820-013
Deep Space Network (DSN)
External Interface Specification

JPL D-16765

TRK-2-18
Tracking System Interfaces
Orbit Data File Interface

Revision E: February 29, 2008

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Change Log

Rev.	Check if Minor Rev.	Issue Date	Affected Sections	Change Summary
--		06/15/1983	All	This is a new document.
1		12/15/1998	All	Reformatted. Contains revisions to match the implementation. Uplink and downlink doppler phase have been added. Provides Y2K clarification for the use of two-digit year.
2		01/15/1999	1.1.1, Appendix A	Adds missing text to clarify the calculation for frequency bias.
3		06/15/2000	1.1.1, Table 3-3b.	Deleted Table 3-3b, Item Number 10 values that are not available and will not be provided. Deleted Tables 3-6a and Table 3-6b. Delete all "PRA" since it no longer exists. Table 3-3b, items 9 and 10, delete DSN or GSTDN.
D		12/29/2006	All	Re-formatted per 820-013, D-16765. Deletion of OPS-6-8 format Updated section 2 and Figure 2-1. Updated section 3 and added Figure 3-1. Updated Doppler observable formula and added definition of VLBI Observables, and sequential ranging in Appendix A.
E	X	02/29/2008	Section 1	Minor changes to update footer tags, change 'DSMS' to 'DSN', edit Section 1 sequence

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Contents

Figures

Tables

Section 1
Introduction

1.1 Purpose and Scope

This module specifies the Orbit Data File (ODF) format of the radio metric data from the Deep Space Network (DSN). The contents and formats of the ODF are herein defined.

1.2 Effectivity

Revision E provides editorial updates only and supersedes Revision D.

The 'Revision D' module update includes: Re-formatted per 820-013, D-16765, deletion of OPS-6-8 format, updated section 2 and Figure 2-1, updated section 3 and added Figure 3-1, updated Doppler observable formula and added definition of VLBI Observables and sequential ranging in Appendix A.

The 'Change 3' update to this module deletes items that are not available and will not be provided. Other updates to clean-up things that do not exist or are no longer applicable.

The 'Change 2' update to this module adds missing text to clarify the calculation for frequency bias in Appendix A.

The 'Change 1' module update corrects the interface specification to be consistent with revisions approved on 15 August 1996 by the Multi-Mission Ground Support Office (MGSO), and implemented in the Radio Metric Data Conditioning (RMDC) software. Uplink and downlink Doppler phase data have been added to the ODF since the original DSN release

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1.3 Revision and Control

Revisions or changes to the information herein presented may be initiated according to the procedure specified in the *Introduction* to Document 820-013.

Documents controlling this version include

DSN 813-109, D-17818	*Preparation Guidelines and Procedures for Deep Space Mission System (DSMS) Interface Specifications* (DSN Internal Use Only*)*

1.4 Relationship to Other Documents

820-013, TRK-2-18 ODF is generated by the RMDC of the TTC (Telemetry, Tracking, and Command) system element. The ODF is converted from 820-013, TRK-2-34 data which is generated by the TDDS (Tracking Data Delivery Subsystem) of the TTC system element.

1.5 Notation and Conventions

1.5.1 Notation

The definitions provided here are intended to clarify the use of certain terms as they apply to this module:

1. The term *byte* is used to refer to an eight-bit quantity.
2. The term *packet* refers to a formatted block of information. A packet consists of two elements: the first element is a header*,* which marks the beginning of the packet; the second element is the data, which contains the information to be carried in the packet.
3. The term *ASCII* refers to the American Standard Code for Information Interchange, a seven-bit code for representing letters, digits, and symbols that has been standardized by the American National Standards Institute. This code has been incorporated into the ISO (International Organization for Standardization) code, which includes other symbols and alphabets. Since the ISO code is an eight-bit code, the ASCII code is embedded in an eight-bit field in which the most significant bit is set to zero. In this module, ASCII always refers to the seven-bit ASCII code embedded, as described, in an eight-bit field.
4. The term restricted ASCII (RA) refers to the subset of ASCII consisting of the codes for the twenty-six upper-case letters (‘A’ ‘Z’) and the ten decimal digits (‘0’ ‘9’). When applied to a multi-byte field, it implies that each byte in the field contains a Restricted ASCII character.
5. The term *Observable* refers to the measurements provided by DSN. Types of *Observables* are VLBI, Doppler, Range, and Angle. A detailed description is in Appendix A.
6. The term *group* is used to distinguish between different types of information in the ODF. There are 7 groups in the ODF. Each group contains a *header* and *data* except End-of-File group (paragraph 3.1.7). A *Header* contains *group* identification, and *data* contains information. Formats of a *header* and *data* are described in tables in paragraph 3.1.
7. The term *block* is used to distinguish between information in the ODF. A *block* is either *group header* or *group data*. Each *block* in the ODF is 36 *bytes* long.
8. The term *data type* is used to distinguish between different types of data in the orbit data group (paragraph 3.1.3). 20 *data types* are currently assigned and available, and *data types* are described in Table 3-3b.
9. The term *EME50* refers to the earth mean equator of epoch Besselian year of January 1, 1950.

1.5.2 Conventions

The following conventions are used in this module.

1. All numbers are expressed in decimal
2. The ODF File Label Data (Table 3-2) specifies a 2-digit year in the File Creation Date (item number 18). This item has no application to processing any data in the file. However, it is constructed with the premise that values from 50 to 99 shall signify dates with respect to 1900, and values between 00 and 49 shall represent dates with respect 2000.

3. Times, except as noted, are given as seconds past zero hours UTC of January 1, 1950.

4. Most data parameters will be provided as binary integers; two's complement will be used for all fields that may have negative values.

5. Single-bit status parameters will be set to one (1) for no, bad, off, out of tolerance, etc.; and will be set to zero (0) for yes, good, on, in tolerance, etc.

6. Data structures are divided into fields, where a field is a sequence of bits. Fields are identified by specifying the starting and ending byte/bits of the field in Byte/Bit (s) column of tables in paragraph 3.2. For fields that cross byte boundaries, bit 8 of byte M is more significant than, and is immediately followed by, bit 1 of byte M+1. A field in the tables is divided into subfields in a similar manner.

7. In the data structure descriptions in this module, many fields are defined to contain a numerical value. *Unsigned integer-m* and *Integer-m* expressing numbers are used, as follows:

   Unsigned integer-m. An integer number is expressed in binary, using all bits of the field as necessary. Negative quantities cannot be expressed. For an *n*-bit field, the range of values that can be represented is from 0 to 2^{n-1}. The number of bits in the *unsigned integer-m* is represented by "*-m*".

   Integer-m. An integer number is expressed in binary, using two's complement notation. For an *n*-bit field, the range of values that can be represented is from -2^{n-1} to $2^{n-1}-1$. The number of bits in the *integer-m* is represented by "*-m*".

1.6 References

Documents

DSN 810-005, Module 107	*DSN Telecommunications Link Design Handbook, Radio Source Catalog*
DSN 810-047	*DSN Antenna and Facility Identifiers, DSN Standard Practice*
	(DSN Internal Use Only)
DSN 820-013, D-16765	*DSN External Interface Specification*
820-013, OPS-6-21	*Standard Code Assignments*
820-013, TRK-2-34	*DSN Tracking System, Data Archival Format*
D-7669, Part 2	*PDS (Planetary Data System) Standards Reference*
D-31224	*PDS archive preparation guide*
ISO/IEC 646-1991	*Information Technology - ISO 7-bit Coded Character Set for Information Interchange*

Web Sites

None.

1.7 Abbreviations

ASCII	American Standard Code for Information Interchange
DCC	Downlink Channel Controller
deg	Degrees
DOM	Distributed Object Manager
DOR	Differential One-way Ranging Subsystem
DSCC	Deep Space Communications Complex
D-DOD	Delta Differential One-way Doppler
D-DOR	Delta Differential One-way Ranging
DSN	Deep Space Network
DSS	Deep Space Station
GCN	Ground Communication Network System
Hz	Hertz
H/P	High Part
ISO	International Organization for Standardization
JPL	Jet propulsion Laboratory
L/P	Low part
MDAS	Mission Control, Data Management, and S/C Analysis System Element
MGSO	Multi-Mission Ground Support Office
mHz	milli-Hertz
MPA	Metric Pointing Assembly
msec	milli-seconds
nsec	nano-seconds
ODF	Orbit Data File
OTS	OVLBI Tracking Subsystem
OVLBI	Orbiting Very Long Baseline Interferometry
PDS	Planetary Data System
PN	Pseudo Noise
RE	Ranging Equipment
RMDC	Radio Metric Data Conditioning Subsystem
RS	Radio Science
RU	Range unit
sec	Seconds
S/C	Spacecraft
TDDS	Tracking Data Delivery Software
TTC	Telemetry, Tracking, and Command System Element
UPL	Uplink Tracking and Command Subsystem
UTC	Universal Time Coordinated
VLBI	Very Long Baseline Interferometry

Section 2
Functional Overview

Figure 2-1 shows the tracking data flow from the Deep Space Communications Complex (DSCC) through the Ground Communication Network (GCN) system and to the Telemetry, Tracking, and Command (TTC) system element to the end users (JPL project, RS, or non JPL navigation).

ODF's are delivered to the end users in a TRK-2-18 data format. Deliveries are made by RMDC according to delivery schedules received from the projects. Daily deliveries are made routinely and special deliveries are also made upon request.

Appendix A defines Observables described in this document.

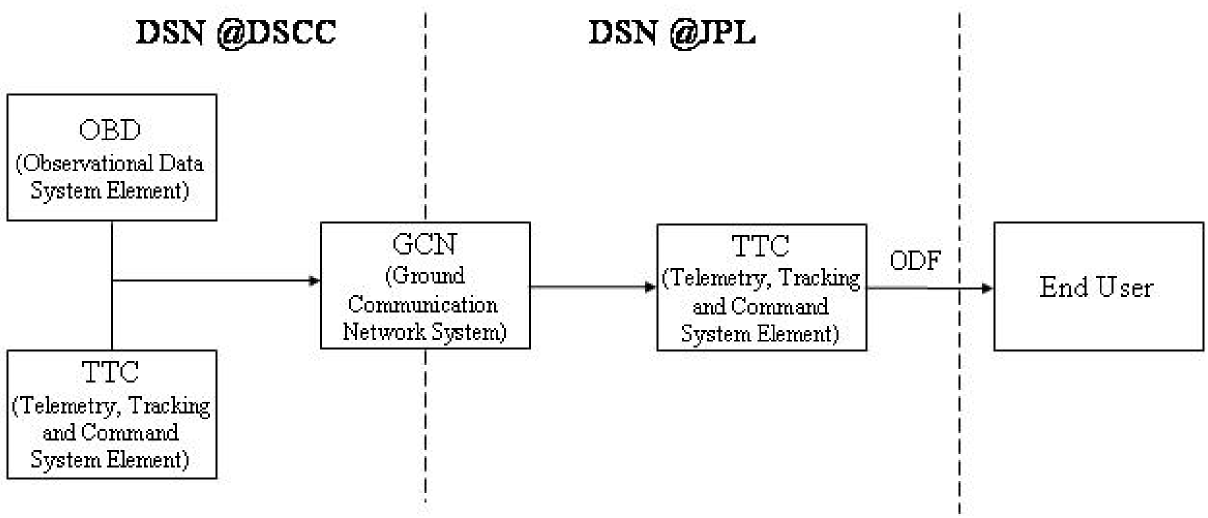

Figure 2-1. Data Flow for Orbit Data File Interface

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Section 3
Detailed Interface Description

3.1 ODF Physical Layout

The physical layout is shown in Figure 3-1. The physical layout is divided into seven groups: the file label, the identifier, the orbit data, ramp, the clock offset, and the end-of-file.

1. Each ODF consists of radio metric data for one spacecraft, zero or more quasars, and one or more stations.

2. A complete ODF will consist of the following data in order listed below:

   a) File Label group – one header and one data block (Tables 3-l and 3-2); required

   b) Identifier group - one header and one data block (Tables 3-1 and 3-3); required

   c) Orbit data group – multiple, time ordered header and data block pairs (Tables 3-1 and 3-4a through 3-4g); required

   d) Ramp group - one group for each DSS, multiple, time ordered header and data block pairs, and (Tables 3-1 and 3-5); optional - VLBI data currently does not utilize this group

   e) Clock Offsets group - time ordered, multiple header and data block pairs (Tables 3-1 and 3-6); optional – this group is currently utilized by VLBI data only.

   f) End-of-File group - one header block (Table 3-1); required

   g) Filler blocks (all bytes are set to zero)

3. The ODF contains an integer multiple of 8064 bytes. When the ODF contains less than an integer multiple of 224 packets, then the remaining will be filled with filler bytes (0).

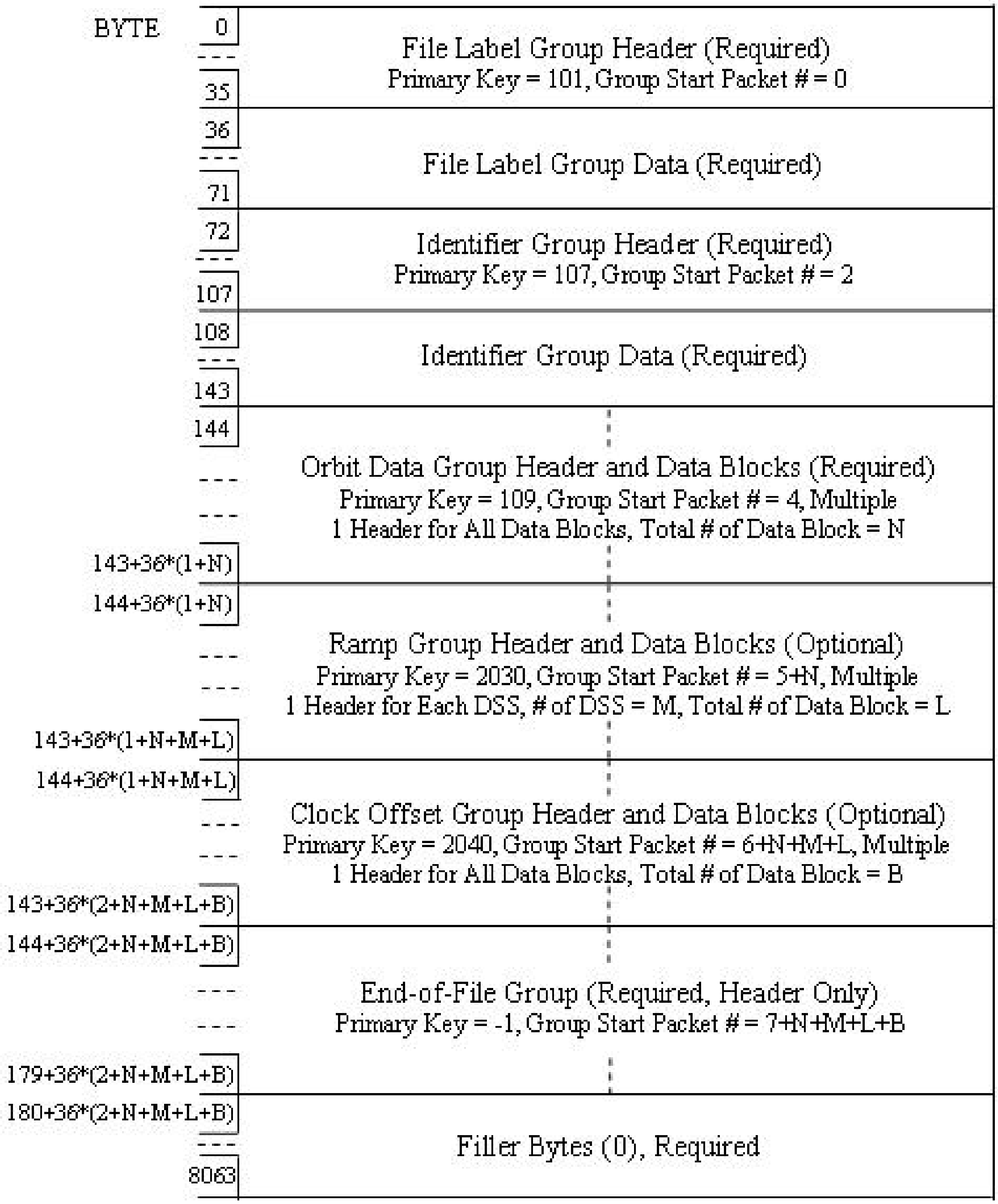

Figure 3-1. ODF Physical Layout

3.2 File Format

Each ODF consists of following groups, and these groups are described in this section.

3.2.1 Header

Each group consists of a header (Table 3-1). Note that if ramps are generated from more than one DSS station, then each station ID will have its own Ramps header followed by one or more Ramp Group Data blocks (i.e., Table 3-5). Item numbers 5 through 9 of all group headers are set to zero (0).

Table 3-1. Header Format

Item #	Byte/ Bit (s)	Item Name and Description	Format	Units	Range
1	0-3	*Primary Key*. -1 => End-of-File header 101 => File Label Header 107 => Identifier Header 109 => Orbit Data Header 2030 => Ramps Header 2040 => Clock Offset Header	Signed Integer-32	N/A	-1, 101, 107, 109, 2030, 2040
2	4-7	*Secondary Key.* For a Ramps Header this number is the station ID per 810-047, it is 0 otherwise.	Unsigned Integer-32	N/A	0 to 99
3	8-11	*Logical Record Length.* 0 for an end-of-file header, 1 otherwise.	Unsigned Integer-32	288-bit packets	0 or 1
4	12-15	*Group Start Packet Number.* The sequential packet number within the ODF for this block. It is always 0 for the File Label Header, 2 for the Identifier Header, and 4 for the Orbit Data Header.	Unsigned Integer-32	288-bit packets	0, 2, 4, 5, 6, 7 thru 222
5	16-19	*Filler 1.*	Unsigned Integer-32	N/A	0
6	20-23	*Filler 2.*	Unsigned Integer-32	N/A	0
7	24-27	*Filler 3.*	Unsigned Integer-32	N/A	0
8	28-31	*Filler 4.*	Unsigned Integer-32	N/A	0
9	32-35	*Filler 5.*	Unsigned Integer-32	N/A	0

3.2.2 File Label Group

The file label group identifies the system that created the file and the time at which the file was created. It also defines the reference time for time values that are expressed as seconds past the reference time. The file label group consists of header (Table 3-1) and data (Table 3-2).

Table 3-2. File Label Group Data Format

Item #	Byte/ Bit (s)	Description	Format	Units	Range

Item #	Byte/ Bit (s)	Description	Format	Units	Range
1	0-7	*System ID.* Left-justified, with blank fill to the right. e.g. 'TDDS'	Restricted ASCII-8	N/A	
2	8-15	*Program ID.* Left-justified, with blank fill to the right. e.g. 'AMMOS'	Restricted ASCII-8	N/A	
3	16-19	*Spacecraft ID Number* per 820-013, OPS-6-21	Unsigned Integer-32	N/A	0 to 255
4	20-23	*File Creation Date.* In the format YYMMDD. It is constructed with the premise that YY values from 50 to 99 shall signify dates with respect to 1900, and values between 00 and 49 shall represent dates with respect 2000.	N/A	year, month, day	0000101 to 9991231
5	24-27	*File Creation Time.* In the format HHMMSS	N/A	hour, minute, second	000000 to 235960
6	28-31	*File Reference Date.* In the format YYYYMMDD. Currently the ODF data time tags are seconds past zero hours UTC 1 January 1950. Hence, this item is set to 19500101. Older ODFs which have file reference date equal to zero will be assumed to refer to 01/01/1950 UTC.	Unsigned Integer-32	year, month, day	0 or 19500101
7	32-35	*File Reference Time.* In the format HHMMSS	Unsigned Integer-32	hour, minute, second	000000 to 235960

3.2.3 Identifier Group

The identifier group consists of a header (Table 3-3) having the primary key set to 107 followed by Table 3-3 below:

Table 3-3. Identifier Group Data Format

Item #	**Byte/ Bit (s)**	**Description**	**Format**	**Units**	**Range**
1	0-7	*Identifier 1*. Left-justified, with blank fill to the right.	Restricted ASCII-8	N/A	TIMETAG
2	8-15	*Identifier 2*. Left-justified, with blank fill to the right.	Restricted ASCII-8	N/A	OBSRVBL
3	16-35	*Identifier 3*. Left-justified, with blank fill to the right.	Restricted ASCII-20	N/A	FREQ, ANCILLARY-DATA

3.2.4 Orbit Data Group

The data portion contains 22 items of information. Items #1 through #14 contain information that is common to all observables, and is defined in Table 3-4a. Items #15 through #22 contain information that is data type dependent. The data type dependent information is defined in Tables 3-4b through 3-4g for the following respective data types:

- Table 3-4b: D-DOD (Delta Differential One-way Doppler, Data Types 1, 2, 3, and 4)
- Table 3-4c: D-DOR (Delta Differential One-way Ranging, Data Types 5 and 6)
- Table 3-4d: Doppler (Data Types 11, 12, and 13)
- Table 3-4e: Sequential Range (Data Type 37)
- Table 3-4f: Tone Range (Data Type 41)
- Table 3-4g: Angle (Data Types 51, 52, 53, 54, 55, 56, 57, and 58)

Note that there is no ODF generation for the pseudo-noise range data.

Table 3-4a. Orbit Data Group Data Format, Common portion

Item #	Byte/ Bit (s)	Item Name and Description	Format	Units	Range
1	0-3	*Record Time Tag, integer part*. In seconds since the reference time specified in the header packet.	Unsigned Integer-32	sec	
2	4/1-5/2	*Record Time Tag, fractional part*.	Unsigned Integer-10	msec	0 to 999
3	5/3-7/8	*Primary Receiving Station Downlink Delay.* This is the downlink delay between the receiving antenna and the receiving electronics. It shall include the array delay for arrayed operations. Note that both this item and item 22 only allow for a maximum delay of about 4 msec.	Unsigned Integer-22	nsec	
4	8-11	*Observable, Integer Part.*	Signed Integer-32	varies; see item 10	
5	12-15	*Observable, Fractional Part.*	Signed Integer-32	10^{-9} of those of item 4	
6	16/1-16/3	*Format ID.*	Unsigned Integer-3	N/A	2
7	16/4-17/2	*Primary Receiving Station ID Number* per 810-47.	Unsigned Integer-7	N/A	1 to 127
8	17/3-18/1	*Transmitting Station ID Number* per 810-47. Zero if the data type does not require a transmitting station.	Unsigned Integer-7	N/A	0 to 127
9	18/2-18/3	*Network ID for the Transmitting Station.* *0 => DSN* *1 => Other* *3 => UPL*	Unsigned Integer-2	N/A	0 to 2

Item #	Byte/ Bit (s)	Item Name and Description	Format	Units	Range
10	18/4- 19/1	*Data Type ID.* 1 => D-DOD, Doppler mode; Hz 2 => D-DOD, phase mode; cycles 3 => D-DOD, Doppler mode; Hz 4 => D-DOD, phase mode; cycles 5 => D-DOR; nsec 6 => D-DOR; nsec 11 => 1-Way Doppler; Hz 12 => 2-Way Doppler; Hz 13 => 3-Way Doppler; Hz 37 => Sequential Range; RU 41 => RE (Tone) Range; nsec 51 => Azimuth Angle; deg 52 => Elevation Angle; deg 53 => Hour Angle; deg 54 => Declination Angle; deg 55 => X Angle (where +X is East); deg 56 => Y Angle (where +X is East); deg 57 => X Angle (where +X is South); deg 58 => Y Angle (where +X is South); deg	Unsigned Integer-6	N/A	1, 2, 3, 4, 5, 6, 11, 12, 13, 36, 37, 41, 51, 52, 53, 54, 55, 56, 57, 58
11	19/2- 19/3	*Downlink Band ID.* 0 => Ku-Band or angle data 1 => S-Band 2 => X-Band 3 => Ka-Band	Unsigned Integer-2	N/A	
12	19/4- 19/5	*Uplink Band ID.* 0 => N/A or Ku-Band 1 => S-Band 2 => X-Band 3 => Ka-Band	Unsigned Integer-2	N/A	
13	19/6- 19/7	*Reference Frequency Band ID.* 0 => Ku-Band or angle data 1 => S-Band 2 => X-Band 3 => Ka-Band	Unsigned Integer-2	N/A	
14	19/8	*Data Validity Indicator.* 0 => valid 1 => invalid	Unsigned Integer-1	N/A	

Table 3-4b. Orbit Data Group Data Format, Data Type Dependent Portion for D-DOD Data (Data Types 1, 2, 3, and 4)

Item #	Byte/ Bit (s)	Item Name and Description	Format	Units	Range
15	20/1-20/7	*Second Receiving Station ID* per 810-047	Unsigned Integer-7	N/A	1 to 127
16	20/8-22/1	*Quasar ID* per 810-005 Module 107 *or Spacecraft ID* per 820-013, OPS-6-21.	Unsigned Integer-10	N/A	
17	22/2	*Phase Point Indicator*	Unsigned Integer-1	N/A	0
18	22/3-24/8	*Reference Frequency, H/P.* Used for charged particle calibrations.	Unsigned Integer-22	2^{24} mHz	
19	25-27	*Reference Frequency L/P.* Used for charged particle calibrations.	Unsigned Integer-24	mHz	
20	28/1-30/4	*Composite 1.* This parameter has the value: (Phase Calibration Flag minus 1) times 100000, plus Channel ID times 10000. Where the phase calibration flag may be one of the following: 1 => no calibration 2 => default calibration 3 => quasar calibration only 4 => S/C calibration only 5 => quasar and S/C calibration	Signed Integer-20	N/A	
21	30/5-33/2	*Compression Time.*	Unsigned Integer-22	0.01 sec	
22	33/3-35/8	*Second Receiving Station Downlink Delay.*	Unsigned Integer-22	nsec	

Note:
1. Item #18 “Reference Frequency, H/P” is trunc(1000*Variable/2^24), where Variable is Reference Frequency in Hz
2. Item #19 “Reference Frequency, L/P” is trunc((1000*Variable)modulo2^24), where Variable is Reference Frequency in Hz

Table 3-4c. Orbit Data Group Data Format, Data Type Dependent Portion for D-DOR Data (Data Types 5 and 6)

Item #	Byte/ Bit (s)	Item Name and Description	Format	Units	Range
15	20/1-20/7	*Second Receiving Station ID* per 810-047	Unsigned Integer-7	N/A	1 to 127
16	20/8-22/1	*Quasar ID number* per 810-005 Module 107 *or Spacecraft ID* per 820-013, OPS-6-21.	Unsigned Integer-10	N/A	
17	22/2	*Modulus Indicator.* 0 => modded, 1 => unmodded	Unsigned Integer-1	N/A	0 or 1
18	22/3-24/8	*Reference Frequency, H/P.* Used for charged particle calibrations.	Unsigned Integer-22	2^{24} mHz	
19	25-27	*Reference Frequency L/P.* Used for charged particle calibrations.	Unsigned Integer-24	mHz	
20	28/1-30/4	*Composite 1.* This parameter has the value: (Channel Sampling Flag minus 1) times 100000, plus Mode ID times 10000, plus Modulus H/P. Channel Sampling Flag: 1 => multiplexed 2 => parallel Mode ID: 0 => 1-way 1 => 2-way	Signed Integer-20	N/A, N/A, 10^{-1} nsec	
21	30/5-33/2	*Modulus L/P.*	Unsigned Integer-22	10^{-7} nsec	
22	33/3-35/8	*Second Receiving Station Downlink Delay.*	Unsigned Integer-22	nsec	

Note:
1. Item #18 “Reference Frequency, H/P” is trunc(1000*Variable/2^24), where Variable is Reference Frequency in Hz
2. Item #19 “Reference Frequency, L/P” is trunc((1000*Variable)modulo2^24), where Variable is Reference Frequency in Hz
3. Item #20 “Modulus H/P” is trunc(Variable*10), where Variable is modulus in nanosecond.
4. Item #21, “Modulus L/P” is trunc((10^7*Variable) modulo 10^6), where Variable is modulus in nanosecond.

Table 3-4d. Orbit Data Group Data Format, Data Type Dependent Portion for Doppler Data (Data Types 11, 12, and 13)

Item #	Byte/ Bit (s)	Item Name and Description	Format	Units	Range
15	20/1-20/7	*Receiver Channel Number*.	Unsigned Integer-7	N/A	0 to 24
16	20/8-22/1	*Spacecraft ID.* Per 820-013, OPS-6-21	Unsigned Integer-10	N/A	0 to 255
17	22/2	*Receiver/Exciter Independent Flag.* This flag indicates whether ramps (if available) should be used to replace the receiver reference frequency. 0 => Both the transmitter and the receiver are ramped. 1=> The transmitter is ramped, but not the receiver.	Unsigned Integer-1	N/A	0 or 1
18	22/3-24/8	*Reference Frequency, H/P.*	Unsigned Integer-22	2^{24} mHz	
19	25-27	*Reference Frequency L/P.*	Unsigned Integer-24	mHz	
20	28/1-30/4	*Reserved*	Signed Integer-20	N/A	0
21	30/5-33/2	*Compression Time.*	Unsigned Integer-22	10^{-2} sec	
22	33/3-35/8	*Transmitting Station Uplink Delay.*	Unsigned Integer-22	nsec	

Note:
1. Item #18 “Reference Frequency, H/P” is trunc(1000*Variable/2^24), where Variable is Reference Frequency in Hz
2. Item #19 “Reference Frequency, L/P” is trunc((1000*Variable)modulo2^24), where Variable is Reference Frequency in Hz

Table 3-4e. Orbit Data Group Data Format, Data Type Dependent Portion for Sequential Range Data (Data Type 37)

Item #	Byte/ Bit (s)	Item Name and Description	Format	Units	Range
15	20/1-20/7	*Lowest Ranging Component.* Component with the lowest frequency	Unsigned Integer-7	N/A	1 to 24
16	20/8-22/1	*Spacecraft ID.* Per 820-013, OPS-6-21	Unsigned Integer-10	N/A	0 to 255
17	22/2	*Reserved*	Unsigned Integer-1	N/A	1
18	22/3-24/8	*Reference Frequency, H/P.*	Unsigned Integer-22	2^{24} mHz	
19	25-27	*Reference Frequency L/P.*	Unsigned Integer-24	mHz	
20	28/1-30/4	*Uplink Ranging Coder In-Phase Time Offset from Sample Time Tag.*	Signed Integer-20	sec	
21	30/5-33/2	*Composite 2.* Highest ranging component times 100000, plus downlink ranging coder in-phase time offset from sample time tag.	Unsigned Integer-22	sec	
22	33/3-35/8	*Transmitting Station Uplink Delay.* For 1-way this is always zero.	Unsigned Integer-22	nsec	

Note:
1. Item #18 “Reference Frequency, H/P” is trunc(1000*Variable/2^24), where Variable is Reference Frequency in Hz
2. Item #19 “Reference Frequency, L/P” is trunc((1000*Variable)modulo2^24), where Variable is Reference Frequency in Hz

Table 3-4f. Orbit Data Group Data Format, Data Type Dependent Portion for RE (Tone) Range Data (Data Type 41)

Item #	Byte/ Bit (s)	Item Name and Description	Format	Units	Range
15	20/1-20/7	Integer Seconds of Observable	Unsigned Integer-7	sec	
16	20/8-22/1	*Spacecraft ID.* Per 820-013, OPS-6-21	Unsigned Integer-10	N/A	0 to 255
17	22/2	*Reserved*	Unsigned Integer-1	N/A	0
18	22/3-24/8	*Reference Frequency, H/P.*	Unsigned Integer-22	2^{24} mHz	
19	25-27	*Reference Frequency L/P.*	Unsigned Integer-24	mHz	
20	28/1-30/4	*Reserved*	Unsigned Integer-1	N/A	0
21	30/5-33/2	*Reserved*	Unsigned Integer-1	N/A	0
22	33/3-35/8	*Transmitting Station Uplink Delay* For 1-way this is always zero.	Unsigned Integer-22	nsec	

Note:
1. Item #18 “Reference Frequency, H/P” is trunc(1000*Variable/2^24), where Variable is Reference Frequency in Hz
3. Item #19 “Reference Frequency, L/P” is trunc((1000*Variable)modulo2^24), where Variable is Reference Frequency in Hz

Table 3-4g. Orbit Data Group Data Format, Data Type Dependent Portion for Angle Data (Data Types 41, 51, 52, 53, 54, 55, 56, 57, and 58)

Item #	Byte/ Bit (s)	Item Name and Description	Format	Units	Range
15	20/1-20/7	*Reserved.*	Unsigned Integer-7	N/A	0
16	20/8-22/1	*Spacecraft ID.* Per 820-013, OPS-6-21	Unsigned Integer-10	N/A	0 to 255
17	22/2	*Reserved.*	Unsigned Integer-1	N/A	0
18	22/3-24/8	*Reserved.*	Unsigned Integer-22	N/A	0
19	25-27	*Reserved.*	Unsigned Integer-24	N/A	0
20	28/1-30/4	*Reserved.*	Signed Integer-20	N/A	0
21	30/5-33/2	*Reserved.*	Unsigned Integer-22	N/A	0
22	33/3-35/8	*Reserved.*	Unsigned Integer-22	N/A	0

Note: Item #20 was used for train axis angle data from OVLBI Tracking Subsystem (OTS). OTS was decommissioned from spacecraft tracking operations on 1 January 2001.

3.2.5 Ramp group Data

Ramp group contains uplink frequency information and consists of header (Table 3-1) and data (Table 3-5). Note that each DSS will generate a ramp group header. The frequency and frequency rate in a ramp group data are always sky level values.

Table 3-5. Ramp Group Data Format

Item #	Byte/ Bit (s)	Item Name and Description	Format	Units	Range
1	0-3	*Ramp Start Time, Integer Part*. In seconds from the reference time.	Unsigned Integer-32	sec	
2	4-7	*Ramp Start Time, Fractional Part*.	Unsigned Integer-32	nsec	0 to 10^9-1
3	8-11	*Ramp Rate, Integer Part.*	Signed Integer-32	Hz/s	
4	12-15	*Ramp Rate, Fractional Part.*	Signed Integer-32	10^{-9} Hz/s	0 to 10^9-1
5	16/1-18/6	Ramp Start Frequency, Integer GHz.	Unsigned Integer-22	GHz	
6	18/7-19/8	*Transmitting Station ID number* per 810-047.	Unsigned Integer-10	N/A	1 to 127
7	20-23	*Ramp Start Frequency, Integer Part Modulo 10^9*.	Unsigned Integer-32	Hz	0 to 10^9-1
8	24-27	*Ramp Start Frequency, Fractional Part.*	Unsigned Integer-32	10^{-9} Hz	0 to 10^9-1
9	28-31	*Ramp End Time, Integer Part*. In seconds from the reference time.	Unsigned Integer-32	sec	
10	32-35	*Ramp End Time, Fractional Part*.	Unsigned Integer-32	nsec	0 to 10^9-1

3.2.6 Clock Offsets Group Data

The clock offsets group contains clock offset information for the observable and consists of a header (Table 3-1) and data as described in table 3-6. Currently clock offset information is generated for D-DOD and D-DOR data only

Table 3-6. Clock Offsets Group Data Format

Item #	Byte/ Bit (s)	Item Name and Description	Format	Units	Range
1	0-3	*Start Time, Integer Part*. In seconds from the reference time.	Unsigned Integer-32	sec	
2	4-7	*Start Time, Fractional Part*.	Unsigned Integer-32	nsec	0 to 10^9-1
3	8-11	*Clock Offset, Integer Part (two's complement).* The clock offset is (UTC minus Station Time) at the primary station minus the same quantity at the secondary station.	Signed Integer-32	sec	
4	12-15	*Clock Offset, Fractional Part.*	Signed Integer-32	nsec	0 to 10^9-1
5	16-19	*Primary Station ID* per 810-047.	Unsigned Integer-32	N/A	
6	20-23	*Secondary Station ID* per 810-047.	Unsigned Integer-32	N/A	
7	24-27	*Reserved.*	Unsigned Integer-32	N/A	
8	28-31	*End Time, Integer Part*. In seconds from the reference time.	Unsigned Integer-32	sec	
9	32-35	*End Time, Fractional Part*.	Unsigned Integer-32	nsec	0 to 10^9-1

3.2.7 End-of-File Group

End-of-file group indicates end of the file and consists of header (Table 3-1) only. There is no data portion for the end-of-file group.

3.3 Dependencies

None identified.

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Appendix A ODF observables

A.1 VLBI Observables

The ODF VLBI observable (Orbit Data item 10) is derived from receiving a signal simultaneously at two tracking stations and then differencing them. The quasar D-DOR observable is the time of signal arrival at station 2 minus the time of signal arrival at station 1. The spacecraft D-DOR observable is the range at station 2 minus the range at station 1. The D-DOR observables are group delay measurements and have units of nsec. They are derived from data recorded in two separated frequency channels. The D-DOD Doppler observables are phase delay rate measurements and have units of Hz. They are derived from data recorded in a single frequency channel.

For D-DOD Doppler observables, the reference frequency is used to convert between units of Hz and units of sec/sec, just as for ordinary Doppler. For quasar D-DOD observables the reference frequency is the centroid of the received channel frequency used for data recording. For spacecraft D-DOD observables the reference frequency is the spacecraft transmitter frequency for the spectral component, e.g. carrier or sidetone, which is recorded in the channel. For D-DOD observables, the reference frequency is the geometric mean of the reference frequencies associated with the two separated channels used for data recording.

The reference frequency is used for scaling the charged particle correction for all VLBI data types.

A.2 Doppler Observables

The ODF Doppler observable (Orbit Data item 10) represents the average received frequency during a given time interval. The midpoint of the interval is the time tag (Orbit Data items 1 and 2), the start of the interval is the time tag minus half of the compression time (Orbit Data item 21), and the end of the interval is the time tag plus half of the compression time.

Doppler observables are generated by RMDC from the TRK-2-34 data, which contains the actual measurements made at the Deep Space Stations (DSS), and provided in the ODF Orbit Data Group (see Table 3-3b).

Doppler Observable [Hz] = Observable + F_{bias}

Where

- **Observable [Hz]** is derived from item 4 and 5 of Table 3-3b
- **F_{bias} [Hz]** is derived from item 18 and 19 of Table 3-3b and defined by one of the following cases:

⇒ Case 1: 1-Way , 2-Way Non-Coherent (TWNC) or 3-Way Non-Coherent Doppler mode

$F_{bias} = C2 * fTo$

Where:

fTo [Hz] is the nominal spacecraft S-band downlink frequency provided by the project (beacon frequency)

C2 = 240/240 for S-band
= 880/240 for X-band downlink
= 3344/240, 3360/240* for Ka-band downlink
*MRO only

⇒ Case 2: 2-Way Coherent, 3-Way Transponded Non-Coherent, or 3-Way Coherent Doppler mode

F_{bias} = (scft_transpd_turn_num / scft_transpd_turn_den) * ul_freq

Where:

ul_freq [Hz] is an arbitrary uplink frequency that can be calculated from the downlink frequency and band at the first good phase count, and the predicted uplink band, using the appropriate turn-around ratio. This frequency shall be reported in the Trk-2-18 as the reference frequency (items 18 and 19). For example:

ul_freq = int (dl_freq / scft_transpd_turn_num *scft_transpd_turn_den)

Where:

scft_transpd_turn_den is the spacecraft transponder turn around ratio denominator.

scft_transpd_turn_num is the spacecraft transponder turn around ratio numerator.

A.3 Range Observables

The ODF range observable (Orbit Data item 10) measures the round trip light time between a DSS reference location and a spacecraft reference location. A range unit (RU) is 2 cycles of an S-band transmitting frequency or (749x2)/221 of an X-band transmitting frequency. The time tag (Orbit Data items 1 and 2) is the reception time at the ranging equipment. The reference frequency (Orbit Data items 18 and 19) shall be the uplink frequency at the time of reception, if there are no ramps, but sometimes is the uplink range calibration frequency for the pass.

For range data, the observable is computed as follows:

Observable = R - C + Z - S

where:

R = range measurement
C = station delay calibration

Z = Z-height correction
S = spacecraft delay

The transmitter time tag delay and the receiver time tag delay are included in the range observable. The receiver time tag delay includes any additional delay created by downlink arraying equipment.

The conversion factor F to convert from seconds to range units depends on the uplink band and the transmitting frequency (f_T). The current DSN standard values are:

S-Band: $F = f_T / 2$ [RU/sec]

X-Band: $F = 221 / 749 * f_T / 2$ [RU/sec]

The observable has an ambiguity (range modulo) of 2^{6+Last_Comp} RU, where Last_Comp is Orbit Data item 15.