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PIONEER 10/11 PROJECT

S-BAND OCCULTATION EXPERIMENT

REDUCED DATA

Explanatory Document

Submitted to the

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by

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Pioneer 10/11 Radio Occultation Experiment Data

Table of Contents

1. Introduction

The material submitted herewith consists of raw, intermediate, and reduced data from the Pioneer 10/11 S-Band Radio Occultation Experiment, covering data on Jupiter and Io. The following data are provided:

a)	Digital raw data	Digital tapes only
b)	Data Files	
	RPP, DIP1, DIP2, ATMOS (input)	Tapes, listings, and microfilm
	ATMOS(output)	Listings and microfilm only

This material is described in detail in subsequent section.

2. Digital Data Tapes

Digital occultation data tapes are prepared by sampling analog spacecraft signal and time from analog recorded tapes. The sample rates are 80,000 samples/sec for Pioneer 10 and Io and 40,000 samples/sec for Pioneer 11. These tapes contain a digital representation of recorded signals received from the spacecraft, the time of reception (UTC) and header information. They are 9-track, 800 BPI tapes with odd parity.

2.1 Format

Digital data tapes for Pioneer 10 and Pioneer 11 are in BCD mode. (odd-parity). Each record on the magnetic tape contains 4096 six-bit binary data words plus 9 six bit BCD words used to identify the time and one header word. The description of information in each record is shown in Table 1.

2.2 List of Digital Data Tapes

Pioneer 10 and Pioneer 11 digital data tapes are listed in Table 2. All tapes are 9-track 800 BPI tapes. The tape number is in the second column and the start and stop times for the tape is given in the last column. Pioneer 10 and 11 and Io tapes are listed seperately.

LEGEND

CODE	MEANING
ρ'	LONGITUDINAL EVEN PARITY BIT
W	DATA SAMPLE BIT
S	STATION CODE 10 - DSS 14 01 - DSS 4X 11 - DSS 6X
DS	DATA SOURCE 0 - ANALOG 1 - DIGITAL
D_1-D_{10}	BCD DAY BITS
H_1-H_6	BCD HOUR BITS
M_1-M_7	BCD MINUTE BITS
S_1-S_7	BCD SECOND BITS
M_1-M_{12}	BCD MILLISECOND BITS
μ_1-μ_{12}	BCD MICROSECOND BITS
ρ	ODD PARITY BIT

START OF RECORD

ρ	0	0	0	0	S	S	1	DS	HEADER
ρ	0	0	D_1	D_2	D_3	D_4	D_5	D_6	
ρ	0	0	D_7	D_8	D_9	D_{10}	H_1	H_2	
ρ	0	0	H_3	H_4	H_5	H_6	M_1	M_2	
ρ	0	0	M_3	M_4	M_5	M_6	M_7	S_1	
ρ	0	0	S_2	S_3	S_4	S_5	S_6	S_7	TIME OF DAY FOR FIRST DATA WORD IN RECORD
ρ	0	0	M_1	M_2	M_3	M_4	M_5	M_6	
ρ	0	0	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}	
ρ	0	0	μ_1	μ_2	μ_3	μ_4	μ_5	μ_6	
ρ	0	0	μ_7	μ_8	μ_9	μ_{10}	μ_{11}	μ_{12}	
ρ	0	0	W_5	W_4	W_3	W_2	W_1	W_0	1ST DATA WORD
ρ	0	0	W_5	W_4	W_3	W_2	W_1	W_0	2ND DATA WORD
ρ	0	0	W_5	W_4	W_3	W_2	W_1	W_0	⋮
ρ	0	0	W_5	W_4	W_3	W_2	W_1	W_0	4000TH DATA WORD
ρ	0	0	W_5	W_4	W_3	W_2	W_1	W_0	4001TH DATA WORD
ρ'	ρ'	ρ'	ρ'	ρ'	ρ'	ρ'	ρ'	ρ'	
									INTERRECORD GAP

NOTE:
μ_1 - μ_{12} NOT USED IN GTA-2

Table 1: Data Record Format - Pioneer 10/11 Digital Occultation Data

Table: 2 Tapes (DSS 43)

PIONEER 10 EVENT	DIGITAL DATA TAPE NO.	TIME, UTC, Dec. 4, 1973
P10N (Entry)	X755	4:27:30 - 4:31:30 (Entry)
P10X (Exit)	X681	5:28:00 - 5:32:00 (Exit)

PIONEER 11	DIGITAL DATA TAPE NO.	TIME, UTC, Dec. 3, 1974
P11NF (Entry FM)	X793	05:39:00 - 05:43:00 (Entry)
P11XF (Exit FM)	X658	06:22:30 - 06:26:30 (Exit)
P11XD (Exit Direct)	X641	06:22:30 - 06:26:30 (Exit)

PIONER 10 (Io)	DIGITAL DATA TAPE NO.	TIME, UTC, Dec. 4, 1973
I01 (Entry)	X899	03:25:07 - 03:28:28
I02 (Exit)	X944	03:28:30 - 03:31:29

3. Data Files

Pioneer 10 and Pioneer 11 data files are created by Processing Pioneer 10 and Pioneer 11 radio occultation data using the subset of occultation software. A brief description of the software and the files is given below.

Occultation Software: consists of the Computer Programs RPP, DIP1, DIP2 and ATMOS. The functions of these programs are:

- RPP — removes drift and bias from frequency residuals supplied from open loop data
- DIP1 — computes refractive bending angle as a function of ray-asymptote distance
- DIP2 — computes refractivity as a function of radius from center of planet
- ATMOS — computes atmospheric information (temperature, pressure, etc.) as a function of radius to center of planet

The Data Files described in Section 3.1 are Input/Output files obtained by executing the computer programs RPP, DIP1, DIP2, and ATMOS on the UNIVAC 1108.

The files are written using standard formatted FORTRAN I/O on the UNIVAC 1108 Exec-8 system. The format statements used are given in Section 3.3 according to the identifying number which is used as a label for each record in the detailed descriptions below.

Definitions and types of each variable are also given in Section 3.2. The type of a variable is either Integer, Real or Double Precision.

These files are written on tapes N936 and W058 (both 7-track, 800 BPI) using the tape processor of the 391*LIB, sub-routine library at JPL.

3.1 Occultation Data Tapes

Pioneer 10 and Pioneer 11 (Jupiter and Io) data files, obtained by executing the computer programs RPP, DIP1, DIP2, and ATMOS are discussed below.

3.1.1 Pioneer 10 and 11 (Jupiter) Data Files

The following data files are on tape N936 (7-track, 800 BPI) and are written using the TAPE processor. The sequence in which files are written is as follows:

File Sequence on N936	Description
1	P10 Entry OCEP
2	P10 Exit OCEP
3	P10 Exit OCEP
4	P11 Entry OCEP
5	P11 Exit OCEP
6	P10 Entry TRAJ
7	P10 Exit TRAJ
8	P11 Entry TRAJ
9	P11 Exit TRAJ
10	P10 Entry RPP Output File

11	P10 Entry DIP1 Output File
12	P10 Entry DIP2 Output File
13	P10 Exit RPP Output File
14	P10 Exit DIP1 Output File
15	P10 Exit DIP2 Output File
16	P11 Exit RPP Output File -B1-
17	P11 Exit DIP1 Output File -B1-
18	P11 Exit DIP2 Output File -B1-
19	P11 Exit RPP Output File -B2-
20	P11 Exit DIP1 Output File -B2-
21	P11 Exit DIP2 Output File -B2-

3.1.2 Pioneer 10 (Io) Data Files

The following are IO - Entry and Exit data files. These files are on tape W758 (7-trk, 800 BPI) and are written using TAPE processor. The first file on the tape is Trajectory file which is in a Type 66 format. All other files are in formatted FORTRAN I/O. The sequence in which files are written on tape is as follows:

File Sequence on W758	Description
1	TRAJ IO-entry and IO-exit T/66 Format
2	OCEP IO-entry
3	OCEP IO-exit
4	RPP output file IO-exit
5	DIP1 output file IO-exit
6	DIP2 output file IO-exit
7	File-13 RPP IO-entry
8	File-14 DIP1 IO-entry
9	File-15 DIP2 IO entry for ATMOS old F898 TRAJ
10	TRAJ IO-entry and IO-exit (FORTRAN Format)

3.2 Description of Data Files

The occultation software consists of the computer programs RPP, DIP1, DIP2, and ATMOS. These programs and the description of input/output files for them are given in the following sections.

3.2.1 Residual Processing Program (RPP)

The function of the Residual Processing Program (RPP) is to remove drift and bias from frequency residuals. The RPP program reads the RADIO DATA file produced by the OCEP (Occultation Editing Program) program which consists of time points and corresponding frequency residuals. RPP then computes a polynomial drift function for a user-specified time interval and subtracts this function from the data. RPP then computes the phase differences in cycles and write an output file consisting of doppler residuals (from which bias and drift has been removed) and amplitude to be used by the DIP1 program.

3.2.1.1 Input File

The input file to be used by RPP is the Radio Occultation data file produced by the OCEP Program. It consists of frequency residuals and power for each time points. This file is in standard formatted FORTRAN I/O and is described as follows. Each line corresponds to one record and the format statement for that record corresponds to the label (e.g. 5*)in section 3.3,definition and type of each variable in the file is also given.

FLTYPE	SCID	PASS	MODE		(Record 1)	1*
XTR	DSS	IW	FBAND		(Record 2)	1*
F1	F2				(Record 3)	2*
SYNFRQ	SYNLO				(Record 4)	2*
IYR	IDAY	TIME	SFREQ	SRES	(Record 5)	3*
SPWR	XPWR	XFREQ	XRES		(Record 6)	4*
.	.	.	.			
:	:	:	:			
IYR	IDAY	TIME	SFREQ	SRES	(Record n-1)	3*
SPWR	XPWR	XFREQ	XRES		(Record n)	4*

Where,

FLTYPE	type of file. 1 for closed loop, 2 for open loop, and 3 for both	(integer)
SCID	spacecraft identification number	(integer)

PASS	orbit or revolution number	(integer)
MODE	1 for entry, 2 for exit	(integer)
XTR	transmitting station number	(integer)
DSS	receiving station number	(integer)
IW	1-way, 2-way or 3-way data	(integer)
FBAND	always 3	(integer)
F1	uplink frequency in hertz	(d. p.)
F2	downlink frequency in hertz	(d. p.)
SYNFRQ	closed loop synthesizer frequency	(d. p.)
SYNLO	open loop synthesizer frequency	(d. p.)
IYR	year of the sample	(integer)
IDAY	day of the sample	(integer)
TIME	time of sample in seconds past midnight	(real)
SFREQ	S-Band frequency in hertz	(d. p.)
SRES	S-Band frequency residuals in hertz	(d. p.)
SPWR	S-Band power in db.	(real)
XPWR	X-Band power in db.	(real)
XFREQ	X-Band frequency in hertz	(d. p.)
XRES	X-Band frequency residuals in hertz	(d. p.)

3.2.1.2 <u>Output File:</u>

RPP output file consists of doppler residuals (from which bias and drift has been removed) and phase for corresponding time points. The file is written with formatted FORTRAN I/O, and is described as follows:

FLTYPE	SCID	PASS	MODE	(Record 1)	1*
XTR	DSS	IW	FBAND	(Record 2)	1*
F1	F2			(Record 3)	2*
TIME	RESIDUAL	PHASE		(Record 4)	5*
⋮	⋮	⋮		⋮	
TIME	RESIDUAL	PHASE		(Record n)	5*

Where,

FLTYPE	type of file. 1 for closed loop, 2 for open loop, and 3 for both	(integer)

SCID	spacecraft identification number	(integer)
PASS	orbit or revolution number	(integer)
MODE	1 for entry, 2 for exit	(integer)
XTR	transmitting station number	(integer)
DSS	receiving station number	(integer)
IW	1-way, 2-way, or 3-way data	(integer)
FBAND	always 3	(integer)
F1	uplink frequency in hertz	(d. p.)
F2	downlink frequency in hertz	(d. p.)
TIME	time of sample in seconds past midnight	(d. p.)
RESIDUAL	frequency sample in hertz	(d. p.)
PHASE	phase difference in cycles	(d. p.)

3.2.2 Data Inversion Program No. 1 (DIP1)

The function of DIP1 Program is to compute refractive bending angle, ray asymptote distance, and range from S/C to the center of the planet for each time point. Computation of the above variables are based on the assumptions of the oblateness in the Planet Jupiter. The exact shape of the planet Jupiter is computed by making use of a spherical harmonic representation of the gravity field of Jupiter and radius of curvature at point of ray tangency.

The input and output for DIP1 are described as follows:

3.2.2.1 Input files

Input files to DIP1 are the trajectory file and RPP output file. The RPP output file is described in Secting 3.2.1.2 on Page 7. The trajectory file is described as follows:

3.2.2.2 Trajectory file:

This file is a Trajectory file produced by the Trajectory link of the OCEP program and based on the DPTRAJ save and plot tape. The file is dynamically catalogued and assigned to the run. The file is written using formatted FORTRAN I/O, and the format is described as follows:

FLTYPE	SCID	PASS	I			(Record 1)	1*
ETSCA	ETMC	LITTM				(Record 2)	5*
S1	S2	S3				(Record 3)	5*
TIME$_{(1)}$	YR$_{(1)}$	DAY$_{(1)}$	HR$_{(1)}$	MIN$_{(1)}$	SEC$_{(1)}$	(Record 4)	6*
DPREC$_{(1,1)}$	DPREC$_{(1,2)}$	DPREC$_{(1,3)}$				(Record 5)	5*
DPREC$_{(1,4)}$	DPREC$_{(1,5)}$	DPREC$_{(1,6)}$				(Record 6)	5*
DPREC$_{(1,7)}$	DPREC$_{(1,7)}$	DPREC$_{(1,8)}$				(Record 7)	5*
DPREC$_{(1,10)}$	DPREC$_{(1,11)}$	DPREC$_{(1,12)}$				(Record 8)	5*
⋮	⋮	⋮				⋮	
TIME$_{(N)}$	YR$_{(N)}$	DAY$_{(N)}$	HR$_{(N)}$	MIN$_{(N)}$	SEC$_{(N)}$	(Record M-4)	6*
DPREC$_{(N,1)}$	DPREC$_{(N,2)}$	DPREC$_{(N,3)}$				(Record M-3)	5*
DPREC$_{(N,4)}$	DPREC$_{(N,5)}$	DPREC$_{(N,6)}$				(Record M-2)	5*
DPREC$_{(N,7)}$	DPREC$_{(N,8)}$	DPREC$_{(N,9)}$				(Record M-1)	5*
DPREC$_{(N,10)}$	DPREC$_{(N,11)}$	DPREC$_{(N,12)}$				(Record M)	5*

Where,

FLTYPE	Type of file, 1 for closed loop, 2 for open loop and 3 for both (INTEGER)
SCID	Spacecraft Identification Number (INTEGER)
PASS	Orbit or Revolution Number (INTEGER)
I	1 for Entry, 2 for Exit (INTEGER)
ETSCA	Time of closest approach - ET (sec/past Midnite 1950) (D.P.)
ETMC	Difference between Ephemeris time and Universal time/sec. (D.P.)
TIME (N)	Time in Seconds (ET) from Jan. 1, 1950.0 for Nth Point (D.P.)
YR (N)	Year for the Nth Point (Real)
DAY (N)	Day number for Nth Point (Real)
MIN (N)	Time at MIN minutes for Nth Point (Real)
SEC (N)	Time at SEC - Seconds for Nth Point (Real)
LITTM	1-way light time (D.P.)
S1, S2, S3	X, Y, Z Coordinates of Sun Position vector relative to Jupiter (D.P.)

DPREC (N,I)	I = 1, 2, 3 X, Y, Z Coordinates of S/C Position vector relative to Jupiter for N^{th} point (D.P.)
DPREC (N,I)	I = 4, 5, 6 X, Y, Z Components of S/C Velocity vector realtive to Jupiter (D.P.) for N^{th} Point
DPREC (N,I)	I = 7, 8, 9 X, Y, Z Coordinates of Earth Position vector for N^{th} Point (D.P.)
DPREC (N,I)	I = 10, 11, 12 X, Y, Z Coordinates of Earth Velocity vector for N^{th} Point (D.P.) N = 1, 2 - - M Points
NOTE:	All above vectors are body centered and referenced to the Earth Equator of 1950.0 coordinate system

3.2.2.3 Output file:

DIP1 output file consists of ray-asymptote, bending angle, gravity and S/C range corresponding to each time point. The file is written with formatted FORTRAN I/O, and is described below.

FLTYPE	SCID	PASS	MODE	(Record 1)	1*
XTR	DSS	IW	FBAND	(Record 2)	1*
F1	F2			(Record 3)	2*
TIME	RD			(Record 4)	2*
BA	R			(Record 5)	2*
G	LAT			(Record 6)	2*
.	.			.	
.	.			.	
.	.			.	
TIME	RD			(Record(n-2))	2*
BA	R			(Record(n-1))	2*
G	LAT			(Record n)	2*

Where,

FLTYPE	Type of file. 1 for closed loop, 2 for open loop and 3 for both	(integer)
SCID	Spacecraft identification number	(integer)

PASS	Orbit or revolution number	(integer)
MODE	1 for entry, 2 for exit	(integer)
XTR	Transmitting station number	(integer)
DSS	Receiving station number	(integer)
IW	1-way, 2-way or 3-way data	(integer)
FBAND	Always 3	(integer)
F1	Uplink frequency in hertz	(d. p.)
F2	Downlink frequency in hertz	(d. p.)
TIME	Time of sample in seconds past midnight	(d. p.)
G	Gravity Value	(d. p.)
LAT	Latitude of ray tangent in degrees	(d. p.)
RD	Asymptotic ray distance in Km	(d. p.)
BA	Refractive bending angle in radians	(d. p.)
R	Range from spacecraft to the center of the planet	(d. p.)

3.2.3 Data Inversion Program No. 2 (DIP2)

The function of the DIP2 program is to compute refractivity as a function of the radial distance to the center of the planet.

DIP2 reads a file of ray distance and corresponding bending angle (among other parameters) produced by the DIP1 program and inverts this data using the Abel Integral Transform to obtain refractivity versus radius.

3.2.3.1 Input file:

DIP2 input file is same as DIP1 output file. This file is in formatted FORTRAN I/O, and is described on Page 10, Section 3.2.2.3.

3.2.3.2 Output file:

The DIP2 output file is written with formatted FORTRAN I/O. It consists of radius, refractivity, gravity and latitude and is described as follows:

FLTYPE	SCID	PASS	MODE	(Record 1)	1*
XTR	DSS	IW	FBAND	(Record 2)	1*
F1	F2			(Record 3)	2*
RADIUS	REF			(Record 4)	2*

GR	LATT	(Record 5) 2*
.	.	.
.	.	.
.	.	.
RADIUS	REF	(Record (n-1)) 2*
GR	LATT	(Record n) 2*

Where,

FLTYPE	type of file. 1 for closed loop, 2 for open loop and 3 for both	(integer)
SCID	spacecraft identification number	(integer)
PASS	orbit or revolution number	(integer)
MODE	1 for entry, 2 for exit	(integer)
XTR	transmitting station number	(integer)
DSS	receiving station number	(integer)
IW	1-way, 2-way or 3-way data	(integer)
FBAND	always 3	(integer)
F1	uplink frequency in hertz	(d. p.)
F2	donwlink frequency in hertz	(d. p.)
RADIUS	radial distance to the center of the planet in Km	(d. p.)
REF	refractivity in N-units	(d. p.)
GR	gravity value obtained from NALPHA	(d. p.)
LATT	latitude of ray tangent in degrees	(d. p.)

3.2.4 Atmospheric Parameter Program (ATMOS)

The function of the AMTOS program is to compute atmospheric information from the refractivity data produced by the DIP2 Program.

A detailed description of ATMOS can be found in the Mariner Mars 1971 occultation Atmospheric Parameter Program - Program document.

3.2.4.1 Input File

ATMOS input file is the same as DIP2 output file. This file is in formatted FORTRAN I/O and is described on Page 11, Section 3.2.3.2.

3.2.4.2 Output

The output of the ATMOS Program consists of hard-copy computer listings and plots containing the following information:

For all points:

RADIUS (km) REFRACTIVITY (n-units)

with bias removed

For negative refractivity points:

RADIUS (km) REFRACTIVITY (n-units) ELECTRON DENSITY (cm^{-3})

(these data are not reliable below main peak)

For all positive refractivity points:

RADIUS (km) REFRACTIVITY (n-units) TEMPERATURE (^{O}K) PRESSURE (mb) NUMBER DENSITY (cm^{-3}) MASS DENSITY (gcm^{-3})

3.3 Formats

The following formats are referred to in the preceding:

1* FORMAT (4I10)

2* FORMAT (2D26.18)

3* FORMAT (I2,I5,F12.4,2D26.18)

4* FORMAT (F9.4,F10.4,2D26.18)

5* FORMAT (3D26.18)

6* FORMAT (3D26.14,4X,4F7.1,F14.8)

7* FORMAT (4D26.18)

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