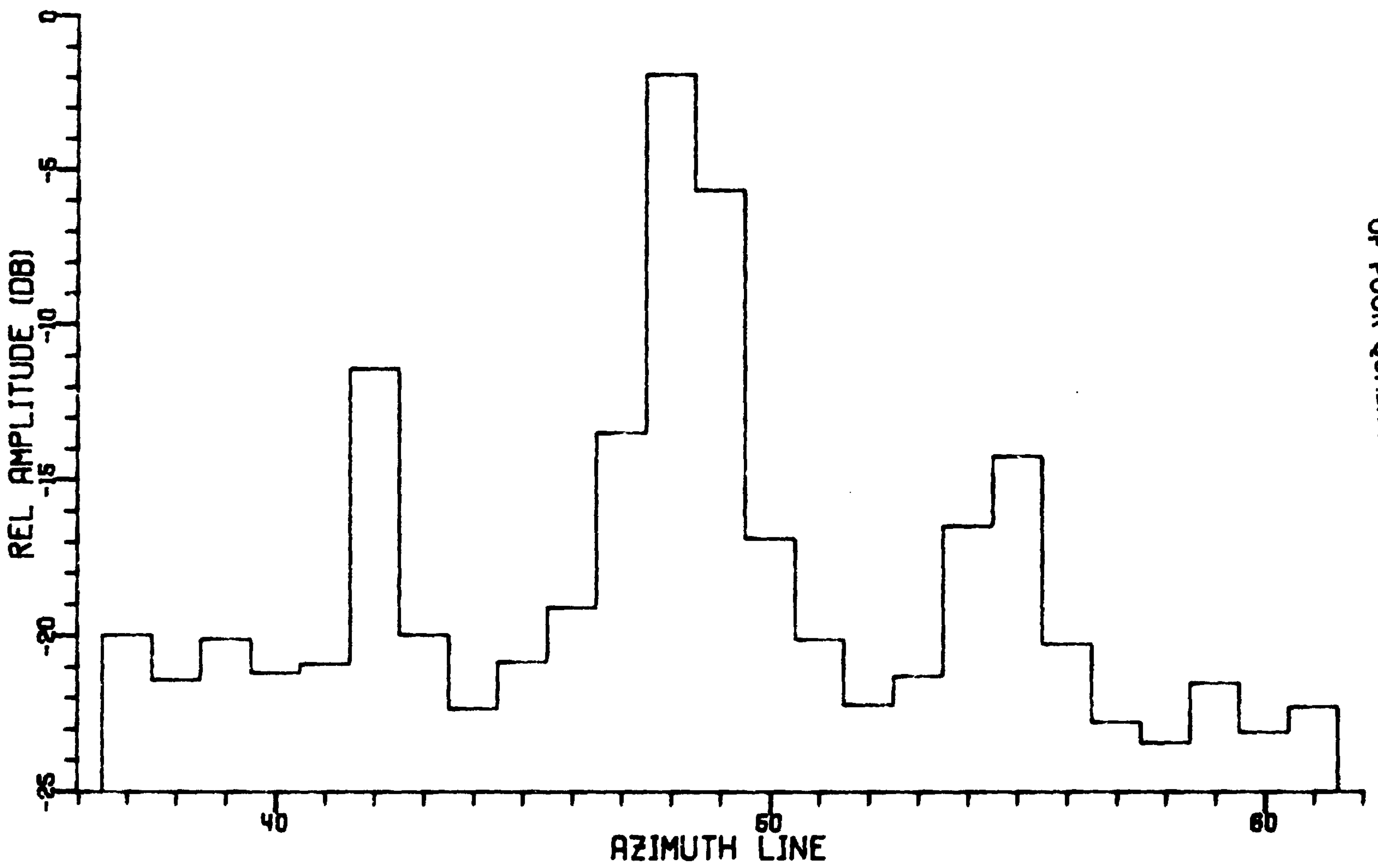

FIGURE 33

SE CORNER REFLECTOR AZIMUTH LINE SPACING, 16.95 m

AS-82-1789

Flare f is due to the area outside the main lobe:

$$f = \frac{W_c - W_t}{W_c} \quad ,$$

from Fig. 30, w_t=25, w_c=58, and f=0.57. Other measurements from the SE corner reflector yield values of 0.35 and 0.4 (see Figs. 32 and 33, respectively.)

C. Peak Sidelobe Ratio (PSLR)

This is the ratio of the peak level of the largest sidelobe to the maximum response. In addition to the usual sidelobe structure for the azimuth dimension, substantial grating lobes are observed to be generated. These are the result of aliasing of the main azimuth filter response due to undersampling, or the generation of spurious responses due to harmonic generation in the radar system.

The pulse sampling rate is based on the ground speed and is supposed to be at a rate of 2 samples/ft of travel or approximately 2 samples/nsec for a spatial sampling frequency of approximately 6.5 samples/m. From analyses of the digital images, and of the optically processed images, it is evident that aliasing in the digital imagery is not the problem. Rather, it appears to be due to Doppler harmonic or spurious frequency generation by the radar receiver.

With decreased azimuth sample spacing, the peak sidelobes are about 20 dB below the maximum response (see Fig. 32, for example). The aliased main lobe responses occur about every 26 azimuth lines, with the strongest one about 11.6 dB below the peak. The sample spacing of 4.24 m means that the spatial interval is about 110 m. At a range of 24373.1 m, the relative radial velocity V_r of the aircraft is

$$V_r = \frac{110}{24373.1} \times 418 \text{ kt} = 3.186 \text{ ft/sec} \quad ,$$

and the associated Doppler frequency is

$$fd = \frac{2V_r}{\lambda} = \frac{6.372}{0.1025} = 62 \text{ Hz} \quad .$$

From Fig. 33, the spacing is about 6.5 azimuth lines, or still 110 m, so these grating lobes are independent of the processing in azimuth.

Another example is that of Fig. 25. The first grating lobes are 33 azimuth lines, at 3 m spacing, or 99 m from the main lobe. They are 9 dB and 15 dB below the peak of the corner reflector, whereas the peak sidelobes are almost 18 dB down from the main lobe response. The only differences are the resolution of 6.0 m, and sample spacing of 3.0 m.

In range, the data of Figs. 21-28 yield (from Fig. 24) a ratio of -8 dB. Data on the SW corner reflector indicate the PSLR to be about -12 dB, exclusive of sampling effects, more in line with the theoretical value for sinx/x distribution.

D. <u>Sampling Ratio</u>

The range sampling ratio is set by the operator selection of the DDRS sample interval. The ratio given by the ratio w_a w_r, where w_a is the highest spatial frequency unambiguously recoverable by the sampling grid. In the case of 52.5 nsec SI, for example, the sampling frequency is 19 MHz, and $w_a=2(9.5\text{X}10^6)$ rad/sec based on the Nyquist criterion. The radar impulse response in range at the 3 dB points is 60 nsec, which corresponds to a spatial frequency bandwidth of 16.7 MHz and a spatial frequency w_r of $2(16.7\text{X}10^6)$, for slant range sampling ratio of 0.57. This is far from an ideal value of r=1.2. For 73.5 nsec SI, the ratio is only 0.41. As an approximation, it is the ratio of the 3 dB width of the impulse response divided by twice the SI.

In azimuth, the normal or default processing sets the azimuth resolution equal to that of the ground range resolution, and thus varies with slant range. The sample spacing is fixed at the range sample interval times the cosecant of the nadir angle at the patch center.

For example (see Fig. 34), the data for the filter processing for the three range bins indicated shows that RESR (range ground resolution in meters) is 15.2, with RESA (azimuth ground resolution) set to the same value. The FILTSP (filter spacing) is 12.6 m. The sample ratio for azimuth is given by

$$r = \frac{w_a}{w_r} \quad \frac{\text{RESA}}{2\ \text{FILTSPC}} = \frac{15.2}{25.2} = 0.603 \quad .$$

E. Processor Signal-to-Noise Ratio (S/N) Gain (G_p)

This is the ratio of processor output S/N to input S/N. Fundamentally, the amount of noise suppression is determined by the amount of signal integration during image formation. In the APQ-102, range compression has already occurred prior to digitizing the video signal, and the processor S/N gain results from the azimuth compression process, or Doppler processing, which involves overlaying the outputs of successive Fourier transform operations. Since the noncoherent integration gain is in theory equal to the square root of the samples summed, from Fig. 34, for example, the value is $G_p = \sqrt{19} = 4.36$, or about 6.4 dB.

A second and important effect of increasing the S/N processing gain is to decrease the background roughness, and the low level of the background roughness parameter is due to the substantial amount of overlay in the formation of the digital imagery.

```
RH-  60   RESR- 15.2   RESA- 15.2   FILTSP- 12.6   RANGE- 20614.1   RNGNADR- 11199.2
          NP- 158   NPFFT- 169   IFRFAM-  24   NFRFAM-  38   NPLMAP-  78   IFILOUT- 1   GI- 1.5613
   1   1  2  2  3  3  4  4  5  5  6  6  7  7  8  8  9  9 10 10 11 11 12 12 13
  13  14 14 15 15 16 16 17 17 18 18 19  1 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19

RH-  61   RESR- 15.2   RE[illegible] 15.2   FILTSP- 12.6   RANGE- 20621.9   RNGNADR- 11213.7
          NP- 158   NPFF[illegible]69   IFRFAM-  24   NFRFAM-  38   NPLMAP-  79   IFILOUT- 1   GI- 1.5613
   1   1  2  2  3  3  4  4  5  5  6  6  7  7  8  8  9  9 10 10 11 11 12 12 13
  13  14 14 15 15 16 16 17 17 18 18 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19

RH-  62   RESR- 15.2   RESA- 15.2   FILTSP- 12.6   RANGE- 20629.8   RNGNADR- 11228.2
          NP- 158   NPFFT- 169   IFRFAM-  24   NFRFAM-  38   NPLMAP-  81   IFILOUT- 1   GI- 1.5613
   1   1  2  2  3  3  4  4  5  5  6  6  7  7  8  8  9  9 10 10 11 11 12 12 13
  13  14 14 15 15 16 16 17 17 18 18 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
  19  19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
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FIGURE 34

FILTER OVERLAY DATA, LINE 1, RUN 1

VII. CONCLUSIONS

The digital image quality compares favorably with the images produced by optical processing, but the study has indicated some substantial limitations in the overall XSAR system for remote sensing applications. The most obvious of these is the limited dynamic range of the radar system. A second serious limitation is the undersampling in range, due to the limitation of the DDRS video sampling rate. The minimum SI was designed to be 40 nsec; however, this was not usable in practice due to hardware problems.

The following specific conclusions evolve from the study of the data supplied, and the processed images.

1. The dynamic range of the system is only about 25 dB. The corner reflector with RCS of less than 10 m^2 could not be discerned in the data and only the 25 cm and larger reflectors provided echoes larger than the background.

2. The system resolution is about half that of the nominal 3 dB range resolution, as the processing is normally performed. The azimuth resolution can be increased, however, to a limit of about 3 m. Resolution varies with the cosecant of the nadir angle.

3. Spurious signals generated by the radar receiving system create substantial azimuth grating lobes. This could be due either to the design of the APQ-102, or due to a poor state of maintenance at the time of the data gathering flights. Because of this, the use of a weighting function on the Doppler array, prior to Fourier transformation, has little effect.

APPENDIX I

GRAY SHADE DATA FOR 3-ELEMENT CORNER REFLECTOR ARRAY

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PIXEL VALUES FOR RANGE BINS 85 TO 145
AZIMUTH LINES 190 TO 270
DB/GRAY SHADE= 2.00, TOP GRAY SHADE VALUE= 170.00

AZIMUTH

```
190       200       210       220       230       240       250       260       270
 :         I         I         I         I         I         I         I         I
434444432444334444443466544445534455553445454455555555444555555434456545555444454
434434544445555555445545544445444544455445565565555565553354545555545545555554344455
232434334444445444445454343345344545544555555455455565454455454435345544444454555
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44444343324443444455444455555344454455455443445535454454455444433554554544444555-200
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STATISTICS ON PRINTED PIXELS
MAX = .16974E+03 MIN = .30510E+00
MEAN= .11439E+01SIGMA= .38225E+01

RB

C R ARRAY

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```
PIXEL VALUES FOR RANGE BINS  95 TO 145
                   AZIMUTH LINES 320 TO 375
DB/GRAY SHADE= 2.00.        TOP GRAY SHADE VALUE= 170.00
```

AZIMUTH

```
320       330       340       350       360
 |         |         |         |         |
43455544345444443443334323433423434333534323444334533454
44444523454344443443345434443332334335332433444445424444
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43455533443454343344434444444354343234754344545454335444
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53543454433355445344545433344443444 332333244445444443 44
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RB

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STATISTICS ON PRINTED PIXELS
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MEAN= .10693E+01SIGMA= .32739E+01
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APPENDIX II

UNIFORM BACKGROUND
Gray Shade Values (Hexadecimal)

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PIXEL VALUES FOR RANGE BINS 240 TO 384

AZIMUTH LINES 119 to 211 RELATIVE TO LEFT OF IMAGE: AZIMUTH LINES 92-184

DB/GRAY SHADE = 1.50 TOP GRAY SHADE VALUE = 10.00

```
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97A9A897A7AA7987888988889877767H788999A98987877A997888A7787888777877778777 6787876/76886767888
897AA78AAA98787687 9A998A78877889H9878788786887A8889887A97A678675778667767777AA679768887888877
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APPENDIX III

DARK BACKGROUNC
Gray Shade Values (Hexadecimal)

PIXEL VALUES FOR RANGE BINS 216 TO 370
AZIMUTH LINES 322 TO 367 RELATIVE TO LEFT OF IMAGE: AZIMUTH LINE 295-340
DB/GRAY SHADE = 1.50 TOP GRAY SHADE VALUE = 10.00

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78778877790876758867877577677765678778776616778
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STATISTICS ON PRINTED PIXELS
MAX = .13846E+01   MIN = .12951E+00
MEAN= .48347E+00SIGMA= .15001E+00

C-2

APPENDIX IV

PROGRAM LISTING FOR GROUND SIGNAL PROCESSOR

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```
      PROGRAM GSP (INPUT,OUTPUT,OUT,RNGBIN=0,FILMAG=0,RIOT=0,TAPE2=OUT) GSP
C                                                                       GSP
C     ---- INITIALIZE ------------------------------------------------GSP
C                                                                       GSP
      COMMON /RIOT/ RIOIST, ITIME,IDATE,LAT,LONG,IALT,HDG,DRIFT,ROLL,   GSP
     1              PITCH,IGSPD,VACC,XIPP,KFN,ISTAT,IMODE,DRMIN,SISR,   GSP
     2              NBIT,MODE,AUX(16), RIOTEND                          GSP
      COMMON WK(6300)                                                   GSP
      DIMENSION WT(512),IWK(1),RNORM(512),RMAP(512),RMINT(2)            GSP
      COMPLEX FOC(512),HV(1025)                                         GSP
      INTEGER IAZLNS,I(2),VIDATA(1024),IANRB(7)                         GSP
      EQUIVALENCE (WK(1),IWK(1)),(I(2),RMAP(1))                         GSP
      DATA IANRB /4096,2048,0,1024,0,0,512/, RMINT /.127E-3,.171E-3/    GSP
C                                                                       GSP
C***********************************************************************GSP
C**** GSP -- GROUND SIGNAL PROCESSOR.  INPUT DATA (FROM FILE- RNGBIN)   GSP
C**** IS FORMATTED BY RANGE BIN AND INPUT TO THE MAIN PROGRAM VIA       GSP
C**** SUBROUTINE- PULSES.  FILE RIOT CONTAINS THE RPE DATA WHICH        GSP
C**** IS IN THE FORMAT OF THE  /RIOT /  COMMON BLOCK.  AZIMUTH          GSP
C**** COVERAGE IS SET AT 360 LINES; RANGE COVERAGE IS VARIABLE UP TO    GSP
C**** THE EXTENT OF AVAILABLE DATA.  BECAUSE OF STORAGE CONSIDERATIONS  GSP
C**** NPMAX IS THE MAXIMUM NUMBER OF PULSES THAT CAN BE PROCESSED       GSP
C**** IN ONE SYNTHETIC ARRAY AND NFFTMAX IS THE MAXIMUM NUMBER OF       GSP
C**** POINTS THAT CAN BE FOURIER TRANSFORMED.                           GSP
C***********************************************************************GSP
C                                                                       GSP
      NFFTMAX=1024                                                      GSP
      NPMAX=512                                                         GSP
      CALL RECOVRY                                                      GSP
      PI=3.14159265358 98                                               GSP
      RTD=180./PI                                                       GSP
      DTR=1./RTD                                                        GSP
      CL=.2997925E+09                                                   GSP
      FPM=3.2808399                                                     GSP
      WL=.031228                                                        GSP
C                                                                       GSP
      LUNLST=2                                                          GSP
      LUNR=4LRIOT                                                       GSP
      LUNT=6LRNGBIN                                                     GSP
```

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```
      LUNO=6LFILMAG                                                     GSP
      LUNTO=6LOUTPUT                                                    GSP
C                                                                       GSP
C     ---- SET-UP DEFAULT PROCESSING VALUES. ---------------------------GSP
C                                                                       GSP
      BBF=1.2/288                                                       GSP
      KWTFTNA=≠TAYLOR≠                                                  GSP
      SHADFAC=30.                                                       GSP
      NBAR=5                                                            GSP
      KQLOOK=0                                                          GSP
      RESSR=8.25                                                        GSP
      TAZLNS=360                                                        GSP
      NRBPC=0                                                           GSP
      USEMAP=1                                                          GSP
      SRA=1.0                                                           GSP
      TRESA=0.                                                          GSP
      TFILTSP=0.                                                        GSP
      PRINT (2,*) ≠1  ≠                                                 GSP
C                                                                       GSP
C     ---- KBRANCH -----------------------------------------------------GSP
C                                                                       GSP
   20 PRINT *, ≠ INPUT KBRANCH≠                                         GSP
      READ *, KBRANCH                                                   GSP
      IF (EOF(5LINPUT).NE.0.0) STOP                                     GSP
      IF (KBRANCH.EQ.≠CHGRBPC≠) GOTO 70                                 GSP
      IF (KBRANCH.EQ.≠QUICKLOOK≠) GOTO 75                               GSP
      IF (KBRANCH.EQ.≠CHGRBMP≠) GOTO 80                                 GSP
      IF (KBRANCH.EQ.≠CHGRES≠) GOTO 90                                  GSP
      IF (KBRANCH.EQ.≠CHGSRA≠) GOTO 95                                  GSP
      IF (KBRANCH.EQ.≠CHGAFWT≠) GOTO 100                                GSP
      IF (KBRANCH.EQ.≠CHGBBF≠) GOTO 110                                 GSP
      IF (KBRANCH.EQ.≠CHGALNS≠) GOTO 115                                GSP
      IF (KBRANCH.EQ.≠PROCESS≠) GOTO 120                                GSP
      GOTO 20                                                           GSP
C                                                                       GSP
C**** CHGRBPC - CHANGE RANGE BIN USED TO COMPUTE THE DISTANCE TO THE    GSP
C****           PATCH CENTER TO BE PROCESSED. DEFAULT IS 0.             GSP
C****           USE CENTER RANGE BIN OF THE ENTIRE SAMPLED PULSE IF     GSP
C****           NRBPC=0 (IE. 256 FOR 7-BIT DATA, 512 FOR 4-BIT DATA,    GSP
```

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```
C****                           1024 FOR 2-BIT DATA, AND 2048 FOR 1-BIT)
C
   70 CONTINUE
      PRINT *, # INPUT NRBPC #,
      READ *, NRBPC
      PRINT (2,*) #  PATCH CENTER RANGE BIN CHANGED TO  #,NRBPC
      GOTO 20
C
C**** QUICKLOOK - NO OVERLAY OF SYNTHETIC FILTERS, I.E. 1-LOOK IMAGE.
   75 CONTINUE
      KQLOOK=KQLOOK+1
      KQLOOK=AND(KQLOOK,1)
      IF (KQLOOK.EQ.1) PRINT (2,*) #  1-LOOK IMAGE OPTION SELECTED#
      IF (KQLOOK.EQ.1) PRINT *, #  1-LOOK IMAGE OPTION SELECTED#
      IF (KQLOOK.EQ.0) PRINT (2,*) #  1-LOOK IMAGE OPTION DE-SELECTED#
      IF (KQLOOK.EQ.0) PRINT *, #  1-LOOK IMAGE OPTION DE-SELECTED#
      GOTO 20
C
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.
C
   80 CONTINUE
      PRINT *,#INPUT IRBFMAP #,
      READ *,IRBFMAP
      PRINT (2,*) #  FIRST RANGE BIN USED AS LEFT EDGE OF IMAGE - #,
     1          IRBFMAP
      GOTO 20
C
C**** CHGRES - OVERIDE PROGRAM CALCULATION OF AZIMUTH RESOLUTION (RESA)
C****             AND SAMPLE SPACING (FILTSPC).  INPUT IS IN METERS,
C****             ENTRY OF A ZERO REVERTS BACK TO PROGRAM CALCULATION.
C
   90 CONTINUE
      PRINT *,#INPUT RESA, FILTSPC #,
      READ *,IRESA,TFILTSP
      PRINT (2,*) #  AZIMUTH RESOLUTION TO BE USED AT EACH RANGE - #,
     1        TRESA,#,  AZIMUTH SAMPLE SPACING - #,TFILTSP
      GOTO 20
```

```
C                                                                       GSP
C***** CHGSRA - CHANGE AZIMUTH SAMPLE RATIO. OUTPUT AZIMUTH SAMPLE      GSP
C*****          SPACING IS SET TO:  FILTSPC/SRA .  DEFAULT IS 1.        GSP
C                                                                       GSP
   95 CONTINUE                                                          GSP
      PRINT *,≠INPUT SRA ≠,                                             GSP
      READ *,SRA                                                        GSP
      PRINT (2,*) ≠  AZIMUTH SAMPLE SPACING CHANGED TO ≠,SRA            GSP
      GOTO 20                                                           GSP
C                                                                       GSP
C***** CHGAPWT - CHANGE APERTURE WEIGHT FUNCTION. DEFAULT IS TAYLOR     GSP
C***** AT 30 DB.                                                        GSP
C*****            KWTFTNA= APERTURE WEIGHT FUNCTION (BCD), EITHER -     GSP
C*****                     HANNING, COSINE**2, TAYLOR, RECT, OR KAISER. GSP
C*****            SHADFAC= SHADING FACTOR -                             GSP
C*****                     HANNING - PERCENT OF APERTURE WITH COSINE TAPERGSP
C*****                     COSINE**2 - VALUE OF ARGUMENT AT APERTURE END- GSP
C*****                                 POINT, DEGREES.                  GSP
C*****                     TAYLOR - PEAK SIDELOBE RATIO (DB).           GSP
C*****                     RECT - UNIFORM WEIGHTING. ALL WEIGHTS=1.0 .  GSP
C*****                     KAISER - AVGERACE SIDELOBE LEVEL, DB.        GSP
C*****            NBAR    = NUMBER OF SIDELOBES OF NEAR UNIFORM LEVEL.  GSP
C*****                     USED ONLY FOR TAYLOR WEIGHTING.              GSP
C                                                                       GSP
  100 CONTINUE                                                          GSP
      PRINT *, ≠ INPUT KWTFTNA,SHADFAC,NBAR ≠,                          GSP
      READ *, KWTFTNA,SHADFAC,NBAR                                      GSP
      PRINT (2,*) ≠  APERTURE SHADING CHANGED TO ≠,KWTFTNA,≠, FACTOR ≠, GSP
     1    SHADFAC,≠,  NBAR ≠,NBAR                                       GSP
      GOTO 20                                                           GSP
C                                                                       GSP
C***** CHGBBF - CHANGE BEAM BROADENING FACTOR. DEFAULT IS 1.27.         GSP
C*****          BBF= BEAM BROADENING FACTOR.                            GSP
C                                                                       GSP
  110 CONTINUE                                                          GSP
      PRINT *, ≠ INPUT BBF ≠,                                           GSP
      READ *, BBF                                                       GSP
      PRINT (2,*) ≠  BEAM BROADENING FACTOR CHANGED TO ≠,BBF            GSP
      GOTO 20                                                           GSP
```

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```
      C                                                                    GSP
      C***** CHGALNS - CHANGE NUMBER OF AZIMUTH LINES GENERATED.           GSP
      C*****               DEFAULT = 360 .                                 GSP
      C                                                                    GSP
        115 CONTINUE                                                       GSP
            PRINT *,*INPUT TAZLNS *,                                       GSP
            READ *,IAZLNS                                                  GSP
            PRINT (2, ) *  NUMBER OF AZIMUTH LINES TO BE GENERATED - *,TAZLNS GSP
            GOTO 20                                                        GSP
      C                                                                    GSP
      C -------------------------------------------------------------------GSP
      C                                                                    GSP
      C***** PROCESS - PROCESS INPUT DOPPLER VIDEO INTO DISPLAY VIDEO.     GSP
      C*****               IFILO= OUTPUT FILE NO.                          GSP
      C*****               IRBF= FIRST RANGE BIN TO PROCESS.               GSP
      C*****               NRBFILS= NUMBER OF INPUT FILES (RANGE BINS) TO PROCESS  GSP
      C                                                                    GSP
        120 CONTINUE                                                       GSP
            PRINT *,*INPUT IFILO, IRBF, NRBPROC, IPSKIP *,                 GSP
            READ *, IFILO,IRBF,NRBPROC,IPSKIP                              GSP
            PRINT (2,*) *  OUTPUT FILE, FIRST RANGE BIN, NUMBER FILES (RANGE BGSP
           1INS) TO PROCESS, PULSES TO SKIP  *,IFILO,IRBF,NRBPROC,IPSKIP   GSP
            CALL LUNPOS (LUNO,IFILO)                                       GSP
      C                                                                    GSP
      C     ---- READ RIOT RECORD FROM FIRST FILE OF LUNR. ----------------GSP
      C                                                                    GSP
            BUFFER IN (LUNR,1) (RIOTST,RIOTEND)                            GSP
            IF (UNIT(LUNR))150,140,130                                     GSP
        130 PRINT *,*P.F. ON LUNR - HEADER *                               GSP
            STOP *P.F. ON LUNR*                                            GSP
        140 PRINT *,*EOF ON LUNR - HEADER *                                GSP
            STOP *EOF ON LUNR*                                             GSP
        150 CONTINUE                                                       GSP
            CALL RPFPRNT(LUNLST)                                           GSP
      C                                                                    GSP
      C     ---- INITIALIZE VARIABLES COMMON TO ALL RANGE BINS. -----------GSP
      C                                                                    GSP
            NRB=IANRB(NBIT)                                                GSP
            STCDLY=RMINT(MODE)-.1E-6*(600-(IALT+50)/.0n)                   GSP
```

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```
      ALT=FLOAT(IALT)/FPM
      RMIN=CL*(STCDLY+DRMIN)/2.
      RPC=RMIN+NRP*SISR*CL/4.
      XNAPC=ACOS(ALT/RPC)
      IF (NRBPC.NE.0) RPC=RMIN+NRBPC*SISR*CL/2.
      IF (NRBPC.NE.0) XNAPC=ACOS(ALT/RPC)
      XNAPCDG=XNAPC*RTD
      RNGEMAP=RMIN+(IRBEMAP-1)*SISR*CL/2.
      FILTSPC=CL*SISR/2./SIN(XNAPC)
      IF (TFILTSP.NE.0.0) FILTSPC=TFILTSP
      FILTSPC=FILTSPC/SRA
      FIFEET=FILTSPC*FPM
C
C**** PRINT THE VARIABLES COMMON TO ALL RANGE BINS.
C
      PRINT (2,1000)
      PRINT (2,1100) NRB,ALT,STCDLY,RMIN,RPC,RNGEMAP,XNAPCDG,FILTSPC
      PRINT (2,1200)
C
C
C     ---- PROCESS- NRBFILS RANGE BINS. ------------------------------------
C
      IRBL=IRBF+NRBPROC-1
      NSTIP=4
      IF (TAZLNS.GT.100) NSTIP=3
      IF (TAZLNS.GT.200) NSTIP=2
      TIP=0
      DO 380 IRBFIL=IRBF,IRBL
      PRINT *,≠ RB - ≠,IRBFIL
      ENDFILE LUNTO
C
C**** INITIALIZE VARIABLES FOR START OF PROCESSING OF ONE RANGE BIN.
C
      CALL SET(RMAP(1),RMAP(TAZLNS),0.)
      CALL SET(RNORM(1),RNORM(TAZLNS),0.)
      NPT=0
      IAZLINE=1
      RANGE=RMIN+(IRBFIL-1)*SISR*CL/2.
      RNGNADR=SQRT(RANGE*RANGE-ALT*ALT)
```

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OF POOR QUALITY

```
      XNARR=ACOS(ALT/RANGE)
      RESR=RESSR/SIN(XNARR)
      RESA=RESR
      IF (TRESA.NE.0.0) RESA=TRESA
      XNP=2.*.4429*BBF*WL*RANGE*FPM/RESA+1.0
      NP=XNP+.5
      NPFFT=WL*FPM*RANGE/FILTSPC+1.5
      FILTSP=WL*RANGE*FPM/(NPFFT-1)
C  COMPUTE NUMBER OF FILTERS IN THE 3 DB WIDTH OF THE REAL BEAM
C  AND THE INDEX (OUT OF THE FFT) OF THE FIRST FILTER.
      NFBEAM=1.3*DTR*RANGE/FILTSPC + 1.5
      IFBEAM=((NPFFT+1)/2-NFBEAM)/2 + 1
      I(1)=IFBEAM
C  IF THE LENGTH OF THE FFT REQUIRED TO PROVIDE THE DESIRED SAMPLE
C  SPACING IS LESS THAN THE LENGTH OF THE SYNTHETIC ARRAY THEN
C  MULTIPLY THE COMPUTED FFT LENGTH BY THE SMALLEST INTEGER (IFILOUT)
C  THAT GIVES A RESULT GREATER THAN THE SYNTHETIC ARRAY LENGTH (NP).
      IFILOUT=INT(FLOAT(NP)/FLOAT(NPFFT))+1
      IF (IFILOUT.NE.1) NPFFT=WL*FPM*RANGE/FILTSPC*IFILOUT + 1.5
      IF (NP.LE.NPMAX) GOTO 265
      PRINT (2,*) ≠ NUMBER OF PULSES PER ARRAY =≠,NP,≠,  NPMAX =≠,
     1          NPMAX
      STOP
  265 CONTINUE
      IF (NPFFT.LE.NFFTMAX) GOTO 267
      PRINT (2,*) ≠ NUMBER OF POINTS IN FFT =≠,NPFFT,≠,  NFFTMAX=≠,
     1               NFFTMAX
      STOP
  267 CONTINUE
C  CALCULATE SYNTHETIC ARRAY WEIGHTS.
      CALL WINDOW (WT,NP,KWTFTNA,SHADFAC,GI,NBAR)
      DO 260 IP=1,NP
         WT(IP)=WT(IP)*GI/NP
  260 CONTINUE
C
C**** COMPUTE ARRAY OF VALUES FOR FOCUSING THE SYNTHETIC ARRAYS.
C
      DO 270 J=1,NP
         D=(ABS(FLOAT(J)-FLOAT(NP)/2.)*.5+.25)/FPM
```

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```
          DPHI=4.*PI/WL*(SQRT(RANGE*RANGE+D*D)-RANGE)
          FOC(J)=CMPLX(COS(DPHI),-SIN(DPHI))
          FOC(J)=FOC(J)*WT(J)
  270 CONTINUE
C
C**** SKIP PULSES SO THAT THE START OF THE MAP COINCIDES WITH THE
C**** START OF THE MAP AT RANGE BIN - IRBFMAP .
C
      NPLMAP=WL*(RANGE-RNGEMAP)/2.*FPM*FPM+.5
      IF (NPLMAP.GE.0) GOTO 275
      PRINT *,*ERROR - NPLMAP LESS THAN 0 *
      STOP
  275 CONTINUE
      INPSKIP=NPLMAP+IPSKIP
      CALL NPULSES(LUNT,IRBFIL,VIDATA,INPSKIP,0,NBIT,NRB,1)
C
C**** PRINT VALUES OF THE COMPUTED PARAMETERS.
C
      IF (I1P.EQ.NSI1P) PRINT (2,1200)
      I1P=I1P+1
      IF (I1P.GT.NSI1P) I1P=1
      PRINT (2,1300) IRBFIL,RESR,RESA,FILTSP,RANGE,RNGNADR
      PRINT (2,1400) NP,NPFFT,IFBEAM,NFBEAM,NPLMAP,IFILOUT,GI
C
C**** RECOVER NP PULSES.
C
  280 CONTINUE
      CALL NPULSES(LUNT,IRBFIL,VIDATA,0,NP,NBIT,NRB,0)
      NPT=NPT+NP
C
C**** APPLY FOCUSING AND WEIGHTING, FOURIER PROCESS, OVERLAY.
C
      DO 310 IP=1,NP
          HV(IP)=FOC(IP)*VIDATA(IP)
  310 CONTINUE
      IFZERO=NP+1
      ILZERO=NPFFT+1
      IF (NP.NE.NPFFT) CALL SET(HV(IFZERO),HV(ILZERO),0.)
      CALL FFTCC(HV,NPFFT,IWK,WK)
```

```
      JEND=IAZLINE+NFBEAM-1
      IF(JEND.GT.IAZLNS)JEND=IAZLNS
      K1=(IFBEAM-1)*IFTLOUT + 1
      DO 330 J=IAZLINE,JEND
         RMAP(J)=(REAL(HV(K1)))**2.+(AIMAG(HV(K1)))**2.+RMAP(J)
         K1=K1+IFTLOUT
         RNORM(J)=RNORM(J)+1
  330 CONTINUE
C
C**** DETERMINE VALUES FOR PROPER ARRAY POSITIONING AND FILTER OVERLAY
C**** OF THE NEXT SYNTHETIC ARRAY FORMED.
C
      IF (KQLOOK.EQ.0) GOTO 353
      IF (IAZLINE+NFBEAM-1.GE.IAZLNS) GOTO 357
      IAZLINE=IAZLINE+NFBEAM
      NPTX=2.*(IAZLINE-1)*FIFFET-FLOAT(NPT)+1.
      CALL NPULSES(LUNI,IRBFIL,VIDATA,NPTX,0,NBIT,NRB,0)
      NPT=NPT+NPTX
      GOTO 280
  353 CONTINUE
      DFLOWN=NPT*.5-.5
      IAZLINE=DFLOWN/FIFFET+1
      FLEFT=AMOD(DFLOWN,FIFFET)
      NPSKIP=(FIFFET-FLEFT)*2.+.5
      IF (NPSKIP.LT.NP) IAZLINE=IAZLINE+1
      IF (NPSKIP.GE.NP) NPSKIP=0
      CALL NPULSES(LUNI,IRBFIL,VIDATA,NPSKIP,0,NBIT,NRB,0)
      NPT=NPT+NPSKIP
      IF(IAZLINE.LT.IAZLNS)GOTO 280
  357 CONTINUE
C
C**** NORMALIZE SUMS OF FILTER MAGNITUDES.
C
      DO 360 J=1,IAZLNS
         IF (RNORM(J).EQ.0) GOTO 360
         RMAP(J)=RMAP(J)/RNORM(J)
  360 CONTINUE
C
C**** PRINT NORMALIZING ARRAY.
```

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```
C                                                                               GSP
      DO 370 II=1,TAZLNS,25                                                     GSP
        II2=II+24                                                               GSP
        PRINT (2,1500) (INT(RNORM(IO)),IO=II,II2)                               GSP
  370 CONTINUE                                                                  GSP
C                                                                               GSP
C**** OUTPUT AMPLITUDE DATA.                                                    GSP
C                                                                               GSP
      BUFFER OUT (LUNO,1) (T(1),RMAP(TAZLNS))                                   GSP
      IF (UNIT(LUNO).GT.0.) GOTO 390                                            GSP
C                                                                               GSP
  380 CONTINUE                                                                  GSP
C                                                                               GSP
C                                                                               GSP
      STOP                                                                      GSP
  390 PRINT  *,≠PARITY ERROR ON OUTPUT≠                                         GSP
      STOP ≠P.E. ON LUNO≠                                                       GSP
C                                                                               GSP
C-------------------------------------------------------------------------------GSP
C                                                                               GSP
 1000 FORMAT(≠1 ≠,///,25X,≠VARIABLES  COMMON  TO  ALL  RANGE  BINS≠,/,          GSP
     1                25X,≠---------  ------  --  ---  -----  ----≠,///)       GSP
 1100 FORMAT(15,≠NUMBER OF RANGE BINS SAMPLED - ≠,I4,                           GSP
     1          150,≠RADAR ALTITUDE (M) - ≠,F7.1,//,                            GSP
     2          15,≠DELAY TO START OF STC (SEC) - ≠,E12.6,                      GSP
     3          150,≠SLANT RANGE TO START SAMPLING (M)- ≠,F7.1,//,              GSP
     4          15,≠SLANT RANGE TO PATCH CENTER (M) - ≠,F7.1,                   GSP
     5          150,≠SLANT RANGE TO MAP START (M) - ≠,F7.1,//,                  GSP
     6          15,≠ANGLE FROM NADIR TO PC (DEG) -≠,F6.2,                       GSP
     7          150,≠FILTER SPACING, AZIMUTH (M) -≠,F6.2,/,≠1  ≠)               GSP
 1200 FORMAT(≠1  ≠)                                                             GSP
 1300 FORMAT(//,≠  RB-≠,I4,≠   RESR-≠,F5.1,≠   RESA-≠,F5.1,≠   FILTSP-≠,GSP
     1          F5.1,≠   RANGE-≠,F8.1,≠   RNGNADR-≠,F8.1)                       GSP
 1400 FORMAT(12X,≠NP-≠,I4,≠   NPFFT-≠,I4,≠   IFBEAM-≠,I4,≠   NFBEAM-≠,          GSP
     2          I4,≠   NPLMAP-≠,I4,≠   IFILOUT-≠,I2,≠   GI-≠,F7.4)              GSP
 1500 FORMAT(5X,25I4)                                                           GSP
C                                                                               GSP
      END                                                                       GSP
```

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