Revision E

Project Magellan
Software Interface Specification

Full-Resolution Basic Image Data Record

SDPS–101

August 31, 1992

National Aeronautics and Space Administration

JPL

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

PROJECT MAGELLAN
SOFTWARE INTERFACE SPECIFICATION
NUMBER: SDPS-101
REVISION: E
DATE: August 31, 1992

SIS NAME:

Full-Resolution Basic Image Data Record (F-BIDR)

SIS COORDINATOR:

K. Leung

DOMAIN:

System	Subsystem	Program	Make/Use
GDS	SDPS–MSPL	BIDRsptr	Make
GDS	IDPS–MIPL	LOGMOS,	Use
"	"	BIDRLOG,	"
"	"	BIDRINDX,	"
"	"	MGNCORR,	"
"	"	VIEW,	"
"	"	CBIDRGEN	"
"	"	BRDRLOG	"
GDS	Science	–Various–	Use

PURPOSE OF INTERFACE (SUMMARY):

This interface provides full-resolution Magellan imagery to various users.

INTERFACE MEDIUM:

9-Track Magnetic Tape, 6250 cpi, and electronic link

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DOCUMENT CHANGE LOG

Revision	Date	MCR/FR	Affected Portions
Original	March 2, 1989		• All (original draft)
A (1)	May 10, 1990		• Add F-XBIDR (expedited F-BIDR)
			• §2.2: Revise BIDR size estimate
			• §2.3.3: Modify source of the orbit & version #s
			• §3.2.1: Modify "Source EDR" field in the BIDR Header record
			• §3.2.1 & 3.2.2: Add F-UBIDR in "Product Name" and "Product Type" fields
			• §3.4.1.2.1: Indicate how C1 & C2 increase for various projections; include NAV Unique ID
			• 3.4.1.2.3: Revise Radiometer record structure
			• 3.4.2.2.2: Removed statement that we would take the log of single-look complex image pixels (since they can be <0)
			• Appendix C: Revise S/C State, Radiometric Comp, and Frame Parameter sections. Add figure C-1.
			• Appendix D: Add NAV Unique ID; add "left/right looking" flag; add "number of looks processed" flag; correct the size of parameter 5
			• Appendicies C & D: Renumber several parameters
			• Appendix F: Revised "Processing Parameter" and "Description of Parameters" documents; added "Algorithm Description" document
B	February 14, 1991	MCR 956	• Revisions are denoted by letter rather than number
			• Shorten name of SIS to "F-BIDR SIS"
			• Additional entry in Change Log for Revision A
			• New acronyms defined
			• Refer to the product generically as "F-BIDR" throughout
			• §1.3: Revise the references
			• §2.3.1: Add references.

Revision	Date	MCR/FR	Affected Portions
		FR 64554	• §2.3.2: Simplify the discussion of external tape labels. Orbit numbers are now required to be five characters; version numbers are required to be two characters.
			• §2.3.3.4: Clarify EOF1 "block count" definition
			• §2.5: Replace "MIPL" with "IDPT"
			• §3.1.2: VAX number formats apply only to files 12-19
			• §3.2.1: Define hardware and software version numbering. Delete reference to "SAR-UEDR"
			• §3.2.2: Correct volume end marker label length
			• §3.4, 3.4.1, 3.4.1.2, 3.5.17, 3.5.18: Correct radiometer record lengths
			• §3.4.1.2.1: Burst counter is non-zero in multi-look image headers. Depends on EDR.
			• §3.4.1.2.1: Clarify pixel spacing definition. Add definition of projection origin latitude. Minor wording corrections
			• §3.4.1.2.1, 3.4.1.2.3, Appendicies C & D: Indicate that longitude ranges from 0 to 360 degrees
			• §3.4.1.2.2: Correct bit range of 52-bit time tag
			• §3.4.2.2: Fix the maximum number of lines and pixels per image record for F-, T-, and X-BIDRs. Differentiate between "pixel" and "byte"
			• §3.4.2.2, 3.4.2.2.1: Clarify definition of "offset" and "pointer"
			• §3.4.2.2.1: Offset & pointer of first line are copied from second line. Clarify "offset" and "pointer" usage. Zero may appear in valid data
			• §3.4.2.2.1, 3.4.2.2.2: Simplify definition of "filler pixel". Number of bytes (not pixels) is specified in header
			• §3.4.2.4: Add reference to definition of radiometer processing algorithm
			• §3.4.2.5: Add items defined in sections 3.4.2.5.1 through 3.4.2.5.6 to data block structure listing
			• §3.4.2.5.1: Minor wording change, typo
			• §3.4.2.5.5: Correct description of the field

Revision	Date	MCR/FR	Affected Portions
			• §3.4.2.5.6: Typo
			• §3.5.1: File 18 may be empty. Minor changes
			• §3.5.1, 3.5.13: Change wording regarding contents of File 13 to delete any information not strictly pertaining to Cycle 1.
			• §3.5.2 thru 3.5.11: Typos
			• §3.5.14, 3.5.16: "record" becomes "file" (sentence 3)
			• §3.5.19: Change Processing Monitor Results file
			• Appendix A: Revised definition of "physical record". Some definitions deleted. Other minor changes
		FR 62792	• Appendix C: Clarify units of time. Clarify quaternion descriptions. Unit vectors are now dimensionless. Parameterss 111-128 are now REAL*4. Clarify annotation of parameters 175-183 and 229-246. Correct parameter numbering in diagram
			• Appendix D: Clarify range of longitude values. Unit vectors are now dimensionless. Clarify units of time. Other minor changes
			• Appendix F: Revised "Processing Parameter" document, and xmit and reciev duration definitions in "Description of Parameter" document.
		FR 65049	• Appendix F, page F-32: Revised 'backscatter constant' used in SDPS as 0.0118 instead of 0.0188.
C	June 30, 1991	MCR 1197	• Appendix C: Clarified usage of Parameters 175 through 183. Added Parameters 301 and 302; and modified the Spare Byte count accordingly.
			• §1.3: Revised reference 5.
			• §3.4.1.2.1 , §3.4.2.2.1 and §3.4.2.2.2: Clarified description of orientation of image line.
			• Appendix C: Corrected mislabelling of parameter 54.
			• Appendix FB1 under Appendix F.1: Clarified derivation of the quaternions used in SDPS.
			• Appendix FB2 under Appendix F.1: Renamed from previously designated Appendix FB.
			• Added Appendix F.4 : memo regarding Magellan Telemetry Data Conditioning.
			• Added Appendix G: Cycle II specific changes.

D	October 18, 1991	MCR 1250	• Appendix C: documented a 0.5 degree offset used in the computation for BIP backscatter coefficient (parameter 54 of file_16.); corrected equation (28) on page F-31 of Appendix F to reflect a 0.5 degree offset used in the computation of the backscatter coefficient term f; i.e. $f(I_b - 0.5)$ instead of $f(I_b)$; deleted the definition for I_m; and added definition for I_b on page F-32 in Appendix F.
		FR 70648	• Appendix C: reordering of parameters 65 through 92, 248 - 249, and 252 - 253 to match the F-BIDR file_16. content: parameters 65 - 74 changed to 75 - 84 respectively; parameters 75 - 82 changed to 85 - 92 respectively; parameters 83 - 92 changed to 65 - 74 respectively; parameter 248 changed to 249, and vice versa; parameter 252 changed to 253, and vice versa.
		FR 70649	• Appendix D: renaming of parameters 2 and 3 in F-BIDR file_12. from 'Orbit' start and stop times to 'Mapping' start and stop times.
D - Ext. 1	March 06, 1992	MCR 1250	• Appendix C: clarified parameter 165 as MRP backscatter coefficient and documented a 0.5 degree offset used in its computation; • corrected equation (28) on page F-31 of Appendix F on the backscatter function 'f'; i.e. $f(I_m$-0.5) instead of $f(I_b$-0.5); • deleted the defintion for I_b and re-instated definition for I_m on page F-32 in Appendix F; • corrected the definition for f(I) on page F-32 in Appendix F to refer to 'I_m-0.5' instead of 'I_b-0.5'.
		NA	• replaced Figures E-1 and E-2 missing form initial release for Rev. D.
E	August 31, 1992	FR 65090	• §3.4.2.2.1: Added notation to point out an implementation error in PSP hardware version 2. Also added Appendix H to explain impacts of PSP H/W V2.0 on output imagery.
		NA	• §3.4.2.2.1: Revised description of 'Multi-look Image Line Structure' to clarify two parameters: 'Offset to first valid pixel' and 'Pointer to last valid pixel';

		also include description of a 4-pixel offset in each of these two parameters for right-looking orbits.
NA	•	Appendix F, page 32: Clarified description of constant K_2 in equation (28) on page 31-32 of Appendix F.

LIST OF TBD ITEMS

Section	Item	Resolution Date

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ACRONYMS & ABBREVIATIONS

ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
AT/CT	Along-Track/Cross Track
BIP	Boresight Intercept Point
CCSDS	Consultative Committee on Space Data Systems
cpi	characters per inch (i. e. bytes per inch)
dB	Decibels
DCS	Digital Correlator Subsystem
DMAS	Data Management and Archive Subsystem
DMAT	Data Management and Archive Team
DOY	Day Of Year
EDR	Experiment Data Record
F–BIDR	Full-Resolution Basic Image Data Record
F–SBIDR	Full-Resolution Special Basic Image Data Record
F–TBIDR	Full-Resolution Temporary Basic Image Data Record
F–UBIDR	a test F-BIDR (not an archived product)
F–XBIDR	Full-Resolution Expedited Basic Image Data Record
FFT	Fast Fourier Transform
GDS	Ground Data System
I/O	Input/Output
IDPS	Image Data Processing Subsystem
JPL	Jet Propulsion Laboratory
MB	Megabytes
MGN	Magellan
MIPL	Multi-mission Image Processing Laboratory
MOS	Mission Operations System
MRP	Mid-Range Point
MSB	Most Significant Bit
MSPL	Multi-mission SAR Processing Laboratory
NJPL	NASA/JPL (see Glossary)
ONU	Output Network Unit
PRF	Pulse Repetition Frequency
RET	Radar Engineering Team
SDPS	SAR Data Processing Subsystem
SDPT	SAR Data Processing Team
SAB	SAR-Altimeter Burst
SAR	Synthetic Aperture Radar
SAR–EDR	SAR Experiment Data Record
SAR–TEDR	SAR Temporary Experiment Data Record
SCET	Spacecraft Event Time
SFDO	Standard Formatted Data Object (see Glossary)
SFDU	Standard Formatted Data Unit (see Glossary)
SIS	Software Interface Specification
TBD	To Be Determined
TDB	Barycentric Dynamical Time
TLV	Type Length Value (see Glossary)

TEDR	Temporary Experiment Data Record
UTC	Coordinated Universal Time

SDPS–101

Full-Resolution Basic Image Data Record

Software Interface Specification

1 INTRODUCTION

1.1 Content Overview

This Software Interface Specification (SIS) describes the form and content of the Full-Resolution Basic Image Data Record (F–BIDR). An F–BIDR is a recording on computer-compatible tape, with an associated copy on Write Once Read Many (WORM) optical disk, used to convey and archive the full-resolution Magellan SAR image data produced by the SAR Data Processing Subsystem (SDPS). The SDPS is the Magellan implementation of the Multi-Mission SAR Processing Laboratory (MSPL).

The F-BIDR contains a copy of the ancillary data provided on the SAR Experiment Data Record (SAR–EDR), full-resolution image data, the processing parameters used to produce the image data, the results of analysis procedures applied to selected raw data and the resulting single-look image data, and the processed radiometer data.

The term "F-BIDR" is used generically throughout this document to refer to all types of F-BIDRs produced by the SDPS: F-BIDRs, F-TBIDRs, F-SBIDRs, F-XBIDRs, and F-UBIDRs.

The F-TBIDR results from processing a SAR Temporary Experiment Data Record (SAR-TEDR), and it has the same structure as an F-BIDR. The spacecraft ephemeris file appearing on the SAR-TEDR that is used for processing, and is subsequently written onto the F-TBIDR, is a preliminary version of that file. The SAR-EDR contains the final version of the spacecraft ephemeris file.

The F-SBIDR results from processing a SAR-EDR or SAR-TEDR, and it has the same structure as an F-BIDR. Special processing involves the use of alternate files or procedures from those used in standard F-BIDR processing. Special processing options are described in section 6.1.2 of ref. [5].

The F-XBIDR is derived from an expedited SAR-EDR, which should contain nearly identical files as the regular SAR-EDR of the same orbit.

The F-UBIDR is any test product intended primarily for engineering evaluation. F-UBIDRs are not ususally distributed outside of the SDPT.

Section 1 of this document contains general information. Section 2 describes characteristics of the physical media used for storing BIDRs, and Section 3 specifies the logical (media-independent) contents of BIDRs.

1.2 Scope

The specifications in this document apply to all F–BIDRs produced during the Magellan mission.

1.3 Applicable Documents

[1] Software Interface Specification for the SAR Experiment Data Record (SIS SFOC-1-MHR-MGN-SCIEDR) — *Ancillary data file contents.*
[2] Recorded Magnetic Tape for Information Interchange (6250 cpi, Group-Coded Recording) (ANSI X3.54–1976); Magnetic Tape Labels and File Structure for Information Interchange (ANSI X3.27–1978) — *Requirements for magnetic tape recording formats.*
[3] VAX Architecture Handbook (Digital Equipment Corporation, Maynard, Massachussetts, 1986) — *Number representation.*
[4] JPL Standard Formatted Data Unit (SFDU) Usage and Description (JJPL–0006–01–00, Issue 5, March 7, 1988)
[5] Magellan MOS Requirements, SAR Data Processing Subsystem (SDPS), Rev. B (VRM-MOS-4-271, June 4, 1991) — *F–BIDR content requirements.*
[6] Planetary Constants and Models (PD 630-79, Rev. C, April 11, 1988) — *Coordinate system definitions.*
[7] SDPS Analysis Program Description Document (PD 630-378, November 2, 1989) — *Description of processing monitor algorithms*
[8] SDPS Functional Design Document (PD 630-369, May 4, 1989) — *Overview of SDPS processing software, and high-level file definitions*
[9] Spacecraft and Planet Ephemerides SIS (SFOC-2-DPS-CDB-Ephemeris, January 9, 1990) — *defines the NAV Unique ID*
[10] Magellan Radar Sensor Compensation Report (HS 513-5029, August 18, 1989) — *defines the format of all radar-generated data, and the meaning and intended usage of radar parameters*
[11] VAX/VMS Exchange Utility Reference Manual (Digital Equipment Corporation, Maynard, Massachussetts, 1990) — *Files-11 definition*

2 INTERFACE CHARACTERISTICS

2.1 Operations Perspective

2.1.1 Data Source, Destinations, and Transfer Method

F–BIDRs will be generated by the SDPS and written to magnetic tape. At the same time, a copy will also be written to magnetic disk in the VAX Files-11 format (see ref. [11]). The computer compatible tapes (CCTs) will be transfered to the DMAT for archiving; the magnetic disk version will be copied to WORM disk within the Image Data Processing Subsystem (IDPS), via an electronic link.

2.1.2 Generation Method and Frequency

The SDPS will generate F–BIDRs from data recorded on each Magellan SAR–EDR / SAR-TEDR. Ancillary data from each EDR shall be copied to the corresponding BIDR. Data from the EDR will be processed and the resulting image data and radiometer data shall be recorded in the BIDR. Other information about the processing will also be recorded in each BIDR.

One F–BIDR will be produced corresponding to each SAR–EDR. Production will occur at an average rate of 52 F-BIDRs per week.

One F-TBIDR will be produced for each of up to two selected SAR-TEDRs per day. Production will average five F-TBIDRs per week.

One F-SBIDR will be produced for each special processing request received from the Data Management and Archive Team. Production will occur at an average rate of nine F-SBIDRs per week.

One F-XBIDR will be produced for each expedited SAR-EDR. Production will occur at an average rate of two F-XBIDRs per week.

2.2 Volume and Size

A typical F–BIDR will contain approximately 106 million bytes of image data, and approximately 39 million bytes of ancillary data.

2.3 BIDRs Stored on Tape

2.3.1 Tape Interface Characteristics

F–BIDRs shall be recorded on 2400 foot reels of 6250 characters per inch (cpi) computer-compatible tape, 9-track magnetic tapes using the 6250 cpi Group Coding Recording method (known as the GCR format), as specified by the American National Standard (ANSI) X3.54-1976 (ref. [2]).

Tape F–BIDRs shall contain a sequence of files. Labeling, block and file structure shall conform to the specifications of ANSI X3.27–1978, Level 3 (ref. [2]). The length of each physical record shall be 32,500 bytes.

The contents of the files shall conform to the specifications in Section 3 of this document.

2.3.2 External Tape Labels

Each F–BIDR tape reel shall have affixed a written label that identifies the orbit number of the SAR-EDR used, and the F-BIDR version number. The label shall be in the format specified below.

Product Label

F–cBIDR.orbnm;vn

where

c =	not used	for the F-BIDR
	'T'	for the F-TBIDR
	'S'	for the F-SBIDR
	'X'	for the F-XBIDR
	'U'	for the F-UBIDR

The letters 'BIDR' will be followed by a period and the 5-digit orbit number in decimal (shown as 'orbnm'). After this will be a semicolon ';' and the 2-digit version number 'vn' in decimal. Version number '01' indicates an original F–BIDR; the version will be incremented whenever an orbit (EDR) is reprocessed and a new F–BIDR is released.

For example, the label F–BIDR.00255;02 indicates that data from orbit number 255 was reprocessed, resulting in a second released F–BIDR for orbit 255.

2.3.3 ANSI Tape Labels

The contents of the fields of the volume (VOL), header 1 (HDR1), header 2 (HDR2), end-of-file 1 (EOF1), and end-of-file 2 (EOF2) labels used on F-BIDR tapes are given in the following subsections. All fields in each label conform to the requirements set by the appropriate ANSI documents [2].

2.3.3.1 Volume Label (VOL1)

bytes	field name	content
1-3	label ID	'VOL'
4	label number	'1'
5-10	volume ID	'Fonumv' for F-BIDR, or 'Tonumv' for F-TBIDR, or 'Sonumv' for F-SBIDR, or 'Xonumv' for F-XBIDR, or 'Uonumv' for a test BIDR
11	accessibility	space
12-37	reserved	spaces
38-51	owner ID	'SDPS;hver,sver'
52-79	reserved	spaces
80	label-standard ver.	'3'

Notes:

volume ID:

— "onum" is the hexadecimal representation of the orbit number, and is derived from the Volume Header file of the EDR

— "v" is the hexadecimal representation of the version number, and is derived from the SDPS Database files

owner ID:

— "hver" is the (decimal) hardware version number
— "sver" is the (decimal) software version number

2.3.3.2 File Header 1 Label (HDR1)

bytes	field name	content
1-3	label ID	'HDR'
4	label number	'1'
5-21	file ID	*see table 2.1*
22-27	file set ID	'Fonumv' for F-BIDR, or 'Tonumv' for F-TBIDR, or 'Sonumv' for F-SBIDR, or 'Xonumv' for F-XBIDR, or 'Uonumv' for a test BIDR
28-31	file section number	'0001'
32-35	file sequence number	*see table 2.1*
36-39	generation number	*instance dependent*; same as the run number from the SDPS Database files in [8]
40-41	generation ver. number	*instance dependent*; same as the release version number from the SDPS Database files in [8]
42-47	creation date	*instance dependent*; space + 'yyddd'
48-53	expiration date	space + '00000'
54	accessibility	space
55-60	block count	'000000'
61-73	system code	spaces
74-80	reserved	spaces

Notes:

volume ID:

— "onum" is the hexadecimal representation of the orbit number, and is derived from the Volume Header file of the EDR
— "v" is the hexadecimal representation of the version number, and is derived from the SDPS Database files

creation date:

— "yy" is the last two digits of the year the BIDR was created
— "ddd" is the day of year (1 to 366) the BIDR was created

2.3.3.3 File Header 2 Label (HDR2)

bytes	field name	content
1-3	label ID	'HDR'
4	label number	'2'
5	record format	'F'
6-10	block length	'32500'
11-15	record length	'32500'
16-50	reserved	spaces
51-52	buffer-offset length	'00'
53-80	reserved	spaces

2.3.3.4 End-of-File 1 Label (EOF1)

The EOF1 label is identical in format and content with the associated HDR1 label, except for the block count field:

55-60	block count	*instance dependent;* the actual number of physical records written to the tape, excluding header and trailer label records

2.3.3.5 End-of-File 2 Label (EOF2)

The EOF2 label is identical in format and content with the associated HDR2 label.

Table 2.1 — BIDR File Identifiers and File Sequence Numbers

File Name	File ID	# of Trailing Blanks	File Sequence #	Description
BIDR Header	'FILE_01'	10	'0001'	Summary BIDR Volume Information
File 2	'FILE_02'	10	'0002'	Orbit Header
File 3	'FILE_03'	10	'0003'	EDR Data Quality Summary
File 4	'FILE_04'	10	'0004'	S/C Ephemeris File (Orbit Description)
File 5	'FILE_05'	10	'0005'	SCLK/SCET Conversion Coefficients
File 6	'FILE_06'	10	'0006'	DSN Monitor Records
File 7	'FILE_07'	10	'0007'	Quaternion Pointing Coefficients
File 8	'FILE_08'	10	'0008'	Processing Bandwidths
File 9	'FILE_09'	10	'0009'	Decommutation & decalibration data
File 10	'FILE_10'	10	'0010'	Engineering Data
File 11	'FILE_11'	10	'0011'	Radar Header Records
File 12	'FILE_12'	10	'0012'	Per-orbit parameters
File 13	'FILE_13'	10	'0013'	Image Data in oblique sinusoidal Projection
File 14	'FILE_14'	10	'0014'	Processing Parameters for oblique sinusoidal Data
File 15	'FILE_15'	10	'0015'	Image Data in Sinusoidal Projection
File 16	'FILE_16'	10	'0016'	Processing Parameters for Sinusoidal Data
File 17	'FILE_17'	10	'0017'	Processed Radiometer Data
File 18	'FILE_18'	10	'0018'	Cold-Sky Calibration Results
File 19	'FILE_19'	10	'0019'	Processing Monitor Results
BIDR Trailer	'FILE_20'	10	'0020'	Additional BIDR Volume Information

2.4 BIDRs Stored on Magnetic Disk

2.4.1 Subdirectory Label

Each F-BIDR will be contained in one and only one VAX Files-11 disk subdirectory when written to disk by the SDPS. Subdirectory names have the following format:

<t>_<orbnm>_<vn>

where

t = 'F' for an F-BIDR
'T' for an F-TBIDR
'S' for an F-SBIDR
'X' for an F-XBIDR
'U' for a test BIDR

orbnm = a five-character, zero-filled, right-justified representation of the orbit number in decimal

vn = a two-character, zero-filled, right-justified representation of the release version number in decimal

("<" and ">" are used to delimit fields, and are not counted as characters)

For example, an F-BIDR containing results of the second attempt to process orbit 951 would have a VAX Files-11 disk subdirectory named 'F_00951_02'.

2.4.2 Subdirectory Structure

When an F-BIDR is written to disk by the SDPS, each file on the BIDR will be written as one and only one file in VAX Files-11 format. File names are identical to the "File ID" used in Table 2.1 above, except trailing blanks are not used. No VAX file type number is assigned to the files. The VAX file version number will always be "1", since a new directory will be created for each attempt at processing a given orbit.

As an example, the Processing Bandwidths file would be named "FILE_08.;1"; that is, the value found in the "File ID" column of Table 2.1, followed by a period, followed by a semicolon, and then by the number "1".

2.5 Duplicate Copies

The SDPS will produce one master tape BIDR from each EDR, and one magnetic disk copy that will be retrieved by the IDPT and copied to WORM disk.

3 F–BIDR CONTENT AND FORMAT

This section gives a detailed description of the format and contents of an F–BIDR.

Recent versions of the JPL Standard Formatted Data Unit (SFDU) concept are defined in ref. [4]. The structural conventions used in the F–BIDR are an attempt to be consistent with the SFDU concepts described in those documents. The reader is directed to those documents for further insight into the SFDU concept.

The specifications in this SIS take precedence over current and future SFDU requirements.

ANSI volume and file labels are specified in the appropriate ANSI documents [2]. The contents of each field of the ANSI volume and file labels are described in section 2.3.3 above.

3.1 General Characteristics

3.1.1 Structure Overview

The following material provides a brief overview of the structures used in constructing an F-BIDR. These structures are specified in detail in Sections 3.2 through 3.5.

All of the F-BIDR data corresponding to one orbit are recorded on a single reel of 6250 cpi computer-compatible tape, and in a separate VAX Files-11 disk subdirectory. The data are recorded as a sequence of files containing SFDU records.

The VAX disk files will be in the VAX Files-11 format with fixed length records.

The tape files will be in ANSI standard fixed length record format. All physical records on tape will be 32,500 bytes in length. For files that are not an integer multiple of 32,500 bytes in length, the last physical record of the file will be filled with the ASCII circumflex character ("^", decimal 94) following the data. Each file on a tape will begin at a physical record boundary.

Each BIDR will contain a header file, a series of data files, and a trailer file. Each file will consist of data records. This structure is illustrated in the following diagram.

It is assumed that the reader is familiar with ANSI standards.

F-BIDR Volume Structure (File level)

```
 ______________________ (Beginning of volume)
|                      |
|   BIDR Header File   |          - First file in volume
|______________________|
||                     |
||       File 2        |          - First data file
||_____________________|
||                     |
||       File 3        |          - Second data file
||_____________________|
/         :::          /          -(more files)
|______________________|
|                      |
|  BIDR Trailer File   |          - Last file in volume
|______________________|
                       (End of data)
```

BIDR header and trailer files identify the BIDR (by orbit number) and provide information about how the BIDR is written to tape. The data files contain information from the Magellan mission.

3.1.2 Conventions and Terminology

Appendix A contains a glossary of useful terms.

The following notational conventions are used in this specification.

Values are shown in decimal unless otherwise indicated. Single quotes '...' are used to indicate a sequence of ASCII characters, with the leftmost character being the first in the sequence. In the example below, the 'S' will occupy the first byte of the value field.

> String Sample: Example of ASCII 8-bit character-valued field.
> length = 6 bytes
> value = **'SAMPLE'**

A field having an integer value is shown in the example below.

> Number Sample: Example of integer-valued field.
> length = 2 bytes
> value = **47** (unsigned 16-bit integer)

Many values in files 12 through 19 will be represented in DEC VAX single-precision (F_floating) and double-precision (D–floating) floating-point formats. These number formats are specified in the VAX Architecture Handbook [3]. For reference, they are also described in Appendix B of this document. Integer formats used in the BIDRs are also given in Appendix B.

All latitude and longitude values in this document are in the Venus Body-Fixed Frame of 1985 (VBF85), specified in the JPL Planetary Constants and Models document [6]. The expression "wall-clock time" refers to local standard or daylight savings time.

3.2 BIDR Header and Trailer Files

The first file on an F–BIDR will contain a single SFDU volume header record; the last file will contain a single SFDU volume trailer record. The BIDR header record uniquely identifies each BIDR by orbit number and creation time. The BIDR trailer record delimits and provides other information about the data contained in the BIDR.

3.2.1 BIDR Header Record

The BIDR header record shall be a Consultative Committee on Space Data Systems (CCSDS) primary (type Z) Standard Formatted Data Object (SFDO) (ref. [4]). It will begin with a CCSDS primary label. Immediately following the CCSDS label will be the volume identifier, a keyword secondary header (type K) containing information identifying the tape. Following the keyword data object is a delimiter block which serves as a start bracket for the other files on the BIDR. This structure is illustrated in the following diagram.

BIDR Header Record Structure

byte #			field
0-11	T		CCSD1Z000001
12-19	L		00000389
20-31	VALUE	T	NJPL1K00HD00
32-39		L	00000273
40-60		VALUE	MAJOR_DATA_CODE=SAR<cr><lf>
61-87			MINOR_DATA_CODE=*corbnm.vn*<cr><lf>
88-105			MISSION_CODE=MGN<cr><lf>
106-141			TAPE_WRITE_DOY=*yr/day-hr:mn:sc.mmm*<cr><lf>
142-160			CRTE_SYS_CODE=MOS<cr><lf>
161-182			CRTE_SBSYS_CODE=SDPS<cr><lf>
183-213			TAPE_CRTE_CODE=SDPS;*hver.sver*<cr><lf>
214-242			TAPE_CRTE_MTHD_NAME=*cmethod*<cr><lf>
243-262			TAPE_DENS_NUM=6250<cr><lf>
263-282			PHYS_REC_LEN=32500<cr><lf>
283-312			DATA_SRC_CODE=SAR_EDR.*conumv*<cr><lf>
313-324		T	CCSD1R000003
325-332		L	00000076
333-351		VALUE	DELIMITER=SMARKER<cr><lf>
352-373			PRODUCT_NAME=*bidr-nm*<cr><lf>
374-392			TYPE=NJPL1I000nnn<cr><lf>
393-408			PROTOCOL=CCSDS<cr><lf>

The detailed contents of the fields in the header record are specified below.

<u>CCSDS primary label type</u> (bytes 0-11): Indicates the start of a CCSDS standard data product.
length = 12 bytes

<u>CCSDS primary label length</u> (bytes 12-19): Length of BIDR header record in bytes starting from byte 20.
length = 8 bytes

<u>Volume identifier type</u> (bytes 20-31): Indicates a keyword-entry secondary header.
length = 12 bytes

<u>Volume identifier length</u> (bytes 32-39): Length in bytes of the volume identifier value (keyword entry) field.
length = 8 bytes

The F-BIDR volume header value field will contain the keyword entries shown below. Keyword entry information consists of uppercase ASCII text with each entry terminated by a carriage return and line feed ("<cr><lf>").

<u>Major data product ID</u> [bytes 40-60]: Indicates SAR data.
length = 21 bytes

<u>Minor data product ID</u> [bytes 61-87]: Indicates an F-BIDR, an F-TBIDR, an F-SBIDR, an F-XBIDR, or a test BIDR.
length = 27 bytes

"c"= 'F' for an F-BIDR

"c"= 'T' for an F-TBIDR

"c"= 'S' for an F-SBIDR

"c" = 'X' for an F-XBIDR

"c" = 'U' for a test BIDR

"orbnm" is a five-character, zero-filled, right-justified ASCII representation of the orbit number in decimal

"vn" is a two-character, zero-filled, right-justified ASCII representation of the version number in decimal

<u>Mission ID</u> [bytes 88-105]: Magellan.
length = 18 bytes

<u>Tape write time</u> [bytes 106-141]: BIDR write date/ time (wall-clock time).
length = 36 bytes

Instance-dependent time in DOY format

<u>Tape creator major ID</u> [bytes 142-160]: System (MOS) which writes the tape.
length = 19 bytes

<u>Tape creator minor ID</u> [bytes 161-182]: Subsystem (SDPS) which writes the tape.
length = 22 bytes

<u>Tape creator version codes</u> [bytes 183-213]: SDPS hardware and software version codes.
length = 31 bytes

"hver" = *instance-dependent* SDPS hardware version code; 4 characters

character	meaning
1 - 4	major field; increments by one for each major hardware update

"sver" = *instance-dependent* SDPS software version code; 4 characters

character	meaning
1 - 3	major field; increments by one for each majorsoftware update
4	minor field; increments by one for each minor software update; rollover is treated as a major update

Tape creation method [bytes 214-242]: Non-realtime for BIDRs (i.e. offline or test).
length = 29 bytes
"cmethod" = '**OFFLINE**' for standard processing (F-BIDR, F-TBIDR, F-SBIDR, F-XBIDR)
"cmethod" = '**TEST**' **+ 3 spaces** (left-justified, space-filled) for a test BIDR.

Tape density [bytes 243-262]: Tape recording density, cpi.
length = 20 bytes

Maximum record size [bytes 263-282]: Physical record length in bytes.
length = 20 bytes

Source EDR [bytes 283-312]: Orbit and version number of EDR used to produce this BIDR. This is derived from the EDR Volume Header file.
length = 30 bytes
"c" = 'S' for a SAR-EDR
"c" = 'T' for a SAR-TEDR
"onum" is a four-character, zero-filled, right-justified ASCII representation of the orbit number, in hexadecimal.
"v" = a one-character ASCII representation of the EDR version number, in hexadecimal.

The volume start marker is specified below. Keyword entry information consists of uppercase ASCII text with each entry terminated by a carriage return and line feed ("<cr><lf>").

CCSDS primary label type (bytes 313-324): Indicates the start of a CCSDS standard data product.
length = 12 bytes

CCSDS primary label length (bytes 325-332): Length of volume start marker in bytes starting from byte 333.
length = 8 bytes

Delimiter type (bytes 333-351): Indicates that this object is an smarker.
length = 19 bytes

Product name (bytes 352-373): Indicates that this marker delimits a BIDR.
length = 22 bytes
"bidr-nm" = '**F-BIDR**' **+ space** (left-justified, space-filled) for an F-BIDR
"bidr-nm" = '**F-TBIDR**' for an F-TBIDR
"bidr-nm" = '**F-SBIDR**' for an F-SBIDR
"bidr-nm" = '**F-XBIDR**' for an F-XBIDR
"bidr-nm" = '**F-UBIDR**' for an F-UBIDR

Product type (bytes 374-392): Gives the numeric type code for a BIDR.
length = 19 bytes
"nnn" = '**104**' for an F-BIDR
"nnn" = '**105**' for an F-TBIDR
"nnn" = '**106**' for an F-SBIDR
"nnn" = '**107**' for an F-XBIDR
"nnn" = '**108**' for an F-UBIDR

SFDU Protocol (bytes 393-408): SFDU Authority code.
length = 16 bytes

3.2.2 BIDR Trailer Record

The F–BIDR trailer record shall be a CCSDS primary (type Z) SFDO. It will begin with a CCSDS primary label identical to that in the BIDR header record. Following the CCSDS label will be the volume trailer, a keyword secondary header (type K) containing additional cataloguing information. Following the keyword data object is a delimiter block which serves as an end bracket for the other files on the BIDR. This is illustrated in the following diagram.

BIDR Trailer Record Structure

byte #			field
0-11	T		CCSD1Z000001
12-19	L		00000116
20-31	VALUE	T	NJPL1K00HD00
32-39		L	00000035
40-74		VALUE	TAPE_CLSD_DOY=*yr/day-hr:mn:sc.mmm*<cr><lf>
75-86		T	CCSD1R000003
87-94		L	00000041
95-113		VALUE	DELIMITER=EMARKER<cr><lf>
114-135			PRODUCT_NAME=*bidr-nm*<cr><lf>

The contents of the fields in the BIDR trailer record are specified below.

CCSDS primary label type (bytes 0-11): Indicates a CCSDS standard data product.
length = 12 bytes
CCSDS primary label length (bytes 12-19): Number of bytes in volume trailer record starting from byte 20.
length = 8 bytes
Volume trailer type (bytes 20-31): Indicates a volume trailer containing keyword entry data.
length = 12 bytes
Volume trailer length (bytes 32-39): Length in bytes of volume trailer value field.
length = 8 bytes

The F–BIDR volume trailer value field will contain the keyword entry shown below. Keyword entry information consists of uppercase ASCII text with each entry terminated by a carriage return and line feed ("<cr><lf>").

Volume-closed time (bytes 40-74): Wall-clock time at end of processing.
length = 35 bytes
Instance-depepndent time in DOY format

The volume end marker is specified below.

CCSDS primary label type (bytes 75-86): Indicates the start of a CCSDS standard data product.
length = 12 bytes
CCSDS primary label length (bytes 87-94): Length of volume end marker in bytes starting from byte 95.
length = 8 bytes
Delimiter type (bytes 95-113): Indicates that this object is an emarker.
length = 19 bytes
Product name (bytes 114-135): Indicates that this marker delimits a BIDR.
length = 22 bytes
"bidr_nm" = '**F-BIDR**' + **space** (left-justified, space-filled) for an F-BIDR
"bidr_nm" = '**F-TBIDR**' for an F-TBIDR
"bidr_nm" = '**F-SBIDR**' for an F-SBIDR
"bidr_nm" = '**F-XBIDR**' for an F-XBIDR
"bidr_nm" = '**F-UBIDR**' for an F-UBIDR

3.3 Data Physical Records

All data physical records on tape will be 32,500 bytes in length.

Bytes will be written to the BIDR in the numerical order specified in this SIS, beginning with the lowest-numbered byte of each field, block, header, record, or file.

3.4 Logical Records

The definitions in this Section apply to all data contained within Files 12 through 19 of each F–BIDR. Five types of F–BIDR logical records are defined:

- **per-orbit parameter records** — contain parameters used in processing that are constant for the entire orbit
- **image data records** — contain image data
- **processing parameter records** — contain parameters used in generating the image data
- **radiometer data records** — contain processed radiometer data
- **processing monitor records** — contain data quality information

Data in the BIDR Header and Trailer files are described in Section 3.2. Data in Files 2 through 11 are copied from the SAR–EDR / SAR-TEDR, and the contents of those files are specified (or defining documents are referenced) in the SAR–EDR SIS [1].

Each BIDR logical record (with the exception of the BIDR Header and BIDR Trailer records) consists of a primary header and its value field. The primary header consists of a type field and a length field. The value field of each record consists of a secondary header and a data block.

Logical Record Structure

byte #		field
0-11	T	NJPL1I000nnn
12-19	L	nnnnnnnn
20-end of logical record	VALUE	Secondary header
		Data block

F–BIDR logical record **primary headers** shall consist of an NJPL type I label, as illustrated below.

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).

length = 12 bytes

"nnn" = '104' for all F-BIDR records

"nnn" = '105' for all F-TBIDR records

"nnn" = '106 for all F-SBIDR records

"nnn" = '107 for all F-XBIDR records

"nnn" = '108 for all F-UBIDR records

NJPL primary label length (bytes 12-19): Number of bytes in this logical record, starting with byte 20.

length = 8 bytes

value = '00000520'	for per-orbit parameter records
instance-dependent	for image data records
'00001295'	for processing parameter records
'00000108'	for processed radiometer data records
'00020452'	for processing monitor records
(8 ASCII characters)	

The secondary header is defined in section 3.4.1, and the data block is discussed in section 3.4.2. The first byte in the data block of a given record immediately follows the last byte in the secondary header of that record.

3.4.1 The Secondary Header

The secondary header consists of a type field, a length field, and a value field. The value field includes the orbit number and an annotation block, which contains ancillary data that helps to identify the contents of the data block following the secondary header.

Secondary Header Structure

byte #		field
0-1	T	BIDR secondary label type
2-3	L	BIDR secondary label length
4-end of secondary header	VALUE	Orbit number
		Annotation block

F–BIDR logical record **secondary headers** shall consist of a type field and a length field, followed by a value field containing the orbit number and the annotation block.

BIDR secondary label type (bytes 0-1): Indicates the type of annotation label.
length = 2 bytes
value = **1** for per-orbit parameter records
2 for image data records
4 for processing parameter records and processing monitor records
8 for processed radiometer data records
(unsigned 16-bit integer)

BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **4** for per-orbit parameter records
68 for image data records
11 for processing parameter records and processing monitor records
92 for processed radiometer data records
(unsigned 16-bit integer)

3.4.1.1 Orbit Number

Orbit Number Structure

byte #	field
0-1	Orbit number

The **orbit number** indicates the orbit during which the data used to create this record was collected. (For test BIDRs, this field will contain the test number.)

Orbit number (bytes 0-1): For F–BIDR logical records, value will be the same as the EDR (TEDR) orbit number in the orbit header record.
length = 2 bytes
value = *instance-dependent* (unsigned 16-bit integer).

3.4.1.2 Annotation Block

Annotation Block Structure

byte #		field
0	T	Data class
1	L	Data annotation label length
2-end	V	Data annotation label (IF ANY)

The **data class** indicates what kind of data is in the data field of the logical record — per-orbit parameters, image data or processing parameters in sinusoidal or oblique sinusoidal projection, radiometer data from the antenna pointed at the planet or at the cold-sky region, or processing monitor data.

Data class (byte 0): Indicates the kind of data in this logical record.
length = 1 byte
value = **1** for per-orbit parameters

2 for image data, sinusoidal projection, multi-look
34 for image data, sinusoidal projection, single-look
66 for image data, oblique sinusoidal projection, multi-look
98 for image data, oblique sinusoidal projection, single-look

4 for processing parameters, sinusoidal projection
68 for processing parameters, oblique sinusoidal projection

8 for processed radiometer data
40 for cold-sky calibration data

16 for processing monitor records
(unsigned 8-bit integer)

Data annotation label length (byte 1): Number of bytes in the data annotation label, starting with byte 2.
length = 1 byte
value = **0** for per-orbit parameter records
64 for image data records
7 for processing parameter records and processing monitor records
88 for processed radiometer data records
(unsigned 8-bit integer)

The **data annotation label** contains reference information about the data field, which follows immediately after the annotation block:

- There is no data annotation label for per-orbit processing parameter records.
- For image data records, it contains information regarding the location and dimensions of the image data.
- For processing parameter records and processing monitor records, it contains a value relating each set of parameters to the corresponding SAR burst.
- For processed radiometer data records, it contains information regarding the location on the planet of the antenna footprint, and parameters used to calculate the radiometer results.

3.4.1.2.1 Data Annotation Label — Image Data Records

In order to make it easier to compare the sinusoidal image data of different orbits, the equator of Venus has been divided into pixels, each of which covers 360 / (6051 * 2 * π / 0.075), or ~$7.1016*10^{-4}$, degrees of longitude. One pixel is centered at 0° longitude, and subsequent pixels are centered every $7.1016*10^{-4}$ degrees eastward.

For sinusoidal image data, the projection origin longitude given in the Data Annotation Label specifies the longitude at which the subsatellite point intersects the planet equator, adjusted to the nearest multiple of $7.1016*10^{-4}$ degrees (longitude is always positive). Thus for sinusoidal data, the projection origin longitude of any orbit can be offset by an integral number of 75-meter pixels from the projection origin longitude of any other orbit.

The projection origin latitude for sinusoidal data is always the equator (0°).

The **reference point** is at the center of the first pixel in the first line of the image data record. The reference point is offset from the projection origin longitude and latitude by an integral number of 75-meter pixels.

For sinusoidal image records, the image line in which the reference point is centered has the greatest Coordinate-1 value; for oblique sinusoidal image records, it has the smallest Coordinate-1 value. (See **Appendix E** for discussion of coordinates.)

The pixel in which the reference point is centered always has the smallest Coordinate-2 value.

The orientation of each image line in the sinusoidal projection is such that the first pixel lies the furthest to the west.

The following diagram illustrates the structure of the image data annotation label.

Data Annotation Label Structure – Image Data Records

byte #	field name	
0-3	Image line count	Image line length
4-7	Projection origin latitude	
8-11	Projection origin longitude	
12-15	Reference point latitude	
16-19	Reference point longitude	
20-23	Reference point offset in lines	
24-27	Reference point offset in pixels	
28-31	Burst counter	
32-63	NAV Unique ID	

Image data record data annotation label values are specified below.

Image Line Count (bytes 0-1): Number of image lines in the record.
length = 2 bytes
value = *Instance-dependent* (unsigned 16-bit integer)

Image Line Length (bytes 2-3): Number of bytes in each image line in data portion of record, including the offset to the first valid pixel, the pointer to the last valid pixel, and all of the data pixels, in bytes.
length = 2 bytes
value = *Instance-dependent* (unsigned 16-bit integer)

Projection Origin Latitude (bytes 4-7): Latitude (in °N) of the origin of the projection system used. For sinusoidal data, this is always 0°. For oblique sinusoidal data, this is the latitude of the origin of the oblique sinusoidal system, and will vary with each orbit.
length = 4 bytes
value = 0.0 for sinusoidal data;
Instance-dependent for oblique sinusoidal data (Single-precision floating-point; format described in Appendix B).

Projection Origin Longitude (bytes 8-11): Longitude (in °E from 0 to 360) of the origin of the projection system used. For sinusoidal data, this is the longitude at which the subsatellite point intersects the planet equator, adjusted to the nearest multiple of 75 meters with respect to a pixel centered at 0° longitude. For oblique sinusoidal data, this is the longitude of the origin of the oblique sinusoidal system, and will vary with each orbit.
length = 4 bytes

value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B).

Reference Point Latitude (bytes 12-15): Latitude (in °N) corresponding to the center of the first pixel in the first image line of the record.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B).

Reference Point Longitude (bytes 16-19): Longitude (in °E from 0 to 360) corresponding to the center of the first pixel in the first image line of the record.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B)

Reference Point Offset in Lines (bytes 20-23): This gives the Coordinate-1 value of the reference point (see **Appendix E**). For the sinusoidal projection, this is the number of 75-meter lines from the projection origin latitude to the first image line in this record; for oblique sinusoidal projection, the number of 75-meter lines from the great circle passing through the oblique sinusoidal origin and the pole to the first image line.
length = 4 bytes
value = *Instance-dependent* (32-bit signed integer)

Reference Point Offset in Pixels (bytes 24-27): This gives the Coordinate-2 value of the reference point (see **Appendix E**). For the sinusoidal projection, this is the number of 75-meter pixels from the projection origin longitude to the first pixel of the first image line in this record; for oblique sinusoidal projection, the number of 75-meter pixels from the nadir track to the first pixel of the first image line.
length = 4 bytes
value = *Instance-dependent* (32-bit signed integer)

Burst counter (bytes 28-31): Burst counter of the burst associated with this image record. Note that the burst count depends on the number of bursts on the EDR, and is not absolute. If an EDR is reprocessed, its BIDR burst numbering may differ from that used in the original BIDR.
length = 4 bytes
value = *Instance-dependent* (unsigned 32-bit integer).

NAV Unique ID (bytes 32-63): Copied from the Catalog and History Data portion of the Spacecraft Ephemeris file SFDU (see ref. [9]). A 32-byte ASCII character string used to identify the NAV solution used to produce the Ephemeris file on the EDR. Will contain 32 blanks for F-SBIDRs which do not use the Ephemeris file.
value = *instance-dependent* (32 byte character string)

3.4.1.2.2 Data Annotation Label — Processing Parameter and Processing Monitor Records

A processing parameter record contains the parameters used to process one SAR burst. A processing monitor record contains data quality information for a selected burst from each Processing Monitor file batch.

Both types of records have annotation blocks containing the time message from the radar burst header, as illustrated below. The data annotation label uniquely identifies the burst to which the record applies.

Data Annotation Label Structure — Processing Parameter and Processing Monitor Records

byte #	field name
0-6	Radar burst ID

Radar burst ID (bytes 0-6): 52-bit time field from SAB header for this burst (uniquely identifies the burst).
length = 7 bytes
value = *Instance-dependent*. The 52 least significant bit positions of the 7 bytes will contain the value of the spacecraft time field of the SAB header (bits 268-319 of the header, counting from 0); the 4 most significant bits of the 7 bytes will be zero. The format of the SAB header is specified in ref. [10].

3.4.1.2.3 Data Annotation Label — Processed Radiometer Data Records

The following diagram illustrates the structure of the processed radiometer data annotation label.

Data Annotation Label Structure – Processed Radiometer Data Records

byte #	field name
0-7	SCET
8-11	Latitude / Q1
12-15	Longitude / Q2
16-19	Incidence angle / Q3
20-23	Terrain elevation / Q4
24-27	Spacecraft position X-coordinate
28-31	Spacecraft position Y-coordinate
32-35	Spacecraft position Z-coordinate
36-39	Receiver gain factor
40-43	Receiver temperature
44-47	Signal-to-sensor input temp coefficient a
48-51	Signal-to-sensor input temp coefficient b
52-55	Signal-to-sensor input temp coefficient c
56-59	Sensor input noise temperature
60-63	Cable segment 1 temperature
64-67	Cable segment 2 temperature
68-71	Cable segment 3 temperature
72-75	Cable segment 4 temperature

(continued)

76-79	Cable segment 5 temperature
80-83	Atmospheric emission temperature
84-87	Atmospheric attenuation factor
88-91	
92-95	
96-99	
100-103	
104-107	
108-111	

Processed radiometer data record annotation block values are specified below.

SCET (bytes 0-7): SCET at mid-point of radiometer measurement in TDB seconds since Epoch 2000.
length = 8 bytes
value = *Instance-dependent* (VAX double precision floating point number; see Appendix B)

Latitude / Q1 (bytes 8-11): Latitude (degrees North) of Boresight-Intercept Point (BIP) at the radiometer measurement time. For cold-sky calibration measurements, this field will contain the quaternion Q1, as defined in [6].
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B)

Longitude / Q2 (bytes 12-15): Longitude (degrees East from 0 to 360) of BIP at the radiometer measurement time. For cold-sky calibration measurements, this field will contain the quaternion Q2, as defined in [6].
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Incidence angle / Q3 (bytes 16-19): Angle between the incident radar beam and the radial vector to the point of incidence at the surface, in degrees. For cold-sky calibration measurements, this field will contain the quaternion Q3, as defined in [6].
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

<u>Terrain elevation / Q4</u> (bytes 20-23): Elevation in meters of the planet surface above the nominal sphere of 6051 km radius at the BIP. For cold-sky calibration measurements, this field will contain the quaternion Q4, as defined in [6].
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

<u>Spacecraft position X-coordinate</u> (bytes 24-27): Spacecraft position vector X-component in meters in the planet centered J2000 inertial coordinate system.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B)

<u>Spacecraft position Y-coordinate</u> (bytes 28-31): Spacecraft position vector Y-component in meters in the planet centered J2000 inertial coordinate system.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B)

<u>Spacecraft position Z-coordinate</u> (bytes 32-35): Spacecraft position vector Z-component in meters in the planet centered J2000 inertial coordinate system.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B)

<u>Receiver gain factor</u> (bytes 36-39): Receiver gain factor derived from the SAB header and a lookup table.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B)

<u>Receiver temperature</u> (bytes 40-43): Telemetry-derived physical temperature of the receiver, in degrees Kelvin.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

<u>Signal-to-sensor input temp coefficient a</u> (bytes 44-47): Second-order polynomial coefficient applied to the difference of the raw radiometer data and calibration values, to give an estimate of the sensor input noise temperature. In degrees Kelvin. (The radiometer algorithm is described in Appendix B of [5].)
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

<u>Signal-to-sensor input temp coefficient b</u> (bytes 48-51): First-order polynomial coefficient applied to the difference of the raw radiometer data and calibration values, to give an estimate of the sensor input noise temperature. In degrees Kelvin.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

<u>Signal-to-sensor input temp coefficient c</u> (bytes 52-55): Zero-order polynomial coefficient applied to the difference of the raw radiometer data and calibration values, to give an estimate of the sensor input noise temperature. In degrees Kelvin.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

<u>Sensor input noise temperature</u> (bytes 56-59): Observed temperature at the receiver, in degrees Kelvin.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Cable segment 1 temperature (bytes 60-63): Temperature in degrees Kelvin of the first segment of cable between the antenna and the radar.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Cable segment 2 temperature (bytes 64-67): Temperature in degrees Kelvin of the second segment of cable between the antenna and the radar.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Cable segment 3 temperature (bytes 68-71): Temperature in degrees Kelvin of the third segment of cable between the antenna and the radar.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Cable segment 4 temperature (bytes 72-75): Temperature in degrees Kelvin of the fourth segment of cable between the antenna and the radar.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Cable segment 5 temperature (bytes 76-79): Temperature in degrees Kelvin of the fifth segment of cable between the antenna and the radar.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Cable segment 1 loss (bytes 80-83): Loss due to the first segment of cable between the antenna and the radar. Unitless.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Cable segment 2 loss (bytes 84-87): Loss due to the second segment of cable between the antenna and the radar. Unitless.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Cable segment 3 loss (bytes 88-91): Loss due to the third segment of cable between the antenna and the radar. Unitless.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Cable segment 4 loss (bytes 92-95): Loss due to the fourth segment of cable between the antenna and the radar. Unitless.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Cable segment 5 loss (bytes 96-99): Loss due to the fifth segment of cable between the antenna and the radar. Unitless.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

Atmospheric emission temperature (bytes 80-83): Table-derived estimate of the temperature of Venus' atmosphere, in degrees Kelvin. Will be 0 for cold sky radiometer records.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

<u>Atmospheric attenuation factor</u> (bytes 84-87): Coefficient used to adjust the observed antenna temperature to remove the effects of pointing through the atmosphere. Unitless. Will be 0 for cold sky radiometer records.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

<u>Cold-sky reference temperature</u> (bytes 108-111): Calibration temperature in degrees Kelvin derived from prior cold-sky measurements, which is subtracted from the observed antenna temperature to remove bias.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating point; format described in Appendix B).

3.4.2 Data Block Formats

The first byte of each data block in a record immediately follows the last byte of the secondary header in that record.

The five types of data blocks, corresponding to the five types of logical records, are discussed in the following sections:

- per-orbit data blocks § 3.4.2.1
- image data blocks § 3.4.2.2
- processing parameter data blocks § 3.4.2.3
- processed radiometer data blocks § 3.4.2.4
- processing monitor data blocks § 3.4.2.5

3.4.2.1 Data Block — Per-Orbit Parameter Records

The following specifications apply to F–BIDR per-orbit parameter records.

The data block of a per-orbit parameter record shall be 512 bytes long and consist of 42 parameters numbered (not surprisingly) 1 through 42, plus spares. Parameters size varies from four to 32 bytes. These parameters are used for processing, and are constant for the orbit corresponding to the BIDR. A list of the per-orbit parameters appears in Appendix D of this document.

Data Block Structure — Per-orbit Parameters Records

field name
Parameter-1
Parameter-2
:
Parameter-42
Spares

3.4.2.2 Data Block — Image Data Records

The following specifications apply to every single-look and multi-look image data record in each F–BIDR.

The data block of an image data record consists of one or more image lines, as shown in the following diagram.

Data Block Structure — Image Data Records

Image line 1
Image line 2
:
Image line N

The annotation block contains the latitude and longitude of the first pixel location (*not* the first valid pixel) in the first image line. Other parameters included in the annotation block are described in section 3.4.1.2.1 above. The coordinate systems used are specified in Appendices E and F.

The number of image lines and the number of pixels per line can vary from burst to burst, but is fixed for any given burst. The number of image lines in the data block is recorded in the annotation block, as is the number of bytes (total of offset, pointer, and pixel bytes) in each line.

For Standard, Temporary, and Expedited BIDRs, the maximum number of image lines in a record is 700, and the maximum number of pixels in a line is 512. Special BIDRs (S-BIDRs) can have more than the above-specified number of lines and/or pixels per line. The maximum number of bytes in an image data record is estimated to be 528,476 (including the SFDU header).

Each image line has the following structure:

- Offset to (# bytes to but NOT including) the first valid pixel in line
- Pointer to (# bytes to AND including) the last valid pixel in line
- Image data consisting of:
  - 0 or more substandard or filler pixels
  - 0 or more valid pixels
  - 0 or more substandard or filler pixels

The terms "valid", "substandard", and "filler" as applied to pixels are defined in the two sections which follow.

3.4.2.2.1 Multi-look Image Data Lines

In multi-look image data, a "valid" pixel incorporates at least the prescribed minimum number of looks (which is four). "Substandard" pixels incorporate at least one but fewer than the prescribed minimum number of looks. "Filler" pixels incorporate zero looks, and are generated by the SDPS as necessary to ensure proper pixel alignment.

An image line begins with two 16-bit fields: an offset to the first valid pixel in the line, and a pointer to the last valid pixel in the line. The offset to the first valid pixel gives the number of pixels from the first pixel to (but NOT including) the first valid pixel in the line. The pointer to the last valid pixel gives the number of pixels from the first pixel to (AND including) the last valid pixel in the line.

The offset and pointer of the first line in each image block are COPIED FROM THE SECOND LINE IN THE BLOCK, and are not generated using data from the first line. (This is due to a problem in the processor hardware. The real values of the offset and pointer can't be recovered, since the number of looks per pixel is not passed out of the hardware. It is assumed that the offset and pointer from line 2 are the best estimators of the true values for line 1.)

The rest of the image line consists of 8-bit pixel values (one byte per pixel). The number of bytes (total of offset, pointer, and pixel bytes) is specified in the annotation block.

The orientation of each image line in the sinusoidal projection is such that the first pixel lies the furthest to the west.

Multi-look pixel values are in units of normalized radar backscatter coefficient given in decibels, represented in an 8-bit data number format. This 8-bit value is obtained by dividing the radar cross-section value (the result of the SAR processing) by the corresponding value in the backscatter coefficient model (defined in the MGN SDPS Functional Requirements [5]). This ratio is converted to decibels and quantized using a step size of 0.2 dB, and values from –20 dB to +30 dB are represented using data numbers 1 through 251:

$$DN = 1 + INT\left[\frac{\left(\min[\,\max(\,RV, -20.0\,), 30.0] + 20.0 + \frac{0.2}{2}\right)}{0.2}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (*)$$

where

DN = data number
RV = 8-bit radar value in decibels
INT = next integer smaller than or equal to the floating point value

A real zero (or processor underflow) will result in DN = 0. This is the case for filler data. In rare cases (on the order of 10 times per mapping cycle), A ZERO MAY APPEAR IN VALID DATA. Data numbers 252 through 255 are not used.

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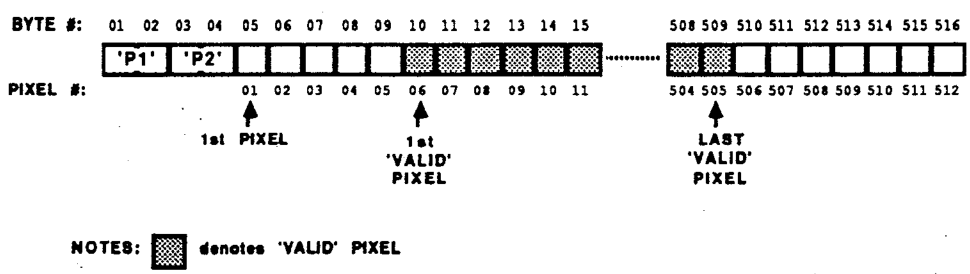
* Note: An implementation error in PSP hardware version 2.0 adversely affected a number of F-BIDRs. Please refer to Appendix H for more detail.

Multi-look Image Line Structure

byte #	field name
0-1	Offset to first valid pixel
2-3	Pointer to last valid pixel
4	Pixel Value 1
5	Pixel Value 2
:	:
M+3	Pixel Value M

Offset to first valid pixel (bytes 0-1): This parameter is also known as 'P1'. It is defined as the offset in number of pixels from the very first pixel in the image line to the first 'valid' pixel incorporating at least the prescribed number of looks (nominally four). For right-looking orbits, this is the offset in number of pixels from the very first pixel in the image line to the first 'valid' pixel incorporating at least the prescribed number of looks (nominally four) plus 4 pixels.
length = 2 bytes
value = *Instance-dependent* (unsigned 16-bit integer)

For example:
- for a left-looking orbit range line with P1 = 5 and P2 = 505; or,
  a right-looking orbit range line from the PSP with P1 = 9 and P2 = 509;



Pointer to last valid pixel (bytes 2-3): This parameter is also known as 'P2'. It is defined as the pixel count starting with the very first pixel in the image line to and including the last 'valid' pixel in the image line incorporating at least the prescribed number of looks (nominally four).
For right-looking orbits, this is the pixel count starting with the very first pixel in the image line to and including the last 'valid' pixel in the image line incorporating at least the prescribed number of looks (nominally four) plus 4 pixels.
length = 2 bytes
value = *Instance-dependent* (unsigned 16-bit integer)

See example shown above.

Pixel Value:
length = 1 byte
value = *Instance-dependent* (8-bit data number defined above)

3.4.2.2.2 Single-look Image Data Lines

In single-look image data, a "valid" pixel incorporates one look. "Filler" pixels incorporate zero looks, and are generated by the SDPS as necessary to ensure proper pixel alignment. There are no "substandard" pixels in single-look image data.

A single-look image line begins with two 16-bit fields: an offset to the first valid pixel in the line, and a pointer to the last valid pixel in the line. The offset to the first valid pixel gives the number of pixels from the first pixel to the first valid pixel in the line. The pointer to the last valid pixel gives the number of pixels from the first pixel to and including the last valid pixel in the line.

The rest of the image line consists of 64-bit complex pixel values, in which the first four bytes form the real part of the pixel value, and the second four bytes are the imaginary part (eight bytes per pixel). The number of bytes (total of offset, pointer, and pixel bytes) is specified in the logical record secondary header.

The orientation of each image line in the sinusoidal projection is such that the first pixel lies the furthest to the west.

Single-look pixel values are obtained by dividing the complex radar cross section value (the result of the SAR processing before detection) by the square-root of the corresponding value in the backscatter coefficient model (defined in the MGN SDPS Functional Requirements [5]). The real and imaginary parts of this ratio are expressed as single-precision floating-point numbers (using the format described in Appendix B). The structure of a single-look image line is illustrated below.

Single-look Image Line Structure

byte #	field name	
0-1	Offset to first valid pixel	
2-3	Pointer to last valid pixel	
4-11	Pixel Value 1	
	Real	Imaginary
12-19	Pixel Value 2	
	Real	Imaginary
:	:	:
8*M - 4 through 8*M + 3	Pixel Value M	
	Real	Imaginary

3.4.2.3 Data Block — Processing Parameter Records

The following specifications apply to every processing parameter record in each F-BIDR.

The data block of a processing parameter record is 1280 bytes long and consists of 300 parameters numbered (after much thought) 1 through 300, plus spares. Parameters are from one to eight bytes in length. The generation and use of these parameters during processing are defined in **Appendix F.** One set of processing parameters is computed for each burst. The particular SAR burst that corresponds to a set of processing parameters is identified in the annotation block. A list of the processing parameters appears in Appendix C of this document.

Data Block Structure — Processing Parameters Records

field name
Parameter-1
Parameter-2
:
Parameter-300
Spares

3.4.2.4 Data Block — Processed Radiometer Data Records

The following specifications apply to processed radiometer data records.

The data block of a processed radiometer data record shall be 12 bytes long and consist of:

- the 12-bit raw data value
- the 12-bit calibration value of the burst following the one from which the raw data value was obtained
- the observed (computed) antenna temperature and the inferred surface brightness temperature (defined in Appendix B of ref. [5])

The surface brightness temperature for cold-sky measurements will be set to 0.

The 12-bit numbers will be stored in the 12 least-significant bits of a 2-byte integer word. The two temperatures will be stored as single-precision floating point numbers. (Single-precision floating-point and integer formats are given in Appendix B.) This structure is illustrated below.

Data Block Structure — Processed Radiometer Data Records

byte #	field name
0-1	Raw data value
2-3	Raw calibration value
4-7	Observed antenna temp.
8-11	Surface brightness temp.

Raw data value (bytes 0-1): 12-bit raw data value
length = 2 bytes
value = *Instance-dependent* unsigned 16-bit integer (4 most significant bits will be set to "0")

Raw calibration value (bytes 2-3): 12-bit calibration value.
length = 2 bytes
value = *Instance-dependent* unsigned 16-bit integer(4 most significant bits will be set to "0")

Observed antenna temperature (bytes 4-7): Temperature (°K) of radiation at the high gain antenna.
length = 4 bytes
value = *Instance-dependent* (Single precision floating point; format described in Appendix B)

Surface brightness temperature (bytes 8-11): Brightness temperature (°K) of the planet surface after correcting for atmospheric attenuation and emission.
length = 4 bytes
value = *Instance-dependent* (Single precision floating point; format described in Appendix B) Will be **0** for cold-sky calibration measurements.

3.4.2.5 Data Block — Processing Monitor Records

The following specifications apply to every processing monitor record in each F–BIDR.

Processing monitor records are produced for selected SAR bursts. The SAR burst is identified in the annotation block.

The data block of a processing monitor record is 20,437 bytes long. It contains the monitor information described in Reference [7]. The structure of the processing monitor record data field is illustrated in the following diagram.

Data Block Structure — Processing Monitor Records

byte #	field name
0-3	Burst counter
4-795	Raw data histograms
796-799	Raw data mean
800-803	Raw data variance
804-1827	Image histogram
1828-1831	Backscatter mean
1832-1835	Backscatter variance
1836-1839	BIP range
1840-1843	Range centroid
1844-1847	Peak-to-mean ratio
1848-1851	Echo peak position standard deviation
1852-3899	Raw data spectrum
3900-3903	Thermal SNR
3904-3907	Quantization SNR
3908-3911	Total SNR
3912-3913	Image Spectrum starting line
3914-3915	Image Spectrum starting pixel

(continued)

3916-	Image spectrum
20300-20312	Clutterlock results
20313-20436	Autofocus results

Burst counter (bytes 0-3): Burst counter of the burst analyzed.
length = 4 bytes
value = *Instance-dependent* (Unsigned 32 bit integer)

Raw Data Histogram (bytes 4-795): See section 3.4.2.5.1.

Raw data mean (bytes 796-799): Mean of the 8-bit samples (both I and Q) in the BAQ reconstructed raw data.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point)

Raw data variance (bytes 800-803): Variance of the 8-bit samples (both I and Q) in the BAQ reconstructed raw data.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point)

Image Histogram (bytes 804-1827): See section 3.4.2.5.2.

Backscatter mean (bytes 1828-1831): Mean value of detected single-look image pixels.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point)

Backscatter variance (bytes 1832-1835): Variance of detected single-look image pixels.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point)

BIP range (bytes 1836-1839): Apparent range in meters to the boresight intercept point.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point)

Range centroid (bytes 1840-1843): Apparent range in meters to range centroid of the corresponding SAR burst.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point)

Peak-to-mean ratio (bytes 1844-1847): Ratio of the peak power in the smoothed range compressed power spectrum, to the mean power.
length = 4 bytes
value = *Instance dependent* (Single-precision floating-point)

Echo peak position standard deviation (bytes 1848-1851): The standard deviation of the cross-correlation peaks of each adjacent pair of echo pulses, compared with the average cross-correlation peak position of all adjacent pairs, of the corresponding SAR burst.
length = 4 bytes
value = *Instance dependent* (Single-precision floating-point)

Raw Data Spectrum (bytes 1852-3899): See section 3.4.2.5.3.

Thermal SNR (bytes 3900-3903): Raw data signal-to-thermal-noise ratio of the corresponding SAR burst.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point)

Quantization SNR (bytes 3904-3907): Raw data signal-to-quantization-noise ratio of the corresponding SAR burst.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point)

Total SNR (bytes 3908-3911): Raw data signal-to-total-noise ratio of the corresponding SAR burst.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point)

Image Spectrum starting line [bytes 3912-3913): The Coordinate-1 value (see **Appendix E**) of the first line included in the Image Spectrum.
length = 2 bytes
value = *Instance dependent* (unsigned 16-bit integer)

Image Spectrum starting pixel [bytes 3914-3915): The Coordinate-2 value (see **Appendix E**) of the first pixel included in the Image Spectrum.
length = 2 bytes
value = *Instance dependent* (unsigned 16-bit integer)

Image Spectrum (bytes 3916-20299): See section 3.4.2.5.4.
Clutterlock Results (bytes 20300-20312): See section 3.4.2.5.5.
Autofocus Results (bytes 20313-20436): See section 3.4.2.5.6.

3.4.2.5.1 Raw Data Histogram Field

The raw data histogram field (bytes 4-795 of the process monitor data block) will consist of 24 four-bin histograms. Each of these histograms will consist of a one-byte threshold value and eight single-precision floating-point numbers. Each of the floating-point numbers will represent the frequency of occurrence of the corresponding 2-bit raw data value (I = in-phase component, Q = quadrature component) for the corresponding threshold value. There may be up to 24 threshold values, each of which was used to encode 16 complex range samples. If fewer than 24 thresholds are used (as would be the case in the event of a shorter range line), the unused threshold value and probability fields will be filled with zeros. The structure is illustrated below.

Raw Data Histogram Field Structure

byte #	field name	
0	Threshold Value 1	
1-8	Probability of I=-1	Probability of Q=-1
9-16	Probability of I=-0	Probability of Q=-0
17-24	Probability of I=+0	Probability of Q=+0
25-32	Probability of I=+1	Probability of Q=+1
	:	:
759	Threshold Value 24	
760-767	Probability of I=-1	Probability of Q=-1
.	:	:
784-791	Probability of I=+1	Probability of Q=+1

<u>Threshold Value n</u>: Threshold value appearing in the burst header.
length = 1 byte
value = *Instance-dependent* (unsigned 8-bit integer). Will be **0** for unused threshold values.

<u>Probability of xxx</u>: Frequency of occurrence of raw data value xxx .
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B). Will be **0** for unused thresholds.

3.4.2.5.2 Image Histogram Field

The image histogram field (bytes 804-1827 of the process monitor data block) will consist of 256 single-precision floating-point numbers. The first number will be the frequency of occurrence of pixel value 0, the second the frequency of occurence of pixel value 1, and so forth. The structure is shown below.

Image Data Histogram Field Structure

byte #	field name
0-3	Histogram value 1
4-7	Histogram value 2
	:
1020-1023	Histogram value 256

Histogram value n: Frequency of occurrence of pixel value n-1.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B)

3.4.2.5.3 Raw Data Spectrum Field

The raw data spectrum field (bytes 1852-3899 of the process monitor data block) will contain 512 four-byte, single-precision numbers. Each number will be the magnitude of the raw data spectral value obtained by applying a Fourier transform to each range line in the burst, then averaging the resulting spectra. The first value in the field will correspond to zero frequency and each subsequent value represents a step of 1/512th of the sampling frequency. This structure is illustrated below.

Raw Data Spectrum Field Structure

byte #	field name
0-3	Spectral value 1
4-7	Spectral value 2
	:
2044-2047	Spectral value 512

Spectral value n: Magnitude of raw data spectral value.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B)

3.4.2.5.4 Image Spectrum Field

The image spectrum field (bytes 3916-20299 of the process monitor data block) will consist of a 64 x 64 two-dimensional spectrum of a square patch of detected imagery (measuring 64 real pixels on a side) centered near the swath center of the selected burst. This field will contain 64 spectrum lines, as illustrated in the following diagram.

Image Spectrum Field Structure

byte #	field name
0-255	Spectrum line 1
256-511	Spectrum line 2
:	
16128-16383	Spectrum line 64

Each image spectrum line will consist of 64 four-byte values, as illustrated in the following diagram.

Image Spectrum Line Structure

byte #	field name
0-3	Spectrum value 1
4-7	Spectrum value 2
:	
252-255	Spectrum value 64

Spectrum value n: Value of spectrum in 2-dimensional array.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B)

3.4.2.5.5 Clutterlock Results Field

The clutterlock results field (bytes 20300-20312 of the process monitor data block) will consist of a one-byte flag indicating whether clutterlock processing has been done, and three single-precision floating-point numbers. The first floating-point number is a coarse measure of the Doppler centroid at the mid-range point, in Hertz, and will appear for every burst analyzed. The second is a more accurate measure of the Doppler centroid at the mid-range point obtained by regression analysis, and will appear only for selected bursts. The third is a measure of the Doppler drift rate at the mid-range point, also obtained by regression. (Clutterlock techniques are described in [7].) The field structure is shown below.

Clutterlock Results Field Structure

byte #	field name
0	Processing flag
1-4	Coarse Doppler centroid
5-8	Refined Doppler centroid
9-12	Doppler drift rate

Clutterlock processing flag: Indicates if clutterlock processing has been done..
length = 1 byte
value = **0** if clutterlock has not been done (remainder of field to be ignored)
1 if clutterlock has been done (remainder of field contains valid data)
(unsigned 8-bit integer)

Coarse Doppler centroid: Doppler centroid in Hertz.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B)

Refined Doppler centroid: Doppler centroid in Hertz obtained by regression analysis.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B) Will be **0** if regression analysis is not done.

Doppler drift rate: Doppler centroid drift rate as a function of range obtained by regression analysis.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B) Will be **0** if regression analysis is not done.

3.4.2.5.6 Autofocus Results Field

The autofocus results field (bytes 20313-20436 of the process monitor data block) will consist of:

- the mid-burst times of the two bursts used for autofocus
- the Coordinate-1 and Coordinate-2 misregistrations in pixel number, and
- a 5x5 cross-correlation matrix.

The structure is shown below.

Autofocus Results Field Structure

byte #	field name
0-7	Mid-burst time 1
8-15	Mid-burst time 2
16-19	Coordinate 1 displacement
20-23	Coordinate 2 displacement
24-123	Cross-correlation matrix

Mid-burst time 1 (bytes 0-7): Time, in TDB seconds since Epoch 2000, of the first burst used for autofocus.
length = 8 bytes
value = *Instance-dependent* (Double-precision floating -point; format described in Appendix B)

Mid-burst time 2 (bytes 8-15): Time, in TDB seconds since Epoch 2000, of the second burst used for autofocus.
length = 8 bytes
value = *Instance-dependent* (Double-precision floating -point; format described in Appendix B)

Coordinate 1 displacement (bytes 16-19): Coordinate 1 offset of image 2 from its expected position with respect to image 1 (see **Appendix E**).
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B)

Coordinate 2 displacement (bytes 20-23): Coordinate 2 offset of image 2 from its expected position with respect to image 1 (see **Appendix E**)
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B)

The cross-correlation matrix will consist of a 5x5 array that is the result of a two-dimensional cross-correlation process. This field will contain 5 matrix lines, as illustrated in the following diagram.

Cross-correlation Matrix Field Structure

byte #	field name
0-19	Matrix line 1
20-39	Matrix line 2
:	:
80-99	Matrix line 5

Line N represents the result of shifting image 2 by "3 - N" lines in the Coordinate-1 dimension.

Each matrix line will consist of 5 four-byte values, as illustrated in the following diagram.

Cross-correlation Matrix Line Structure

byte #	field name
0-3	Matrix value 1
4-7	Matrix value 2
:	:
16-19	Matrix value 5

Value N represents the result of shifting image 2 by "3 - N" pixels in the Coordinate-2 dimension.

Matrix value n: Value of cross-correlation in 2-dimensional array.
length = 4 bytes
value = *Instance-dependent* (Single-precision floating-point; format described in Appendix B)

3.5 BIDR Data Files

3.5.1 Introduction

Every F–BIDR will contain 20 files. The following sections describe the BIDR data files. The BIDR Header (**File 1**) is discussed in section 3.2.1, and the BIDR Trailer (**File 20**) is discussed in section 3.2.2.

The first ten files following the BIDR Header (**Files 2-11**) will contain ancillary data copied from the SAR–EDR / SAR-TEDR from which the F–BIDR was made.

File 12 will contain parameters used in processing that are constant for the entire orbit.

File 13 will contain polar image data (corresponding to terrain north of 80°N latitude on the Venusian surface) in oblique sinusoidal projection. The processing parameters used to produce the oblique sinusoidal image data from the raw data will be recorded in **File 14**. Note that Files 13 and 14 will be empty (ANSI null files) for orbits in which no polar observations are made (i.e. every other orbit in the alternating swath scheme).

Files 15 and **16** will, respectively, contain image data in sinusoidal projection and the associated processing parameters for terrain south of 89°N and north of 89°S latitude on the Venusian surface.

File 17 will contain the results of processing the radiometer data.

File 18 will contain the results of processing the radiometer data from the cold-sky calibrations. Cold-sky calibration data are acquired three times during the nominal mission. File 18 will contain all of the cold-sky calibration data acquired as of the processing date. This file will be empty (ANSI null file) if no cold sky data is available.

File 19 will contain quality information about the raw SAR data and the resulting image data. This information is produced from two preselected regions of each orbit, and requires that up to 16 contiguous bursts be available in each region. If neither region contains the necessary number of contiguous bursts, this file will be empty (an ANSI null file).

Table 3.1 — Summary of BIDR Files

File Name	Ref.§	Copied From EDR?	Description
BIDR Header	3.2.1	n	Summary BIDR Volume Information
File 2	3.5.2	y	Orbit Header
File 3	3.5.3	y	EDR Data Quality Summary
File 4	3.5.4	y	S/C Ephemeris File (Orbit Description)
File 5	3.5.5	y	SCLK/SCET Conversion Coefficients
File 6	3.5.6	y	DSN Monitor Records
File 7	3.5.7	y	Quaternion Pointing Coefficients
File 8	3.5.8	y	Processing Bandwidths
File 9	3.5.9	y	Decommutation & decalibration data
File 10	3.5.10	y	Engineering Data
File 11	3.5.11	y	Radar Header Records
File 12	3.5.12	n	Per-orbit parameters
File 13	3.5.13	n	Image Data in Oblique Sinusoidal Projection
File 14	3.5.14	n	Processing Parameters for Oblique Sinusoidal Data
File 15	3.5.15	n	Image Data in Sinusoidal Projection
File 16	3.5.16	n	Processing Parameters for Sinusoidal Data
File 17	3.5.17	n	Processed Radiometer Data
File 18	3.5.18	n	Cold-Sky Calibration Results
File 19	3.5.19	n	Processing Monitor Results
BIDR Trailer	3.2.2	n	Additional BIDR Volume Information

3.5.2 File 2: Orbit Header

This file will contain an exact copy of the data in the Orbit Header File contained in the SAR–EDR, unless an F-SBIDR is created using a substitute Orbit Header file, in which case it will include that file. SIS SFOC-1-MHR-SCIEDR [1] specifies the contents of this file.

3.5.3 File 3: EDR Data Quality Summary

This file will contain an exact copy of the data in the EDR Data Quality File contained in the SAR–EDR, unless an F-SBIDR is created using a substitute EDR Data Quality Summary file, in which case it will include that file. SIS SFOC-1-MHR-SCIEDR [1] specifies the contents of this file.

3.5.4 File 4: Spacecraft Ephemeris File

This file will contain an exact copy of the data in the Spacecraft Ephemeris File contained in the SAR–EDR, unless an F-SBIDR is created using a substitute Spacecraft Ephemeris file, in which case it will include that file. SIS SFOC-1-MHR-SCIEDR [1] identifies the SIS which specifies the contents of this file.

3.5.5 File 5: SCLK/SCET Conversion Coefficients

This file will contain an exact copy of the data in the SCLK/SCET Conversion Coefficients File contained in the SAR-EDR, unless an F-SBIDR is created using a substitute SCLK/SCET Conversion Coefficients file, in which case it will include that file. SIS SFOC-1-MHR-SCIEDR [1] identifies the SIS which specifies the contents of this file.

3.5.6 File 6: DSN Monitor Records

This file will contain an exact copy of the data in the DSN Monitor Records File contained in the SAR-EDR, unless an F-SBIDR is created using a substitute DSN Monitor Records file, in which case it will include that file. SIS SFOC-1-MHR-SCIEDR [1] specifies the structure and identifies the SIS which specifies the contents of this file.

3.5.7 File 7: Quaternion Polynomial Coefficients

This file will contain an exact copy of the data in the Quaternion Polynomial Coefficients File contained in the SAR-EDR, unless an F-SBIDR is created using a substitute Quaternion Polynomial Coefficients file, in which case it will include that file. SIS SFOC-1-MHR-SCIEDR [1] identifies the SIS which specifies the contents of this file.

3.5.8 File 8: Processing Bandwidths

This file will contain an exact copy of the data in the Processing Bandwidths File contained in the SAR-EDR, unless an F-SBIDR is created using a substitute Processing Bandwidths file, in which case it will include that file. SIS SFOC-1-MHR-SCIEDR [1] identifies the SIS which specifies the contents of this file.

3.5.9 File 9: Decommutation and Decalibration Data

This file will contain an exact copy of the data in the Decom/Decal File contained in the SAR-EDR, unless an F-SBIDR is created using a substitute Decommutation and Decalibration Data file, in which case it will include that file. SIS SFOC-1-MHR-SCIEDR [1] specifies the structure and identifies the SIS which specifies the contents of this file.

3.5.10 File 10: Engineering Data

This file will contain an exact copy of the data in the Engineering Data File contained in the SAR-EDR, unless an F-SBIDR is created using a substitute Engineering Data file, in which case it will include that file. SIS SFOC-1-MHR-SCIEDR [1] specifies the structure and identifies the document which specifies the contents of this file.

3.5.11 File 11: SAR Header Records

This file will contain an exact copy of the data in the SAR Header Records File contained in the SAR-EDR, unless an F-SBIDR is created using a substitute SAR Header Records file, in which case it will include that file. SIS SFOC-1-MHR-SCIEDR [1] specifies the structure and identifies the document which specifies the contents of this file.

Except for F-SBIDRs using a substitute SAR Header Records file, this file is copied byte-for-byte from the EDR, and the SAB header fields are in the same bit order as in the telemetry.

3.5.12 File 12: Per-orbit Parameters

This file consists of per-orbit parameter records. Each logical record will contain parameters used for processing that are constant for the entire orbit.

The following values shall appear in the per-orbit parameters record primary header (see section 3.4):

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).
length = 12 bytes
value = **'NJPL1I000104'**, for F-BIDR,
'NJPL1I000105', for F-TBIDR,
'NJPL1I000106', for F-SBIDR,
'NJPL1I000107', for F-XBIDR,
'NJPL1I000108', for F-UBIDR.

NJPL primary label length (bytes 12-19): Number of bytes in logical record starting with byte 20.
length = 8 bytes
value = **'00000520'**

The following values shall appear in the per-orbit parameters record secondary header (see section 3.4.1):

BIDR secondary label type (bytes 0-1): No annotation field.
length = 2 bytes
value = **1** (unsigned 16-bit integer)

BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **4** (unsigned 16-bit integer)

The format of the orbit number field is specified in section 3.4.1.1. The following values shall appear in the per-orbit parameters record annotation block (see section 3.4.1.2):

Data class (byte 0): Per-orbit parameters.
length = 1 byte
value = **1** (unsigned 8-bit integer)

Data annotation label length (byte 1): Number of bytes in the annotation field.
length = 1 byte
value = **0** (unsigned 8-bit integer).

The data block is specified in sections 3.4.2 and 3.4.2.1, and Appendix D.

3.5.13 File 13: Image Data in Oblique Sinusoidal Projection

This file consists of image data records. Each logical record will contain multi-look image data in the oblique sinusoidal projection. The image data will correspond to the mapped area north of 80°N latitude on the Venusian surface. If there is no such data for the corresponding orbit segment, this file will be empty. Pixel values shall be 8 bits each. Filler pixels shall contain the value **0** (8-bit integer).

The following values shall appear in the image data record primary header (see section 3.4):

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).
length = 12 bytes
value = **'NJPL1I000104'**, for F-BIDR,
'NJPL1I000105', for F-TBIDR,
'NJPL1I000106', for F-SBIDR,
'NJPL1I000107', for F-XBIDR,
'NJPL1I000108', for F-UBIDR.

The following values shall appear in the image data record secondary header (see section 3.4.1):

BIDR secondary label type (bytes 0-1): Image data annotation field.
length = 2 bytes
value = **2** (unsigned 16-bit integer)

BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **68** (unsigned 16-bit integer)

The format of the orbit number field is specified in section 3.4.1.1. The following values shall appear in the image data record annotation block (see sections 3.4.1.2 and 3.4.1.2.1):

Data class (byte 0): Image data, multi-look, oblique sinusoidal projection.
length = 1 byte
value = **66** (unsigned 8-bit integer)

Data annotation label length (byte 1): Number of bytes in the annotation field.
length = 1 byte
value = **64** (unsigned 8-bit integer).

The data block is specified in sections 3.4.2, 3.4.2.2, and 3.4.2.2.1.

3.5.14 File 14: Processing Parameters for Oblique Sinusoidal Data

This file consists of processing parameter records. Each logical record shall contain the parameters used to control the SAR processing that produced the image data in the Image Data in Oblique Sinusoidal Projection file. If there is no such data for the corresponding orbit segment, this file will be empty. This file is provided for diagnostic use, and to facilitate sophisticated interpretation of image data.

One processing parameter record will be recorded in this file for each burst of SAR data for which processing into oblique sinusoidal imagery is attempted.

The following values shall appear in the processing parameter record primary header (see section 3.4):

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).
length = 12 bytes
value = **'NJPL1I000104'**, for F-BIDR,
'NJPL1I000105', for F-TBIDR,
'NJPL1I000106', for F-SBIDR,
'NJPL1I000107', for F-XBIDR,
'NJPL1I000108', for F-UBIDR.

NJPL primary label length (bytes 12-19): Number of bytes in logical record starting with byte 20.
length = 8 bytes
value = **'00001295'**

The following values shall appear in the processing parameter record secondary header (see section 3.4.1):

BIDR secondary label type (bytes 0-1): Burst ID annotation field.
length = 2 bytes
value = **4** (unsigned 16-bit integer)

BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **11** (unsigned 16-bit integer)

The format of the orbit number field is specified in section 3.4.1.1. The following values shall appear in the processing parameter record annotation block (see sections 3.4.1.2 and 3.4.1.2.2):

Data class (byte 0): Processing parameters, oblique sinusoidal projection.
length = 1 byte
value = **68** (unsigned 8-bit integer)

Data annotation label length (byte 1): Number of bytes in the annotation field.
length = 1 byte
value = **7** (unsigned 8-bit integer).

The data block is specified in sections 3.4.2 and 3.4.2.3, and Appendix C.

3.5.15 File 15: Image Data in Sinusoidal Projection

This file consists of image data records. Each logical record will contain multi-look image data in the sinusoidal projection. The image data will include all available data between 89° N and 89°S latitude. Pixel values shall be 8 bits each. Filler pixels shall contain the value 0.

The following values shall appear in the image data record primary header (see section 3.4):

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).
length = 12 bytes
value = **'NJPL1I000104'**, for F-BIDR,
'NJPL1I000105', for F-TBIDR,
'NJPL1I000106', for F-SBIDR,
'NJPL1I000107', for F-XBIDR,
'NJPL1I000108', for F-UBIDR.

The following values shall appear in the image data record secondary header (see section 3.4.1):

BIDR secondary label type (bytes 0-1): Image data annotation field.
length = 2 bytes
value = **2** (unsigned 16-bit integer)
BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **68** (unsigned 16-bit integer)

The format of the orbit number field is specified in section 3.4.1.1. The following values shall appear in the image data record annotation block (see sections 3.4.1.2 and 3.4.1.2.1):

Data class (byte 0): Image data, multi-look, sinusoidal projection.
length = 1 byte
value = **2** (unsigned 8-bit integer)
Data annotation label length (byte 1): Number of bytes in the annotation field.
length = 1 byte
value = **64** (unsigned 8-bit integer).

The data block is specified in sections 3.4.2, 3.4.2.2, and 3.4.2.2.1.

3.5.16 File 16: Processing Parameters for Sinusoidal Projection Data

This file consists of processing parameter records. Each logical record shall contain the parameters used to control the SAR processing that produced the image data in the Image Data in Sinusoidal Projection file. This file is provided for diagnostic use, and to facilitate sophisticated interpretation of image data.

One processing parameter record will be recorded in this file for each burst of SAR data for which processing into sinusoidal imagery is attempted.

The following values shall appear in the processing parameter record primary header (see section 3.4):

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).
length = 12 bytes
value = **'NJPL1I000104'**, for F-BIDR,
'NJPL1I000105', for F-TBIDR,
'NJPL1I000106', for F-SBIDR,
'NJPL1I000107', for F-XBIDR,
'NJPL1I000108', for F-UBIDR.

NJPL primary label length (bytes 12-19): Number of bytes in logical record starting with byte 20.
length = 8 bytes
value = **'00001295'**

The following values shall appear in the processing parameter record secondary header (see section 3.4.1):

BIDR secondary label type (bytes 0-1): Burst ID annotation field.
length = 2 bytes
value = **4** (unsigned 16-bit integer)

BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **11** (unsigned 16-bit integer)

The format of the orbit number field is specified in section 3.4.1.1. The following values shall appear in the processing parameter record annotation block (see sections 3.4.1.2 and 3.4.1.2.2):

Data class (byte 0): Processing parameters, sinusoidal projection.
length = 1 byte
value = **4** (unsigned 8-bit integer).

Data annotation label length (byte 1): Number of bytes in the annotation field.
length = 1 byte
value = **7** (unsigned 8-bit integer).

The data block is specified in sections 3.4.2 and 3.4.2.3, and Appendix C.

3.5.17 File 17: Processed Radiometer Data

This file consists of processed radiometer data records. Each logical record will contain processed radiometer data and the parameters used for processing. One processed radiometer data record will be recorded in this file for each burst of SAR data containing a radiometer measurement.

The algorithm used for processing radiometer data is described in Appendix B of [5].

The following values shall appear in the processed radiometer data record primary header (see section 3.4):

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).
length = 12 bytes
value = **'NJPL1I000104'**, for F-BIDR,
'NJPL1I000105', for F-TBIDR,
'NJPL1I000106', for F-SBIDR,
'NJPL1I000107', for F-XBIDR,
'NJPL1I000108', for F-UBIDR.

NJPL primary label length (bytes 12-19): Number of bytes in logical record starting with byte 20.
length = 8 bytes
value = **'00000108'**

The following values shall appear in the processed radiometer data record secondary header (see section 3.4.1):

BIDR secondary label type (bytes 0-1): Radiometer data annotation field.
length = 2 bytes
value = **8** (unsigned 16-bit integer)

BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **92** (unsigned 16-bit integer)

The format of the orbit number field is specified in section 3.4.1.1. The following values shall appear in the processed radiometer data record annotation block (see sections 3.4.1.2 and 3.4.1.2.3):

Data class (byte 0): Processed radiometer data.
length = 1 byte
value = **8** (unsigned 8-bit integer).

Data annotation label length (byte 1): Number of bytes in the annotation field.
length = 1 byte
value = **88** (unsigned 8-bit integer).

The data block is specified in sections 3.4.2 and 3.4.2.4.

3.5.18 File 18: Cold-Sky Calibration Results

This file consists of processed radiometer data records. Each logical record will correspond to a single radiometer measurement, and will contain the results of operating the radiometer while pointing the spacecraft's antenna at "cold space". The blackbody source temperature (radiation temperature) expected from such a measurement is that of the cosmic background: 2.7K.

Cold-sky calibration measurements will be performed three times during the mission: at the beginning, the end, and once at "mid-mission". The data will be processed to obtain the blackbody source temperature and saved. Each F–BIDR will contain in this file all of the collected cold-sky calibration data.

The orbit number of the particular measurement will appear in the logical record secondary header. The radiometer data will be processed to obtain an effective blackbody source temperature, but no surface brightness temperature will be produced. The surface brightness temperature data field will be set to zero.

The following values shall appear in the radiometer data record primary header (see section 3.4):

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).
length = 12 bytes
value = **'NJPL1I000104'**, for F-BIDR,
'NJPL1I000105', for F-TBIDR,
'NJPL1I000106', for F-SBIDR,
'NJPL1I000107', for F-XBIDR,
'NJPL1I000108', for F-UBIDR.

NJPL primary label length (bytes 12-19): Number of bytes in logical record starting with byte 20.
length = 8 bytes
value = **'00000108'**

The following values shall appear in the radiometer data record secondary header (see section 3.4.1):

BIDR secondary label type (bytes 0-1): Radiometer data annotation field.
length = 2 bytes
value = **8** (unsigned 16-bit integer)

BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **92** (unsigned 16-bit integer)

The format of the orbit number field is specified in section 3.4.1.1. The following values shall appear in the radiometer data record annotation block (see sections 3.4.1.2 and 3.4.1.2.3):

Data class (byte 0): Processed cold-sky calibration data.
length = 1 byte
value = **40** (unsigned 8-bit integer).

Data annotation label length (byte 1): Number of bytes in the annotation field.
length = 1 byte
value = **88** (unsigned 8-bit integer).

The data block is specified in sections 3.4.2 and 3.4.2.4.

3.5.19 File 19: Processing Monitor Results

This file consists of processing monitor records containing raw data and image data quality information; image data records containing single-look imagery; processing parameter records containing the parameters used to obtain that imagery; and a multilook image.

These four types of records will be written to File 19 for selected "batches" of bursts each orbit. A "batch" consists of a number of consecutive SAR bursts, where the number is the number of looks (between 1 and 3). One of the bursts will be selected for detailed analysis. Batches will be selected on the basis of true anomaly within an orbit. The number of batches per orbit is 2.

Processing Monitor File Structure

Results for first batch
Results for second batch

A variable number of records is associated with each selected batch: up to three processing monitor records, up to three single-look image records and three corresponding processing parameter records, and one multilook image record.

The first one to three records written in each batch are processing monitor records.

Following the processing monitor record will be up to three pairs of records. Each pair will correspond to one burst in the batch, and will consist of an image data record containing single-look data, and a processing parameter record.

This sequence of records is then repeated for the second batch, as illustrated in the following diagram.

Processing Results — Record Structure

```
 _____________________
| Process Monitor Record |       - beginning of first batch
|__________1__________|
| Process Monitor Record |
|__________2__________|
| Process Monitor Record |
|__________3__________|
||  Single-look Imagery  |             }- first burst in first batch
||____________________|             }
|| Processing Parameter |             }
||________Record_______|
||  Single-look Imagery  |             }- second burst in first batch
||____________________|             }
|| Processing Parameter |             }
||________Record_______|
||  Single-look Imagery  |             }- third burst in first batch
||____________________|             }
|| Processing Parameter |             }
||________Record_______|
||   Multi-look Imagery  |
||____________________|
| Process Monitor Record |       - beginning of second batch
|__________1__________|
| Process Monitor Record |
|__________2__________|
| Process Monitor Record |
|__________3__________|
||  Single-look Imagery  |             }- first burst in second batch
||____________________|             }
|| Processing Parameter |             }
||________Record_______|
||  Single-look Imagery  |             }- second burst in second batch
||____________________|             }
|| Processing Parameter |             }
||________Record_______|
||  Single-look Imagery  |             }- third burst in second batch
||____________________|             }
|| Processing Parameter |             }
||________Record_______|
||   Multi-look Imagery  |
||____________________|
```

Processing Monitor Record:

The following values shall appear in the processing monitor record primary header (see section 3.4):

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).
length = 12 bytes
value = **'NJPL1I000104'**, for F-BIDR,
'NJPL1I000105', for F-TBIDR,
'NJPL1I000106', for F-SBIDR,
'NJPL1I000107', for F-XBIDR,
'NJPL1I000108', for F-UBIDR.

NJPL primary label length (bytes 12-19): Number of bytes in logical record starting with byte 20.
length = 8 bytes
value = **'00020452'**

The following values shall appear in the processing monitor record secondary header (see section 3.4.1):

BIDR secondary label type (bytes 0-1): Burst ID annotation field.
length = 2 bytes
value = **4** (unsigned 16-bit integer)

BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **11** (unsigned 16-bit integer)

The format of the orbit number field is specified in section 3.4.1.1. The following values shall appear in the processing monitor record annotation block (see sections 3.4.1.2 and 3.4.1.2.2):

Data class (byte 0): Processing monitor records.
length = 1 byte
value = **16** (unsigned 8-bit integer).

Data annotation label length (byte 1): Number of bytes in the annotation field.
length = 1 byte
value = **7** (unsigned 8-bit integer).

The data block is specified in sections 3.4.2 and 3.4.2.5 (in its entirety).

Single Look Image Data Records:

The following values shall appear in the image data record primary header (see section 3.4):

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).
length = 12 bytes
value = **'NJPL1I000104'**, for F-BIDR,
'NJPL1I000105', for F-TBIDR,
'NJPL1I000106', for F-SBIDR,
'NJPL1I000107', for F-XBIDR,
'NJPL1I000108', for F-UBIDR.

The following values shall appear in the image data record secondary header (see section 3.4.1):

BIDR secondary label type (bytes 0-1): Image data annotation field.
length = 2 bytes
value = **2** (unsigned 16-bit integer)
BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **68** (unsigned 16-bit integer)

The format of the orbit number field is specified in section 3.4.1.1. The following values shall appear in the image data record annotation block (see sections 3.4.1.2 and 3.4.1.2.1):

Data class (byte 0): Single-look image data.
length = 1 byte
value = **34** (unsigned 8-bit integer) for sinusoidal projection
98 (unsigned 8-bit integer) for oblique sinusoidal projection
Data annotation label length (byte 1): Number of bytes in the annotation field.
length = 1 byte
value = **64** (unsigned 8-bit integer).

The data block is specified in sections 3.4.2, 3.4.2.2, and 3.4.2.2.2.

Processing Parameter Records:

The following values shall appear in the processing parameter record primary header (see section 3.4):

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).
length = 12 bytes
value = **'NJPL1I00000104'**, for F-BIDR,
'NJPL1I00000105', for F-TBIDR,
'NJPL1I00000106', for F-SBIDR,
'NJPL1I00000107', for F-XBIDR,
'NJPL1I00000108', for F-UBIDR.
NJPL primary label length (bytes 12-19): Number of bytes in logical record starting with byte 20.
length = 8 bytes
value = **'00001295'**

The following values shall appear in the processing parameter record secondary header (see section 3.4.1):

BIDR secondary label type (bytes 0-1): Burst ID annotation field.
length = 2 bytes
value = **4** (unsigned 16-bit integer)

BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **11** (unsigned 16-bit integer)

The format of the orbit number field is specified in section 3.4.1.1. The following values shall appear in the processing parameter record annotation block (see sections 3.4.1.2 and 3.4.1.2.2):

Data class (byte 0): Processing parameters.
length = 1 byte
value = **4** (unsigned 8-bit integer) for sinusoidal projection
68 (unsigned 8-bit integer) for oblique sinusoidal projection
Data annotation label length (byte 1): Number of bytes in the annotation field.
length = 1 byte
value = **7** (unsigned 8-bit integer).

The data block is specified in sections 3.4.2 and 3.4.2.3, and Appendix C.

Multi-Look Image Data Records:

The following values shall appear in the image data record primary header (see section 3.4):

NJPL primary label type (bytes 0-11): Indicates an NJPL logical record (ASCII length field).
length = 12 bytes
value = **'NJPL1I000104'**, for F-BIDR,
'NJPL1I000105', for F-TBIDR,
'NJPL1I000106', for F-SBIDR,
'NJPL1I000107', for F-XBIDR,
'NJPL1I000108', for F-UBIDR.

The following values shall appear in the image data record secondary header (see section 3.4.1):

BIDR secondary label type (bytes 0-1): Image data annotation field.
length = 2 bytes
value = **2** (unsigned 16-bit integer)
BIDR secondary label length (bytes 2-3): Number of bytes in secondary header starting with byte 4.
length = 2 bytes
value = **68** (unsigned 16-bit integer)

The format of the orbit number field is specified in section 3.4.1.1. The following values shall appear in the image data record annotation block (see sections 3.4.1.2 and 3.4.1.2.1):

Data class (byte 0): Single-look image data.
length = 1 byte
value = **2** (unsigned 8-bit integer) for sinusoidal projection
66 (unsigned 8-bit integer) for oblique sinusoidal projection
Data annotation label length (byte 1): Number of bytes in the annotation field.
length = 1 byte
value = **64** (unsigned 8-bit integer).

The data block is specified in sections 3.4.2, 3.4.2.2, and 3.4.2.2.1.

APPENDIX A
GLOSSARY

aggregation: A collection of objects. An SFDO may be an aggregation of data objects, provided it is delimited using approved labeling techniques (see ref. [4]).

barycentric dynamical time (TDB): Used as a time scale of ephemerides referred to the barycenter of the solar system.

byte: Eight contiguous bits starting on an eight-bit boundary; octet. A byte may be used to store one ASCII character.

contiguous: Physically adjacent; containing no gaps.

data object: A set of related data treated as a unit. May consist of several fields.

data physical record, data record: For the F–BIDR, any physical record which is not a tape volume header/trailer or a file header/trailer.

data unit: A collection of data objects defined by data interchange standards that incorporate format-referencing methodologies.

DOY time format: Use of decimal digits to represent a time, with separate fields for year A. D., day of year, hour, minutes, seconds, and thousandths of seconds. For example, 87/046-16:23:32.109 represents 4:23:32.109 p.m., March 15, 1987.

field: A component of a data object with attributes of length and representation (number or alphanumeric) and which is contiguous. The instance of a field is the field value.

file (magnetic tape): A named set of data records, delimited by special header and trailer records.

flag: Any binary-valued datum.

image data record: F–BIDR logical record containing image data in the format specified in 3.4 of this document.

interrecord gap: A blank space deliberately placed between physical records on the recording surface of a magnetic tape.

label: A field in a data object that describes and/or delimits the object. A header label appears at the beginning of an object; a trailer label appears at the end. If an object has several header labels, the first one is the primary header; the second is the secondary header; the third, if any, is the tertiary header; and so forth. In a TLV object, the header label comprises the type and length fields.

logical record: An F–BIDR logical record is an NJPL0001 SFDO.

NJPL: Identifier for the NASA/JPL SFDU Control Authority, which keeps a catalog of formats and codes for locally defined data objects. Used in primary header type fields.

NJPL0001: Envelope structure defined by JPL, used to aggregate JPL compressed-header data objects. See the JPL SFDU Usage and Description document, JJPL0006-00-01.

observed (computed) antenna temperature: The temperature an infinite blackbody would have to account for the radiation power incident upon the receiving antenna.

physical record: All physical records have a fixed length of 32500 bytes. Magnetic tape physical records are separated by inter-record gaps. Within a file, physical records are created every 32500 bytes regardless of logical record size and boundaries.

processing parameter record: F–BIDR logical record containing parameters used in generating the F–BIDR, in the format specified in 3.4 of this document.

record: A set of related data treated as a unit. May consist of several fields. See logical record and physical record.

SCLK 15-character ASCII format: A 15-byte ASCII character string representing a time generated by the 48-bit spacecraft clock. The format is

"XXXXXXXX.YY.Z.A",

where

"XXXXXXXX"= 8 characters representing the RIM count
"YY" = 2 characters representing the Mod91 count
"Z" = 1 character representing the Mod10 count
"A" = 1 character representing the Mod8 count

A period (decimal 46) is used to separate each field.

Standard Formatted Data Object (SFDO): A data object whose contents conform to the set of guidelines given in ref. [4].

Standard Formatted Data Unit (SFDU): Data units that conform to CCSDS standards for structure and field specification definition. An SFDU consists of two or more SFDOs, the first of which has to be a Primary SFDO (a "Z" class SFDO).

string: A contiguous set of bytes containing ASCII characters.

surface brightness temperature: If the planet were a perfect blackbody, the temperature that blackbody would be to account for the power originating from the planet surface. For the algorithm to be used for radiometer processing, the radiation originating from the planet surface includes thermal radiation emitted by the surface, and radiation emitted by the atmosphere and reflected from the surface.

TLV object: A data object consisting of a TYPE field, a LENGTH field, and a VALUE field, in that order.

volume (magnetic tape): A reel of magnetic tape, whose meaningful contents are delimited by special header and trailer records.

APPENDIX B
DATA REPRESENTATION

Floating-point values written on F-BIDRs will be represented using DEC F_floating and D_floating formats. Integer values will be represented using unsigned binary and signed two's-complement formats. The following descriptions were obtained from the VAX Architecture Handbook (Digital Equipment Corporation, Maynard, Massachussetts, 1986).

B.1 Single-Precision Floating-Point Data

A single-precision floating-point number (also called "F_floating") occupies four contiguous bytes. The bits are labeled from the left starting at 0 and terminating with 31. Within each field, bits are ordered from most-significant to least-significant as follows:

field	MSB-to-LSB
exponent	14-7
fraction	6-0, 31-16

Bytes are numbered in the order they will appear on tape (byte 0 written first, byte 1 second, etc.). Bits are assigned to bytes as follows:

byte	bits
0	0-7
1	8-15
2	16-23
3	24-31

The F_floating format is illustrated below.

Single-Precision Floating-Point Format

```
bit number      0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
               ________________________________________________
bytes 0-1      |     FRACTION      |     EXPONENT        |SIGN|
               |___________________|_____________________|____|
bytes 2-3      |                 FRACTION                     |
               |______________________________________________|
                16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
```

Bit 15, the sign bit, is 1 if the value is negative. Bits 7 through 14 express an excess-128 binary exponent, and bits 0 through 6 and 16 through 31 are a normalized 24-bit fraction with the redundant most significant fraction bit not represented.

The exponent field is 8 bits long. If it contains 0, the entire number has a value of zero. Exponent values are excess-128; i. e., values of 1 through 255 represent true binary exponents of –127 through +127.

It should be noted that an F_floating number with a sign bit value of '1' and an exponent value of '0' is "reserved" by VAX/VMS, and is not a valid number.

F_floating data values are in the approximate range 0.29×10^{-38} through 1.7×10^{38}. The precision is approximately one part in 2^{23} or seven decimal digits.

B.2 Double-Precision Floating-Point Data

A double-precision floating-point number (also called "D_floating") occupies eight contiguous bytes. The bits are labeled from the left starting at 0 and terminating with 63. Within each field, bits are ordered from most-significant to least-significant as follows:

field	MSB-to-LSB
exponent	14-7
fraction	6-0, 31-16, 47-32, 63-48

Bytes are numbered in the order they will appear on tape (byte 0 written first, byte 1 second, etc.). Bits are assigned to bytes as follows:

byte	bits
0	0-7
1	8-15
2	16-23
3	24-31
4	32-39
5	40-47
6	48-55
7	56-63

The D_floating format is illustrated below.

Double-Precision Floating-Point Format

```
bit number     0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
              _________________________________________________
bytes 0-1    |     FRACTION        |         EXPONENT     |SIGN|
             |_____________________|______________________|____|
bytes 2-3    |                   FRACTION                       |
             |__________________________________________________|
bytes 4-5    |                   FRACTION                       |
             |__________________________________________________|
bytes 6-7    |                   FRACTION                       |
             |__________________________________________________|
               48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63
```

The form of D_floating data is identical to F_floating data except for an additional 32 low-significance bits.

Bit 15, the sign bit, is 1 if the value is negative. Bits 7 through 14 express an excess-128 binary exponent, and bits 0 through 6 and 16 through 63 are a normalized 56-bit fraction with the redundant most significant fraction bit not represented.

The exponent field is 8 bits long. If it contains 0, the entire number has a value of zero. Exponent values are excess-128; i. e., values of 1 through 255 represent true binary exponents of –127 through +127.

It should be noted that an D_floating number with a sign bit value of '1' and an exponent value of '0' is "reserved" by VAX/VMS, and is not a valid number.

D_floating data values are in the approximate range 0.29×10^{-38} through 1.7×10^{38}. The precision is approximately one part in 2^{55} or 16 decimal digits.

B.3 Integer Data

Integer data are stored in a binary format that may be unsigned or signed. Unsigned integers are interpreted as being strictly positive.

Signed integers are represented in two's complement form. In this format, if the Most Significant Bit (MSB) is zero, a number is interpreted as being positive; if the MSB is one, then the number is negative. A negative number is represented by the value which is one greater than the bit-by-bit complement of its positive counterpart.

The value of an eight-bit unsigned integer is in the range of 0 through 255. The value of an eight-bit signed integer is in the range of –128 to 127.

The value of an 16-bit unsigned integer is in the range of 0 through 65,535. The value of a 16-bit signed integer is in the range of –32,768 to 32,767.

The value of an 32-bit unsigned integer is in the range of 0 through 4,294,967,295. The value of a 32-bit signed integer is in the range –2,147,483,648 to 2,147,483,647.

On a magnetic tape, the bytes of an integer increase in significance in the order in which they are written. That is, the first byte written is the lowest-order byte; the last byte is the highest.

APPENDIX C
TABLE OF SDPS PROCESSING PARAMETERS

This table identifies the processing parameters that shall be written on F–BIDRs. The structure of the records in which they will be stored is specified in Section 3.4 of this document. Definition of the quantities is given in **Appendix F** of this document.

Notes:

1. All values are instance-dependent, and except where noted, are single-precision floating-point numbers. Data formats are described in Appendix B.

2. The apparent ranges and the Doppler frequencies for both the radiometric reference and geometric non-centered reference points are relative to the center reference point.

3. All longitudes are given in degrees East and range from 0 to 360.

General Processing Parameters

Parameter 1 (bytes 0-3): EDR burst counter (increments from 1 beginning with the first burst on the EDR), unsigned VAX integer.

Parameter 2 (bytes 4-11): Burst start time in TDB seconds since epoch J2000, double-precision VAX floating point.
Parameter 3 (bytes 12-19): Burst reference time in TDB seconds since epoch J2000, double-precision VAX floating point.
Parameter 4 (bytes 20-27): Burst center time in TDB seconds since epoch J2000, double-precision VAX floating point.
Parameter 5 (bytes 28-31): Echo delay time in seconds.

Parameter 6 (bytes 32-35): "Test" flag (1 = burst consists of test data, 0 = otherwise), unsigned VAX integer.
Parameter 7 (bytes 36-39): "Anomaly" flag (1 = burst is below data quality threshold and so was not processed, 0 = otherwise), unsigned VAX integer.
Parameter 8 (bytes 40-43): "Error" flag (1 = an error occured during processing which prevented this burst from being processed, 0 = otherwise), unsigned VAX integer.
Parameter 9 (bytes 44-47): Projection used for this processing parameter record (1=sinusoidal; 2=oblique sinusoidal; 3=record is sinusoidal, burst is processed into both; 4=record is oblique sinusoidal, burst is processed into both), unsigned VAX integer.

Spacecraft State Parameters

Parameter 10 (bytes 48-51): X-component of spacecraft position vector in J2000 coordinates, in meters.
Parameter 11 (bytes 52-55): Y-component of spacecraft position vector in J2000 coordinates, in meters.
Parameter 12 (bytes 56-59): Z-component of spacecraft position vector in J2000 coordinates, in meters.

Parameter 13 (bytes 60-63): X-component of spacecraft position vector in VBF85 coordinates, in meters.
Parameter 14 (bytes 64-67): Y-component of spacecraft position vector in VBF85 coordinates, in meters.
Parameter 15 (bytes 68-71): Z-component of spacecraft position vector in VBF85 coordinates, in meters.

Parameter 16 (bytes 72-75): X-component of spacecraft velocity vector in J2000 coordinates, in meters/sec.
Parameter 17 (bytes 76-79): Y-component of spacecraft velocity vector in J2000 coordinates, in meters/sec.
Parameter 18 (bytes 80-83): Z-component of spacecraft velocity vector in J2000 coordinates, in meters/sec.

Parameter 19 (bytes 84-87): X-component of spacecraft velocity vector in VBF85 coordinates, in meters/sec.
Parameter 20 (bytes 88-91): Y-component of spacecraft velocity vector in VBF85 coordinates, in meters/sec.
Parameter 21 (bytes 92-95): Z-component of spacecraft velocity vector in VBF85 coordinates, in meters/sec.

Parameter 22 (bytes 96-99): X-component of spacecraft acceleration vector in J2000 coordinates, in meters/sec^2.
Parameter 23 (bytes 100-103): Y-component of spacecraft acceleration vector in J2000 coordinates, in meters/sec^2.
Parameter 24 (bytes 104-107): Z-component of spacecraft acceleration vector in J2000 coordinates, in meters/sec^2.

Parameter 25 (bytes 108-111): X-component of spacecraft acceleration vector in VBF85 coordinates, in meters/sec^2.
Parameter 26 (bytes 112-115): Y-component of spacecraft acceleration vector in VBF85 coordinates, in meters/sec^2.
Parameter 27 (bytes 116-119): Z-component of spacecraft acceleration vector in VBF85 coordinates, in meters/sec^2.

Parameter 28 (bytes 120-123): q1, first boresight pointing quaternion (derived from MQPC file).
Parameter 29 (bytes 124-127): q2, second boresight pointing quaternion (derived from MQPC file).
Parameter 30 (bytes 128-131): q3, third boresight pointing quaternion (derived from MQPC file).
Parameter 31 (bytes 132-135): q4, fourth boresight pointing quaternion (derived from MQPC file).

Parameter 32 (bytes 136-139): Delta q1, difference between uplinked and measured value of first boresight pointing quaternion element (uplinked - measured), as reported in telemetry. Will be zero if not used.
Parameter 33 (bytes 140-143): Delta q2, difference between uplinked and measured value of second boresight pointing quaternion element (uplinked - measured), as reported in telemetry. Will be zero if not used.
Parameter 34 (bytes 144-147): Delta q3, difference between uplinked and measured value of third boresight pointing quaternion element (uplinked - measured), as reported in telemetry. Will be zero if not used.
Parameter 35 (bytes 148-151): Delta q4, difference between uplinked and measured value of fourth boresight pointing quaternion element (uplinked - measured), as reported in telemetry. Will be zero if not used.

Parameter 36 (bytes 152-155): X-component of boresight unit pointing vector in VME85 spacecraft-centered coordinates.
Parameter 37 (bytes 156-159): Y-component of boresight unit pointing vector in VME85 spacecraft-centered coordinates.
Parameter 38 (bytes 160-163): Z-component of boresight unit pointing vector in VME85 spacecraft-centered coordinates.

Parameter 39 (bytes 164-167): X-component of boresight unit pointing vector in VBF85 spacecraft-centered coordinates.
Parameter 40 (bytes 168-171): Y-component of boresight unit pointing vector in VBF85 spacecraft-centered coordinates.
Parameter 41 (bytes 172-175): Z-component of boresight unit pointing vector in VBF85 spacecraft-centered coordinates.

Parameter 42 (bytes 176-179): Look angle, in degrees.

Boresight Intercept Point (BIP) Parameters

Parameter 43 (bytes 180-183): X-component of Boresight Intercept Point (BIP) vector in VBF85 coordinates, in meters.
Parameter 44 (bytes 184-187): Y-component of BIP vector in VBF85 coordinates, in meters.
Parameter 45 (bytes 188-191): Z-component of BIP vector in VBF85 coordinates, in meters.

Parameter 46 (bytes 192-195): BIP longitude, in degrees.
Parameter 47 (bytes 196-199): BIP latitude, in degrees.
Parameter 48 (bytes 200-203): Terrain elevation at BIP above nominal planet surface of radius 6051, in meters.

Parameter 49 (bytes 204-207): BIP incidence angle in degrees.
Parameter 50 (bytes 208-211): BIP apparent range, in meters.

Parameter 51 (bytes 212-215): BIP instantaneous Doppler frequency, in Hertz.

Parameter 52 (bytes 216-219): Doppler drift rate along range, in Hertz/meter.

Mid-Range Point (MRP) Parameters

Parameter 53 (bytes 220-223): MRP Incidence angle.
Parameter 54 (bytes 224-227): BIP backscattering coefficient expressed as a function of 'BIP incidence angle (reference parameter #49) - 0.5 degrees'.
Parameter 55 (bytes 228-231): MRP latitude, in degrees.
Parameter 56 (bytes 232-235): MRP longitude, in degrees.

Parameter 57 (bytes 236-239): MRP elevation, in meters.

Parameter 58 (bytes 240-243): Apparent range to the first range sample in the truncated framelet, in meters.
Parameter 59 (bytes 244-247): MRP apparent range, in meters.

Parameter 60 (bytes 248-251): MRP instantaneous Doppler frequency, in Hertz.
Parameter 61 (bytes 252-255): MRP instantaneous Doppler frequency rate, in Hertz/second.

Parameter 62 (bytes 256-259): X-component of MRP position vector in VME85 coordinates , in meters.
Parameter 63 (bytes 260-263): Y-component of MRP position vector in VME85 coordinates , in meters.
Parameter 64 (bytes 264-267): Z-component of MRP position vector in VME85 coordinates , in meters.

Radiometric Compensation Parameters - I

Parameter 65 (bytes 268-271): Sensor-processor gain from calibration.
Parameter 66 (bytes 272-275): Range FFT length in bins, unsigned VAX integer.

Parameter 67 (bytes 276-279): Azimuth FFT length in bins, unsigned VAX integer.
Parameter 68 (bytes 280-283): Number of pulses in the burst, unsigned VAX integer.

Parameter 69 (bytes 284-287): Time to ground range conversion factor.
Parameter 70 (bytes 288-291): Doppler to Along-Track distance conversion factor.
Parameter 71 (bytes 292-295): BAQ reconstruction scaling factor.

Parameter 72 (bytes 296-299): Transmitter power correction factor.
Parameter 73 (bytes 300-303): Receiver gain correction factor.
Parameter 74 (bytes 304-307): Gain correction factor for Nonstandard redundancy configuration.

Reference Control Parameters

Parameter 75 (bytes 308-311): Range reference group index, unsigned VAX integer.
Parameter 76 (bytes 312-315): Absolute range walk across all pulses this burst (number of slant range samples).
Parameter 77 (bytes 316-319): Range walk correction coefficient (order 0) in range bins.
Parameter 78 (bytes 320-323): Range walk correction coefficient (order 1) in range bins per

interpulse period.

Sensor States and Temperatures

Parameter 79 (bytes 324-327): Transmitter A state (0 = transmitter B on, 1 = transmitter A on), unsigned VAX integer.
Parameter 80 (bytes 328-331): Receiver A state (0 = receiver B on, 1 = receiver A on), unsigned VAX integer.
Parameter 81 (bytes 332-335): ONU A state (0 = ONU B on, 1 = ONU A on), unsigned VAX integer.

Parameter 82 (bytes 336-339): Transmitter A stage 1 temperature in degrees C.
Parameter 83 (bytes 340-343): Receiver A Temperature in degrees C.
Parameter 84 (bytes 344-347): ONU A temperature in degrees C.
Parameter 85 (bytes 348-351): Transmitter B stage 1 temperature in degrees C.
Parameter 86 (bytes 352-355): Receiver B Temperature in degrees C.
Parameter 87 (bytes 356-359): ONU B temperature in degrees C.
Parameter 88 (bytes 360-363): Sensor-antenna Cable 1 temperature in degrees C.
Parameter 89 (bytes 364-367): Sensor-antenna Cable 2 temperature in degrees C.
Parameter 90 (bytes 368-371): Sensor-antenna Cable 3 temperature in degrees C.
Parameter 91 (bytes 372-375): Sensor-antenna Cable 4 temperature in degrees C.
Parameter 92 (bytes 376-379): Sensor-antenna Cable 5 temperature in degrees C.

Radiometric Compensation Parameters - II

Parameter 93 (bytes 380-383): Radiometric reference point (1,1) apparent range relative to point (2,2), in meters.
Parameter 94 (bytes 384-387): Radiometric reference point (2,1) apparent range relative to point (2,2), in meters.
Parameter 95 (bytes 388-391): Radiometric reference point (3,1) apparent range relative to point (2,2), in meters.
Parameter 96 (bytes 392-395): Radiometric reference point (1,2) apparent range relative to point (2,2), in meters.
Parameter 97 (bytes 396-399): Radiometric reference point (2,2) apparent range, in meters.
Parameter 98 (bytes 400-403): Radiometric reference point (3,2) apparent range relative to point (2,2), in meters.
Parameter 99 (bytes 404-407): Radiometric reference point (1,3) apparent range relative to point (2,2), in meters.
Parameter 100 (bytes 408-411): Radiometric reference point (2,3) apparent range relative to point (2,2), in meters.
Parameter 101 (bytes 412-415): Radiometric reference point (3,3) apparent range relative to point (2,2), in meters.

Parameter 102 (bytes 416-419): Radiometric reference point (1,1) Doppler relative to point (2,2), in Hertz
Parameter 103 (bytes 420-423): Radiometric reference point (2,1) Doppler relative to point (2,2), in Hertz
Parameter 104 (bytes 424-427): Radiometric reference point (3,1) Doppler relative to point (2,2), in Hertz
Parameter 105 (bytes 428-431): Radiometric reference point (1,2) Doppler relative to point (2,2), in Hertz
Parameter 106 (bytes 432-435): Radiometric reference point (2,2) Doppler, in Hertz
Parameter 107 (bytes 436-439): Radiometric reference point (3,2) Doppler relative to point (2,2), in Hertz
Parameter 108 (bytes 440-443): Radiometric reference point (1,3) Doppler relative to point (2,2), in Hertz
Parameter 109 (bytes 444-447): Radiometric reference point (2,3) Doppler relative to point (2,2), in Hertz
Parameter 110 (bytes 448-451): Radiometric reference point (3,3) Doppler relative to point (2,2), in Hertz

Parameter 111 (bytes 452-455): Radiometric reference point (1,1) Coordinate-1 (number of 75 meter spacing).
Parameter 112 (bytes 456-459): Radiometric reference point (2,1) Coordinate-1 (number of 75 meter spacing).
Parameter 113 (bytes 460-463): Radiometric reference point (3,1) Coordinate-1 (number of 75 meter spacing).
Parameter 114 (bytes 464-467): Radiometric reference point (1,2) Coordinate-1 (number of 75 meter spacing).
Parameter 115 (bytes 468-471): Radiometric reference point (2,2) Coordinate-1 (number of 75 meter spacing).
Parameter 116 (bytes 472-475): Radiometric reference point (3,2) Coordinate-1 (number of 75 meter spacing).
Parameter 117 (bytes 476-479): Radiometric reference point (1,3) Coordinate-1 (number of 75 meter spacing).
Parameter 118 (bytes 480-483): Radiometric reference point (2,3) Coordinate-1 (number of 75 meter spacing).
Parameter 119 (bytes 484-487): Radiometric reference point (3,3) Coordinate-1 (number of 75 meter spacing).

Parameter 120 (bytes 488-491): Radiometric reference point (1,1) Coordinate-2 (number of 75 meter spacing).
Parameter 121 (bytes 492-495): Radiometric reference point (2,1) Coordinate-2 (number of 75 meter spacing).
Parameter 122 (bytes 496-499): Radiometric reference point (3,1) Coordinate-2 (number of 75 meter spacing).
Parameter 123 (bytes 500-503): Radiometric reference point (1,2) Coordinate-2 (number of 75 meter spacing).
Parameter 124 (bytes 504-507): Radiometric reference point (2,2) Coordinate-2 (number of 75 meter spacing).
Parameter 125 (bytes 476-479): Radiometric reference point (3,2) Coordinate-2 (number of 75 meter spacing).
Parameter 126 (bytes 512-515): Radiometric reference point (1,3) Coordinate-2 (number of 75 meter spacing).
Parameter 127 (bytes 516-519): Radiometric reference point (2,3) Coordinate-2 (number of 75 meter spacing).
Parameter 128 (bytes 520-523: Radiometric reference point (3,3) Coordinate-2 (number of 75 meter spacing).

Parameter 129 (bytes 524-527): Distance from sensor to Radiometric reference point (1,1), in meters.
Parameter 130 (bytes 528-531): Distance from sensor to Radiometric reference point (2,1), in meters
Parameter 131 (bytes 532-535): Distance from sensor to Radiometric reference point (3,1), in meters.
Parameter 132 (bytes 536-539): Distance from sensor to Radiometric reference point (1,2), in meters.
Parameter 133 (bytes 540-543): Distance from sensor to Radiometric reference point (2,2), in meters.
Parameter 134 (bytes 544-547): Distance from sensor to Radiometric reference point (3,2), in meters.
Parameter 135 (bytes 548-551): Distance from sensor to Radiometric reference point (1,3), in meters.
Parameter 136 (bytes 552-555): Distance from sensor to Radiometric reference point (2,3), in meters.
Parameter 137 (bytes 556-559): Distance from sensor to Radiometric reference point (3,3), in meters.

<u>Parameter 138</u> (bytes 560-563): Off-boresight elevation angle at Radiometric reference point (1,1), in degrees.
<u>Parameter 139</u> (bytes 564-567): Off-boresight elevation angle at Radiometric reference point (2,1), in degrees.
<u>Parameter 140</u> (bytes 568-571): Off-boresight elevation angle at Radiometric reference point (3,1), in degrees.
<u>Parameter 141</u> (bytes 572-575): Off-boresight elevation angle at Radiometric reference point (1,2), in degrees.
<u>Parameter 142</u> (bytes 576-579): Off-boresight elevation angle at Radiometric reference point (2,2), in degrees.
<u>Parameter 143</u> (bytes 580-583): Off-boresight elevation angle at Radiometric reference point (3,2), in degrees.
<u>Parameter 144</u> (bytes 584-587): Off-boresight elevation angle at Radiometric reference point (1,3), in degrees.
<u>Parameter 145</u> (bytes 588-591): Off-boresight elevation angle at Radiometric reference point (2,3), in degrees.
<u>Parameter 146</u> (bytes 592-595): Off-boresight elevation angle at Radiometric reference point (3,3), in degrees.

<u>Parameter 147</u> (bytes 596-599): Off-boresight horizontal angle at Radiometric reference point (1,1), in degrees.
<u>Parameter 148</u> (bytes 600-603): Off-boresight horizontal angle at Radiometric reference point (2,1), in degrees.
<u>Parameter 149</u> (bytes 604-607): Off-boresight horizontal angle at Radiometric reference point (3,1), in degrees.
<u>Parameter 150</u> (bytes 608-611): Off-boresight horizontal angle at Radiometric reference point (1,2), in degrees.
<u>Parameter 151</u> (bytes 612-615): Off-boresight horizontal angle at Radiometric reference point (2,2), in degrees.
<u>Parameter 152</u> (bytes 616-619): Off-boresight horizontal angle at Radiometric reference point (3,2), in degrees.
<u>Parameter 153</u> (bytes 620-623): Off-boresight horizontal angle at Radiometric reference point (1,3), in degrees.
<u>Parameter 154</u> (bytes 624-627): Off-boresight horizontal angle at Radiometric reference point (2,3), in degrees.
<u>Parameter 155</u> (bytes 628-631): Off-boresight horizontal angle at Radiometric reference point (3,3), in degrees.

<u>Parameter 156</u> (bytes 632-635): Antenna gain to Radiometric reference point (1,1).
<u>Parameter 157</u> (bytes 636-639): Antenna gain to Radiometric reference point (2,1).
<u>Parameter 158</u> (bytes 640-643): Antenna gain to Radiometric reference point (3,1).
<u>Parameter 159</u> (bytes 644-647): Antenna gain to Radiometric reference point (1,2).
<u>Parameter 160</u> (bytes 648-651): Antenna gain to Radiometric reference point (2,2).
<u>Parameter 161</u> (bytes 652-655): Antenna gain to Radiometric reference point (3,2).
<u>Parameter 162</u> (bytes 656-659): Antenna gain to Radiometric reference point (1,3).
<u>Parameter 163</u> (bytes 660-663): Antenna gain to Radiometric reference point (2,3).
<u>Parameter 164</u> (bytes 664-667): Antenna gain to Radiometric reference point (3,3).

<u>Parameter 165</u> (bytes 668-671): MRP Backscatter coefficient at Radiometric reference point (2,2) expressed as a function of 'MRP incidence angle (reference parameter #53) - 0.5 degree'.

Parameter 166 (bytes 672-675): Radiometric compensation factor at Radiometric reference point (1,1).
Parameter 167 (bytes 676-679): Radiometric compensation factor at Radiometric reference point (2,1).
Parameter 168 (bytes 680-683): Radiometric compensation factor at Radiometric reference point (3,1).
Parameter 169 (bytes 684-687): Radiometric compensation factor at Radiometric reference point (1,2).
Parameter 170 (bytes 688-691): Radiometric compensation factor at Radiometric reference point (2,2).
Parameter 171 (bytes 692-695): Radiometric compensation factor at Radiometric reference point (3,2).
Parameter 172 (bytes 696-699): Radiometric compensation factor at Radiometric reference point (1,3).
Parameter 173 (bytes 700-703): Radiometric compensation factor at Radiometric reference point (2,3).
Parameter 174 (bytes 704-707): Radiometric compensation factor at Radiometric reference point (3,3).

Parameter 175 (bytes 708-711): Second-order compensation coefficient given apparent range for generating second-order coefficient given Doppler (μ_{r33}); note that this parameter is not used by the DCS when the value of Parameter 301 exceeds 40.
Parameter 176 (bytes 712-715): First-order compensation coefficient given apparent range for generating second-order coefficient given Doppler (μ_{r23}); note that this parameter is not used by the DCS when the value of Parameter 301 exceeds 40.
Parameter 177 (bytes 716-719): Zero-order compensation coefficient given apparent range for generating second-order coefficient given Doppler (μ_{r13}); note that this parameter is not used by the DCS when the value of Parameter 301 exceeds 40.
Parameter 178 (bytes 720-723): Second-order compensation coefficient given apparent range for generating first-order coefficient given Doppler (μ_{r32}); note that this parameter is not used by the DCS when the value of Parameter 301 exceeds 40.
Parameter 179 (bytes 724-727): First-order compensation coefficient given apparent range for generating first-order coefficient given Doppler (μ_{r22}); note that this parameter is not used by the DCS when the value of Parameter 301 exceeds 40.
Parameter 180 (bytes 728-731): Zero-order compensation coefficient given apparent range for generating first-order coefficient given Doppler (μ_{r12}); note that this parameter is not used by the DCS when the value of Parameter 301 exceeds 40.
Parameter 181 (bytes 732-735): Second-order compensation coefficient given apparent range for generating zero-order coefficient given Doppler (μ_{r31}); note that this parameter is not used by the DCS when the value of Parameter 301 exceeds 40.
Parameter 182 (bytes 736-739): First-order compensation coefficient given apparent range for generating zero-order coefficient given Doppler (μ_{r21}); note that this parameter is not used by the DCS when the value of Parameter 301 exceeds 40.
Parameter 183 (bytes 740-743): Zero-order compensation coefficient given apparent range for generating zero-order coefficient given Doppler (μ_{r11}); note that this parameter is not used by the DCS when the value of Parameter 301 exceeds 40.

Geometric Correction Parameters

Parameter 184 (bytes 744-747): Geometric reference point (1,1) Coordinate-1 (number of 75 meter spacing), signed VAX integer.
Parameter 185 (bytes 748-751): Geometric reference point (2,1) Coordinate-1 (number of 75 meter spacing), signed VAX integer.
Parameter 186 (bytes 752-755): Geometric reference point (3,1) Coordinate-1 (number of 75 meter spacing), signed VAX integer.
Parameter 187 (bytes 756-759): Geometric reference point (1,2) Coordinate-1 (number of 75 meter spacing), signed VAX integer.
Parameter 188 (bytes 760-763): Geometric reference point (2,2) Coordinate-1 (number of 75 meter spacing), signed VAX integer.
Parameter 189 (bytes 764-767): Geometric reference point (3,2) Coordinate-1 (number of 75 meter spacing), signed VAX integer.
Parameter 190 (bytes 768-771): Geometric reference point (1,3) Coordinate-1 (number of 75 meter spacing), signed VAX integer.
Parameter 191 (bytes 772-775): Geometric reference point (2,3) Coordinate-1 (number of 75 meter spacing), signed VAX integer.
Parameter 192 (bytes 776-779): Geometric reference point (3,3) Coordinate-1 (number of 75 meter spacing), signed VAX integer.

Parameter 193 (bytes 780-783): Geometric reference point (1,1) Coordinate-2 (number of 75 meter spacing), signed VAX integer.
Parameter 194 (bytes 784-787): Geometric reference point (2,1) Coordinate-2 (number of 75 meter spacing), signed VAX integer.
Parameter 195 (bytes 788-791): Geometric reference point (3,1) Coordinate-2 (number of 75 meter spacing), signed VAX integer.
Parameter 196 (bytes 792-795): Geometric reference point (1,2) Coordinate-2 (number of 75 meter spacing), signed VAX integer.
Parameter 197 (bytes 796-799): Geometric reference point (2,2) Coordinate-2 (number of 75 meter spacing), signed VAX integer.
Parameter 198 (bytes 800-803): Geometric reference point (3,2) Coordinate-2 (number of 75 meter spacing), signed VAX integer.
Parameter 199 (bytes 804-807): Geometric reference point (1,3) Coordinate-2 (number of 75 meter spacing), signed VAX integer.
Parameter 200 (bytes 808-811): Geometric reference point (2,3) Coordinate-2 (number of 75 meter spacing), signed VAX integer.
Parameter 201 (bytes 812-815): Geometric reference point (3,3) Coordinate-2 (number of 75 meter spacing), signed VAX integer.

Parameter 202 (bytes 816-819): Geometric reference point (1,1) terrain elevation, in meters.
Parameter 203 (bytes 820-823): Geometric reference point (2,1) terrain elevation, in meters.
Parameter 204 (bytes 824-827): Geometric reference point (3,1) terrain elevation, in meters.
Parameter 205 (bytes 828-831): Geometric reference point (1,2) terrain elevation, in meters.
Parameter 206 (bytes 832-835): Geometric reference point (2,2) terrain elevation, in meters.
Parameter 207 (bytes 836-839): Geometric reference point (3,2) terrain elevation, in meters.
Parameter 208 (bytes 840-843): Geometric reference point (1,3) terrain elevation, in meters.
Parameter 209 (bytes 844-847): Geometric reference point (2,3) terrain elevation, in meters.
Parameter 210 (bytes 848-851): Geometric reference point (3,3) terrain elevation, in meters.

Parameter 211 (bytes 852-855): Geometric reference point (1,1) apparent range relative to point (2,2), in meters.
Parameter 212 (bytes 856-859): Geometric reference point (2,1) apparent range relative to point (2,2), in meters.
Parameter 213 (bytes 860-863): Geometric reference point (3,1) apparent range relative to point (2,2), in meters.
Parameter 214 (bytes 864-867): Geometric reference point (1,2) apparent range relative to point (2,2), in meters.
Parameter 215 (bytes 868-871): Geometric reference point (2,2) apparent range, in meters.
Parameter 216 (bytes 872-875): Geometric reference point (3,2) apparent range relative to point (2,2), in meters.
Parameter 217 (bytes 876-879): Geometric reference point (1,3) apparent range relative to point (2,2), in meters.
Parameter 218 (bytes 880-883): Geometric reference point (2,3) apparent range relative to point (2,2), in meters.
Parameter 219 (bytes 884-887): Geometric reference point (3,3) apparent range relative to point (2,2), in meters.

Parameter 220 (bytes 888-891): Geometric reference point (1,1) Doppler relative to point (2,2),in Hertz
Parameter 221 (bytes 892-895): Geometric reference point (2,1) Doppler relative to point (2,2), in Hertz
Parameter 222 (bytes 896-899): Geometric reference point (3,1) Doppler relative to point (2,2), in Hertz
Parameter 223 (bytes 900-903): Geometric reference point (1,2) Doppler relative to point (2,2), in Hertz
Parameter 224 (bytes 904-907): Geometric reference point (2,2) Doppler, in Hertz
Parameter 225 (bytes 908-911): Geometric reference point (3,2) Doppler relative to point (2,2), in Hertz
Parameter 226 (bytes 912-915): Geometric reference point (1,3) Doppler relative to point (2,2), in Hertz
Parameter 227 (bytes 916-919): Geometric reference point (2,3) Doppler relative to point (2,2), in Hertz
Parameter 228 (bytes 920-923): Geometric reference point (3,3) Doppler relative to point (2,2), in Hertz

Parameter 229 (bytes 924-927): Second-order range resampling coefficient given C2 for generating second-order coefficient given Doppler (μ_{g33}).
Parameter 230 (bytes 928-931): First-order range resampling coefficient given C2 for generating second-order coefficient given Doppler (μ_{g23}).
Parameter 231 (bytes 932-935): Zero-order range resampling coefficient given C2 for generating second-order coefficient given Doppler (μ_{g13}).
Parameter 232 (bytes 936-939): Second-order range resampling coefficient given C2 for generating first-order coefficient given Doppler (μ_{g32}).
Parameter 233 (bytes 940-943): First-order range resampling coefficient given C2 for generating first-order coefficient given Doppler (μ_{g22}).
Parameter 234 (bytes 944-947): Zero-order range resampling coefficient given C2 for generating first-order coefficient given Doppler (μ_{g12}).
Parameter 235 (bytes 948-951): Second-order range resampling coefficient given C2 for generating zero-order coefficient given Doppler (μ_{g31}).
Parameter 236 (bytes 952-955): First-order range resampling coefficient given C2 for generating zero-order coefficient given Doppler (μ_{g21}).
Parameter 237 (bytes 956-959): Zero-order range resampling coefficient given C2 for generating zero-order coefficient given Doppler (μ_{g11}).

Parameter 238 (bytes 960-963): Second-order Doppler resampling coefficient given C1 for generating second-order coefficient given C2 (μ_{a33}).
Parameter 239 (bytes 964-967): Second-order Doppler resampling coefficient given C1 for generating first-order coefficient given C2 (μ_{a23}).
Parameter 240 (bytes 968-971): Second-order Doppler resampling coefficient given C1 for generating zero-order coefficient given C2 (μ_{a13}).
Parameter 241 (bytes 972-975): First-order Doppler resampling coefficient given C1 for generating second-order coefficient given C2 (μ_{a32}).
Parameter 242 (bytes 976-979): First-order Doppler resampling coefficient given C1 for generating first-order coefficient given C2 (μ_{a22}).
Parameter 243 (bytes 980-983): First-order Doppler resampling coefficient given C1 for generating zero-order coefficient given C2 (μ_{a12}).
Parameter 244 (bytes 984-987): Zero-order Doppler resampling coefficient given C1 for generating second-order coefficient given C2 (μ_{a31}).
Parameter 245 (bytes 988-991): Zero-order Doppler resampling coefficient given C1 for generating first-order coefficient given C2 (μ_{a21}).
Parameter 246 (bytes 992-995): Zero-order Doppler resampling coefficient given C1 for generating zero-order coefficient given C2 (μ_{a11}).

Framelet Parameters

Note: In terms of Doppler (f) and range (r) coordinates,
framelet corner (1, 1) corresponds to ($r_{smallest}$, $f_{smallest}$);
framelet corner (1, 2) corresponds to ($r_{smallest}$, $f_{greatest}$);
framelet corner (2, 1) corresponds to ($r_{greatest}$, $f_{smallest}$);
framelet corner (2, 2) corresponds to ($r_{greatest}$, $f_{greatest}$).

Parameter 247 (bytes 996-999): Apparent range of framelet corner (1, 1), in meters.
Parameter 248 (bytes 1000-1003): Apparent range of framelet corner (2, 1), in meters.
Parameter 249 (bytes 1004-1007): Apparent range of framelet corner (1, 2), in meters.
Parameter 250 (bytes 1008-1011): Apparent range of framelet corner (2, 2), in meters.

Parameter 251 (bytes 1012-1015): Doppler of framelet corner (1, 1), in Hertz
Parameter 252 (bytes 1016-1019): Doppler of framelet corner (2, 1), in Hertz
Parameter 253 (bytes 1020-1023): Doppler of framelet corner (1, 2), in Hertz
Parameter 254 (bytes 1024-1027): Doppler of framelet corner (2, 2), in Hertz

Parameter 255 (bytes 1028-1031): Coordinate-1 of framelet corner (1,1) (number of 75 meter spacing), signed VAX integer.
Parameter 256 (bytes 1032-1035): Coordinate-1 of framelet corner (2,1) (number of 75 meter spacing), signed VAX integer.
Parameter 257 (bytes 1036-1039): Coordinate-1 of framelet corner (1,2) (number of 75 meter spacing), signed VAX integer.
Parameter 258 (bytes 1040-1043): Coordinate-1 of framelet corner (2,2) (number of 75 meter spacing), signed VAX integer.

Parameter 259 (bytes 1044-1047): Coordinate-2 of framelet corner (1,1) (number of 75 meter spacing), signed VAX integer
Parameter 260 (bytes 1048-1051): Coordinate-2 of framelet corner (2,1) (number of 75 meter spacing), signed VAX integer.
Parameter 261 (bytes 1052-1055): Coordinate-2 of framelet corner (1,2) (number of 75 meter spacing), signed VAX integer.
Parameter 262 (bytes 1056-1059): Coordinate-2 of framelet corner (2,2) (number of 75 meter spacing), signed VAX integer.

Burst Size Parameters

Parameter 263 (bytes 1060-1063): Pulse Repetition Frequency (PRF), in Hertz
Parameter 264 (bytes 1064-1067: Number of pulses in burst, unsigned VAX integer.
Parameter 265 (bytes 1068-1071): Number of samples per pulse, unsigned VAX integer.

Parameter 266 (bytes 1072-1075): Processing Bandwith, in Hertz
Parameter 267 (bytes 1076-1079): Processing range swath, in meters.

Process Monitor Parameters

Parameter 268 (bytes 1080-1083): Minimum number of looks to flag in output, unsigned VAX integer.

Parameter 269 (byte 1084): Block Adaptive Quantization (BAQ) threshold #1, unsigned VAX integer.

Parameter 270 (byte 1085): Block Adaptive Quantization (BAQ) threshold #2, unsigned VAX integer.

Parameter 271 (byte1086): Block Adaptive Quantization (BAQ) threshold #3, unsigned VAX integer.

Parameter 272 (byte 1087): Block Adaptive Quantization (BAQ) threshold #4, unsigned VAX integer.

Parameter 273 (byte 1088): Block Adaptive Quantization (BAQ) threshold #5, unsigned VAX integer.

Parameter 274 (byte 1089): Block Adaptive Quantization (BAQ) threshold #6, unsigned VAX integer.

Parameter 275 (byte 1090): Block Adaptive Quantization (BAQ) threshold #7, unsigned VAX integer.

Parameter 276 (byte 1091): Block Adaptive Quantization (BAQ) threshold #8, unsigned VAX integer.

Parameter 277 (byte 1092): Block Adaptive Quantization (BAQ) threshold #9, unsigned VAX integer.

Parameter 278 (byte 1093): Block Adaptive Quantization (BAQ) threshold #10, unsigned VAX integer.

Parameter 279 (byte 1094): Block Adaptive Quantization (BAQ) threshold #11, unsigned VAX integer.

Parameter 280 (byte 1095): Block Adaptive Quantization (BAQ) threshold #12, unsigned VAX integer.

Parameter 281 (byte 1096): Block Adaptive Quantization (BAQ) threshold #13, unsigned VAX integer.

Parameter 282 (byte 1097): Block Adaptive Quantization (BAQ) threshold #14, unsigned VAX integer.

Parameter 283 (byte 1098): Block Adaptive Quantization (BAQ) threshold #15, unsigned VAX integer.

Parameter 284 (byte 1099): Block Adaptive Quantization (BAQ) threshold #16, unsigned VAX integer.

Parameter 285 (byte 1100): Block Adaptive Quantization (BAQ) threshold #17, unsigned VAX integer.

Parameter 286 (byte 1101): Block Adaptive Quantization (BAQ) threshold #18, unsigned VAX integer.

Parameter 287 (byte 1102): Block Adaptive Quantization (BAQ) threshold #19, unsigned VAX integer.

Parameter 288 (byte 1103): Block Adaptive Quantization (BAQ) threshold #20, unsigned VAX integer.

Parameter 289 (byte 1104): Block Adaptive Quantization (BAQ) threshold #21, unsigned VAX integer.

Parameter 290 (byte 1105): Block Adaptive Quantization (BAQ) threshold #22, unsigned VAX integer.

Parameter 291 (byte 1106): Block Adaptive Quantization (BAQ) threshold #23, unsigned VAX integer.

Parameter 292 (byte 1107): Block Adaptive Quantization (BAQ) threshold #24, unsigned VAX integer.

Frame Parameters

Refer to figure C-1.

Parameter 293 (bytes 1108-1111): The C1 address of the frame edge associated with the greatest Doppler coordinate. (This is the smallest C1 coordinate for sinusoidal bursts, the greatest C1 coordinate for oblique sinusoidal bursts.) Unsigned VAX integer.
Parameter 294 (bytes 1112-1115): For left-looking bursts, the C2 address of the frame edge associated with the smallest range coordinate. For right-looking bursts, the C2 address of the frame edge associated with the greatest range coordinate. (This is the smallest C2 coordinate of the frame.) Unsigned VAX integer.
Parameter 295 (bytes 1116-1119): The C2 address of the azimuth-processed frame edge associated with the smallest range coordinate. (This is the smallest C2 coordinate of the azimuth-processed frame.) Unsigned VAX integer.
Parameter 296 (bytes 1120-1123): The C1 address of the frame edge associated with the smallest Doppler coordinate. (This is the greatest C1 coordinate for sinusoidal bursts, the smallest C1 coordinate for oblique sinusoidal bursts.) Unsigned VAX integer.
Parameter 297 (bytes 1124-1127): For left-looking bursts, the C2 address of the frame edge associated with the greatest range coordinate. For right-looking bursts, the C2 address of the frame edge associated with the smallest range coordinate. (This is the greatest C2 coordinate of the frame.) Unsigned VAX integer.
Parameter 298 (bytes 1128-1131): The C2 address of the azimuth-processed frame edge associated with the greatest range coordinate. (This is the greatest C2 coordinate of the azimuth-processed frame.) Unsigned VAX integer.

Parameter 299 (bytes 1132-1135): "X" (along-track) offset between the current and the previous frames. Unsigned VAX integer.
Parameter 300 (bytes 1136-1139): "Y" (cross-track) offset between the current and the previous frames. Unsigned VAX integer.
Parameter 301 (bytes 1140-1143): Set number of cross-track (projection domain) weights. Unsigned VAX integer. There are a total of 128 sets available.
Parameter 302 (bytes 1144-1147): Offset within one set of cross-track weights. Unsigned VAX integer.

Spares (bytes 1148-1279): For future expansion.
value = 0 (binary zero)

Frame, Post-Azimuth Frame, and Output from Burst N

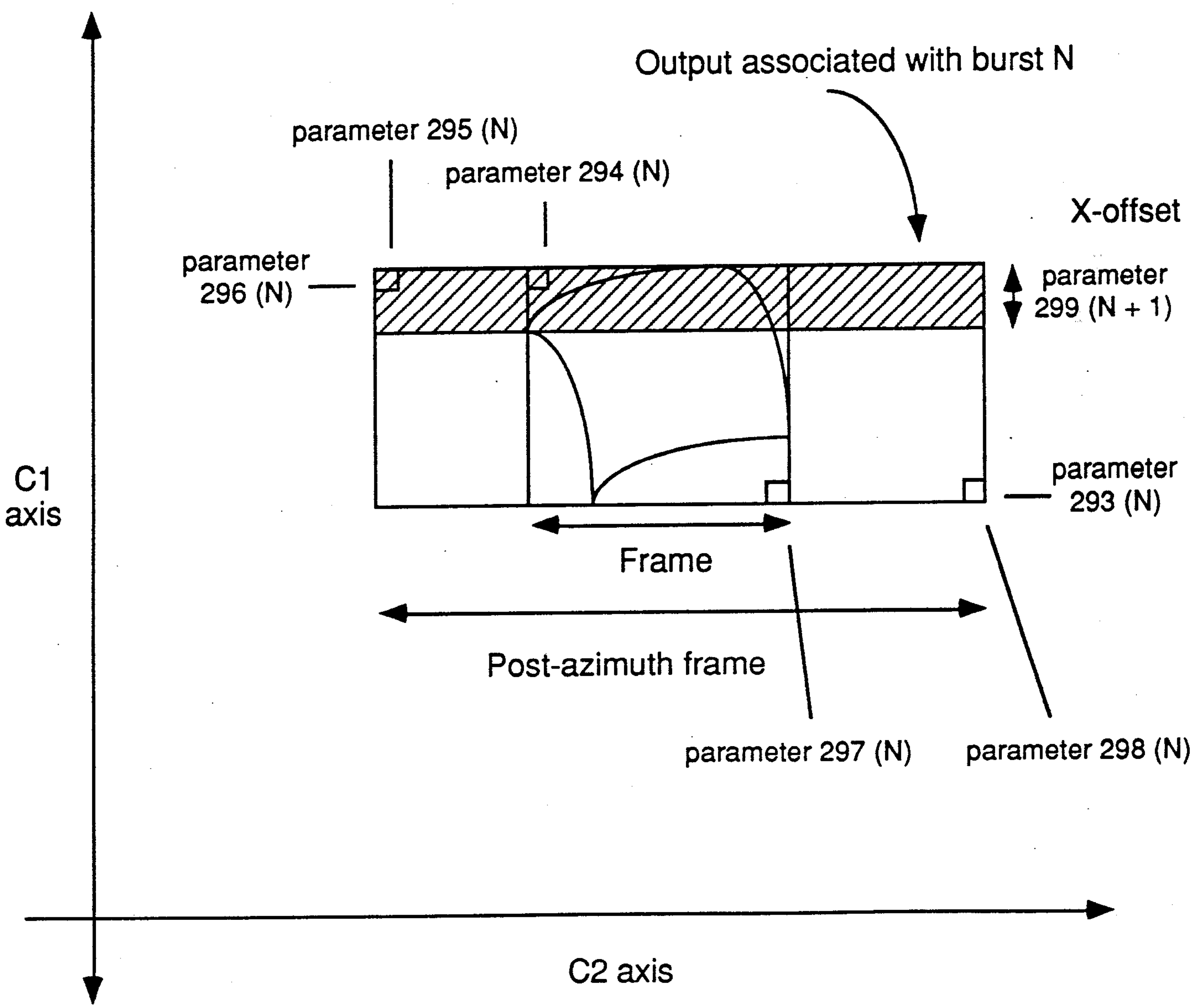


Figure C-1

J. Gilbert
10/05/90

APPENDIX D
TABLE OF SDPS PER-ORBIT PARAMETERS

All values are instance-dependent, and except where noted, are single-precision VAX floating-point numbers.

General Parameters

Parameter 1 (bytes 0-3): Orbit number, unsigned VAX integer.

Parameter 2 (bytes 4-11): Mapping start time (SCET) in TDB seconds from epoch J2000, double-precision VAX floating point.
Parameter 3 (bytes 12-19): Mapping stop time (SCET) in TDB seconds from epoch J2000, double-precision VAX floating point.
Parameter 4 (bytes 20-23): Total number of bursts on the EDR this orbit, unsigned VAX integer.

Parameter 5 (bytes 24-32): Product ID (same as the value of the MINOR_DATA_CODE keyword in the BIDR Header Record), 9-character ASCII string.
Parameter 6 (bytes 33-38): Volume ID (same as ANSI Volume Label "volume ID"), six-character ASCII string.

Parameter 7 (bytes 39-57): Wall-clock time of start of processing (same as the value of the TAPE_WRITE_DOY keyword in the BIDR Header Record), 19-character ASCII string.

Parameter 8 (bytes 58-61): Number of looks to process this orbit (0 to 16; 0 means use all available looks). Unsigned VAX integer.

Parameter 9 (bytes 62-65): Left-looking (0) or right-looking (1) orbit. Unsigned VAX integer.

Parameter 10 (bytes 66-97): NAV Unique ID of the Spacecraft Ephemeris File. Will be blank if ephemeris file wasn't used. 32-character ASCII string.

Orbit Keplerians

Parameter 11 (bytes 98-112): Predicted time of periapsis in SCLK, 15-character ASCII string (see Appendix A).
Parameter 12 (bytes 113-120): Predicted time of periapsis in TDB seconds from epoch J2000, double-precision VAX floating point.

Parameter 13 (bytes 121-128): Orbit semi-major axis in meters from the Orbit Header file on the EDR, double-precision VAX floating point.
Parameter 14 (bytes 129-136): Orbit eccentricity from the Orbit Header file on the EDR, double precision VAX floating point.
Parameter 15 (bytes 137-144): Orbit inclination angle in degrees from the Orbit Header file on the EDR, J2000 coordinates, double precision VAX floating point.

Parameter 16 (bytes 145-152): Longitude of the ascending node in degrees (0 to 360) from the Orbit Header file on the EDR, J2000 coordinates, double precision VAX floating point.
Parameter 17 (bytes 153-160): Argument of periapsis in degrees from the Orbit Header file on the EDR, J2000 coordinates, double precision VAX floating point.
Parameter 18 (bytes 161-164): Orbit period in seconds.

SCLK-to-SCET Conversion Coefficients

Parameter 19 (bytes 165-177): Reference SCLK factor (SCLK0), 13-character ASCII string.
Parameter 20 (bytes 178-189): Slope coefficient of the SCLK/SCET conversion (A1), 12-character ASCII string.
Parameter 21 (bytes 190-208): Intercept coefficient of the SCLK/SCET conversion (A0), 19-character ASCII string.
Parameter 22 (bytes 209-214): UTC-to-epoch J2000 correction factor (DUT), 6-character ASCII string.

Projection Burst Counters

Parameter 23(bytes 215-218): Burst counter of the first oblique sinusoidal burst processed, unsigned VAX integer.
Parameter 24 (bytes 219-222): Burst counter of the last oblique sinusoidal burst processed, unsigned VAX integer.
Parameter 25 (bytes 223-226): Burst counter of the first sinusoidal burst processed, unsigned VAX integer.
Parameter 26 (bytes 227-230): Burst counter of the last sinusoidal burst processed, unsigned VAX integer.

Projection Parameters

Parameter 27 (bytes 231-234): Sinusoidal projection reference longitude, in degrees (0 to 360).

Parameter 28 (bytes 235-238): Burst counter of burst with BIP closest to 85° latitude. (This burst is used to produce an estimate of the instantaneous body-fixed orbit plane, which is then used to determine the oblique sinusoidal origin.) Unsigned VAX integer.
Parameter 29 (bytes 239-246): Time at which the spacecraft crosses 85° latitude, in seconds from epoch J2000, double-precision VAX floating point.

Parameter 30 (bytes 247-250): X-component of the oblique sinusoidal $\hat{x}$-axis in VBF85 coordinates.
Parameter 31 (bytes 251-254): Y-component of the oblique sinusoidal $\hat{x}$-axis in VBF85 coordinates.
Parameter 32 (bytes 255-258): Z-component of the oblique sinusoidal $\hat{x}$-axis in VBF85 coordinates.
Parameter 33 (bytes 259-262): X-component of the oblique sinusoidal $\hat{y}$-axis in VBF85 coordinates.
Parameter 34 (bytes 263-266): Y-component of the oblique sinusoidal $\hat{y}$-axis in VBF85

coordinates.
Parameter 35 (bytes 267-270): Z-component of the oblique sinusoidal $\hat{y}$-axis in VBF85 coordinates.
Parameter 36 (bytes 271-274): X-component of the oblique sinusoidal $\hat{z}$-axis in VBF85 coordinates.
Parameter 37 (bytes 275-278): Y-component of the oblique sinusoidal $\hat{z}$-axis in VBF85 coordinates.
Parameter 38 (bytes 279-282): Z-component of the oblique sinusoidal $\hat{z}$-axis in VBF85 coordinates.

Parameter 39 (bytes 283-286): Longitude of the oblique sinusoidal origin, which lies along the line formed by the oblique sinusoidal $\hat{x}$-axis 0 to 360). This is the angle of the first of two rotations which together translate points given in VBF85 coordinates to the oblique rectangular coordinate system. (See **Appendix FH**, α_1, for further details.)
Parameter 40 (bytes 287-290): Additive inverse of the latitude of the oblique sinusoidal origin, which lies along the line formed by the oblique sinusoidal $\hat{x}$-axis. This is the angle of the second of two rotations which together translate points given in VBF85 coordinates to the oblique rectangular coordinate system. (See **Appendix FH**, α_2, for further details.)

Parameter 41 (bytes 291-298): oblique sinusoidal start time (SCET) in TDB seconds from epoch J2000, double-precision VAX floating point.
Parameter 42 (bytes 299-306): oblique sinusoidal stop time (SCET) in TDB seconds from epoch J2000, double-precision VAX floating point.

Spares (bytes 307-511): For future expansion.
value = **0** (binary zero)

APPENDIX E
IMAGE COORDINATE SYSTEMS

Image data is mapped using one of two projections: a sinusoidal projection for all data between 89°N and 89°S, and an oblique sinusoidal projection for data in the 10 degrees between 80°N/S and the corresponding pole. It is common to assign the terms "horizontal" and "vertical" (or "H" and "V") to the two axes of a sinusoidal projection. Detailed information on the transformation from spherical coordinates to the appropriate projection coordinates is given in **Appendix F**, "Processing Parameter Algorithms".

This Appendix defines another system who's axes have a fixed relation to the order of data. This system has one axis which runs in the approximate direction of the satellite azimuth track (labelled "Coordinate-1", or "C1"), and another which runs approximately perpendicular to that track (labelled "Coordinate-2", or "C2"). For ease of comparing it to the sinusoidal system, the positive direction of its axes is defined to be the same for both descending and ascending tracks, and for both left- and right-looking orbits.

For sinusoidal data, C1 is identical to the V axis, and C2 to the H axis. For oblique sinusoidal data, C1 is identical to the H axis, and C2 to the V axis.

The C1 coordinate of a point represents the number of 75-meter image lines from the origin, and the C2 coordinate the number of 75-meter pixels.

See Figures **E-1** and **E-2** below.

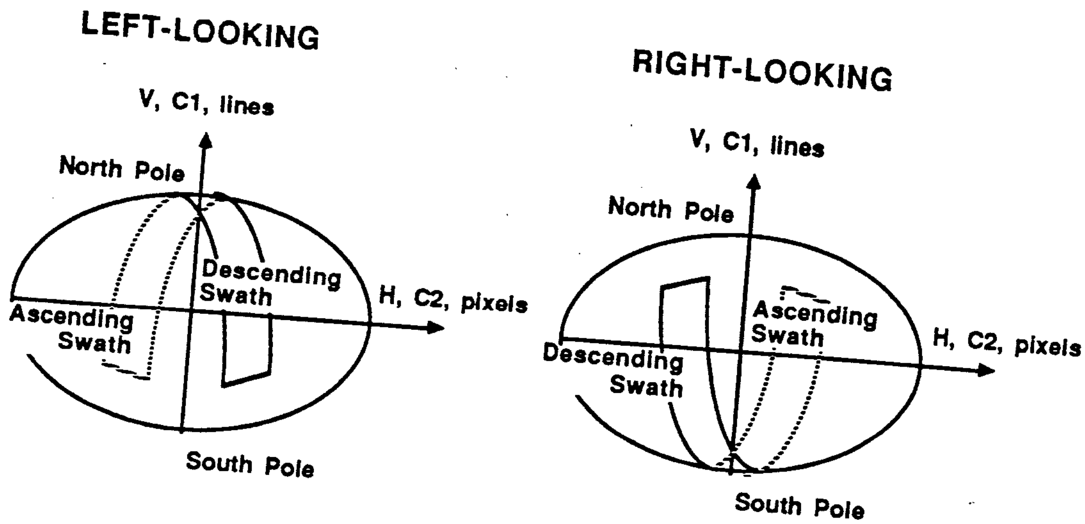


Figure E-1: Relation between the Sinusoidal and C1/C2 Axes

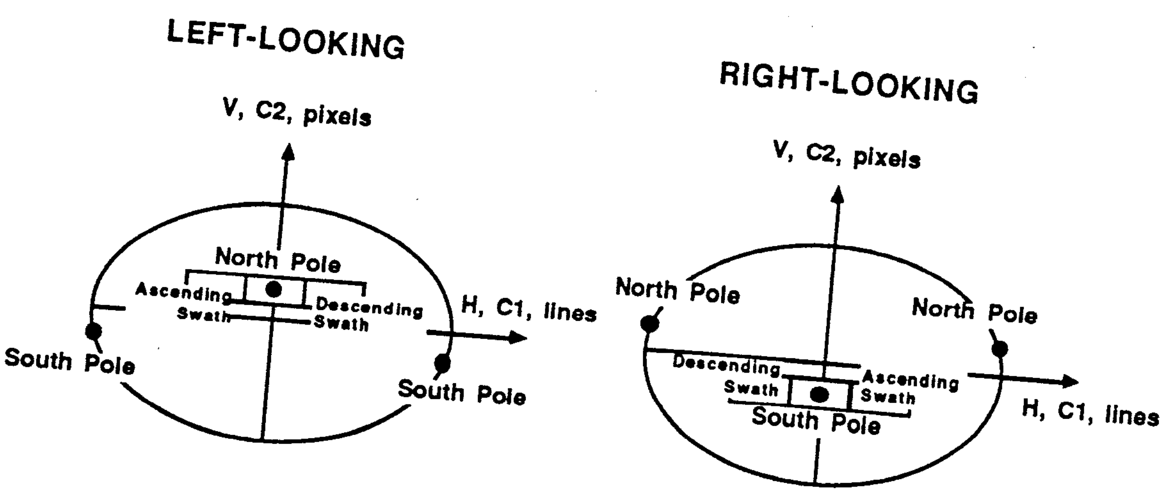


Figure E-2: Relation between the Oblique Sinusoidal and C1/C2 Axes

J. Gilbert
12/20/88

APPENDIX F
PROCESSING PARAMETER ALGORITHMS

This Appendix consists of two documents and a memo which describe the algorithms used to generate the contents of the Processing Parameters and the Per-Orbit Parameters files.

DEFINITION AND GENERATION OF SDPS PROCESSING PARAMETERS

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26 July 1991

APPENDIX F - PROCESSING PARAMETER ALGORITHMS

This Appendix consists of two documents and a memo which describe the algorithms used to generate the contents of Processing Parameters and the Per-Orbit Parameters files.

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0. Reference

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2. IOM 3344-87-015, M. Jin, February 23, 1988
3. MGN Radar System Requirements (PD 630-200E, 1 June, 1987)
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5. "Magellan Planetary Constants and Models", (PD 630-79, 11 April, 1988)
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8. JPL IOM 3344-89-085, K. Leung, "SAR Data Processing Algorithm Description", September 11, 1989 (attached).
9. IOM 3344-88-085, J. Gilbert, Revised Aug 15, 1990 (attached).
10. IOM 3344-91-027, D. Swantek, "Telemetry Data Conditioning Revised", July 24, 1991 (attached).

1. Introduction

SAR data will be acquired during the mapping phase of the Magellan (MGN) mission. These data will be processed by the Magellan SAR Data Processing Subsystem (SDPS) to form basic image products which consist of a large number of image strips, each corresponding to one orbit. These basic image products will then be processed by the Image Data Processing Subsystem (IDPS) to form mosaicked data products.

In reducing the SAR data to the basic image data products, knowledge of the orbit parameters, SAR pointing direction, sensor status information such as the redundancy states and the temperature readings, and radar system parameters such as PRF and the burst dimensions are essential. This knowledge will be transformed into the control parameters which will then be converted into control bytes directly usable by the SAR processor. These control parameters plus a number of parameters to be generated in intermediate steps are referred to as the processing parameters in this document.

2. Document Objective

This document serves three purposes: (1) to allow the reader to have a complete understanding of the SDPS processing at a functional level, (2) to serve as a system level design document for the design of the parameter generation software, and (3) to lead to the interpretation of the processing parameter files as well as the image pixel values contained in the Full Resolution Basic Image Data Record (F-BIDR).

2.1 Document Scope

This document defines the SDPS processing parameters pertaining to the SDPS and describes the operations involved in generating these parameters. This document also gives brief descriptions of the processing algorithms used in each stage of the SDPS processing. More detailed description about the SAR processing algorithms is given in Reference 8.

This documents has been revised to include changes made to meet requirements for processing Magellan cycle II data. Some SDPS design changes for cycle II were made for accommodating DCS constraints. Those change do not affect the processing parameter generation algorithms.

3. Background

This section gives a brief introduction to the principles of the MGN burst mode SAR system, the SAR processing functions, processor architecture, and descriptions of the input and output files of the SAR processor.

3.1. Principles of Burst Mode SAR Operation

A conventional SAR is operated in a continuous mode, in which radar pulses and echoes are transmitted and received, respectively, according to a constant pulse repetition frequency (PRF). The MGN SAR is, however, operated in a burst mode, which is driven by periodic bursts of radar pulses and echoes. This is mainly to reduce the data rate for the limited bandwidth of the Venus-Earth link.

The spacecraft will be put into an elliptical orbit around Venus with periapsis altitude of 250 km and period of 3.15 hours. In a 36-minute interval of each orbit, the spacecraft will map Venus starting from a position above the north pole and continuing to a point near latitude of 67°s. Along the mapping track, about 6000 echo bursts will be received and recorded by a tape recorder. These bursts will then be played back to the earth during the rest of the orbit period. The bursts will be processed into single-look image framelets, each covering approximately the area of the radar footprint on the Venus. These image framelets are then superposed to form a multi-look image strip.

The first stage of burst processing is to sharpen the resolution by performing pulse compression along the range dimension and spectral analysis along the azimuth dimension. This process results in an image referred to as the range-Doppler image where the corresponding locations of its image samples are on intersections of iso-range lines and iso-Doppler lines on the planet surface as shown in Figure 1. Since the range-Doppler coordinate system is defined based on the spacecraft position and it differs from a rectangular coordinate system, multi-look images cannot be obtained by directly superposing range-Doppler images resulting from different bursts.

The second stage of burst processing is to accomplish the following: (1) eliminate edge image pixels with substandard quality, (2) locate the final image pixels on the grid of a specified projection coordinate system, and (3) convert pixel values into normalized backscattering coefficients. The resulting data products are referred to as single-look image framelets. These products can be used to form the multi-look images.

3.2. Projection Coordinates and Projection Grid Systems

Two types of projection coordinates shall be employed for the SDPS image data. These projections are the sinusoidal equal-area projection (see Reference 1 for definition) and the oblique sinusoidal equal-area projection (see Appendix FH for definition). All SAR image data products covering areas equatorward of 89° latitude shall utilize the sinusoidal projection. Image data corresponding to the area north of 80° latitude or south of 80° latitude shall be output in the oblique sinusoidal projection.

Since images are given by discrete samples and a uniform spacing is usually required, the locations of these samples are constrained. The collection of all possible image sample locations can be defined as a set of image grid points. Below, we will refer this set to the projection grid systems.

For the sinusoidal projection, the projection grid system contains the origin of the sinusoidal coordinate and two sets of points. The origin is at 0° latitude and a given reference meridian. In the first set of points, each point has the same longitude as the origin and is spaced an integer multiple of 75 meters from the origin. In the second set, each point has a latitude equal to that of one point in the first set and is spaced an integer multiple of 75 meters from that point. A unique sinusoidal projection grid system shall be applied for image data acquired over one orbit. From one orbit to another, the projection grid system shall be changed according to a newly defined reference meridian.

The oblique sinusoidal equal-area projection grid system is described in Appendix FH. This grid system is applied for both south pole and north pole area. The meridian of this projection grid system will be updated on an orbit by orbit basis.

Below, we will denote coordinate-1 (or $C1$) as the variable along the north-south axis for the sinusoidal projection or along the oblique east-west axis for the oblique sinusoidal projection. Similarly, we will denote coordinate-2 (or $C2$) as the variable along the east-west axis for the sinusoidal projection or along the oblique north-south axis for the oblique sinusoidal projection. Both $C1$ and $C2$ are given in units of meters. The directions of $C1$ and $C2$ for both the sinusoidal projection and the oblique sinusoidal projection are shown in Figure 1 together with the directions of the range and Doppler.

3.3. Range-Doppler Coordinates for the Range-Doppler Image

To rectify properly each range-Doppler image into an image in the projection coordinate, the range and Doppler value of each image pixel must be determined correctly. According to the processing algorithm, the range-Doppler images reduced from the MGN processor will have the following characteristics: (1) In the slant range dimension, the first pixel is associated with a slant range equal to $(ct_d - RW - cdT(N_{rs} - N_c))/2$.. Where t_d is the delay time defined in 5.1.1.1, c is the speed of light, dT is the range sampling interval, RW is the total amount of range walk within the burst, N_{rs} is the number of chips in the range reference function and N_c is the number of chips in the range code. (2) Pixel spacing in the Doppler frequency dimension is given by PRF/N_{FFT}, where N_{FFT} is the FFT size selected for azimuth compression. (3) Pixel spacing in the range dimension is given by $c/(2f_s)$, where f_s is the range sampling frequency.

3.4. SAR Processing Functions

This section gives a brief description of the SAR processing functions to reduce a burst into a single-look framelet and to form multi-look images. The processes described here are on the functional level, so they may not be directly related to the actual computation performed by the SAR processor. For example a convolution process described here may be implemented by computations involving FFT, spectral multiply, and inverse FFT. However, these functional level descriptions do allow one to predict accurately the final pixel values reduced from given burst data and processing parameters.

3.4.1. BAQ Data Reconstruction

Each MGN echo burst (simply referred to as "burst" in the following paragraph) consists of hundreds of echo pulses and a set of indexes threshold established by the Block Adaptive Quantizer (BAQ). Each echo pulse is a one-dimensional sample stream, where each sample contains a 2-bit in-phase (I) component and a 2-bit quadrature (Q) component. Each threshold index can be used to derive the threshold value pertaining to a subset of the burst. This subset covers 16 samples in range and has the same number of samples as the burst in azimuth.

In an ideal BAQ reconstruction, each 2-bit SAR sample and associated threshold index Th would be converted into the floating point number given in Table I.

TABLE I.

2 bit sample	Reconstructed Value
0 0	.5227 $(Th+1)$
1 0	-.5227 $(Th+1)$
0 1	1.7436 $(Th+1)$
1 1	-1.7436 $(Th+1)$

However, because of constraints of the SDPS, the I or Q component of each sample has to be converted into an 8-bit signed integer ranging from -128 to 127. In order to achieve maximum dynamic range for data after BAQ reconstruction and maintaining a constant gain factor for all samples in a given burst, the idealized conversion values given in Table I needs to be scaled by a factor determined by $Thm+1$, where $Thm+1$ is the maximum of the threshold values in a given burst. The resulting look-up table is given in Table II.

TABLE II.

2 bit sample	Reconstructed Value
0 0	Nint(38.1734*S1)
1 0	-Nint(38.1734*S1)
0 1	Nint(127.*S1)
1 1	-Nint(127.*S1)

$$S1 = S2 \cdot (Th+1), \text{ where}$$
$$S2 = \exp -(S3 \cdot \ln(127)/31), \text{ where}$$
$$S3 = \text{Integer}(31 \cdot \ln(Thm+1)/\ln(127)) + 1$$
$$\text{Nint } (.) = \text{Nearest Integer to } (.)$$

Because of a design flaw in the sensor, the quadrature components output from the sensor are sign-reversed according to conventional definition. The SAR processor is therefore designed to correct for the sign change by using a look-up Table that is a sign-reversed version of Table II.

3.4.2. Range Compression

In range compression, three tasks must be accomplished. First, the large linear phase drift in range due to the change of radial position of the spacecraft needs to be compensated. Second, a correlation between the echo samples and a predetermined reference function needs to be performed to achieve range resolution. Third, a constant offset of the range positions of all the samples in each echo pulse needs to be made to correct for the range walk.

Range compression for the i-th echo pulse of a burst involves two steps: (1) a convolution with a range reference function selected from the range reference function set, and (2) a left circular shift (sample with greater range index shifted to a position of smaller range index). The number of bins to be shifted is the integer part of the range walk, $N_{rw}(i)$, which is given in 5.5.2.

Denote the i-th echo pulse by $S(j,i), j = 1,2,3,...,N_s$, where N_s is the total number of samples in the pulse. Denote the reference function by $R(j, I_{RG}, I_R), j = 1,2,3,...,N_{rs}$, where N_{rs} is the total number of samples in the reference function indexed by I_{RG} and I_R. I_{RG} is the group index of the reference functions. I_R is the reference index within a group. Reference functions of the same group index enable compensation of the same amount of phase drift. Reference functions of the same reference index enable compensation of the same amount of range walk. The processes to determine the values of I_{RG} and I_R can be found in 5.5.1 and 5.5.3, respectively.

Denote the convolved result from the i-th echo pulse by $S_1(j,i), j = 1,2,3,...,N_{rs}+N_s$. These functions are related by

$$S_1(j,i) = \sum_{n=1}^{N_{rs}} R(n, I_{RG}, I_R) S(j+n-1, i)$$

The reference function $R(j, I_{RG}, I_R)$ is given by

$$R(j, I_{RG}, I_R) = \sum_{n=-N_{rs}/2+1}^{N_{rs}/2} \mathrm{sinc}(n, I_R) W_{rng}(j+n) R_{ps}(j+n, I_{RG})$$

where $W_{rng}(j), j = 1,2,...,N_{rs}$ is the range weight given in Appendix FQ. This range weight is a normalized one. The summation of the squares of all the weight values is equal to one. $\mathrm{sinc}(n, I_R)$ is a sinc function given by

$$\mathrm{sinc}(n, I_R) = \frac{\sin(\pi(n + (I_R - 1)/8))}{\pi(n + (I_R - 1)/8)}$$

$R_{ps}(n, I_{RG})$ is the function to compensate for the linear phase drift. It is given by

$$R_{ps}(n, I_{RG}) = \exp^{-j2\pi\Delta f(I_{RG} - 16)ndT}$$

where dT is the sampling time interval in range and Δf is the bandwidth allocated to each group of references. dT is given by the reciprocal of 2.26 MHz. Δf shall be given by 2550Hz.

3.4.3. Azimuth Compression

To help the reader understand the processing algorithm, this section begins with a brief description of the characteristics of the range compressed responses. It is then followed by the description of the process function.

Each 1-D sample stream taken from a range compressed burst can be viewed as the superposition of many echo responses, each from a target having a distinctive "squint" angle from the spacecraft. Each of these echo responses is given by the product of an intensity factor proportional to the reflectivity and a linear FM sinusoid with center frequency determined by the squint angle. For a short burst, the linear FM sinusoid approaches a monotonic sinusoid, of which the corresponding spectrum is an impulse located at the center frequency.

The azimuth compression process will be accomplished by using a so called Deramp-FFT algorithm. The Deramp process is applied to remove the linear term of the frequency change in the echo so that the best azimuth resolution can be accomplished. The FFT separates the energies of targets of different squint angles. The spectrum resulting from the FFT gives the intensity profile as a function of the Doppler frequency or the squint angle.

In the Deramp process, a Kaiser weighting is also applied to the burst data. This controls the integrated sidelobe ratio in azimuth. Also included in the Deramp reference is a monotonic signal to shift the spectrum such that it is centered at PRF/2.

For a burst with N_p echo pulses and an average Doppler frequency of f_{d-m} (see 5.2.2.), the Deramp reference function is given by

$$R_{drmp}(i) = W_{Ksr}(i, N_p, \alpha_w)\exp(j\theta_{drmp}(i))$$

where $W_{Ksr}(i, N_p, \alpha_w)$ is the Kaiser weight with parameter α_w. $W_{Ksr}(.,\ldots)$ is given in Appendix FK.

$\theta_{drmp}(i)$ is the phase function of the Deramp reference. It is given by

$$\theta_{drmp}(i) = 2\pi((\frac{\mathrm{PRF}}{2} - f_{d-m})(i - \frac{N_p}{2})dT - \frac{f_{r-m}}{2}((i - \frac{N_p}{2})dT)^2)$$

where i is the pulse count, which ranges from 1 to N_p and dT is the inter-pulse period which is equal to 1/PRF. f_{r-m} is the average Doppler frequency rate of the processed burst and is defined in 5.2.4. f_{d-m} is the average Doppler centroid frequency of the processed burst and is defined in 5.2.2.

Denote the deramped result by $S_2(j,i)$. It can be expressed by

$$S_2(j,i) = S_1(j,i) \cdot R_{drmp}(i)$$

where $S_1(j,i)$ is the range compressed result given in 3.4.2.

The Deramped data will be padded with zeros to make the total number of samples equal to an integer power of two. This is to satisfy the FFT constraint.

To a user concerned about the numerical result of the F-BIDR data, the FFT process described here can be viewed simply as a continuous Fourier transform. There is no need to know the FFT length and the number of zeroes needed to fill in the data before FFT.

Since the number of echo pulses in a burst is a variable, it is costly to generate the Kaiser weights matching the burst size each time they are needed. In the real implementation, a set of Kaiser weights varying in size will be precomputed and stored in memory buffers for use. The form of these weights is described in Appendix FK.

3.4.4. Radiometric Compensation

The radiometric compensation process consists of multiplying each image value by the proper scale factor such that the final pixel value represents the backscattering coefficient normalized by the predicted scattering function $f(I)$, which is given by

$$f(I) = \frac{.0118\cos(I)}{(\sin(I) + .111\cos(I))^3}$$

where I is the incidence angle.

The scale factor includes all the radiometric factors such as the transmitted power, antenna pattern, slant range, sensor loss, processor loss, wavelength, time-space conversion factors and receiver gain. Detailed description of this scale factor is given in 5.4.5.

After azimuth compression, radiometric compensation is achieved by multiplying each sample in the range-Doppler array by a gain compensation factor. This factor is derived from a quadratic polynomial with coefficients being quadratic functions of the slant range. The equation for computing the radiometric compensation factor is given in 5.5.6.

3.4.5. Geometric Rectification

Geometric rectification converts complex image pixels from the range-Doppler coordinate system into one of the two specified projection grid systems - the sinusoidal projection or the oblique sinusoidal projection. The final F-BIDR image pixel spacing is required to be 75 meters in each dimension.

Geometric rectification is achieved by two cascaded one-dimensional resampling processes. The first resampling is to extract signal values at the intersections of iso-Doppler lines and lines of constant coordinate-2 values. The geometry of the intersections and all the lines is illustrated in Figure 3a. This extraction is done by interpolation along the range dimension which means that the extracted value is given by the weighted summation of values of neighboring samples of constant Doppler frequency but different range values. Implemented in the SDPS is a four-point interpolator which uses four neighboring samples. The weight coefficients are normalized SINC values (the summation of the squares of all four weight coefficients is equal to 1). The range value of any intersection point is computed by a quadratic polynomial with a form given in 5.5.7.

The second resampling is to extract signal values at the intersections of lines of constant coordinate-2 values and lines of constant coordinate-1 values in the projection grid. The geometry of the intersections and all mentioned lines is illustrated in Figure 3b. This extraction is done by interpolation along the Doppler dimension which means that the extracted value is given by the weighted summation of values of neighboring samples of the same coordinate-2 value but different Doppler values. Implemented in the SDPS is a four-point interpolator which uses four neighboring samples. The weight coefficients are normalized SINC values. The Doppler value of any intersection point is computed by a quadratic polynomial with a form given in 5.5.8.

3.4.6. Framelet Truncation

Framelet truncation is to eliminate image samples with substandard signal-to-noise ratio. This process will be performed in the range-Doppler domain. The first step is to determine the boundary for truncation. The second step is to replace sample values by zeros for samples outside the boundary. The framelet boundary is defined by the framelet corners given in 5.3.6.

3.4.7. Multi-Look Overlay

All single-look framelets of one orbit which have passed through the processes described in 3.4.1 to 3.4.6 will then be overlayed to form a multi-look image strip. The first step in the overlay process is to take the square magnitude of all sample values in the framelet. The squared value of each sample is then added to the corresponding sample (same position on the projection coordinate) in the overlay buffer. For every sample in the overlay buffer, the number of add operation needs to be monitored during the process of adding framelets in order to know the number of looks acquired. The last step in the overlay process is to normalize the value of each cell by the acquired number of looks and to convert the resultant value to a number expressed in decibels through a look-up table.

3.5. Processor Architecture

It is planned to use the Multi-mission SAR Processing Laboratory (MSPL) to process SAR data for several missions including the Shuttle Imaging Radar (SIR) series and Magellan (MGN). When the MSPL is operated in its MGN configuration it is referred to as SDPS. The SDPS is comprised of a primary SAR processor (PSP) and an engineering SAR processor (ESP). The PSP is comprised of three subsystems: the digital correlator subsystem (DCS), the control processor subsystem (CPS), and the input/output subsystem (IOS). A backup processor, the ESP is very similar to the PSP except that two Numerix array processors in the ESP play the role of the DCS in the PSP.

The DCS is composed of some custom-designed hardware inherited from the ADSP-EM (Advanced Digital SAR Processor, Engineering Model), plus some additional custom-designed hardware required for the MGN data processing. The DCS interfaces with the IOS to receive the decoded SAR data, performs all the data processing functions to reduce them to the multi-look image product, and outputs the image data back to the IOS. The DCS processing is controlled by control bytes, of which a major portion are converted from CPS control parameters through interface software.

The CPS consists of a general purpose computer, an array processor, and the operational software. The major function of the CPS is to interface with the system user, to monitor data processing, to generate control parameters, and to convert these parameters into control bytes for controlling the DCS. The array processor will be used to process a small amount of bursts and perform some analysis functions to obtain performance estimates on the quality of both the SAR data and image data.

The IOS consists of fast interface units, the main function of which is to transfer SAR echo data from digital tapes via the interface units into the DCS, to read the image data from the DCS, to add ancillary data to the image data, and to write them to both disks and tapes. The IOS also provides the link between the CPS and DCS for transferring control bytes and the DCS status data.

3.6. Processor Input and Output

The input to the SDPS processor is the SAR experiment data record (EDR) which contains SAR echo bursts, orbit ephemeris data, antenna pointing information, and a complete set of engineering data. The SAR burst contains hundreds of SAR echo pulses. Each echo pulse consists of a prescribed number of complex samples. Each complex sample has a 2-bit in-phase component and a 2-bit quadrature component. In the engineering data field, there is one set of threshold values associated with each burst. These threshold values are required in the BAQ reconstruction process.

The primary output of the SDPS processor is the full-resolution basic image data record (F-BIDR). This data product is a strip of multi-look image of the planet surface mapped by the radar during each orbit pass. This image is the superposed result of about 6000 single-look image framelets, each of which is reduced from one SAR echo burst. Included with the image data are the ancillary data from the EDR, the processing parameters, and the image annotation data.

4. Overview of SAR Processing Parameter Generation

Aside from some special circumstances mentioned in the subsections below, the sequence of generating the processing parameters is straightforward. A simplified description of the parameter generation sequence is given below:

(1) The burst reference time is derived from the header data of the EDR.
(2) The spacecraft position and velocity vectors at the burst reference time are extracted from the S-Kernel file.
(3) The antenna pointing vector is computed from the pointing quaternion.
(4) The position of the boresight intercept point (BIP) is computed based upon the spacecraft position, pointing direction, the atmospheric refraction model, and the surface topography model.
(5) The position of the Mid-Range Point (MRP) is computed based upon the position, range, and Doppler of the BIP and the burst center time.
(6) The projection coordinates of the MRP as well as those of the other nine geometric reference points are computed.
(7) The position vectors and the range and Doppler values of the nine geometric reference points are derived.
(8) The polynomial coefficients for the range and azimuth resampling processes are computed from the results of (7).
(9) Parameters for defining the valid framelet boundaries are derived from the average range and Doppler values, the processing bandwidth, and the available range swath.
(10) Nine pairs of range-Doppler coordinates are computed based upon the framelet size. The radiometric compensation factors for these points are derived.
(11) The polynomial coefficients for the radiometric compensation process are obtained through polynomial fit for results obtained from (10).

5. Definitions and Generation Process

The processing parameters are classified into five sets which include those related to the BIP, those related to the Mid-Range Point, those related to the geometric reference points, those related to the radiometric compensation factors, and those related to the control parameters. These parameter sets are treated in the same order as that they are generated in the control processor.

5.1. Processing Parameters Related to BIP

5.1.1. Burst reference time, t_b:

Definition: The burst reference time is the center of the time interval between the times that the leading edge of the first and the the leading edge of the last radar pulses of a burst are radiated away from the antenna.

Process: The process to generate the burst reference time is described in Reference 9.

5.1.1.1. Echo delay time, t_d:

Definition: The echo delay time is the difference between the burst reference time and the center time of the interval between the times that the leading edges of the first and the last radar echo pulses of a burst received by the antenna.

Process: The process to generate the echo delay time is described in Reference 4.

5.1.2. Spacecraft Status, $(\vec{X}_s(t_b), \vec{V}_s(t_b), \vec{A}_s(t_b))$:

Definition: The spacecraft status includes the spacecraft position, velocity, and acceleration vectors given in one of the four coordinate systems including J2000 (J2000 Inertial Reference System), VME85 (Venus Mean Equator of 1985 Coordinate System), VBF85 (Venus Body-Fixed Coordinate of 1985), and Venus Latitude and Longitude (see Reference 5 for details). For each burst, a set of spacecraft status parameters, associated with the burst reference time, shall be derived. They are denoted as $\vec{X}_s(t_b), \vec{V}_s(t_b), \vec{A}_s(t_b)$.

Process: The spacecraft status in the J2000 coordinate system shall be derived from the ephemeris data contained in the S-Kernel file by calling the S-Kernel reader subroutine (see reference 6 for details). The spacecraft status in the other three coordinate systems shall be obtained through coordinate transformations described in Appendix FA.

5.1.3. Boresight Pointing Vector, $\hat{P}(t_b)$:

Definition: The boresight pointing vector is a unit vector along the SAR antenna boresight pointing direction. This vector shall be given in one of the three coordinate systems including J2000, VME85, and VBF85. For each burst, the boresight pointing vector to be generated is the one at the burst reference time. It is denoted as $\hat{P}(t_b)$.

range bin by $(c/2)*(1+\hat{P}\cdot\vec{V}_s/c))$. In subsequent paragraphs of this document, the one-way apparent range will be simply referred to as range unless the meaning would be ambiguous.

5.1.6. Velocity Vector of the BIP, $\vec{V}_b(t_b)$:

Definition: This is the BIP velocity at the burst reference time plus the one-way delay time R_b/c. This velocity is caused by the spin of the planet. This vector shall be represented in either VME85 or J2000. It is denoted as $\vec{V}_b(t_b)$ or simply $\vec{V}_b$.

Process: This velocity is given by the cross product of the position vector of the BIP $(\vec{X}_b)$ and the angular velocity of the spin of the planet (ω), i.e.

$$\vec{V}_b = \omega(\hat{Z} \times \vec{X}_b) \tag{2}$$

where $\hat{Z}$ is the unit vector in the Z direction. Note that the angular velocity of Venus, ω, is a negative number in VME85 and is equal to zero in VBF85.

5.1.7. BIP Doppler Frequency, $f_{d-b}(t_b)$:

Definition: This is the instantaneous Doppler frequency of the echo signal reflected from the BIP and received by the radar at the burst reference time plus the delay of $2R_b(t_b)/(c(1+\hat{P}\cdot\vec{V}_s/c))$. The BIP Doppler frequency shall be denoted as $f_{d-b}(t_b)$ or simply f_{d-b}.

Process: The Doppler frequency of the BIP is given by the following equation:

$$f_{d-b}(t_b) = \frac{2\langle\vec{V}_s(t_b) - \vec{V}_b(t_b),\ \hat{P}(t_b)\rangle}{\lambda} \tag{3}$$

where λ is the radar wavelength.

5.1.8. Doppler Drift Rate at the BIP, $f_{dr}(t_b)$:

Definition: The Doppler drift rate at the BIP is the ratio of the Doppler difference to the range difference between the BIP and a point in the X-Z plane of the spacecraft, with a look angle slightly greater than the boresight look angle and with an elevation equal to that of the BIP. The Doppler drift rate is denoted as $f_{dr}(t_b)$ or simply f_{dr}.

Process: To derive the Doppler drift rate at the BIP, the range and Doppler values of a second point need to be computed first. Let this pointing vector be associated with a look angle of $\theta_L + \theta_d$, the values of the vector components can be determined using the method described in Appendix FF. With this pointing vector and the elevation of the BIP, the location of the intercept point on the ground can be obtained using the method described in 5.1.5. The position vector of this intercept point is denoted as $\vec{X}_{b2}$. The Doppler of this intercept point can be obtained using the method described in 5.1.7. If R_{b2} and f_{d-b2} are the range and Doppler of this point, the Doppler drift rate f_{dr} is given by:

$$f_{dr} = (f_{d-b2} - f_{d-b})/(R_{b2} - R_b) \tag{4}$$

5.2. Processing Parameters Related to the Mid-Range Point

The Mid-Range Point (MRP) is the point on the antenna centroid line with a two-way apparent range to the spacecraft position $\vec{X}_s(t_b)$ equal to $(t_m - t_b) \cdot c$, where t_m is the burst center time defined below.

5.2.1. Burst Center Time, t_m:

Definition: The burst center time is thirty chips less the time of the center of the interval between the times that the first and the last samples in a burst are received by the antenna, where each chip is the inverse of the radar sampling frequency, thirty is half of the total chips in a radar pulse.

Process: The process to generate the burst center time is described in Reference 9.

5.2.2. Range, R_m, and Doppler, f_{d-m}, of the MRP :

Definition: These are the apparent range and the Doppler frequency of the MRP.

Process: According to the definition of MRP, the apparent range, denoted as R_m, is given by:

$$R_m = \frac{c}{2}(t_m - t_b) \cdot (1 + \hat{P} \cdot \vec{V}_s/c) \tag{5}$$

The Doppler frequency of the MRP, denoted as f_{d-m} is given by

$$f_{d-m} = f_{d-b} + f_{dr} \cdot (R_m - R_b) \tag{6}$$

5.2.3. Position of the MRP, $\vec{X}_m$:

Definition: This is the position vector of the MRP in VBF85 coordinate systems.

Process: The position of the MRP shall be derived from the positions of the BIP and $\vec{X}_{b2}$ (see 5.1.8) using a bilinear interpolation, i.e.,

$$\vec{X}_m = \vec{X}_b + (R_m - R_b) \cdot \frac{\vec{X}_{b2} - \vec{X}_b}{R_{b2} - R_b} \tag{7}$$

5.2.4. MRP Doppler frequency Rate, f_{r-m}:

Definition: This is the instantaneous Doppler frequency rate of the MRP observed at the burst center time.

Process: Since the Doppler frequency rate is proportional to the 2nd order derivative of the apparent range, it is not sensitive to small time variations. Therefore, the Doppler frequency rate at the burst center time will be simply evaluated at the burst reference time. The Doppler frequency rate is evaluated from the following equation:

$$f_{r-m} = \frac{-2\,\vec{V}_s|^2}{\lambda\,|\vec{X}_{s-m}|} + \frac{2\,(\langle\vec{V}_s,\,\vec{X}_{s-m}\rangle)^2}{\lambda\,|\vec{X}_{s-m}|^3} \tag{8}$$

$$\vec{X}_{s-m} = \vec{X}_s - \vec{X}_m \tag{9}$$

where $\vec{X}_s$ and $\vec{V}_s$ are the position and velocity vectors of the spacecraft at the burst reference time. $\vec{X}_m$ is the position vector of the MRP at the burst center time.

5.3. Processing Parameters Related to Geometric Reference Points and Image Frame

To convert the range-Doppler image into an image with a specified projection, a resampling process needs to be performed. One major step in resampling is to determine the range and Doppler values of any grid point in the projection. In the DCS, both range and Doppler are generated by 2nd order polynomials. The coefficients of these polynomials are determined from the range and Doppler values of nine pixels with given projection coordinates. These nine pixels are referred to as the geometric reference points.

5.3.1. Reference Meridian, θ_0:

Definition: The reference meridian is the longitude of the origin of the sinusoidal projection coordinate. It is selected as the intersection of the equatorial plane and the nadir path.

Process: First, an estimate of the time (t_0) at which the nadir point crosses the equator is made. Then, the spacecraft position is computed from the S-Kernel. This position is further transformed into the VME85 coordinates. If the Z component of the spacecraft position in VME85 deviates from zero, a new estimate of the time t_0 is then made based upon an estimate of the ground projection of the spacecraft velocity at the equator. The same process is repeated until two successive Z components of the nadir points differ by less than a small number (on the order of meters). The VME85 coordinates are then transformed into spherical coordinates, and the resulting longitude is used to find the nearest positive longitude falling an integral multiple of 75 meters along the equator from 0° longitude.

5.3.2. Projection Coordinates of Geometric Reference Points, $C1_g(i,j), C2_g(i,j), (i,j = 1,2,3)$:

Definition: The projection coordinates of each geometric reference point belong to the projection grid system (see 3.2.). The projection coordinates of the center geometric reference point are given by the grid point on the projection grid nearest to the mid-range point (MRP). The projection coordinates of all nine points are located at the intersections of three equally spaced lines of constant coordinate-1 values and three equally spaced lines of constant coordinate-2 values. The outer four lines form a rectangle with a dimension 2/3 of that corresponding to a framelet, the size of which is determined from the Radar Engineering Team (RET) supplied processing bandwidth and the good range swath. The geometric reference points are indexed by two numbers i and j, each ranging from 1 to 3. The projection coordinates of the (i,j)-th geometric reference point are denoted as $C1_g(i,j)$ and $C2_g(i,j)$.

Process: A coordinate transformation is performed to obtain the projection coordinates of the MRP from its latitude and longitude values. The transformations from spherical coordinates into sinusoidal coordinates and oblique sinusoidal coordinates are described in Appendixes FG and FH, respectively. Denote the projection coordinates of the MRP as $(C1_m, C2_m)$; the projection coordinates of the center geometric reference point are then given by

$$C1_g(2,2) = \delta g \cdot \mathrm{Nint}(C1_m/\delta g) \tag{10}$$

$$C2_g(2,2) = \delta g \cdot \mathrm{Nint}(C2_m/\delta g) \tag{11}$$

where δg is the spacing between two adjacent grid points and Nint is the nearest integer function. For the full-resolution basic image data record (F-BIDR) produced by the SAR processor, δg is given by 75 meters. The projection coordinates of the other eight geometric reference points are then given by

$$C1_g(i,j) = C1_g(2,2) + (i-2)\delta g \cdot \mathbf{Integer}((\Delta Fa/3)/\delta g) \tag{12}$$

$$C2_g(i,j) = C2_g(2,2) + (j-2)\delta g \cdot \mathbf{Integer}((\Delta Fc/3)/\delta g) \tag{13}$$

where ΔFa is the framelet size in the along-track dimension. It is given by

$$\Delta Fa = R_m \frac{\lambda}{2|\vec{V}_s|\sqrt{1-(\langle\hat{V}_s,\hat{P}\rangle)^2}} \mathbf{PBW} \tag{14}$$

where $\hat{V}_s$ is a unit vector parallel to $\vec{V}_s$ and PBW is the processing bandwidth which comes from the PBW file. In case that it is not specified by the PBW file, it is given by 60 percent of the PRF of the burst processed. ΔFc is the framelet size in the cross-track dimension. It is given by

$$\Delta Fc = MAX(\,MIN(\,(D_r/\sin(I_b))(N_s - N_{rs} - N_w - Nintp), 35km), 23km) \tag{15}$$

where D_r is the range sample spacing, 35km is the maximum swath constraint of the DCS, and 23 km is the minimum swath required for mosaicking. It is given by

$$D_r = c\frac{dT}{2} \tag{16}$$

where c is the speed of light and dT is the range sampling interval defined in 3.4.2. I_b is the incidence angle at the BIP, N_s is the number of range samples in each echo pulse of the EDR, N_{rs} is the number of samples in the range reference function used for range compression, N_w is the number of range walk samples, and N_{intp} is the additional number of pixels to be truncated due to degradation resulting from interpolation. Since a four-point interpolation is used in the DCS, N_{intp} is equal to four.

Range walk is the range distance migrated by the echo from a point target across a burst. N_w is given by

$$N_w = |f_{d-m}|\,(N_p - 1)\lambda/(2\mathbf{PRF}\ D_r) \tag{17}$$

where N_p is the total number of echo pulses in the burst and PRF is the pulse repetition frequency of the SAR.

Note that the geometric reference points with different i index values are associated with different $C1$ values and also different Doppler frequencies. Similarly, geometric reference points with different j index values are associated with different $C2$ values and also different range values.

5.3.3. Elevation of Geometric Reference Points, $E_g(i,j),(i,j=1,2,3)$:

Definition: The elevation at each geometric reference point is based upon the project specified topography model.

Process: The first step is to obtain the latitude and longitude of the geometric reference point from its projection coordinates. A 3x3 Lagrangian interpolation (see Appendix FE) shall be performed to get the elevation from 9 neighboring samples in the topography file.

5.3.4. Position of Geometric Reference Point, $\vec{X}_g(i,j),(i,j=1,2,3)$:

Definition: The position of the geometric reference point is given in one of the two coordinate systems VME85 and VBF85.

Process: The position of the geometric reference point in spherical coordinates is derived from the projection coordinate first (see Appendix FG and FH). The elevation is then added to the mean radius for each reference point. The position in VME85 and/or VBF85 coordinate is obtained through coordinate transformations given in Appendix FA.

5.3.5. Range and Doppler of Geometric Reference Point, $R_g(i,j), f_{d-g}(i,j),(i,j=1,2,3)$:

Definition: The range of the geometric reference point is the one-way apparent range between the geometric reference point and the spacecraft position at the burst reference time. The Doppler of the geometric reference point is the Doppler frequency of the echo reflected from the geometric reference point and observed at a time near the burst center time.

Process: The apparent range of each geometric reference point is approximated by:

$$R_g(i,j) = |\vec{X}_s - \vec{X}_g(i,j)| + f_{\Delta R}(|\vec{X}_s|, \alpha_g(i,j), E_g(i,j)) \tag{18}$$

In this equation, the first term is the straight-line distance between the spacecraft and the geometric reference point. The second term provides the difference between the apparent range and the straight distance of the geometric reference point. This term is given by a polynomial with predetermined coefficients. It is a function of three variables: the distance from the spacecraft to the planet center, the elevation of the geometric reference point, and the angle between the geometric reference point, the planet center, and the position of the spacecraft. Processing for generating the coefficients for $f_{\Delta R}(|\vec{X}_s|, \alpha_g, E_g)$ is described in Appendix FI.

The Doppler frequency of each geometric reference point is approximated by:

$$f_{d-g}(i,j) = \frac{-2\,\langle \vec{V}_s - \vec{V}_g(i,j),\ \vec{X}_s - \vec{X}_g(i,j) \rangle}{\lambda\,|\vec{X}_s - \vec{X}_g(i,j)|} + \left(f_{d-b} - \frac{-2\,\langle \vec{V}_s - \vec{V}_b,\ \vec{X}_s - \vec{X}_b \rangle}{\lambda\,|\vec{X}_s - \vec{X}_b|}\right) \quad (19)$$

The second term is the difference between the actual Doppler frequency and the Doppler frequency of the BIP under atmosphere free environment. Though the above equation used for estimating the Doppler frequency is an approximation, the accuracy is good enough to meet the processing requirements.

5.3.6. Range and Doppler of Framelet Corners, $R_{low}, R_{high}, f_{low}, f_{high}$:

Definition: These are the ranges and Doppler frequencies of the four corner points of a single-look image framelet. A framelet is centered at the MRP and is bounded by two iso-range lines and two iso-Doppler lines. The slant range swath is determined by the difference between the length of the collected range samples and the sum of the length of the range reference, the length of the range walk, and the number of samples lost on the framelet edge due to the interpolation process. The frequency width is given by the processing bandwidth specified in the EDR.

Process:

The Doppler frequencies of the four corners are given by

$$f_{low} = f_{d-m} - \mathbf{PBW}/2 \quad (20)$$

$$f_{high} = f_{d-m} + \mathbf{PBW}/2 \quad (21)$$

The two ranges are given by

$$R_{low} = R_m - \sin(I_b) \cdot \Delta Fc/2 \quad (22)$$

$$R_{high} = R_m + \sin(I_b) \cdot \Delta Fc/2 \quad (23)$$

where ΔFc and $\sin(I_b)$ are defined in 5.3.2.

5.3.7. Projection Coordinates of the Framelet Corners, $C1_{FC}(i,j), C2_{FC}(i,j), (i,j = 1,2)$:

Definition: The projection coordinates of the framelet corners. The indexes i, and j for the framelet corners are defined such that R_{low} corresponds to $i = 1$, R_{high} corresponds to $i = 2$, f_{low} corresponds to $j = 1$, and f_{high} corresponds to $j = 2$.

Process: The projection coordinates of the framelet corners shall be obtained using the process described in Appendix FJ with given range and Doppler coordinates of the corner points.

5.4. Parameters Related to the Radiometric Compensation Process

One DCS design constraint is that the radiometric compensation must be performed in the range-Doppler domain. Therefore, the radiometric compensation pattern must be expressed as a function of both range and Doppler. The radiometric compensation function generated by the DCS is a second order polynomial of the Doppler frequency. Each coefficient of this polynomial is a second order polynomial of range. In order to construct these polynomial functions, the radiometric compensation factors of nine selected points need to be computed. These nine points are referred to as the radiometric reference points.

The range-Doppler coordinates of the center radiometric reference point are given by the sample on the range-Doppler grid nearest to the Boresigt Intercept Point (BIP). The range-Doppler coordinates of all nine points are located at the intersections of three equally spaced lines of constant range. and three equally spaced lines of constant Doppler values. The outer four lines form a rectangle with a dimension being 2/3 of that corresponding to a framelet.

5.4.1 Range and Doppler of the Radiometric Reference Points, $R_{rg}(i,j), f_{d-rg}(i,j), (i,j \doteq 1,2,3)$:

Definition: These are the apparent range and Doppler frequency associated with the radiometric reference points.

Process: The range and Doppler of the radiometric reference points are given by

$$R_{rg}(i,j), = \text{Integer}(R_b/D_r)D_r + (i-2)\text{Integer}(\Delta Fc\sin(I_b)/(3D_r))S_1 D_r \quad \textbf{(24)}$$

and

$$f_{d-rg}(i,j) = \text{Integer}(f_{d-b}/df)df + (j-2)\text{Integer}(PBW/(3df))df, \tag{25}$$

where $s_1 = 1.25 - |t_m - t_p| \cdot .75/1250.$, respectively, where df is the frequency sampling interval in the range-Doppler image.

Note that the radiometric reference points with different i index values are associated with different range values. Similarly, radiometric reference points with different j index values are associated with different Doppler frequency values. This is opposite to the index order used for the geometric reference points (see 5.3.2).

5.4.2 Projection Coordinates of the Radiometric Reference Points, $C1_{rg}(i,j), C2_{rg}(i,j), (i,j = 1,2,3)$:

Definition: The projection coordinates of the radiometric reference points are given in sinusoidal or oblique sinusoidal projection system.

Process: The projection coordinates of the radiometric reference points are determined by using the method described in Appendix FJ.

5.4.3 Positions of the Radiometric Reference Points, $\vec{X}_{rg}(i,j), (i,j = 1,2,3)$:

Definition: The positions of the radiometric reference points are given in the VME85 or VBF85 coordinate system.

Process: The spherical coordinates of these points are computed from the projection coordinates according to equations given in Appendix FG and FH. The elevations of the radiometric reference points are then obtained by interpolating the topography model using the method described in Appendix FE. The positions are then obtained from their spherical coordinates and elevations.

5.4.4 Elevation and Horizontal Components of the Off-Boresight Angles of the Radiometric Reference Points, $\theta_e(i,j), \theta_h(i,j), (i,j = 1,2,3)$:

Definition: The off-boresight angle of a radiometric reference point is the angle between the boresight pointing direction and a line containing the spacecraft position and tangential to the ray path, which ends at the radiometric reference point. The antenna pattern to be incorporated in the radiometric compensation process is a two-dimensional function, with dimensions named elevation and horizontal. The elevation component of the off-boresight angle is in the X-Z plane of the spacecraft coordinate system (see Reference 5). The horizontal component of the off-boresight angle is in the Y-Z plane of the spacecraft coordinate system.

Process: The off-boresight angle shall be approximated by taking the angle between the BIP, the spacecraft, and the radiometric reference point. This approximation differs from the actual angle. However, it is accurate enough for meeting the performance requirement.

Denote $\theta_e(i,j)$ and $\theta_h(i,j)$ to be the elevation and horizontal components of the off-boresight angle, respectively. They are given by

$$\theta_e(i,j) = \tan^{-1}\left(\frac{\langle \vec{X}_{rg}(i,j) - \vec{X}_s - \langle \vec{X}_{rg}(i,j) - \vec{X}_s, \hat{P}\rangle \cdot \hat{P}, \hat{e}\rangle}{\langle \vec{X}_{rg}(i,j) - \vec{X}_s, \hat{P}\rangle}\right) \quad (26)$$

$$\theta_h(i,j) = \tan^{-1}\left(\frac{\langle \vec{X}_{rg}(i,j) - \vec{X}_s - \langle \vec{X}_{rg}(i,j) - \vec{X}_s, \hat{P}\rangle \cdot \hat{P}, \hat{h}\rangle}{\langle \vec{X}_{rg}(i,j) - \vec{X}_s, \hat{P}\rangle}\right) \quad (27)$$

where $\hat{P}$ is the spacecraft pointing vector given by $(\vec{X}_b - \vec{X}_s)/|\vec{X}_b - \vec{X}_s|$. $\hat{h}$ and $\hat{e}$ are the unit vectors along the horizontal and elevation directions, respectively. They are also given as the unit vectors along the negative-Y and positive-X axes of the MGN spacecraft body coordinate system (see reference 5).

5.4.5. Radiometric Compensation Factor of the Radiometric Reference Points, $C_{rg}(i,j), (i,j = 1,2,3)$:

Definition: The radiometric compensation process converts the value of each pixel of a compressed image into the normalized backscattering coefficient σ_n by multiplying it by a radiometric compensation factor. This compensation factor shall be a function of range and Doppler frequency. It is given by:

$$C_{rg}(r,f) = \frac{(4\pi)^3 N_r^2 N_a^2 R^4(r,f) K_2}{\bar{P}_T(t) K_1 N_p G_{BAQ} G_A^2(\theta_e, \theta_h) C_r C_d \bar{G}_r(t) \lambda^2 e_{kw}(PRF/PRF_{ref}) f(I_m - 0.5) G_{state}} \quad (28)$$

where

- r is the range coordinate of the pixel to be compensated
- f is the Doppler frequency of the pixel to be compensated
- $R(r,f)$ is the straight-line distance between the spacecraft and the location of the pixel
- $\bar{P}_T(t)$ is the ratio of the transmitted power of the burst to the transmitted power during calibration
- N_r is the range FFT length

- N_a is the azimuth FFT length
- N_p is the number of pulses in the burst
- K_1 is the product of the transmitted power during calibration, the sensor gain, and the gain of part of the processor including range and azimuth compressions. K_1 will be obtained through a sensor-processor calibration effort
- K_2 is the inverse of the gain product of the interpolation module and the radiometric compensation module that is not engaged when K_1 is measured
- $G_A^2(\theta_e, \theta_h)$ is the two-way antenna pattern function which includes the loss of the cable connecting the sensor and the antenna
- G_{BAQ} is the residual gain factor left out of the BAQ reconstruction process, G_{BAQ} is given by $(127./1.73 \cdot S2)^{-2}$, where S2 is given in 3.4.1.
- G_{state} is the Gain correction factor for nonstandard redundency configuration.
- θ_e and θ_h are the elevation and horizontal components of the off-boresight angle.
- C_r is the conversion factor from time to ground range
- C_d is the conversion factor from Doppler to along-track distance
- ϵ_{ku} is Kaiser weight constant which is given by the total energy divided by the product of the peak value and the number of samples in the weight
- PRF is the pulse repetition frequency
- PRF_ref is the pulse repetition frequency in the SAR data used for calibration
- $\bar{G}_r(t)$ is the ratio of the receiver gain of the burst to the receiver gain during calibration
- λ is the radar wavelength
- I_m is the incidence angle at the MRP.
- $f(I)$ is a function of I. $f(I) = .0118\cos(I)/(\sin(I) + .111\cos(I))^3$. In the above equation, I was planned to be I_m. However, it is actually $I_m - 0.5$ due to implementation error.

The conversion factor C_r is given by

$$C_r = \frac{c}{2\sin(I_m)} \tag{29}$$

The conversion factor C_d is given by

$$C_d = R_m\left(\frac{\lambda}{2|\vec{V}_s|\sqrt{1-(\langle\hat{V}_s,\hat{P}\rangle)^2}}\right) \tag{30}$$

The normalized backscattering coefficient can be expressed as the product of the square of the pixel value and the radiometric compensation factor $C_{rg}(r,f)$, i.e.,

$$\sigma_n(r,f) = |X(r,f)|^2 C_{rg}(r,f) \tag{31}$$

Process:

For the (i,j)-th radiometric reference point, the radiometric compensation factor is given by inserting its range and Doppler (given in 5.4.1) into equation (28).

5.4.6. Relative Radiometric Compensation Factor of the Radiometric Reference Point, $\bar{C}_{rg}(i,j).(i,j=1,2,3)$:

Definition: The relative radiometric compensation factor is the radiometric compensation factor of 5.4.5 normalized by its maximum value. The maximum before normalization is also referred to as the absolute radiometric compensation factor.

Process: Divide the radiometric compensation factors of 5.4.5 by their maxima.

5.5. Control Parameters

The SDPS will perform the following signal processing functions: (1) range pulse compression, (2) azimuth SAR processing, (3) radiometric compensation, (4) geometric rectification, (5) framelet truncation, and (6) multi-look overlay. The associated control parameters for each processing function are shown in Figure 5. The processing parameters required by the range compression module include the range walk polynomial coefficients and the reference group index. The processing parameters required by the azimuth compression module include the Deramp reference coefficient and the Kaiser weight index. The processing parameters required by the radiometric compensation module are the radiometric compensation coefficients. The processing parameters required by the geometric rectification module include the range resampling coefficients and the azimuth resampling coefficients. The processing parameters required by the framelet truncation module include the high and low bounds for both the range and the Doppler dimensions. At the functional level, there are no processing parameters required by the multi-look overlay module.

5.5.1. Reference Group Index, I_{RG}:

Definition: This is a number for selecting one group of range reference functions from the range reference buffer. The range reference buffer houses 32 groups of reference functions, each of which has 8 reference functions. Each group is used for compensating the phase drift caused by the Doppler frequency over a 2550Hz bandwidth. Each reference function is used for range compression plus interpolation to shift the response by an integer multiple of 1/8 range bin.

Process: The reference group index is given by

$$I_{RG} = \begin{cases} 1 & f_{d-m} < -14.5\Delta f_d \\ \mathrm{Nint}(f_{d-m}/\Delta f_d) + 16 & -14.5\Delta f_d < f_{d-m} < 15.5\Delta f_d \\ 32 & f_{d-m} > 15.5\Delta f_d \end{cases} \tag{32}$$

where $\mathrm{Nint}(x)$ is the nearest integer to x, Δf_d is the bandwidth allocated to each group of references. Δf_d shall be given by 2550Hz.

5.5.2. Range Walk Polynomial Coefficients, $d0_{rw}, d1_{rw}$:

Definition: These are the coefficients used to construct a polynomial that represents the number of range bins, as a function of the echo pulse count, to be shifted in the range walk correction process. In DCS processing, the range walk correction will be performed by a left circular shift (sample with greater range index shifted to position of smaller range index). The amount of range walk to be corrected and its polynomial coefficients are related by

$$N_{rw}(i) = d1_{rw} \cdot (i-1) + d0_{rw} \quad i = 1, 2, 3, \ldots\ldots, N_p \tag{33}$$

where i is the index of the echo pulse and N_p is the total number of pulses in the burst.

Process: These coefficients are obtained from the Doppler frequency of the MRP and the number of echo pulses in the burst processed. They are given by:

$$d0_{rw} = \begin{cases} f_{d-m}\,(N_p - 1)\frac{\lambda}{2D_r}\frac{1}{\mathbf{PRF}} & f_{d-m} > 0 \\ 0 & f_{d-m} < 0 \end{cases} \tag{34}$$

$$d1_{rw} = -f_{d-m}\,\frac{\lambda}{2D_r}\frac{1}{\mathbf{PRF}} \tag{35}$$

where N_p is the number of pulses in a burst, λ is the wavelength, and D_r is the range sample spacing (5.3.2)

5.5.3. Range Reference Index, I_R:

Definition: This is the index used to select a range reference function from the selected group of reference functions.

Process: The range reference index is given by

$$I_R = \mathbf{Integer}(\mathbf{Frac}(N_{rw}(i)) \cdot 8) + 1 \tag{36}$$

where both $N_{rw}(i)$ and i are given in 5.5.2. and Frac(x) is the fractional part of x.

5.5.4. Deramp Reference Coefficients, $d1_{rmp}, d2_{rmp}$:

Definition: The Deramp reference function is designed to remove the quadratic phase of the SAR echo along azimuth. This is a linear FM function. The 1st and 2nd order coefficients of the phase function are referred to as the Deramp reference coefficients.

Process: The phase function of the Deramp reference is given in 3.4.3. The Deramp reference coefficients are directly determined by PRF, the Doppler frequency of the MRP, and the Doppler frequency rate of the MRP, i.e.

$$d1_{rmp} = 2\pi(\frac{\mathbf{PRF}}{2} - f_{d-m} + \frac{f_{r-m}N_p}{2})\,dT \tag{37}$$

$$d2_{rmp} = -\pi f_{r-m}\,dT^2 \tag{38}$$

The phase of the deramp reference function is given by

$$\theta_{drmp}(i) = d1_{rmp} \cdot i + d2_{rmp} \cdot i^2 \tag{39}$$

5.5.5. Range and Doppler of Framelet Corners, $f_{low}, f_{high}, R_{low}, R_{high}$

Process:

Due to the frequecy shift introduced by the deramp process, the Doppler frequencies of the four corners are then given by

$$f_{low} = \mathbf{PRF/2 - PBW/2} \tag{40}$$

$$f_{high} = \mathbf{PRF/2 + PBW/2} \tag{41}$$

The two ranges are given by

$$R_{low} = R_m - \sin(I_b) \cdot \Delta Fc/2 \tag{42}$$

$$R_{high} = R_m + \sin(I_b) \cdot \Delta Fc/2 \tag{43}$$

where ΔFc and $\sin(I_b)$ are defined in 5.3.2.

5.5.6. Radiometric Compensation Coefficients, $\mu_{r-ij}, (i, j = 1, 2, 3)$:

Definition: These coefficients are used to generate a two-dimensional polynomial. The control processor uses these coefficients to generate the radiometric compensation factor. Denote the radiometric compensation coefficients by μ_{r-ij}; the radiometric compensation factor $C_{rg}(r, f)$ for a sample with range r and Doppler f is given by

$$C(r, f) = C_0(e_2(\Delta f)^2 + e_1(\Delta f) + e_0)^2 \tag{44}$$

$$\begin{bmatrix} e_0 \\ e_1 \\ e_2 \end{bmatrix} = \begin{bmatrix} \mu_{r-11} & \mu_{r-21} & \mu_{r-31} \\ \mu_{r-12} & \mu_{r-22} & \mu_{r-32} \\ \mu_{r-13} & \mu_{r-23} & \mu_{r-33} \end{bmatrix} \begin{bmatrix} 1 \\ \Delta R \\ (\Delta R)^2 \end{bmatrix} \tag{45}$$

where C_0 is the absolute radiometric compensation factor.

$$C_0 = C_{rg}(R_{rg}(2,2), f_{d-rg}(2,2)) \tag{46}$$

ΔR and Δf are given by

$$\Delta R = r - R_{rg}(2,2) \tag{47}$$

$$\Delta f = f - f_{d-rg}(2,2) \tag{48}$$

Note: For both cycle I and cycle II, the radiometric compensation coefficients given in F-BIDR file 14 and 16 are derived from the above equations. For cycle I processing, these radiometric compensation coefficients used directly by the radiometric compensation module of the DCS. For cycle II processing, for the bursts associated with wide antenna beam (defined in Appendix FN2), the radiometric compensation coefficients used by the DCS is derived from the radiometric compensation factor multiplied by the relative antenna gain, i.e. $C_{rg}(r,f) \cdot G_A^2(\theta_e,\theta_h)/G_A^2(0.,0.)$. The compensation for the antenna pattern is performed by a Cross-track weight module in the DCS. In this module, cross-track weights determined by the antenna pattern, incidence angle, and angle between MRP and BIP are be multiplied to the SAR image in the C2 vs. Doppler grid. Detail control to this module is described in Appendix FP.

Process: The radiometric compensation coefficients are generated from the relative compensation factor of the radiometric reference points. Processes involved are two matrix inverses described in Appendix FL.

5.5.7. Range Resampling Coefficients, $\mu_{g-ij}, (i,j = 1,2,3)$:

Definition: These are the coefficients used to construct a set of polynomials that represent the ranges of a set of iso-coordinate-2 lines as a function of the Doppler frequency. In the range interpolation process. sample values are extracted from these iso-coordinate-2 lines. Denote the range resampling coefficients by $\mu_{g-ij}, (i,j = 1,2,3)$. The range coordinate r of the sample with Doppler frequency of f and coordinate-2 value of $C2$ is given by

$$r(f,C2) = r_g(2,2) + e_2(f - f_{d-g}(2,2))^2 + e_1(f - f_{d-g}(2,2)) - e_0, \tag{49}$$

where

$$\begin{bmatrix} e_0 \\ e_1 \\ e_2 \end{bmatrix} = \begin{bmatrix} \mu_{g-11} & \mu_{g-21} & \mu_{g-31} \\ \mu_{g-12} & \mu_{g-22} & \mu_{g-32} \\ \mu_{g-13} & \mu_{g-23} & \mu_{g-33} \end{bmatrix} \begin{bmatrix} 1 \\ C2 - C2_g(2,2) \\ (C2 - C2_g(2,2))^2 \end{bmatrix} \tag{50}$$

Process: To get the range resampling coefficients, the involved process contains two matrix (3x3) inverses. Detailed description is given in Appendix FM.

5.5.8. Azimuth Resampling Coefficients $\mu_{a-ij}, (i, j = 1, 2, 3)$:

Definition: These are the coefficients used to construct a set of polynomials that represent the Doppler frequencies of a set of iso-coordinate-2 lines as a function of the coordinate-1 values of the projection. In the azimuth interpolation process, sample values are extracted from these Doppler frequencies. Denote the azimuth resampling coefficients by $\mu_{a-ij}, (i, j = 1, 2, 3)$. The Doppler frequency f of the sample with projection coordinate of $(C1, C2)$ is given by

$$f(C1, C2) = f_{d-g}(2, 2) + e_2(C1 - C1_g(2, 2))^2 + e_1(C1 - C1_g(2, 2)) + e_0, \qquad (51)$$

where

$$\begin{bmatrix} e_0 \\ e_1 \\ e_2 \end{bmatrix} = \begin{bmatrix} \mu_{a-11} & \mu_{a-21} & \mu_{a-31} \\ \mu_{a-12} & \mu_{a-22} & \mu_{a-32} \\ \mu_{a-13} & \mu_{a-23} & \mu_{a-33} \end{bmatrix} \begin{bmatrix} 1 \\ C2 - C2_g(2,2) \\ (C2 - C2_g(2,2))^2 \end{bmatrix} \tag{52}$$

Process: To get the azimuth resampling coefficients, the involved process contains two matrix (3x3) inverses. Detailed description is given in Appendix FN.

APPENDIX FA. COORDINATE TRANSFORMS

(A.1) TRANSFORM FROM J2000 INTO VME85

This transform is given by:

$$\begin{bmatrix} x_V \\ y_V \\ z_V \end{bmatrix} = \begin{bmatrix} .99889808 & .04693211 & .00000000 \\ -.04325546 & .92064453 & .3879982 \\ .01820958 & -.38757068 & .92166012 \end{bmatrix} \begin{bmatrix} x_J \\ y_J \\ z_J \end{bmatrix}$$

where $[x_J, y_J, z_J]^T$ is the position in the J2000 coordinate system and $[x_V, y_V, z_V]^T$ is the position in the VME85 coordinate system. The inverse transform is given by:

$$\begin{bmatrix} x_J \\ y_J \\ z_J \end{bmatrix} = \begin{bmatrix} .99889808 & -.04325546 & .01820958 \\ .04693211 & .92064453 & -.38757068 \\ .00000000 & .38799822 & .92166012 \end{bmatrix} \begin{bmatrix} x_V \\ y_V \\ z_V \end{bmatrix}$$

(A.2) TRANSFORM FROM VME85 INTO VBF85

This transform involves a coordinate rotation about the Z axis through an angle ω. This is given by:

$$\begin{bmatrix} x_B \\ y_B \\ z_B \end{bmatrix} = \begin{bmatrix} \cos\omega & \sin\omega & 0 \\ -\sin\omega & \cos\omega & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_V \\ y_V \\ z_V \end{bmatrix}$$

where $[x_V, y_V, z_V]^T$ is the position in the VME85 coordinates, $[x_B, y_B, z_B]^T$ is the position in the VBF85 coordinates, and ω is given by:

$$\omega = \omega_{2000} - \xi \cdot D$$

where ξ is the angular rate of the spin of Venus and D is the number of days since 2000 ET.

The inverse transform is given by:

$$\begin{bmatrix} x_V \\ y_V \\ z_V \end{bmatrix} = \begin{bmatrix} \cos\omega & -\sin\omega & 0 \\ \sin\omega & \cos\omega & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_B \\ y_B \\ z_B \end{bmatrix}$$

(A.3) TRANSFORM FROM VBF85 INTO VENUS LATITUDE-LONGITUDE COORDINATES

The latitude ψ and longitude θ of $[x_B, y_B, z_B]^T$ are given by:

$$\psi = \sin^{-1}(z_B/r)$$

$$\theta = \tan^{-1}(y_B/x_B)$$

$$r = (x_B^2 + y_B^2 + z_B^2)^{1/2}$$

The inverse transform is given by

$$z_B = r \cdot \sin(\psi)$$

$$x_B = r\cos(\psi) \cdot \cos(\theta)$$

$$y_B = r\cos(\psi) \cdot \sin(\theta)$$

APPENDIX FB-1. DERIVATION OF QUATERNIONS

The procedure used to generate the quaternions used by the SDPS is as follows:

1. Given the predicted time of periapsis and the burst reference time, the time since periapsis is computed.
2. The time since periapsis is then normalized by the time scale factor in the MQPC file.
3. Obtain the initial quaternions by applying the MQPC coefficients to the scaled time obtained in step 2.
4. Use the burst reference time to interpolate on the delta quaternions provided in the Engineering Data file. (Note: if any of the 4 delta quaternions is greater than 0.001, the delta quaternions are defaulted to 0.0).
5. Apply the interpolated delta quaternions to the initial quaternions obtained in step 3, to arrive at the pointing quaternions.

APPENDIX FB-2. TRANSFORM FROM POINTING QUATERNION INTO J2000 VECTOR

Let $[q_1, q_2, q_3, q_4]^T$ represent the pointing quaternion and $[x_p, y_p, z_p]^T$ represents the boresight pointing vector in the J2000 coordinate system. The transformation from pointing quaternion to J2000 vector is given by:

$$\begin{bmatrix} x_p \\ y_p \\ z_p \end{bmatrix} = \begin{bmatrix} Q_{13} + Q_{24} \\ Q_{23} - Q_{14} \\ -Q_{11} - Q_{22} + Q_{33} + Q_{44} \end{bmatrix}$$

where

$$Q_{ii} = q_i^2$$

$$Q_{ij} = 2\, q_i\, q_j \qquad i \neq j$$

APPENDIX FC. POLYNOMIAL COEFFICIENTS OF α_1, INCIDENCE ANGLE AT THE PLANET SURFACE, I, AND APPARENT RANGE, R_{ao}

Figure 6a illustrates the geometry of the atmosphere surface, planet surface, ray path, and spacecraft position to be used for this Appendix. The segmented ray path shown here is the result of assuming that the atmosphere consists of a number of shells, each associated with a constant index of refraction within the entire shell.

This appendix describes the process for obtaining three sets of polynomial coefficients to be used to construct polynomials for evaluating α_1, I, and R_{ao}. All three polynomials are functions of two variables: the incidence angle at the top surface of the atmosphere, and the radius of an assumed spherical surface. α_1 is the angle defined by the boresight ray intercept point at the top surface of the atmosphere, the center of planet, and the BIP on the assumed spherical surface. I is the incidence angle at the BIP with respect to an assumed spherical planet surface. R_{ao} is the apparent range between the boresight ray intercept point on the top surface of the atmosphere and the BIP on the assumed spherical surface.

To generate these coefficients, the first step is to compute α_1, I, and R_{ao} for selected examples of varying incidence angle θ_a and varying radius of the planet surface. The second step is to perform polynomial fits to extract the polynomial coefficients. The fit process involves solving a set of linear equations to be given at the end of this Appendix. The following illustrates the process for computing α_1 and R_{ao} for a given incidence angle θ_a and elevation.

The project specified atmosphere model has an altitude range from 6041 km to 6126 km above the planet center. This atmosphere is approximated by 86 shells, each of which is 1 km wide and has uniform density.

As shown in Figure 6b, α_1 is given by

$$\alpha_1 = \sum_{n=1}^{N} \gamma_n$$

where N is determined by the elevation of the selected sample. N is given by

$$N = 1 + Integer(6126 - R_p)$$

where R_p is the radius of the assumed spherical surface. The apparent range within the atmosphere is given by the sum of the apparent ranges from each 1km shell, i.e.

$$R_{ao} = \sum_{n=1}^{N} R_{ao-n}$$

The following equations describe how to compute γ_n and R_{ao-n}. R_{ao-n} is the apparent range in the n-th shell.

1. Compute θ_n (see Figure 6.b) using Snell's law, i.e.

$$n_{n-1}\sin(\theta_a) \;=\; n_n \sin(\theta_n)$$

where n_{n-1} and n_n are the index of refraction of the n-th and $(n-1)$-th shell, respectively.

2. Compute the incidence angle I_n at the spherical surface n km down from the top surface of the atmosphere (I_N is the incidence angle on the assumed planet surface approximately N km down from the top surface of the atmosphere). It is given by

$$I_n = \sin^{-1}((R_{n-1}/R_n)\sin(\theta_n))$$

where $R_n = R_{n-1} - 1$, for $n = 1, 2, 3,.., N$-1, since each shell is 1km deep. However, R_N is equal to the radius of the assumed planet surface.

3. γ_n is then given by

$$\gamma_n = I_n - \theta_n$$

4. The distance between the ray intercept point at the n-th and $(n+1)$-th surfaces of the atmosphere shells is given by

$$d_n = R_n \cdot \sin(\gamma_n)/\sin(\theta_n)$$

5. The apparent range R_{ao-n} is then given by

$$R_{ao-n} = n_n R_n \cdot \sin(\gamma_n)/\sin(\theta_n)$$

POLYNOMIAL FIT EQUATIONS

Let y be a function of x; an N-th order polynomial is used to characterize this function, i.e.

$$y(x) = \sum_{n=0}^{N} a_n x^n$$

Given K pairs of $(x_k, y_k(x_k))$ where $K > N$, the polynomial coefficients $a_n, (n = 0, 1, 2, .., N)$ can be solved from the following equation.

$$\begin{bmatrix} \sum_{n=1}^{K} x_n^{2N} & \sum_{n=1}^{K} x_n^{2N-1} & . & . & \sum_{n=1}^{K} x_n^{N} \\ \sum_{n=1}^{K} x_n^{2N-1} & \sum_{n=1}^{K} x_n^{2N-2} & . & . & \sum_{n=1}^{K} x_n^{N-1} \\ . & . & . & . & . \\ \sum_{n=1}^{K} x_n^{N+1} & \sum_{n=1}^{K} x_n^{N} & . & . & \sum_{n=1}^{K} x_n \\ \sum_{n=1}^{K} x_n^{N} & \sum_{n=1}^{K} x_n^{N-1} & . & . & K \end{bmatrix} \begin{bmatrix} a_N \\ a_{N-1} \\ . \\ . \\ a_0 \end{bmatrix} = \begin{bmatrix} \sum_{n=1}^{K} y_n x_n^{N} \\ \sum_{n=1}^{K} y_n x_n^{N-1} \\ . \\ \sum_{n=1}^{K} y_n x_n \\ \sum_{n=1}^{K} y_n \end{bmatrix}$$

APPENDIX FD. CONVERSION FROM α_b TO THE BIP POSITION

Given α_b (see Figure 6a), the elevation of the BIP, the pointing unit vector $\hat{P}$, and the spacecraft position in the VBF85 coordinate system, the BIP position is given by:

$$\vec{X}_b = (R_v + E_b)(\cos\alpha_b\,\hat{r} + \sin\alpha_b\,\hat{P}_g)$$

where

$$\hat{r} = \vec{X}_s/|\vec{X}_s|$$

$$\hat{P}_g = (\hat{P} - \hat{r}\langle\hat{r},\hat{P}\rangle)/|\hat{P} - \hat{r}\langle\hat{r},\hat{P}\rangle|$$

R_v is the mean radius of Venus and E_b is the elevation at the BIP which is computed by interpolating the topo model at the given latitude and longitude of the BIP using method described in Appendix FE. $\hat{P}$ is the boresight pointing vector.

APPENDIX FE. ELEVATION OF A POINT WITH GIVEN SPHERICAL COORDINATES:

A 3x3 Lagrangian interpolation shall be performed to get the surface elevation from 9 neighboring samples in the topography file. Let (ψ, θ) denote the spherical coordinates of the given point, (ψ_i, θ_j) (for $i, j = 1, 2, 3$) denote the spherical coordinates of the neighboring samples in the topography file, and $E(\psi, \theta)$ denote the elevation from the mean planet radius. The elevation of this point is given by:

$$E(\psi,\theta) = \sum_{i=1}^{3}\sum_{j=1}^{3} E(\psi_i,\theta_j)\,\frac{(\theta-\theta_{j'})(\theta-\theta_{j''})(\psi-\psi_{i'})(\psi-\psi_{i''})}{(\theta_j-\theta_{j'})(\theta_j-\theta_{j''})(\psi_i-\psi_{i'})(\psi_i-\psi_{i''})}$$

where $i', i'' \in \{(1,2,3) - (i)\},\ i' \neq i''$

and $j', j'' \in \{(1,2,3) - (j)\},\ j' \neq j''$

APPENDIX FF. FAR RANGE POINTING VECTOR

Let $[q_1, q_2, q_3, q_4]^T$ represent the pointing quaternion, the Magellan spacecraft axes w. r. t. the J2000 coordinate system are given by

$$X = \begin{bmatrix} Q_{11} - Q_{22} - Q_{33} + Q_{44} \\ Q_{12} + Q_{34} \\ Q_{13} - Q_{24} \end{bmatrix}$$

$$Y = \begin{bmatrix} Q_{12} - Q_{34} \\ -Q_{11} + Q_{22} - Q_{33} + Q_{44} \\ Q_{23} + Q_{14} \end{bmatrix}$$

$$Z = \begin{bmatrix} Q_{13} + Q_{24} \\ Q_{23} - Q_{14} \\ -Q_{11} - Q_{22} + Q_{33} + Q_{44} \end{bmatrix}$$

where

$$Q_{ii} = q_i^2$$

$$Q_{ij} = 2\, q_i\, q_j \qquad i \neq j$$

To derive the Doppler drift rate in range, a second pointing vector needs to be evaluated. This pointing vector has a slightly different look angle and is in the X-Z plane of the spacecraft coordinate system (see Reference 5). Let the look angle associated with this pointing vector be greater than the boresight look angle by θ_d. Let $[x_p, y_p, z_p]^T$ represent the far range pointing vector in the J2000 coordinate system. It is given by:

$$\begin{bmatrix} x_p \\ y_p \\ z_p \end{bmatrix} = \cos\theta_d \cdot Z - \sin\theta_d \cdot X$$

APPENDIX FG. TRANSFORM FROM SPHERICAL INTO SINUSOIDAL COORDINATES

The horizontal and the vertical coordinates (h, v) in unit of meters in the sinusoidal projection corresponding to latitude-longitude (ψ, θ), in units of degrees, are given by:

$$h = \pi/180^\circ \cdot (\theta - \theta_0)\, R_v \cos(\psi)$$

$$v = \pi/180^\circ \cdot R_v\, \psi$$

where R_v is the mean radius of Venus and θ_0 is the reference meridian.

The inverse transform is given by:

$$\psi = 180^\circ/\pi \cdot (v/R_v)$$

$$\theta = \theta_0 + 180^\circ/\pi \cdot (h/(R_v \cos(\psi)))$$

APPENDIX FH. TRANSFORM FROM VBF85 INTO OBLIQUE SINUSOIDAL COORDINATES

This appendix begins with the definition of an AT/CT rectangular coordinate system or the so called oblique sinusoidal coordinate system. Then, the transformation from the VBF85 coordinates into the oblique sinusoidal coordinates is described.

In the oblique sinusoidal coordinate system, the Z axis is in the direction of the angular rate of the spacecraft. The Y axis is given by the cross product of the Z axis of the oblique sinusoidal coordinate and the Z axis of the VBF85. The X axis completes the right hand rule.

To transform from the VBF85 into the oblique sinusoidal coordinates requires two rotations. The first is a rotation about the Z axis of the VBF85 through an angle α_1. The second is a rotation about the resultant Y axis through an angle α_2. Denote $[x_A, y_A, z_A]^T$ as a vector in the oblique sinusoidal coordinate and $[x_B, y_B, z_B]^T$ as a vector in the VBF85 system, they are related by the following equation.

$$\begin{bmatrix} x_A \\ y_A \\ z_A \end{bmatrix} = \begin{bmatrix} \cos\alpha_2 & 0 & -\sin\alpha_2 \\ 0 & 1 & 0 \\ \sin\alpha_2 & 0 & \cos\alpha_2 \end{bmatrix} \begin{bmatrix} \cos\alpha_1 & \sin\alpha_1 & 0 \\ -\sin\alpha_1 & \cos\alpha_1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_B \\ y_B \\ z_B \end{bmatrix}$$

where α_1 and α_2 are given by

$$\alpha_1 = \tan^{-1}(A_y/A_x)$$

$$\alpha_2 = -\sin^{-1}(A_z)$$

where A_x, A_y, and A_z are the VBF vector components of $\hat{A}$, which is the unit vector of the X axis of the oblique sinusoidal coordinate system. Denote $\vec{X}_s$ and $\vec{V}_s$ as the position and velocity vectors of the spacecraft near 85°N (left looking) or 85°S (right looking) in VBF85. Then, $\hat{A}$ is given by

$$\hat{A} = \frac{\hat{y} \times \hat{z}}{|\hat{y} \times \hat{z}|}$$

where

$$\hat{y} = \frac{\hat{z} \times \bar{Z}}{|\hat{z} \times \bar{Z}|}$$

where

$$\hat{z} = \frac{\vec{X}_s \times \vec{V}_s}{|\vec{X}_s \times \vec{V}_s|}$$

and $\bar{Z}$ is the Z axis of the VBF85.

The next step is to transform from the AT/CT rectangular coordinates into the spherical coordinates and then the oblique sinusoidal coordinate system. Denote H as the along-track coordinate value and V as the cross-track coordinate value. These values are in units of meters and given by

$$H = \pi/180^\circ \cdot \theta\, R_v \cos(\psi)$$

$$V = \pi/180^\circ \cdot R_v\, \psi$$

where

$$\theta = \tan^{-1}(y_A/x_A)$$

$$\psi = \sin^{-1}(z_A/r_A)$$

APPENDIX FI. GENERATION OF COEFFICIENTS OF POLYNOMIAL $f_{\Delta R}(|\vec{X}_s|, \alpha_g, E_g)$

The form of the polynomial is given by

$$f_{\Delta R}(|\vec{X}_s|, \alpha_g, E_g) = \sum_{i=0}^{I} \sum_{j=0}^{J} \sum_{k=0}^{K} E_{ijk} |\vec{X}_s|^k \alpha_g^j \, E_g^i$$

To generate the coefficients of the polynomial, the first step is to compute the straight-line distances and the apparent ranges between the spacecraft and the geometric reference points for a set of distances between the spacecraft and the planet center, elevations of the geometric reference points, and angles between the geometric reference points, the planet center, and the spacecraft position. The differences between the straight-line distances and the apparent ranges are then taken. The second step is to perform polynomial fits to extract the polynomial coefficients C_i according to the first equation given below. Then, polynomial fits are performed to extract polynomial coefficients D_{ij} according to the second equation given below. Finally, polynomial fits are performed to extract polynomial coefficients E_{ijk} according to the third equation given below.

$$(1).\quad f_{\Delta R}(|\vec{X}_s|, \alpha_g, E_g) = \sum_{i=0}^{I} C_i(|\vec{X}_s|, \alpha_g) \, E_g^i$$

$$(2).\quad C_i(|\vec{X}_s|, \alpha_g) = \sum_{j=0}^{J} D_{ij}(|\vec{X}_s|) \alpha_g^j$$

$$(3).\quad D_{ij}(|\vec{X}_s|) = \sum_{k=0}^{K} E_{ijk} |\vec{X}_s|^k$$

APPENDIX FJ. PROJECTION COORDINATE DETERMINATION FROM RANGE AND DOPPLER

The projection coordinates $(C1, C2)$ of the target with range R and Doppler f are determined as follows:

1. Solve for $C2$ from

$$\Delta R = \begin{bmatrix} 1 & (f - f_{d-g}(2,2)) & (f - f_{d-g}(2,2))^2 \end{bmatrix} \left(\begin{bmatrix} \mu_{g-11} & \mu_{g-21} & \mu_{g-31} \\ \mu_{g-12} & \mu_{g-22} & \mu_{g-32} \\ \mu_{g-13} & \mu_{g-23} & \mu_{g-33} \end{bmatrix} \begin{bmatrix} 1 \\ (C2 - C2_g(2,2)) \\ (C2 - C2_g(2,2))^2 \end{bmatrix} \right)$$

where

$$\Delta R = R - r_g(2,2)$$

where matrix $[\mu_{g-ij}]$ is defined in 5.5.7. It can be shown that $C2$ is given by

$$C2 = \frac{-B + S\sqrt{B^2 - 4AC}}{2A} + C2_g(2,2)$$

where S is equal to 1 since $dR/dC2$ must be positive.

$$A = \langle 1, (f - f_{d-g}(2,2)), (f - f_{d-g}(2,2))^2 \rangle \langle \mu_{g-31}, \mu_{g-32}, \mu_{g-33} \rangle^T$$

$$B = \langle 1, (f - f_{d-g}(2,2)), (f - f_{d-g}(2,2))^2 \rangle \langle \mu_{g-21}, \mu_{g-22}, \mu_{g-23} \rangle^T$$

$$C = \langle 1, (f - f_{d-g}(2,2)), (f - f_{d-g}(2,2))^2 \rangle \langle \mu_{g-11}, \mu_{g-12}, \mu_{g-13} \rangle^T - \Delta R$$

2. Solve for $C1$ from

$$\Delta f = \begin{bmatrix} 1 & (C1 - C1_g(2,2)) & (C1 - C1_g(2,2))^2 \end{bmatrix} \left(\begin{bmatrix} \mu_{a-11} & \mu_{a-21} & \mu_{a-31} \\ \mu_{a-12} & \mu_{a-22} & \mu_{a-32} \\ \mu_{a-13} & \mu_{a-23} & \mu_{a-33} \end{bmatrix} \begin{bmatrix} 1 \\ (C2 - C2_g(2,2)) \\ (C2 - C2_g(2,2))^2 \end{bmatrix} \right.$$

where

$$\Delta f = f - f_{d-g}(2,2)$$

where matrix $[\mu_{a-ij}]$ is defined in 5.5.8. It can be shown that $C1$ is given by

$$C1 = \frac{-B + S \cdot \sqrt{B^2 - 4AC}}{2A} + C1_g(2,2)$$

where S is equal to -1 for sinusoidal projection and 1 for oblique sinusoidal projection.

$$A = \langle 1, (C2 - C2_g(2,2)), (C2 - C2_g(2,2))^2 \rangle \langle \mu_{a-13}, \mu_{a-23}, \mu_{a-33} \rangle^T$$

$$B = \langle 1, (C2 - C2_g(2,2)), (C2 - C2_g(2,2))^2 \rangle \langle \mu_{a-12}, \mu_{a-22}, \mu_{a-32} \rangle^T$$

$$C = \langle 1, (C2 - C2_g(2,2)), (C2 - C2_g(2,2))^2 \rangle \langle \mu_{a-11}, \mu_{a-21}, \mu_{a-31} \rangle^T - \Delta f$$

APPENDIX FK. KAISER WEIGHTS

There are 40 Kaiser weight sets stored in the weight memory of the DCS. Each weight set takes the form of a Kaiser weight with a coefficient of 0.8. However, these weight sets differ from one another by their size or the total number of samples. The total number of samples in the k-th weight is given by

$$N(k) = \text{Integer}(90 \cdot (1.05)^{k-1}), k = 1, 2, 3..., 40$$

where k is the index of the weight. The k-th Kaiser weight set is given by

$$W_{Ksr}(n, N(k), \alpha_w) = \frac{I_0(\pi\,\alpha_w(1 - (n/(N(k)/2))^2)^{1/2})}{I_0(\pi\alpha_w)} \qquad 0 \leq |n| \leq N(k)/2$$

$$I_0(x) = \sum_{m=0}^{20} (\frac{(x/2)^m}{m!})^2$$

where α_w is the weight coefficient. α_w is chosen to be 0.8 according to the radar system design.

APPENDIX FL. RADIOMETRIC COMPENSATION COEFFICIENTS

Denote $C_{ij}, (i,j = 1,2,3)$ to be the square root of the relative radiometric compensation factor for the nine radiometric reference points. The first step in obtaining the radiometric compensation coefficients is to solve for matrix $[G]$ from the following equation.

$$\begin{bmatrix} 1 & DF_1 & DF_1^2 \\ 1 & DF_2 & DF_2^2 \\ 1 & DF_3 & DF_3^2 \end{bmatrix} \begin{bmatrix} g_{i1} \\ g_{i2} \\ g_{i3} \end{bmatrix} = \begin{bmatrix} C_{i1} \\ C_{i2} \\ C_{i3} \end{bmatrix} \quad i = 1,2,3$$

where

$$DF_k = f_{d-rg}(1,k) - f_{d-rg}(1,2)$$

for k=1,2,3

The second step is to solve for the coefficient matrix $[\mu_r]$ from the following matrix equation. The solution to the matrix equation is given by Appendix FN1.

$$\begin{bmatrix} 1 & R_1 & R_1^2 \\ 1 & R_2 & R_2^2 \\ 1 & R_3 & R_3^2 \end{bmatrix} \begin{bmatrix} \mu_{r-11} & \mu_{r-12} & \mu_{r-13} \\ \mu_{r-21} & \mu_{r-22} & \mu_{r-23} \\ \mu_{r-31} & \mu_{r-32} & \mu_{r-33} \end{bmatrix} = \begin{bmatrix} g_{11} & g_{12} & g_{13} \\ g_{21} & g_{22} & g_{23} \\ g_{31} & g_{32} & g_{33} \end{bmatrix}$$

where

$$R_k = R_{rg}(k,1) - R_{rg}(2,1)$$

for k=1,2,3

APPENDIX FM. RANGE RESAMPLING COEFFICIENTS

The first step in obtaining the range resampling coefficients is to obtain matrix $[A]$ through solving the following matrix equation.

$$\begin{bmatrix} 1 & DF_{1j} & DF_{1j}^2 \\ 1 & DF_{2j} & DF_{2j}^2 \\ 1 & DF_{3j} & DF_{3j}^2 \end{bmatrix} \begin{bmatrix} a_{j1} \\ a_{j2} \\ a_{j3} \end{bmatrix} = \begin{bmatrix} dR_g(1,j) \\ dR_g(2,j) \\ dR_g(3,j) \end{bmatrix} \quad j = 1,2,3$$

where

$$DF_{ij} = f_{d-g}(i,j) - f_{d-g}(2,2)$$

$$dR_g(i,j) = R_g(i,j) - R_g(2,2)$$

The range resampling coefficients are given by the solution of the following matrix equation. The solution to the matrix equation is given by Appendix FO.

$$\begin{bmatrix} 1 & DC2_1 & DC2_1^2 \\ 1 & 0 & 0 \\ 1 & DC2_3 & DC2_3^2 \end{bmatrix} \begin{bmatrix} \mu_{g-11} & \mu_{g-12} & \mu_{g-13} \\ \mu_{g-21} & \mu_{g-22} & \mu_{g-23} \\ \mu_{g-31} & \mu_{g-32} & \mu_{g-33} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

where

$$DC2_j = C2_g(1,j) - C2_g(1,2)$$

APPENDIX FN. AZIMUTH RESAMPLING COEFFICIENTS

The first step in obtaining the azimuth resampling coefficients is to solve for matrix $[B]$ from the following equation.

$$\begin{bmatrix} 1 & DC1_1 & DC1_1^2 \\ 1 & 0 & 0 \\ 1 & DC1_3 & DC1_3^2 \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} = \begin{bmatrix} DF_{11} & DF_{12} & DF_{13} \\ DF_{21} & DF_{22} & DF_{23} \\ DF_{31} & DF_{32} & DF_{33} \end{bmatrix}$$

where

$$DC1_k = C1_g(k,1) - C1_g(2,1)$$

and

$$DF_{ij} = f_{d-g}(i,j) - f_{d-g}(2,2)$$

The azimuth resampling coefficients are given by the solution to the following matrix equation. The solution to the matrix equation is given by Appendix FO.

$$\begin{bmatrix} 1 & DC2_1 & DC2_1^2 \\ 1 & 0 & 0 \\ 1 & DC2_3 & DC2_3^2 \end{bmatrix} \begin{bmatrix} \mu_{a-11} & \mu_{a-12} & \mu_{a-13} \\ \mu_{a-21} & \mu_{a-22} & \mu_{a-23} \\ \mu_{a-31} & \mu_{a-32} & \mu_{a-33} \end{bmatrix} = \begin{bmatrix} b_{11} & b_{21} & b_{31} \\ b_{12} & b_{22} & b_{32} \\ b_{13} & b_{23} & b_{33} \end{bmatrix}$$

where

$$DC2_k = C2_g(1,k) - C2_g(1,2)$$

APPENDIX FO. SOLUTION TO MATRIX EQUATIONS OF SPECIAL FORMS

The matrix equations to solve for the polynomial coefficients for the range interpolator, the azimuth interpolator, and the radiometric compensation processes are associated with special matrix forms. Methods given in this Appendix are derived to solve these matrix equations. These methods shall be implemented in the processing parameter generation software.

The first type of the matrix is given in the following form:

$$\begin{bmatrix} 1 & a12 & a13 \\ 1 & a22 & a23 \\ 1 & a32 & a33 \end{bmatrix}$$

Let the matrix equation given by

$$\begin{bmatrix} 1 & a12 & a13 \\ 1 & a22 & a23 \\ 1 & a32 & a33 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} = \begin{bmatrix} a14 \\ a24 \\ a34 \end{bmatrix}$$

By subtracting the third row from the second row and subtracting the third row from the second row, we have the following result

$$\begin{bmatrix} 0 & a12 - a22 & a13 - a32 \\ 0 & a22 - a32 & a23 - a33 \\ 1 & a32 & a33 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} = \begin{bmatrix} a14 - a24 \\ a24 - a34 \\ a34 \end{bmatrix}$$

Furthermore, by eliminating the second element in the first row, the following result can be obtained

$$\begin{bmatrix} 0 & 0 & a \\ 0 & b & c \\ 1 & d & e \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} = \begin{bmatrix} f \\ g \\ h \end{bmatrix}$$

where

$$a = (a13 - a23)(a22 - a32) - (a23 - a33)(a12 - a22)$$

$$b = a22 - a32$$

$c = a23 - a33$

$d = a32$

$e = a33$

$f = (a14 - a24)(a22 - a32) - (a24 - a34)(a12 - a22)$

$g = a24 - a34$

$h = a34$

Therefore, we have

$x3 = f/a$

$x2 = (g - c \cdot x3)/b$

$x1 = h - (d \cdot x2 + e \cdot x3).$

The second type of the matrix is given in the following form:

$$\begin{bmatrix} 1 & a12 & a13 \\ 1 & 0 & 0 \\ 1 & a32 & a33 \end{bmatrix}$$

Let the matrix equation given by

$$\begin{bmatrix} 1 & a12 & a13 \\ 1 & 0 & 0 \\ 1 & a32 & a33 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} = \begin{bmatrix} a14 \\ a24 \\ a34 \end{bmatrix}$$

Since $x1$ is equal to $a24$, this equation can be reduced to a 2 X 2 matrix equation given by

$$\begin{bmatrix} a12 & a13 \\ a32 & a33 \end{bmatrix} \begin{bmatrix} x2 \\ x3 \end{bmatrix} = \begin{bmatrix} a14 - a24 \\ a34 - a24 \end{bmatrix}$$

Therefore, we have the folowing result.

$x1 = a24$

$x2 = ((a14 - a24) \cdot a33 - (a34 - a24) \cdot a13)/(a12 \cdot a33 - a32 \cdot a13)$

$x3 = ((a34 - a24) - a32 \cdot x2)/a33$

APPENDIX FP. Cross-track Weight Function Generation, Selection, and Offset

There are a total of 88 sets of cross-track weight functions. Each weight function has 256 weight coefficients for compensating 512 image samples in cross-track. The weight function $W_{cw}(i,j)$ is given by

$$W_{cw}(i,j) = G_A^2(\theta_e(i,j), 0.)$$

where i = 41, 42, ..., 128, j = 1,2,...,256, and $\theta_e(i,j)$ is illustrated in Figure FP.1. The altitude and look angle of the spacecraft is determined based on the constraint of 25 degree incidence angle and a specified arc angle $\psi(i)$. This arc angle spans in the cross-track direction with one line being the boresight and one line with a length greater than the first one by two times the slant range sample spacings.

$$\psi(i) = \theta_{sr0} + (i-1) \cdot d\theta_{sr}$$

where

$$\theta_{sr0} = .005$$

and

$$d\theta_{sr} = \frac{.055 - \theta_{sr0}}{127.}$$

The set index of the cross-track weights I_{cw} is given by

$$I_{cw} = 1 + Nint((\theta_{sr} - \theta_{sr0})/d\theta_{sr})$$

where

$$\theta_{sr} = \frac{180}{\pi} \cdot \frac{2D_r}{tan(I_m) \cdot R_m}$$

The offset of the cross-track weights R_{offset} is given by

$$R_{offset} = Nint(128 - (C2_{rg}(2,2) - C2start)/(2\delta g)$$

where

$$C2start = (C2min + C2max)/2 - 256 \cdot \delta g$$

$$C2min = Min(C2_{FC}(i,j), i = 1,2,3, \;\; j =, 1,2,3$$

$$C2max = Max(C2_{FC}(i,j), i = 1,2,3, \;\; j =, 1,2,3$$

APPENDIX FQ. RANGE CODE AND RANGE WEIGHT TABLES

(1) Range Code (from Hughes Document SE011 [7]):

1	1.	31	-1.
2	-1.	32	-1.
3	-1.	33	1.
4	-1.	34	-1.
5	1.	35	-1.
6	-1.	36	1.
7	-1.	37	-1.
8	-1.	38	-1.
9	1.	39	1.
10	-1.	40	1.
11	1.	41	1.
12	1.	42	1.
13	1.	43	-1.
14	1.	44	-1.
15	1.	45	-1.
16	1.	46	-1.
17	1.	47	1.
18	1.	48	1.
19	1.	49	1.
20	1.	50	1.
21	-1.	51	-1.
22	-1.	52	-1.
23	1.	53	-1.
24	1.	54	1.
25	-1.	55	-1.
26	-1.	56	1.
27	1.	57	1.
28	1.	58	-1.
29	1.	59	1.
30	1.	60	-1.

APPENDIX FQ. RANGE CODE AND RANGE WEIGHT TABLES (continued)

(1) Range Weight (from Hughes Document SE011[7]):

1	-0.4384491E-02	34	-0.5296899E-01
2	-0.2225779E-01	35	0.5540462E-01
3	0.5354758E-01	36	-0.9464215E-02
4	-0.4104397E-01	37	-0.4048682E-01
5	-0.8401699E-02	38	0.4896035E-01
6	-0.3442371E-01	39	-0.3601827E-01
7	0.3892643E-01	40	-0.3078206E-01
8	-0.5255547E-01	41	0.4744129E-01
9	-0.1331334E-01	42	0.4151193E-01
10	-0.2317263E-01	43	0.3138351E-01
11	0.5334887E-01	44	0.4837552E-02
12	-0.6228379E-01	45	-0.3887837E-01
13	0.3312364E-01	46	-0.8359325E-02
14	0.3321978E-01	47	-0.1655219E-01
15	0.4609214E-01	48	-0.3654476E-01
16	0.4403492E-01	49	0.2430890E-01
17	0.3693976E-01	50	-0.8585490E-02
18	0.3715146E-01	51	0.6790558E-01
19	0.5361022E-01	52	0.3357632E-01
20	0.2060528E-01	53	-0.4247935E-01
21	0.4733653E-01	54	-0.1039911E-02
22	0.4798826E-01	55	-0.5146898E-01
23	-0.7138307E-01	56	0.5031022E-01
24	-0.3505699E-01	57	-0.4078527E-01
25	0.5670669E-01	58	0.3123699E-01
26	0.4886354E-01	59	0.3005443E-01
27	-0.1803486E-01	60	-0.5422885E-01
28	-0.5528961E-01	61	0.4596115E-01
29	0.2640690E-01	62	-0.4502328E-01
30	0.6102030E-01	63	0.2866051E-01
31	0.4383456E-01	64	0.2738833E-02
32	0.3326226E-01		
33	-0.2981596E-01		

APPENDIX FR. ACRONYM DEFINITIONS

ADSP	Advance Digital SAR Processor
ADSP-EM	The engineering model of ADSP
AT/CT	Along-track and Cross-track
BAQ	The block adaptive quantizer
BIP	Boresight Intercept Point
CPS	Control Processor Subsystem
DCS	Digital Correlator Subsystem
EDR	Experiment Data Record
F-BIDR	Full-resolution Basic Image Data Record
FFT	Fast Fourier Transform
FM	Frequency Modulation
IDPS	Image Data Processing Subsystem
MGN	Magellan
MRP	Mid-Range Point
MSPL	Multi-mission SAR Processing Laboratory
PBW	Processing bandwidth
PRF	Pulse repetition frequency
RET	Radar Engineering Team
SAR	Synthetic Aperture Radar
SDPS	SAR Data Processing Subsystem
VBF85	JPL/IAU Venus Body Fixed
VME85	JPL/IAU Venus Centered Inertial

GLOSSARY OF KEY SYMBOLS

In the following list, the section number in parentheses points to definition in text.

$\alpha_g(i,j)$ Angle between the Spacecraft, Planet Center, and the Geometric Reference Point (i,j) (5.3.5)

α_b Angle between the Sensor, Center of Venus, and the BIP (5.1.5)

α_0 Angle between the Sensor, Center of Venus, and the BIP at the Top of the Atmosphere (5.1.5)

α_1 Angle between the BIP, Center of Venus, and the BIP at the Top of the Atmosphere (5.1.5)

α_w Kaiser weight coefficient (Appendix FK)

$\vec{A}_s(t_b)$ Spacecraft Acceleration (5.1.2)

c Speed of Light (5.1.5)

$C1_g(i,j)$ Coordinate-1 Value of Geometric Reference Point (i,j) (5.3.2)

$C2_g(i,j)$ Coordinate-2 Value of Geometric Reference Point (i,j) (5.3.2)

$C1_m$ Coordinate-1 Value of the Mid-Range Point (5.3.2)

$C2_m$ Coordinate-2 Value of the Mid-Range Point (5.3.2)

$C1_{FC}(i,j)$ Coordinate-1 Value of Framelet Corner Point (i,j) (5.3.7)

$C2_{FC}(i,j)$ Coordinate-2 Value of Framelet Corner Point (i,j) (5.3.7)

C_d Conversion Factor from Doppler to Along-track Distance (5.4.5)

C_o Absolute Radiometric Compensation Factor (5.5.6)

C_r Conversion Factor from Time to Ground Range (5.4.5)

$C(r,f)$ Radiometric Compensation Factor (5.5.6)

$C_{rg}(i,j)$ Radiometric Compensation Factor of the Radiometric Reference Point (i,j) (5.4.5)

$\bar{C}_{rg}(i,j)$ **Relative Radiometric Compensation Factor of the Radiometric Reference Point** (i,j) **(5.4.6)**

$C1_{rg}$ **Projection Coordinate of the Radiometric Reference Points (5.4.2)**

$C2_{rg}$ **Projection Coordinate of the Radiometric Reference Points (5.4.2)**

$d0_{rw}$ **0-th Order Range Walk Polynomial Coefficients (5.5.2)**

$d1_{rw}$ **1st Order Range Walk Polynomial Coefficients (5.5.2)**

$d1_{rmp}$ **1st Order Deramp Reference Coefficients (5.5.4)**

$d2_{rmp}$ **2nd Order Deramp Reference Coefficients (5.5.4)**

D_r **Slant Range Sample Spacing (One Way) (5.3.2)**

$\hat{e}$ **The Elevation Direction Unit Vector for Defining the Antenna Pattern (5.4.4)**

$E_g(i,j)$ **Elevation of Geometric Reference Point** (i,j) **(5.3.2)**

f **Frequency of a Pixel (5.4.5)**

$f_{d-b}(t_b)$ **Doppler Frequency of the Boresight Intercept Point (5.1.7)**

$f_{d-b2}(t_b)$ **Doppler Frequency of a point in the Doppler Centroid Line (5.1.8)**

f_{d-m} **Doppler Frequency of the Mid-Range Point (5.2.2)**

$f_{d-g}(i,j)$ **Doppler of Geometric Reference Point** (i,j) **(5.3.5)**

$f_{d-rg}(i,j)$ **Doppler of the Radiometric Reference Point** (i,j) **(5.4.1)**

f_l **The predicted backscattering coefficient functions (5.4.5)**

f_{low} **Lower Frequency Bound of the Framelet (5.3.6)**

f_{high} **Higher Frequency Bound of the Framelet (5.3.6)**

f_{r-m} **Doppler frequency Rate of the Mid-Range Point (5.2.4)**

$f_{dr}(t_b)$ **Doppler Drift Rate of the Boresight Intercept Point (5.1.8)**

Δf_d **The quantization step of the Doppler frequency to be compensated (5.5.1)**

Δf **Doppler relative to the center radiometric grid reference point (5.5.5)**

ΔFa **Framelet Size in the Along-Track Dimension. (5.3.2)**

ΔFc **Framelet Size in the Cross-Track Dimension. (5.3.2)**

δg **Spacing between Adjacent Grid Points. (5.3.2)**

G **is the gravitational constant (5.2.4)**

$G_A^2(\theta_e, \theta_h)$ **Antenna gain (5.4.5)**

G_{BAQ} **Gain Factor from BAQ Data Reconstruction (5.4.5)**

$G_r(t)$ **Receiver Gain (5.4.5)**

$\hat{h}$ **The Horizontal Direction Unit Vector for Defining the Antenna Pattern (5.4.4)**

$I_b(t_b)$ **Incidence Angle of the Boresight Intercept Point (5.1.5)**

I_R **Range Reference Index (5.5.3)**

I_{RG} **Range Reference Group Index (5.5.1)**

K **is the product of the transmitted power during calibration, the sensor gain, and the gain of part of the processor including range and azimuth compressions. (5.4.5)**

λ **Wavelength**

$\theta_L(t_b)$ **Radar Look Angle (5.4.5)**

M_v **is the mass of Venus (5.2.4)**

N_p **Number of echo pulses in a burst (5.3.2)**

N_r **The range FFT length (5.4.5)**

N_{rc} **The Number of Samples in the Range Pulse Function Used for mapping**

N_{rs} **The Number of Samples in the Range Reference Function Used for Range Compression (3.3.2)**

N_a **Azimuth FFT length (5.4.5)**

N_s **Number of Range Samples in Each Echo Pulse of the EDR (5.3.2)**

N_w **Number of Range Walk Samples (5.3.2)**

N_{intp} **Number of Pixels to be Truncated due to Degradation from Interpolation (5.3.2)**

$\hat{P}(t_b)$ **Boresight Pointing Vector (5.1.3)**

$P_T(t)$ **The Transmitted Power (5.4.5)**

PRF Pulse Repetition Frequency (3.3.3)

PBW Processing Bandwidth (5.3.2)

r **Range of a Pixel (5.4.5)**

R_a **One-Way Apparent Range from the Spacecraft to the BIP (5.1.5)**

R_{a0} **Apparent Range between the BIP and the BIP at the Top of the Atmosphere (5.1.5)**

$R_b(t_b)$ **Apparent Range of the Boresight Intercept Point (5.1.5)**

$R_{b2}(t_b)$ **The Apparent Range of a Second Point in the Doppler Centroid Line (5.1.8)**

R_m **Apparent Range of the Mid-Range Point (5.2.2)**

$R_g(i,j)$ **Apparent Range of Geometric Reference Point** (i,j) **(5.3.5)**

R_{low} **Lower Range Bound of the Framelet (5.3.6)**

R_{high} **Higher Range Bound of the Framelet (5.3.6)**

$R(r,f)$ **The Straight-Line Distance between the Spacecraft and the Location of the Pixel (5.4.5)**

$R_{rg}(i,j)$ **Range of the Radiometric Reference Point** (i,j) **(5.4.1)**

ΔR **Apparent Range relative to the Central Radiometric Grid Point (5.5.6)**

S_{AD} **The Scale Factor in the A/D Conversion (5.4.5)**

$S(j,i)$ **The j-th Sample in the i-th Pulse of the Radar Echo Burst (3.3.2)**

$S_1(j,i)$ **The j-th Sample in the i-th Pulse of the Range Compressed Burst (3.3.2)**

$S_2(j,i)$ **The j-th Sample in the i-th Pulse of the Range Compressed and Deramped Burst (3.3.3)**

S_e **Polarity Sign of the Antenna Pattern Coordinate (5.4.4)**

S_h **Polarity Sign of the Antenna Pattern Coordinate (5.4.4)**

$\sigma_n(r, f)$ **The normalized Backscattering Coefficient (5.4.5)**

t_0 **The time at which the nadir point (5.3.1)**

t_b **Burst reference time (5.1.1)**

Thm **The maximum of all the threshold values in one burst (3.3.1)**

t_m **Burst Center Time (5.2.1)**

dT **radar echo sampling interval (3.3.2)**

$\mu_{r-ij}, (i, j = 1, 2, 3)$ **Radiometric Compensation Coefficients (5.5.6)**

$\mu_{g-ij}, (i, j = 1, 2, 3)$ **Range Resampling Coefficients (5.5.7)**

$\mu_{a-ij}, (i, j = 1, 2, 3)$ **Azimuth Resampling Coefficients (5.5.8)**

$\vec{V}_s(t_b)$ **Spacecraft Velocity (5.1.2)**

$\vec{V}_b(t_b)$ **Velocity of the Boresight Intercept Point (5.1.6)**

$\vec{V}_g(i, j)$ **Velocity of the Geometric Reference Point (5.3.5)**

ω **The angular velocity of Venus (5.1.6)**

W'_{ksr} **Kaiser weight value (Appendix Fk)**

$\vec{X}_s(t_b)$ **Spacecraft Position (5.1.2)**

$\vec{X}_b(t_b)$ **Position of the Boresight Intercept Point (5.1.5)**

$\vec{X}_{b2}$ **Position of the Second Point in the Doppler Centroid Line (5.1.8)**

$\vec{X}_{s-m}$ **relative position from sensor to mid-range point (5.2.4)**

$\vec{X}_m$ **Position of the Mid-Range Point (5.2.3)**

$\vec{X}_g(i, j)$ **Position of Geometric Reference Point** (i, j) **(5.3.4)**

$\vec{X}_{rg}(i, j)$ **Position of the Radiometric Reference Point** (i, j) **(5.4.3)**

θ_0 **Reference Meridian (5.3.1)**

$\theta_e(i, j)$ **Elevation Angle of the Radiometric Reference Point** (i, j) **(5.4.4)**

$\theta_h(i, j)$ **Horizontal Angle of the Radiometric Reference Point** (i, j) **(5.4.4)**

MGN SDPS SAR DATA PROCESSING ALGORITHM DESCRIPTION

K. Leung

TABLE OF CONTENTS

I. INTRODUCTION

The Magellan SAR Data Processing Sub-system (MGN-SDPS) is the segment of the Magellan Ground Data System that is responsible for processing the raw SAR data and radiometer data into SAR image data and surface brightness temperature data respectively. The SDPS consists of two data processors. The Primary SAR Processor (PSP) is based on a high speed custom hardware SAR correlator and is responsible for supporting routine data processing operations. The back-up processor is developed as part of the Engineering SAR Processor (ESP) which uses commercial hardware such as array processors to provide limited back-up processing capability in the event of PSP failure.

1 Objective

The objective of this document is to provide a brief description of the SAR data processing algorithms used in the Magellan SAR Data Processing Sub-system (MGN-SDPS). The algorithms used on the Primary SAR Processor (PSP) and on the back-up processor implemented on the Engineering SAR Processor (ESP) are essentially the same except for precision and other minor differences which are pointed out in the appropriate sections.

2 Scope

The scope of this document is confined to describing the SDPS SAR data processing algorithm only. The processing algorithm for the radiometer data is not included here but can be found in Appendix B of the 'MOS Requirements - SAR Data Processing Sub-system', document number PD 630-300, VRM-MOS-4-271. Detail of the processing parameter definition and generation as well as a functional level description of the processing algorithm can be found in the 'Definition and Generation of SDPS Processing Parameters', document number TBD (see reference (1)).

3 References

(1) M. Jin, 'Definition And Generation Of SDPS Processing Parameters', Appendix 'F' to F-BIDR SIS (SDPS-101), August 15, 1989.

(2) M. Jin, 'Magellan Mission Operations System Requirements - SAR Data Processing Subsystem', VRM-MOS-004-271, August 8, 1989.

(3) J. Gilbert, 'SAR Data Format on the SAR-EDR', JPL IOM#3344-88-097, October 12, 1988.

(4) M. Jin, 'Azimuth FFT Length For Magellan DCS Correlator', JPL IOM#3344-87-176, November 5, 1987.

II. OVERVIEW

The Magellan SAR operates in a burst mode. Each data burst consists of hundreds of pulses that are separated by 1/PRF seconds apart. Successive bursts are designed to cover overlapping areas on the planet surface. Each orbit consists of roughly 6000 bursts covering a track on the planet surface spanning from the north pole to approximately 67^{o} south latitude. Each burst is to be processed into a single-look image framelet covering approximately the area of the radar footprint on Venus. Framelets from successive bursts are then superimposed to form multi-look images. The data is recorded as range lines that are sampled and (block adaptive) quantized into a 2I/2Q per sample format together with a set of threshold indices. The SAR data, together with radiometer data and engineering data are packed into engineering data records (EDR's) recorded on computer compatible tapes (CCT's).

III. INPUT DATA CONDITIONING

Input data conditioning consists of header data extraction, SAR data sample decoding and data I/O buffering. Each input tape is referred to as an engineering data record (EDR) and is in form of a 3600' 6250bpi computer compatible tape (CCT). Recorded on the EDR are four types of data: engineering, SAR/altimeter burst (SAB) headers, SAR data, and radiometer data. The SAR data on the EDR CCT is in form of a collection of echoes from (~6000) successive SAR bursts. Each burst consists of the return echoes from hundreds of pulses within the burst. Each return echo in turn consists of digitized and coded data samples. These samples are block adaptive quantized (BAQ) into a 2I/2Q per sample coded format. The associated sets of threshold indices are stored in the SAB headers; each threshold index governs a subset of the SAR data samples spanning 16 samples in the range dimension and the entire burst length in the along track dimension. Each BAQ coded sample is to be decoded into an 8I/8Q format with decimal values ranging between -128 and 127. The decoding of each BAQ coded sample is accomplished by a look-up table as follows:

sample	decoded decimal value (I)	decoded decimal value (Q)
00	+Nint(38.1734 * S1)	-Nint(38.1734 * S1)
10	-Nint(38.1734 * S1)	+Nint(38.1734 * S1)
01	+Nint(127.0 * S1)	-Nint(127.0 * S1)
11	-Nint(127.0 * S1)	+Nint(127.0 * S1)

where:

$$
\begin{aligned}
S1 &= S2 * (Th + 1); \\
S2 &= \exp\{-S3 * \ln(127) / 31\}; \\
S3 &= \text{integer part of } (31 * \ln(Thm + 1) / \ln(127); \\
\mathrm{Nint}(\cdot) &= \text{nearest integer to } (\cdot); \\
\ln(\cdot) &= \text{natural log of } (\cdot) \\
Th &= \text{threshold index for the sample;} \\
(Thm + 1) &= \text{maximum threshold value in the burst.}
\end{aligned}
$$

Note that while this BAQ decoding scheme achieves maximum dynamic range utilization for each individual burst, relative burst-to-burst gain factors (Thm's) have to be accounted for during radiometric compensation processing.

Once the data is properly decoded, it is buffered into the digital correlator subsystem (DCS) for SAR correlation processing. The custom hardware residing in the DCS is capable of performing range compression, data corner-turning, azimuth processing, radiometric and geometric processing, and multi-look formation. In the ESP, these same processing functions are duplicated in software utilizing the VAX and APTEC as well as array processors. The algorithm used in each of these processing step is further described below.

IV. DATA FORMAT AND PRECISION

The input data is in the form of range lines with lengths varying from 168 to 332 samples in increments of 4. The DCS accepts inputs in 8I/8Q sample format. Most arithmetic in the DCS is performed at 44 bits (16 bits magnitude and 6 bit exponent for each of the I and Q component), and internal storage memories are 24 bits (6 bits common exponent, 9 bits magnitude for each of the I and Q component).

In the ESP, arithmetic is performed at the VAX or NUMERIX precision; data storage follows the VAX's 32 bits, APTEC's 32 bits, or NUMERIX's 32 bits format.

Both the PSP and ESP produce output in 8 bits per pixel format.

V. RANGE PROCESSING

Range processing is performed to achieve high pixel resolution in the range dimension. This process is performed in the range compression module in the DCS. Range processing is accomplished by means of an FFT fast convolution algorithm. The input data range line (with samples taken in the time-domain) is converted to the frequency domain via a forward FFT. The resulting frequency spectrum is multiplied with a selected range reference function (each range reference is presented as a frequency spectrum of a composite function to be described in a later section). The result is then converted back into time-domain samples via an inverse FFT. Although the typical range line length can vary from 168 to 332 samples, each range line is padded with 'zero' samples to form a length 512 vector before a 512 point forward FFT is taken. The range reference is in the form of a 512 point frequency spectrum (associated with a 64 point range code). The inverse FFT taken on the resulting product (of the data spectrum and the reference) is also 512 points in length.

In additional to the pulse compression and side-lobe control functions, compensations for range walk and linear phase shift (due primarily to the spacecraft radial velocity component and to much lesser extent planet rotation) are also performed during range processing. Range walk in fractional number of range bins as well as linear phase shift components are compensated by manipulating the range reference function. Appropriate range weights are applied to the range code to control the range side-lobe performance. Range walk in whole number of range bins is compensated through a circular shift of the range processed (compressed, weighted and fractionally walk compensated) line by the integer number of range processed samples.

1 Range Reference Function Generation

As mentioned earlier, the range reference function is designed to perform range walk compensation (fractional bin), side-lobe control weighting, as well as phase shift compensation in addition to performing range compression. The range reference function is therefore defined as the frequency spectrum of a composite of three functions as follows:

$$FFT\{R_{rg}(j,I_{RG},I_R)\} = FFT\{\Sigma_n F1(n,I_R) * F2(j+n) * F3(j+n,I_{RG})\};$$

$$\begin{aligned} j &= 1,2,\ldots,64 \\ I_{RG} &= 1,2,\ldots,32 \\ I_R &= 1,2,\ldots,8 \\ n &= -31,-30,\ldots,32 \end{aligned}$$

where j is the reference length index, I_{RG} is the phase shift index, and I_R is the range walk index. F1 denotes the fractional range bin compensation function. To allow range walk compensation down to 1/8th range bin resolution, F1 takes the form of a set of 8 functions as follows:

$$\begin{aligned} F1(n,I_R) &= \mathrm{sinc}(n+(I_R-1)/8)) \\ &= \sin(\pi(n+(I_R-1)/8)) \,/\, (\pi(n+(I_R-1)/8)); \\ I_R &= 1,2,\ldots,8 \end{aligned}$$

Depending on the residual fractional bin value (i.e. -3/8, -2/8,-1/8,0,1/8,2/8,3/8, or 4/8) of the computed range walk, the appropriate one of the 8 functions is selected. F2 denotes the sign of the range code multiplied by the weighting function to be applied to the composite reference to control side-lobe performance. The range code and range weights are given below in a later section but can also be found in reference (1), appendix 'FO'. F3 denotes the phase shift compensation term. Phase shift due to the significant spacecraft radial velocity component is estimated to cause a Doppler frequency error up to +/-40KHz. A set of 32 functions are utilized to limit the Doppler frequency error to be +/-1275Hz. F3 takes on the form of:

$$\begin{aligned} F3 &= \exp(-j2\pi\Delta f(I_{RG}-16)n\Delta t); \\ I_{RG} &= 1,2,\ldots,32 \\ \Delta f &= 2550\text{Hz} \\ \Delta t &= 1/2.26\text{MHz} \end{aligned}$$

where 2.26MHz is the range code sampling frequency.

With 8 range walk and 32 phase shift compensation functions, there are a total of 256 different range references. In the PSP, these 256 reference function are pre-computed (generated and converted into frequency spectra) and stored in the DCS. However, in the ESP case, limitation in storage memory dictates that F1, F2 and F3 be stored independently (i.e. 8+1+32 functions) and the composite reference is computed as needed.

2 Range Weights

The range weight component in the range reference serves to compress the range pulse and to enhance the side-lobe performance of the range target response. To avoid erroneous scaling effects, the range weights are normalized (i.e. the sum of the squares of all 64 weights equals unity). The range code and the range weights are given in reference (1), appendix 'FO' and are also reproduced below for easy reference.

#	Code	Weights	#	Code	Weights	#	Code	Weights
1	0	-0.4384491E-02	23	-1	-0.7138307E-01	45	-1	-0.3887837E-01
2	0	-0.2225779E-01	24	-1	-0.3505699E-01	46	-1	-0.8359325E-02
3	1	+0.5354758E-01	25	1	+0.5670669E-01	47	-1	-0.1655219E-01
4	-1	-0.4104397E-01	26	1	+0.4886354E-01	48	-1	-0.3654476E-01
5	-1	-0.8401699E-02	27	-1	-0.1803486E-01	49	1	+0.2430890E-01
6	-1	-0.3442371E-01	28	-1	-0.5528961E-01	50	1	-0.8585490E-02
7	1	+0.3892643E-01	29	1	+0.2640690E-01	51	1	+0.6790558E-01
8	-1	-0.5255547E-01	30	1	+0.6102030E-01	52	1	+0.3357632E-01
9	-1	-0.1331334E-01	31	1	+0.4383456E-01	53	-1	-0.4247935E-01
10	-1	-0.2317263E-01	32	1	+0.3326226E-01	54	-1	-0.1039911E-02
11	1	+0.5334887E-01	33	-1	-0.2981596E-01	55	-1	-0.5146898E-01
12	-1	-0.6228379E-01	34	-1	-0.5296899E-01	56	1	+0.5031022E-01
13	1	+0.3312364E-01	35	1	+0.5540462E-01	57	-1	-0.4078527E-01
14	1	+0.3321978E-01	36	-1	-0.9464215E-02	58	1	+0.3123699E-01
15	1	+0.4609214E-01	37	-1	-0.4048682E-01	59	1	+0.3005443E-01
16	1	+0.4403492E-01	38	1	+0.4896035E-01	60	-1	-0.5422885E-01
17	1	+0.3693976E-01	39	-1	-0.3601827E-01	61	1	+0.4596115E-01
18	1	+0.3715146E-01	40	-1	-0.3078206E-01	62	-1	-0.4502328E-01
19	1	+0.5361022E-01	41	1	+0.4744129E-01	63	0	+0.2866051E-01
20	1	+0.2060528E-01	42	1	+0.4151193E-01	64	0	+0.2738833E-02
21	1	+0.4733653E-01	43	1	+0.3138351E-01			
22	1	+0.4798826E-01	44	1	+0.4837552E-02			

3 Range Walk Correction

The range walk effect is caused primarily by the large space-craft radial velocity component and needs to be compensated to achieve specified image resolution. The range walk can be broken down into two components: an integer part of the range walk in whole number of range bins and the residual part in fractional range bins. The former component can be easily taken care of by shifting the range samples in each range line in the appropriate direction by the proper number of bins. However, the latter fractional component can only be compensated through interpolation. This is achieved in both the PSP and ESP by utilizing a set of 8 range reference functions that are each offset by 1/8th of a range bin.

4 Doppler Compensation

Large Doppler shift is induced by the large radial component of the spacecraft velocity. This Doppler shift will lead to range focusing problems if uncorrected for. A set of 32 phase shift compensating functions spanning a Doppler shift ranging from -38250Hz to 40800Hz with a frequency resolution (bandwidth) of 2550Hz each are used.

VI. CORNER-TURNING

Data corner-turning is necessary when the processing is decomposed into basically two one-dimensional processing operations, i.e. range and azimuth. After range processing as discussed in the earlier section(s) where the data is accessed in the range dimension (i.e. range line by range line) and range compressed, the data needs to go through a corner-turning process so that it can be accessed in the azimuth dimension to facilitate azimuth processing.

For the PSP, corner-turning in the DCS is accomplished via a corner-turn memory where output data to be shipped to the azimuth module can be accessed in the azimuth dimension while the input data coming from the range compression module is written into the memory in the range dimension.

For the ESP, corner-turning is performed in the NUMERIX memory.

VII. AZIMUTH PROCESSING

Azimuth processing consists of an azimuth compression process to obtain the necessary pixel resolution in the azimuth dimension, a weighting process to control the sidelobe performance, and an interpolation process to yield pixels at finer azimuth spacing (to facilitate the later geometric rectification process).

The azimuth compression process is effected via a 'deramp-FFT' algorithm. The azimuth data is first multiplied with a deramp reference function to remove effectively the linear FM component in the data. The resulting data is then converted into a frequency spectrum via a forward FFT to produce image pixels that lie on a range-Doppler frequency grid.

In the DCS, the data is accessed from the corner-turn memory in the azimuth dimension. The azimuth line length varies (between 120 and 850) from burst to burst but is fixed for each burst. Each sample in the azimuth line is a complex 24-bit number in a 6-9-9 format (6-bit common exponent, 9-bit real and 9-bit imaginary).

1 Azimuth Reference Function Generation

The azimuth processing utilizes a deramp-FFT algorithm. The corner-turned data is accessed by azimuth line. The line length can range from a low of 120 to a high of 850. The azimuth reference function R_{az} is a composite of a deramp reference and a Kaiser weighting function, i.e.:

$$R_{az}(i) = F4(i,Np,a) * F5(PRF,Np,fd,fr);$$
$$i = 1,2,..,Np$$
$$a = 0.8$$

where Np is the burst length (ranges from 120 to 850) in number of pulses, PRF is the pulse repetition frequency, fd and fr are respectively the Doppler frequency and Doppler frequency rate at the mid-range point. F4 denotes the Kaiser weighting function with coefficient a set at 0.8. F5 denotes a modified deramp reference function and is given by:

$$F5(PRF,Np,fd,fr) = \exp(-j2\pi[(PRF/2-fd)(i-Np/2)\Delta t]) * \exp(-j2\pi[-fr/2((i-Np/2)\Delta t)^2]);$$

where Δt is the inter-pulse period given by 1/PRF second. The second exponent represents the deramp function carrying a linear FM term that matches (but opposite in sign) with the data. The first exponent effects a circular shift in the frequency spectrum (after the forward FFT is taken) by (PRF/2-fd) Hz so that the output pixels will center around the boresight (note: boresight is at 0 Hz after deramp multiply). In the DCS implementation, this first exponent term is actually omitted from the deramp reference; and the FFT'ed result (range-Doppler image) is circularly shifted by half the vector length instead.

2 Azimuth Weighting

Kaiser weighting with a coefficient of 0.8 is chosen to enhance the side-lobe performance of the azimuth processing. Since the burst length ranges from 120 to 850, potentially 731 sets of Kaiser weights will have to be generated and stored, one for each burst length. In the PSP, memory constraint dictates that only 40 sets of Kaiser weights be stored and utilized. The length of each set is chosen to be:

$$N(k) = \text{Integer}(128 * (1.05)^{k-1}); \; k = 1,2,...,40$$

Formula to generate the Kaiser weights can be found in reference (1), appendix 'FK'. The k^{th} weight set is applied when $N(k) \geq$ *burst length* $> N(k-1)$. Also, for cases with $N(k) >$ *burst length*, weights shall be truncated from the set equally at both ends. In the ESP implementation, an appropriate Kaiser weight set for each burst is created by subsampling an 8K-point long Kaiser weight sequence. This 8K-point long Kaiser weight sequence is pre-generated and stored as a 4K-point vector (representing the first 4K-point of the 8K-point Kaiser weight sequence and taking advantage of the sequence symmetry).

3 Forward FFT

After the azimuth data line is multiplied with the composite azimuth reference function, the resulting vector (which is still the length of the burst long) is padded with "zero" samples. In the PSP implementation, enough "zero's" are added to form a vector with length defined as follows:

Burst Length	"Zero"-filled Vector Length
90 - 174	1024
175 - 349	2048
350 - 698	4096
699 - 1396	8192

This resulting power of two length vector is forward FFT'ed to yield an azimuth line of the complex range-Doppler image. This "zero" padding scheme is designed (reference (4)) to interpolate effectively the output complex image sufficiently to simplify the geometric rectification process performed later in the DCS hardware. However, in the ESP's software implementation, the deramped vector is padded with "zero" samples so that its length comes to the next power of 2 only. This allows for a shorter, more efficient FFT; and any further interpolation required for geometric rectification is implemented in the geometric rectification software.

VIII. RADIOMETRIC COMPENSATION AND FRAMING

Radiometric compensation consists of determining and compensating the data for radiometric effects such as transmitter power level changes, antenna pattern effects, slant range variation, atmospheric loss, sensor and processor losses, time-space conversion factors, burst-to-burst gain factors and receiver gain changes. Framing has to do with determining and keeping the portion of the processed burst that meets the radiometric accuracy standard as determined by the processing bandwidth, range reference length and range line length.

1 Framing

After the deramp-FFT processing, the resulting complex image is truncated (framed) by discarding the unnecessary pixels. The image is circularly shifted in the frequency dimension and then again in the range dimension so that the boresight pixel is centered in the image. Then based on the azimuth processing bandwidth specified, all pixels lying outside of the bandwidth that is centered around the boresight point are discarded. In the range dimension, the number of pixels kept is equal to the original range line length less the range reference length and the maximum range walk extent for the burst.

2 COMPENSATION PROFILE

As a result of the deramp-FFT azimuth processing algorithm, the resulting complex image pixels fall on a uniform range-frequency grid (i.e. with slant range units in the cross-track dimension and frequency units in the along-track dimension). The radiometric compensation algorithm assumes a compensation profile C(r,f) that is quadratic as a function of frequency in the along-track direction and quadratic as a function of range in the cross-track dimension, i.e.:

$$C(r,f) = C_0 * (e_0 + e_1(\Delta f) + e_2(\Delta f)^2)^2,$$

$$\begin{vmatrix} e_0 \\ e_1 \\ e_2 \end{vmatrix} = \begin{vmatrix} u_{r11} & u_{r21} & u_{r31} \\ u_{r12} & u_{r22} & u_{r32} \\ u_{r13} & u_{r23} & u_{r33} \end{vmatrix} \begin{vmatrix} 1 \\ \Delta r \\ (\Delta r)^2 \end{vmatrix}$$

where:
$C_0 = C(r(2,2),f(2,2))$,
$\Delta r = r - r(2,2)$,
$\Delta f = f - f(2,2)$,

and r(2,2) and f(2,2) are the range and frequency values of the estimated boresight point in the processed burst. 'u_{rij}' represents the nine coefficients that characterize the two-dimensional quadratic compensation profile. Each pixel in the output imagery is to be radiometrically compensated by multiplying its complex pixel values with the corresponding compensating factor computed at its location.

3 Compensation Coefficients Determination

The algorithm used to determine the nine compensation coefficients 'u_{rij}' is detailed in reference (1), appendix 'FL'. These coefficients are selected such that the two-dimensional quadratic function C(r,f) fits the compensation factors C(i,j)'s of the nine selected radiometric reference points where C(2,2) (equivalent to C(r(2,2),f(2,2))) is the absolute radiometric compensation factor associated with the boresight point. The other eight reference points are selected to be situated equal distance in the range-Doppler co-ordinates amongst each other, i.e.

$$|f(i,1) - f(i,2)| = |f(i,2) - f(i,3)| = PBW/3,$$
$$|r(1,j) - r(2,j)| = |r(2,j) - r(3,j)| = R/3,$$

where
PBW = azimuth processing bandwidth,
R = total range extent of data after framing.

The nine radiometric references C(i,j)'s are determined (using equation [28] on page 30 of reference (1)) based on engineering data pertaining to spacecraft/sensor attitude and position, surface locations, sensor look angles, transmitter and receiver gain values, etc. These nine references points (with their corresponding compensation factors (C(i,j)'s), range values (r(i,j)'s), and frequency values (f(i,j)'s)) will also be used for deriving the range and azimuth resampling coefficients in the geometric rectification process.

IX. GEOMETRIC RECTIFICATION

Geometric rectification is the process by which the complex imagery is converted from the range-Doppler domain into one of two specified projection grid systems (the sinusoidal projection or the oblique sinusoidal projection as denoted by a c1-c2 grid) having a constant pixel spacing of 75 meters in each dimension. This rectification process consists of two cascaded one-dimensional resampling processes i.e., the range interpolation and the azimuth interpolation.

1 Range Interpolation

In the first resampling process, pixel values corresponding to points intersected by iso-c2 lines (spaced 75 meters apart) and the iso-Doppler lines are computed through range interpolation; thereby creating a new uniform c2-Doppler grid. This is referred to as range interpolation and is implemented in the form of a 4-point interpolator that utilizes four neighboring range samples. The four interpolation weights are normalized 'sinc' values. The range value of each interpolated point (along the c2-axis) is determined by a quadratic function in the form of:

$$r(f,c2) = r(2,2) + e_0 + e_1(\Delta f) + e_2(\Delta f)^2,$$

$$\begin{vmatrix} e0 \\ e1 \\ e2 \end{vmatrix} = \begin{vmatrix} u_{g11} & u_{g21} & u_{g31} \\ u_{g12} & u_{g22} & u_{g32} \\ u_{g13} & u_{g23} & u_{g33} \end{vmatrix} \begin{vmatrix} 1 \\ \Delta c2 \\ (\Delta c2)^2 \end{vmatrix}$$

where $\Delta f = f - f(2,2)$,
$\Delta c2 = c2 - c2(2,2)$.

The algorithm used to determine the nine coefficients u_{gij}'s is detailed in reference (1), appendix 'FM'.

2 Azimuth Interpolation

In the second resampling process, pixel values corresponding to points intersected by iso-c1 lines (spaced 75 meters apart) and the iso-c2 lines are computed; thereby creating a uniformly spaced (75 meters) c1-c2 grid. This is referred to as azimuth interpolation. In the PSP implementation, the data is already oversampled properly in the Doppler dimension (through zero-padded FFT's) so that a nearest neighbor value can be selected as the corresponding pixel value. However, in the ESP implementation, a four-point interpolator similar to the one used for range interpolation is used. The frequency value of each point on the c1-axis is determined by the following quadratic function:

$$f(c1,c2) = f(2,2) + e_0 + e_1(\Delta c1) + e_2(\Delta c1)^2,$$

$$\begin{vmatrix} e_0 \\ e_1 \\ e_2 \end{vmatrix} = \begin{vmatrix} u_{a11} & u_{a21} & u_{a31} \\ u_{a12} & u_{a22} & u_{a32} \\ u_{a13} & u_{a23} & u_{a33} \end{vmatrix} \begin{vmatrix} 1 \\ \Delta c2 \\ (\Delta c2)^2 \end{vmatrix}$$

where $\Delta c1 = c1 - c1(2,2),$
$\Delta c2 = c2 - c2(2,2).$

The algorithm used to determine the nine coefficients u_{aij}'s is detailed in reference (1), appendix 'FN'.

X. MULTI-LOOK OVERLAY

The multi-look overlay process consists of converting each complex pixel into a squared magnitude (intensity) number and then overlaying corresponding pixels from successive bursts that pertain to the same location on the projection grid. Overlaying is referred to the averaging of the intensity values.

Complex pixels from each burst (framelet) are first converted into their squared magnitude values. Then pixels from successive bursts (framelets) that correspond to the same location are added in the overlay buffer memory with the number of add operations each pixel has accumulated kept in a separate buffer. Pixels from each line (iso-c1) that is ready for output are first divided by the number of looks (number of add operations plus one) and then converted to decibel values (RVs). These decibel values are then scaled to 8-bit integer data numbers (DNs, with each number representing one of 251 levels, 1 to 251, covering a range of -20 dB to 30 dB at 0.2 dB per level) using the following conversion:

$$DN = 1 + \mathrm{Int}[\ [\min(\max\{RV, -20.0\}, 30.0) + 20.0 + (0.2/2)]\ /\ 0.2\ ]$$

Pixels that do not contain the specified minimum number of looks are then replaced by 'zero' values. The starting and ending locations of the non-zero portion within the line is then inserted at the beginning of the multi-look image line. This composite output image line is finally output and recorded as a line in the F-BIDR.

JET PROPULSION LAB

INTEROFFICE MEMO
IOM# 3344-88-085 (reissue)

February 1, 1990
Revised August 15, 1990 (*)

TO: M. Jin

FROM: J. Gilbert

SUBJECT: Description of Parameters Appearing in the F-BIDR SIS (v. 3)

REFERENCES:

1) SDPS-101, F-BIDR & F-TBIDR & F-SBIDR SIS
2) M. Jin, Definition and Generation of MSPL-MGN SAR Processing Parameters
3) PD 630-79, Magellan Planetary Constants and Models
4) TPS-101, Magellan Science EDR SIS
5) SFOC-1-CDB-Mgn-SCLKvSCET, MGN SCLK/SCET Coefficients SIS
6) The Astonomical Almanac for the Year 1989, National Almanac Office, U.S. Naval Observatory

This memo outlines the derivation of several of the parameters in the Processing Parameters and Per-Orbit files (appendicies C & D of ref. [1]). Those parameters not discussed here are described in ref. [2].

Appendix C:

1)	Parameter 2 (bytes 4-11): Burst start time in seconds since epoch J2000, double-precision VAX floating point.

The burst start time (BS_{TDB}) is defined to be the moment when the leading edge of the first radar pulse in a burst leaves the surface of the antenna. It is computed as follows:

a) The 52-bit time tag in the SAR Status Field of the SAB Header gives the time of Cycle Reset. Convert the time tag to RIM counts according to the following method (see § 8.3.2 of ref. [3]):

```
CRRIM      = RIM_count
           + Mod91_count / 91.0
           + (RTI_count + 1) / 910.0
           + Mod210_count / 191100.0
```

b) Convert the four character strings representing the time conversion coefficients from the SCLK/SCET Coefficient file (ref. [5]) into the following double-precision variables:

```
SCLK0:     s_rim_cnt, s_mod91_cnt, s_mod10_cnt
A0:        year, doy, hour, min, sec
A1:        A1_sec
DUT:       DUT_sec
```

c) Compute SCLK0 in RIM counts:

```
sclk0_rim  = s_rim_cnt
           + s_mod91_cnt / 91.0
           + s_mod10_cnt / 910.0
```

d) Convert A0 "year" and "doy" to number of days since noon, Jan. 1, 4713 BC (which is defined to be Julian Date (JD) 0.0):

```
if ( year > 87 ) then
        year = year + 1900
else
        year = year + 2000
end if
days = int(( year + 4712) * 365.25 + 0.75) — 13 + doy — 1
```

e) Convert A0 "hour", "min", and "sec" to fraction of days:

```
if ( hour ≥ 12 ) then
        hour = hour - 12
else
        hour = hour + 12
        days = days — 1
end if
A0_fracday = hour / 24.0 + min / 1440.0 + sec / 86400.0
```

f) Compute A0 in TDB seconds since J2000. Note that DUT is identical to ΔET given in ref. 6, that is, DUT = ET - UTC = TDB - UTC:

```
A0_days = (days — 2451545.0) + A0_fracday
A0_seconds = A0_days * 86400.0 + DUT_sec
```

g) Compute Cycle Reset in TDB seconds since J2000:

$$CR_{TDB} = (CR_{RIM} - \text{sclk0\_rim}) * \text{A1\_sec} + \text{A0\_seconds}"$$

h) Compute t_0, the time in "spacecraft seconds" (the local epoch) from Cycle Reset to the time of "Actual RF Pulse Out" (ARPO).

ARPO occurs 10 clock cycles after the rising edge of the PRF pulse, and is the time at which the Range Dispersion Unit begins to generate the transmitted waveform. (The actual transimission occurs at a later time than ARPO due to delays within the radar, and the delay caused by the cables connecting the radar and the antenna. Radar delays are measured by Hughes and JPL, while cable delays will be measured by Martin. The delays are added to produce a constant zero-range correction factor, which appears in step (3-b) below):

$$t_0 = [-\text{cr\_cs\_offset} + \text{cs\_dur} + ((512 - PC) - 1) + \text{prf\_arpo\_offset}] * (32 / f_{STALO}),$$

where

cr_cs_offset = offset between Cycle Reset and Cycle Start = 7
cs_dur = Cycle Start duration = 453
prf_arpo_offset = offset between PRF rising edge and "Actual RF pulse out" = 10
PC = bits 10-16 of the SAR Status Field of the SAB Header
$32 / f_{STALO} = 32 / 72.272727\ \text{MHz} \approx 0.4428 \mu\text{sec}.$

i) Use ZRCF, the zero-range correction factor developed by Hughes, Martin and JPL, and t_0 to compute the burst start time in TDB seconds. Note that it's not necessary to convert delta times measured in "spacecraft seconds" to TDB seconds, since the two are nearly identical over short intervals:

$$BS_{TDB} = CR_{TDB} + t_0 + (ZRCF / 2)$$

2)	Parameter 3 (bytes 12-19): Burst reference time in seconds since epoch J2000, double-precision VAX floating point.

The burst reference time (BRT_{TDB}) is a measure of the center time of the SAR transmission period of each burst. It is computed as follows:

a) Compute transmission duration in spacecraft seconds:

|(*) $$TD_{SCLK} = [(2048 - NP - 1) * (512 - PC)] * (32 / f_{STALO})$$

where

NP = bits 33-43 of the SAR Status Field of the SAB Header
PC = bits 10-16 of the SAR Status Field of the SAB Header
$32 / f_{STALO} = 32 / 72.272727 \text{ MHz} \approx 0.4428\mu\text{sec}.$

b) Add half of this to the burst start time in TDB, epoch J2000 (don't bother to convert TD_{SCLK} to TDB seconds, since spacecraft seconds should be equal to TDB seconds over a short interval):

$$BRT_{TDB} = BS_{TDB} + (TD_{SCLK} / 2)$$

3)	Parameter 4 (bytes 20-27): Burst center time in seconds since epoch J2000, double-precision VAX floating point.

The burst center time (BCT_{TDB}) is a measure of the center time of the SAR echo reception period of each burst. It computed as follows:

a) Compute receive duration represented by a post-range compressed line in spacecraft seconds:

(*)

$$RD_{SCLK} = [(2048 - NP - 1) * (512 - PC) + 2 * (256 - RGL) - pw] * (32 / f_{STALO})$$

where

NP = bits 33-43 of the SAR Status Field of the SAB Header
PC = bits 10-16 of the SAR Status Field of the SAB Header
RGL = bits 25-32 of the SAR Status Field of the SAB Header
pw = pulse width = 60
$32 / f_{STALO} = 32 / 72.272727$ MHz $\approx 0.4428\mu$sec.

b) Determine the echo delay time (ED_{TDB}), which is the offset from Burst Start to the leading edge of the first sample envelope in spacecraft seconds (don't bother to convert ED_{TDB} to TDB seconds, since spacecraft seconds should be equal to TDB seconds over a short interval):

$$ED_{TDB} = [(256 - SCR) * (512 - PC) + 2 * (256 - FR) - 9] * (32 / f_{STALO}) - ZRCF$$

where

SCR = bits 17-24 of the SAR Status Field of the SAB Header
PC = bits 10-16 of the SAR Status Field of the SAB Header
FR = bits 2-9 of the SAR Status Field of the SAB Header
$32 / f_{STALO} = 32 / 72.272727$ MHz $\approx 0.4428\mu$sec.

c) Add this to the burst start time in TDB, epoch J2000, and add half the receive duration:

$$BCT_{TDB} = BS_{TDB} + ED_{TDB} + (RD_{SCLK} / 2)$$

4)	Parameter 5 (bytes 28-31): Echo delay time in seconds.

The echo delay time (ED_{TDB}) is the difference between Burst Start time and the time at which the first echo sample is received at the antenna. It is computed directly from values appearing in the SAR Status Field and the zero-range calibration factor. No correction is made to take spacecraft seconds into TBD seconds, since they should be approximately the same over small intervals.

The echo delay time is computed in step (3-b) above.

5)	Parameter 268 (bytes 1080-1083): Minimum number of looks to flag in output, unsigned VAX integer.

The Advanced Digital SAR Processor (ADSP) appends two tags to each line of multilook image data. The first gives the offset in pixels to the first pixel having a certain number of looks; the second gives the offset in pixels to the last pixel having a certain number of looks.

This parameter gives the number of looks used in creating these two tags. It is set by the processing engineer at run time, and its default value is 4.

Appendix D:

6)	Parameter 5 (bytes 24-32): Product ID (same as the value of the MINOR_DATA_CODE keyword in the BIDR Header Record), 9-character ASCII string.

This is identical to the MINOR_DATA_CODE keyword in the BIDR Header Record, described in §3.2.1 of ref. [1].

7)	Parameter 6 (bytes 33-38): Volume ID (same as ANSI Volume Label "volume ID"), six-character ASCII string.

This is identical to the ANSI Volume Label "volume ID" field, described in §2.3.3.1 of ref. [1], and will appear in the Per-Orbit file of both tape and disk BIDRs.

8)	Parameter 7 (bytes 39-57): Wall-clock time of start of processing (same as the value of the TAPE_WRITE_DOY keyword in the BIDR Header Record), 19-character ASCII string.

This is identical to the TAPE_WRITE_DOY keyword in the BIDR Header Record, described in §3.2.1 of ref. [1].

9) Parameter 11 (bytes 98-112): Predicted time of periapsis in SCLK, 15-character ASCII string (see Appendix A of ref. [1]).

This is copied from the Orbit Header Record of the SAR-EDR (ref. [4]), and is identical in format.

10) Parameter 12 (bytes 113-120): Predicted time of periapsis in seconds from epoch J2000, double-precision VAX floating point.

This is derived from the predicted time of periapsis in SCLK format, using the SCLK/SCET Coefficient file (ref. [5]). The procedure used is described in section 1 above.

11) Parameter 13 (bytes 121-128): Orbit semi-major axis in meters from the Orbit Header file on the EDR, double-precision VAX floating point.

This is derived from the "AOE — Semi-major Axis" in the SAR-EDR Orbit Header Record (ref. [4]), by converting from ASCII characters to double-precision VAX floating point format.

12) Parameter 14 (bytes 129-136): Orbit eccentricity from the Orbit Header file on the EDR, double precision VAX floating point.

This is derived from the "AOE — Eccentricity" in the SAR-EDR Orbit Header Record (ref. [4]), by converting from ASCII characters to double-precision VAX floating point format.

13) Parameter 15 (bytes 137-144): Orbit inclination angle in degrees from the Orbit Header file on the EDR, J-2000 coordinates, double precision VAX floating point.

This is derived from the "AOE — Inclination" in the SAR-EDR Orbit Header Record (ref. [4]), by converting from ASCII characters to double-precision VAX floating point format.

14) Parameter 16 (bytes 145-152): Longitude of the ascending node in degrees from the Orbit Header file on the EDR, J-2000 coordinates, double precision VAX floating point.

This is derived from the "AOE — Longitude of Ascending Node" in the SAR-EDR Orbit Header Record (ref. [4]), by converting from ASCII characters to double-precision VAX floating point format.

15) Parameter 17 (bytes 153-160): Argument of periapsis in degrees from the Orbit Header file on the EDR, J-2000 coordinates, double precision VAX floating point.

This is derived from the "AOE — Argument of Periapsis" in the SAR-EDR Orbit Header Record (ref. [4]), by converting from ASCII characters to double-precision VAX floating point format.

16) Parameter 20 (bytes 178-189): Slope coefficient of the SCLK/SCET conversion.

This is the coefficient "A1" from the SCLK/SCET Coefficient file (ref. [5]).

17) Parameter 21 (bytes 190-208): Intercept coefficient of the SCLK/SCET conversion.

This is the coefficient "A0" from the SCLK/SCET Coefficient file (ref. [5]).

18) Parameter 22 (bytes 209-214): UTC-to-epoch J2000 correction factor.

This is the coefficient "DUT" from the SCLK/SCET Coefficient file (ref. [5]). (It is used in step (1-f) above.)

JET PROPULSION LABORATORY

INTEROFFICE MEMO
IOM# 334-91-027
July 25, 1991

To: M. Jin
From: D. Swantek
Subject: Magellan Telemetry Data conditioning, Revised

INTRODUCTION

Magellan telemetry data is extracted from the EDR file ENG_DAT using software provided by Peter Ford at MIT and the decom and decal files in EDR file ENG_DECOM_DECAL. The data to be extracted are chosen by their associated channel values. These data include the delta quaternions, cable temperatures, SAR temperatures, and SAR states.

DATA CONDITIONING FOR DELTA QUATERNIONS

Because the delta quaternions represent small refinements to the quaternions themselves, they should have a small value usually less than 0.001. For this reason the delta quaternions are filtered by simply scanning through the common block that contains them and resetting to zero every set that has a member with a value greater than 0.001.

DATA CONDITIONING FOR SAR AND CABLE TEMPERATURES

The present algorithm for filtering the SAR and cable temperatures proceeds as follows. The first sample is obtained by averaging the first eight samples that differ from the preceding value by less than 10 degrees. For samples 2 to n, if the difference DT = T(n) - T(n - 1) is greater than 5 degrees than T(n) is replaced by the average of the two samples on either side of it, otherwise it is left unchanged. If the difference DT = T(n) - T(n - 1) is still greater than 5 degrees than T(n) is replaced by the previous value T(n - 1), this is to insure that several bad values in a row will not effect the filtered data set.

SAR STATES

The SAR States are used to show which transmitter is active (A or B), and the associated set of SAR temperatures that should be used in preprocessing. When the engineering data file is read several hundred sets of SAR states are collected, and although they should all match in some cases they do not. This is corrected by counting the number of times that each state is high, and then selecting the state with the largest count at the end of the engineering file. This is done because the number of incorrect state values is small compared to the total number of values read.

APPENDIX G
CYCLE II SPECIFIC CHANGES

In cycle II, a right-looking data acquisition orientation is added to complement the left-looking orientation in cycle I. Also, data take for each orbit initiates no higher than 78 degree north latitude and ends further south; with the odd numbered orbits covering the south pole region. A constant 25 degree incidence angle profile is also chosen for the right-looking data takes. And data take is estimated to be as long as 8550 bursts, up from the estimated 6000 bursts or so for cycle I. These new additional operating configurations impact the F-BIDR in the following ways:

1. Right-looking data orientation -
   The data take orientation of the F-BIDR is specified in parameter 9 (bytes 62 - 65) of file 12: 'SDPS Per-Orbit Parameters'. Reference Appendix D for details.

2. South pole oblique sinusoidal data -
   The data taken south of 80 degree south latitude is processed into image data in the oblique sinusoidal projection domain. The corresponding image data records reside in file 13 and the processing parameters reside in file 14. (Note: for cycle I, file 13 and file 14 contain oblique sinusoidal image data and processing parameters respectively for the north pole region north of 80 degree north latitude). Other pertinent information given in Section 3.5.13 and Section 3.5.14 remains in effect.

3. Constant 25 degree incidence angle profile -
   The constant 25 degree incidence angle profile for the cycle II right-looking orbits dictates that a wider range antenna beamwidth be utilized near periapsis to maintain the desirable swath width. This necessitates the implementation of a new weighting function to compensate for the range antenna pattern effect due to the widened antenna beam. This change is described in Section 5.5.6: 'Radiometric Compensation Coefficients, u_{r-ij}' as well as Appendix FP: 'Cross-track Weight Function Generation, Selection, and Offset' under Appendix F.

4. Up to 8550 Bursts per Orbit -
   The processing of up to 8550 bursts per orbit does not impact specifications as given in Section 3.5.15 and 3.5.16 for file 15 and file 16 respectively.