Interpretation and Use of Binary ATDF/TDF Data

The Archival Tracking Data File (ATDF or TDF) was generated by the NASA Deep Space Network (DSN) and contained the most detailed results from radio tracking of spacecraft over three decades ending in the mid-2000s. ATDFs were written in very densely packed binary formats, which have been difficult for some users to parse.

This document describes and illustrates extraction of values from TDFs with emphasis on files created since the mid-1980s. These files were generated according to the TRK-2-25 interface specification, a module within the DSN 820-013 External Interface Specification. The TRK-2-25 format has evolved; but the general structure and content of the files have remained relatively stable[#]. When production of TDFs was discontinued in the mid-2000s; users were encouraged to switch to the TRK-2-34 product, which was based on higher precision phase measurements.

This document does not address how one might *use* data found in a TDF file. Readers interested in use are referred to Morabito and Asmar (1995) and to Moyer (2000), which are cited in the PDS4 label for this document.

The following versions of the TRK-2-25 document were included in the Planetary Data System (PDS) Radio Science Documentation (RSD) bundle as of mid-2020. Other versions may be added as they become available.

[1] *Document 820-013 (Rev. A), DSN System Requirements, Detailed Interface Design, TRK-2-25, DSN Tracking System Interfaces, Archival Tracking Data File Interface,* initial release data 1986-01-01.

[2] *Document 820-013 (Rev. A), DSN System Requirements, Detailed Interface Design, TRK-2-25, DSN Tracking System Interfaces, Archival Tracking Data File Interface,* reissued 1988-10-15.

[3] *MGSO System Requirements, Detailed Interface Design, SFOC-NAV-TRK-2-25, MGSO Tracking System Interfaces, Archival Tracking Data File Interface,* reissued 1996-07-31.

File and Record Formats:

Each TDF comprises one or more blocks of 8064 bytes, divided into 288-byte (2304-bit) records. When the volume of data records is not an integer multiple of 8064 bytes, zero-filled records are used to pad the final block to 8064 bytes.

There may be up to three record types — usually a File Identification Record, followed by a Transponder record, and then one or more Tracking Data Records in chronological order. Tracking Data Records may contain either high- or low-rate data, but both have the same record format. If/when data from two or more DSN passes are concatenated into a single file, there may be additional File Identification and/or Transponder Records marking the beginning of data from the new source.

[#] Earlier versions of the TDF contained similar (but not identical) information, organized into similar (but not identical) records. See Appendix A for more information.

The TDF was originally created on Univac computers which had six 6-bit bytes per word; a double precision number occupied two words or 72 bits. Data were written to tape with most-significant byte first (MSB order). With the industry transition to 8-bit bytes, specifications were revised; but the bits remained largely unchanged so that files could be read on both 32-bit and 36-bit machines. The industry transition from MSB to least significant byte first (LSB order) has complicated extraction of values from the binary data on some platforms since TDF data have always been written in MSB order. Displaying data in byte order should provide the same view whether the user's platform is MSB or LSB.

Normally, the File Identification Logical Record is the first record in an ATDF/TDF; it gives the creation date, time, and source of the file. Its contents are specified in Table 0 below, adapted from [1-3]. The structures of the ATDF Transponder Logical Record and ATDF Tracking Data Logical Record are documented in Tables 3-2 and 3-3 of [1-3]. Packed format 'i*mn*' denotes an unsigned integer with *mn* bits where bits are continuous across byte boundaries (as viewed in byte, or MSB, order). Packed format 's*mn*' denotes signed integers in two's-complement storage.

Table 0. ATDF File Identification Logical Record

Item Number	Packed Format	Description
1	i32	Record format (set to '0'**)**
2	i8	Reserved (set to '128')
3	i32	Record type (set to '10')
4	i12	File creation year modulo 1900
5	i16	File creation day-of-year
6	i8	File creation hour
7	Ii2	File creation minute
8	i8	File creation second
9	i12	Reserved (set to '0')
10	i16	Spacecraft ID number
11	I8	First character of source
12	I8	Second character of source
13	I8	Third character of source
14	I12	Fourth character of source
15	I16	Fifth character of source
16	I8	Sixth character of source
17	I12	Seventh character of source
18	I8	Eighth character of source
19	I16	Not used (set to '0')
20	I4	Not used (set to '0')
21-84	64*i32	Not used (set to '0'

The eight characters identifying the source (items 11-18 in Table 0) vary depending on the era during which the file was written; in 1986 [1], they were ASCII ‘IDR ATDF’, in 1988 [2], they were either ‘IDR ATDF’ or ‘SPR ATDF’, and in 1996 [3] and 1998 they were ‘R/T ATDF’. There may be other values, especially in years before 1986.

The uneven parsing (for example, 16 bits for some characters and 8 or 12 bits for others) is an artifact of the original Univac structure.

Example Data File:

An example TDF generated during the Cassini mission has been included in the Radio Science Documentation bundle. Data were collected at DSN ground station 25 over about 10.3 hours on 26 November 2001. To save space, only the first 504 and the last 56 records of the original TDF are included in the example. The logical identifier (LID) for the example file is

urn:nasa:pds:radiosci_documentation:dsn_trk-2-25:tdf01330

A hexadecimal dump of the first 4 records of the example file is shown in Figure 1 below

```
Record 1:
0000000    00  00  00  00  80  00  00  00  0a  06  60  05  01  20  26  0a
0000016    00  00  05  25  22  f5  40  20  00  41  54  04  44  60  00  00
0000032    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
                                  ...
Record 2:
0000288    00  00  00  00  80  00  00  00  1e  06  50  14  a0  50  04  26
0000304    00  00  05  20  00  00  00  65  01  4a  0f  01  42  10  00  00
0000320    00  03  81  c9  00  03  10  ab  00  00  00  00  00  00  00  00
0000336    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
                                  ...
Record 3:
0000576    00  00  00  08  00  00  00  00  5a  06  50  14  a0  50  42  60
0000592    00  00  06  40  06  00  00  52  00  00  00  00  00  00  00  40
0000608    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
                                  ...
0000752    00  00  00  00  03  00  00  00  00  00  00  00  00  00  00  00
0000768    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
                                  ...
0000800    00  04  00  00  00  00  00  00  00  00  00  20  b9  ff  20  35
0000816    49  5b  80  00  20  00  00  00  00  00  00  00  00  00  00  00
0000832    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
                                  ...
Record 4:
0000864    00  00  00  08  00  00  00  00  5b  06  50  14  a0  50  42  70
0000880    00  00  06  40  81  22  00  52  00  00  00  00  7d  0c  14  40
0000896    00  00  00  64  00  00  10  43  1c  76  16  81  b8  00  00  00
0000912    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
0000928    00  00  00  00  00  00  00  00  00  00  02  04  de  72  e4  0d
0000944    20  00  00  00  00  00  00  01  04  34  39  a2  b1  35  80  00
0000960    01  04  36  ab  e3  fe  37  80  00  01  04  39  1e  25  4a  fb
0000976    00  00  01  04  3b  90  66  9a  6e  00  00  01  04  3e  02  a7
0000992    ea  1f  80  00  01  04  40  74  e9  3c  fd  80  00  01  04  42
0001008    e7  31  06  73  80  00  01  04  45  59  72  5e  ef  00  00  01
0001024    04  47  cb  b3  b6  af  0f  ff  ff  c1  51  00  00  00  00  00
0001040    03  c0  00  dd  03  00  00  00  00  00  9f  fa  3d  01  2c  c8
0001056    01  2c  c8  00  00  00  00  00  00  00  00  00  00  00  00  00
0001072    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
0001088    00  00  00  00  00  00  ff  f6  c7  c0  00  00  00  00  00  00
0001104    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
0001120    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
0001136    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
```

Figure 1. Hexadecimal dump of the first 4 records of the example data file. Byte addresses (in decimal) are in the left column. The dump was created using the unix command *od -t x1 tdf01330.dat +0.*

A complete ASCII listing of the non-zero contents of the example file is included in accompanying file *tdf01330.csv*. Each record contains 1180 bytes, including an ASCII <CR><LF> record delimiter in bytes 1179 and 1180. Fields within each record are separated by commas. To pad the file to an integer multiple of 8064 bytes, there are nine 'empty' records at the end of *tdf01330.dat*; they are not included in *tdf01330.csv*.

The first record has fields corresponding to items 1-18 in Table 1 below. An extra field has been added in *tdf01330.csv* after field 18; it contains the character string formed from the contents of items 11-18. The remainder of the first *tdf01330.csv* record is filled with ASCII blanks except for the <CR><LF> delimiter in bytes 1179 and 1180.

The second record has fields corresponding to items 1-23 in Table 2 below. An extra field has been added in *tdf01330.csv* after field 23; it contains the reconstructed value from items 21 and 23 using scientific notation (1p1d22.15). The remainder of the record is filled with ASCII blanks except for the <CR><LF> delimiter in bytes 1179 and 1180.

Records 3-551 have fields corresponding to items 1-141 in Tables 3 and 4 below. Extra fields have been added after items 32, 35, 44, 48, 51, 54, 57, 60, 63, 66, 69, 72, 121, 125, and 141 to contain reconstructed values of preceding H/P, I/P, and/or L/P items using scientific notation (1p1d22.15). The <CR><LF> record delimiter is in bytes 1179 and 1180.

Table 1 – Extraction of Values from Record 1

Item	Pack Format	s/i	bits	cum bits	Description	hex	decimal	ASCII
1	i32	i	32	32	record format	00000000	0	
2	i8	i	8	40	reserved	80	128	
3	i32	i	32	72	record type	0000000a	10	
4	i12	i	12	84	file creation year (mod 1900)	066	102	
5	i16	i	16	100	file creation day-of-year	0050	80	
6	i8	i	8	108	file creation hour	12	18	
7	i12	i	12	120	file creation minute	026	38	
8	i8	i	8	128	file creation second	0a	10	
9	i12	i	12	140	reserved	000	0	
10	i16	i	16	156	spacecraft ID number	0052	82	
11	i8	i	8	164	character	52	82	R
12	i8	i	8	172	character	2f	47	/
13	i8	i	8	180	character	54	84	T
14	i12	i	12	192	character	020	32	<space>
15	i16	i	16	208	character	0041	65	A
16	i8	i	8	216	character	54	84	T
17	i12	i	12	228	character	044	68	D
18	i8	i	8	236	character	46	70	F
19	i16	i	16	252	reserved	0000	0	
20	i4	i	4	256	not used	0	0	
			2048		other unused bits (256 bytes)			
			2304		total bits			
			288		total bytes			

Table 2 – Extraction of Values from Record 2

Item	Pack Format	s/i	bits	cum bits	Description	hex	decimal
1	i32	i	32	32	record format	00000000	0
2	i8	i	8	40	reserved	80	128
3	i32	i	32	72	record type	0000001e	30
4	i12	i	12	84	file start year (mod 1`900)	065	101
5	i16	i	16	100	file start day-of-year	014a	330
6	i8	i	8	108	file start hour	05	5
7	i12	i	12	120	file start minute	004	4
8	i8	i	8	128	file start second	26	38
9	i12	i	12	140	reserved	000	0
10	i16	i	16	156	spacecraft ID number	0052	82
11	i8	i	8	164	reserved	00	0
12	i8	i	8	172	reserved	00	0
13	i8	i	8	180	reserved	00	0
14	i12	i	12	192	file end year (mod 1900)	065	101
15	i16	i	16	208	file end day-of-year	014a	330
16	i8	i	8	216	file end hour	0f	15
17	i12	i	12	228	file end minute	014	20
18	i8	i	8	236	file end second	21	33
19	i16	i	16	252	reserved	0000	0
20	i12	i	12	264	sign bits	000	0
21	i24	i	24	288	spacecraft transponder frequency - H/P	0381c9	229833
22	i12	i	12	300	sign bits	000	0
23	i24	i	24	324	spacecraft transponder frequency - L/P	310ab0	3214000
24	i28	i	28	352	not used	0000000	0
			1952	2304	other unused bits (244 bytes)		
			2304		total bits		
			288		total bytes		

The spacecraft transponder frequency (items 20-23) may be reconstructed using the expression following Table 3-2 in [3]:

$$\text{spacecraft\_transponder\_frequency} = (H/P)*10^{4} + (L/P) * 10^{-3} = 2298333214.0 \text{ Hz}$$

Table 3a – Extraction of Values from Record 3 (items 1-55)

Item	Pack Format	s/i	bits	cum bits	Unit	Description	hex	binary	decimal
1	i32	i	32	32		record format	00000008		8
2	i8	i	8	40		reserved	00		0
3	i32	i	32	72		record type	0000005a		90
4	i12	i	12	84	year	sample year (mod 1`900)	065		101
5	i16	i	16	100	day	sample day-of-year	014a		330
6	i8	i	8	108	hour	sample hour	05		5
7	i8	i	8	116	minute	sample minute	04		4
8	i8	i	8	124	second	sample second	26		38
9	i20	i	20	144		reserved	00000		0
10	i10	i	10	154		receiving station ID number		0000011001	25
11	i8	i	8	162		receiver/downlink frequency band		00000000	0
12	i6	i	6	168		sample data type ID		000110	6
13	i4	i	4	172		Doppler/phase channel number	0		0
14	i4	i	4	176		ground mode	0		0
15	i16	i	16	192		spacecraft ID number	0052		82
16	i8	i	8	200		range type	00		0
17	i8	i	8	208		angles type	00		0
18	i8	i	8	216		DRVID type	00		0
19	i1	i	1	217		Doppler good/bad indicator		0	0
20	s18	s	18	235	kHz 10^15 cy	Doppler bias		0000000000000000000	0
21	i1	i	1	236		angles good/bad indicator		0	0
22	i1	i	1	237		frequency level indicator		0	0
23	i1	i	1	238		simulation synthesizer indicator		0	0
24	i1	i	1	239		receiver loop lock indicator		0	0
25	i1	i	1	240		transmitter on/off indicator		0	0
26	i6	i	6	246		Doppler reference receiver type		000000	0
27	i6	i	6	252		source designation/exciter type		000100	4
28	i4	i	4	256		no process flag and cause		0000	0
29	i32	i	32	288	0.01 s	sample interval	00000000		0
30	i24	i	24	312	10^-6 cy	No. 1 Doppler count or downlink phase - H/P	000000		0
31	i24	i	24	336	10^-6 cy	No. 1 Doppler count or downlink phase - I/P	000000		0
32	i24	i	24	360	10^-6 cy	No. 1 Doppler count or downlink phase - L/P	000000		0
33	i24	i	24	384	10^-6 (RU; ns)	range- H/P (ns item 16 is 1; RU otherwise)	000000		0
34	i24	i	24	408	10^-6 (RU; ns)	range- I/P	000000		0
35	i24	i	24	432	10^-6 (RU; ns)	range- L/P	000000		0
36	i8	i	8	440		lowest (last) ranging component	00		0
37	i28	i	28	468	2^-32 cy	uplink phase - part 1	0000000		0
38	i24	i	24	492	2^-32 cy	uplink phase - part 2	000000		0
39	i24	i	24	516	2^-32 cy	uplink phase - part 3	000000		0
40	i24	i	24	540	2^-32 cy	uplink phase - part 4	000000		0
41	s24	s	24	564	0.001 deg	angle 1 (azimuth, hour angle, or X)	000000		0
42	s24	s	24	588	0.001 deg	angle 2 (elevation, declination, or Y)	000000		0
43	i32	i	32	620	10^-6 Hz	Doppler reference/receiver frequency - H/P	00000000		0
44	i32	i	32	652	10^-6 Hz	Doppler reference/receiver frequency - L/P	00000000		0
45	133	s	32	684	0.01 RU	DRVID	00000000		0
46	i24	i	24	708	10^-6 cy	No. 2 H/R Doppler or downlink phase - H/P	000000		0
47	i24	i	24	732	10^-6 cycles; or 10^-17; or 10^-6	No. 2 H/R Doppler or downlink phase - I/P; or 0.1 s Allan deviation - I/P; or 0.1 s smoothed noise I/P	000000		0
48	i24	i	24	756	10^-6 cy; seconds; 10^-17; 10^-6	No. 2 H/R Doppler or downlink phase - L/P; or round-trip light time; or 0.1 s Allan deviation - I/P; or 0.1 s smoothed noise I/P	000000		0
49	i24	i	24	780	10^-6 cy	No. 3 H/R Doppler or downlink phase - H/P	000000		0
50	i24	i	24	804	10^-6 cycles; 10^-17; or 10^-6	No. 3 H/R Doppler or downlink phase - I/P; or 1 s Allan deviation - I/P; or 1 s smoothed noise I/P	000000		0
51	i24	i	24	828	10^-6 cy; seconds; 10^-17; 10^-6	No. 3 H/R Doppler or downlink phase - L/P; or end of range acquisition time (s past 0h); or 1 s Allan deviation - L/P; or 1 s smoothed noise L/P	000000		0
52	i24	i	24	852	10^-6 cycles	No. 4 H/R Doppler or downlink phase - H/P	000000		0
53	i24	i	24	876	10^-6 cycles; or 10^-17; or 10^-6	No. 4 H/R Doppler or downlink phase - I/P; or 10-second Allan deviation - I/P; or 10 second smoothed noise - I/P	000000		0
54	i24	i	24	900	10^-6 cycles; or seconds; or 10^-17; or 10^-6	No. 4 H/R Doppler or downlink phase - L/P; or T1 integration time constant; or 10-second Allan deviation - L/P; or 10 second smoothed noise - L/P	000000		0
55	i24	i	24	924	10^-6 cycles	No. 5 H/R Doppler or downlink phase - H/P	000000		0

Table 3b – Extraction of Values from Record 3 (items 56-100)

Item	Pack Format	s/i	bits	cum bits	Unit	Description	hex	binary	decimal
56	i24	i	24	948	10^-6 cycles; or 10^-17; or 10^-6	No. 5 H/R Doppler or downlink phase - I/P; or 100-second Allan deviation - I/P; or 100 second smoothed noise - I/P	000000		0
57	i24	i	24	972	10^-6 cycles; or seconds; or 10^-17; or 10^-6	No. 5 H/R Doppler or downlink phase - L/P; or T2 integration time constant; or 100-second Allan deviation - L/P; or 100 second smoothed noise - L/P	000000		0
58	i24	i	24	996	10^-6 cycles	No. 6 H/R Doppler or downlink phase - H/P	000000		0
59	i24	i	24	1020	10^-6 cycles; or 10^-17; or 10^-6	No. 6 H/R Doppler or downlink phase - I/P; or 1000-second Allan deviation - I/P; or 200 second smoothed noise - I/P	000000		0
60	i24	i	24	1044	10^-6 cycles; or seconds; or 10^-17; or 10^-6	No. 6 H/R Doppler or downlink phase - L/P; or T3 integration time constant; or 1000-second Allan deviation - L/P; or 200 second smoothed noise - L/P	000000		0
61	i24	i	24	1068	10^-6 cycles	No. 7 H/R Doppler or downlink phase - H/P	000000		0
62	i24	i	24	1092	10^-6 cycles; or 10^-6	No. 7 H/R Doppler or downlink phase - I/P; or 600 second smoothed noise - I/P	000000		0
63	i24	i	24	1116	10^-6 cycles; or 0.001 volts; or 10^-6	No. 7 H/R Doppler or downlink phase - L/P; or reference (0-degree) correlation voltage; or 600 second smoothed noise - L/P	000000		0
64	i24	i	24	1140	10^-6 cycles	No. 8 H/R Doppler or downlink phase - H/P	000000		0
65	i24	i	24	1164	10^-6 cycles	No. 8 H/R Doppler or downlink phase - I/P	000000		0
66	i24	i	24	1188	10^-6 cycles; or 0.001 volts	No. 8 H/R Doppler or downlink phase - L/P; or quadrature (90-degree) correlation voltage	000000		0
67	i24	i	24	1212	10^-6 cycles	No. 9 H/R Doppler or downlink phase - H/P	000000		0
68	i24	i	24	1236	10^-6 cycles	No. 9 H/R Doppler or downlink phase - I/P	000000		0
69	i24	i	24	1260	10^-6 cycles; or dB	No. 9 H/R Doppler or downlink phase - L/P; or carrier suppression	000000		0
70	i24	i	24	1284	10^-6 cycles	No. 10 H/R Doppler or downlink phase - H/P	000000		0
71	i24	i	24	1308	10^-6 cycles	No. 10 H/R Doppler or downlink phase - I/P	000000		0
72	i24	i	24	1332	10^-6 cycles; or n/a	No. 10 H/R Doppler or downlink phase - L/P; or highest (first) ranging component	000000		0
73	s4	s	4	1336		sign bits for item 74	0		0
74	s32	s	32	1368	0.001 Hz	Doppler or downlink phase pseudo-residual	00000000		0
75	s4	s	4	1372		sign bits for item 76	0		0
76	s32	s	32	1404	0.001 RU	range pseudo-residual	00000000		0
77	s18	s	18	1422	0.001 deg; or n/a	angle 1 pseudo-residual; or numerator for spacecraft turnareound ratio		000000000000000000	0
78	s18	s	18	1440	0.001 deg; or n/a	angle 2 pseudo-residual; or dumerator for spacecraft turnareound ratio		000000000000000000	0
79	i8	i	8	1448		exciter/uplink frequency band and input network/source ID	03		3
80	i4	i	4	1452		angle mode	0		0
81	i2	i	2	1454		conscan mode		00	0
82	i1	i	1	1455		angle 1 pseudo-residual tolerance		0	0
83	i1	i	1	1456		angle 2 pseudo-residual tolerance		0	0
84	i1	i	1	1457		Doppler/downlink phase pseudo-residual tolerance		0	0
85	i1	i	1	1458		Doppler noise tlerance		0	0
86	i8	i	8	1466	percent; or 0.01 RU	percentage of data used for Allan devistion; or ranging equipment delay overflow		00000000	0
87	i10	i	10	1476	cycles	total slipped cycles during count		0000000000	0
88	s18	s	18	1494	0.001 Hz	Doppler noise		000000000000000000	0
89	s18	s	18	1512	0.01 dBm	received signal strength		000000000000000000	0
90	i24	i	24	1536	nanoseconds	exciter station delay	000000		0
91	i24	i	24	1560	nanoseconds	receiver station delay	000000		0
92	i1	i	1	1561		range modulation on/off		0	0
93	i1	i	1	1562		prime ranging channel		0	0
94	i1	i	1	1563		pipelining on/off		0	0
95	i1	i	1	1564		chopper frequency on/off		0	0
96	i1	i	1	1565		range good/bad indicator		0	0
97	i1	i	1	1566		range calibration tolerance		0	0
98	i1	i	1	1567		range configuration change		0	0
99	i1	i	1	1568		range pseudo-residual tolerance		0	0
100	i1	i	1	1569		pseudo DRVID tolerace		0	0

Table 3c – Extraction of Values from Record 3 (items 101-141)

Item	Pack Format	s/i	bits	cum bits	Unit	Description	hex	binary	decimal
101	i4	i	4	1573		amplifier type; or ramp type indcator		0	0
102	i1	i	1	1574		transmitter low power indicator		0	0
103	i10	i	10	1584	kilowatts; or n/a	transmitter power; or ramp number		0000000000	0
104	i24	i	24	1608	0.01 RU	ranging equipment delay	000000		0
105	s12	s	12	1620	0.1 dB	range or DRVID power/noise ratio	000		0
106	s4	s	4	1624		sign bits for item 107	0		0
107	s32	s	32	1656	0.001 Hz; or 0.001 deg	average Doppler pseudo-residual; or OVLBI train axis (wedge) angle	00000000		0
108	s4	s	4	1660		sign bits for item 109	0		0
109	s32	s	32	1692	0.01 RU; or 10^-14	pseudo-DRVID; or delta frequency/frequency - I/P	00000000		0
110	i4	i	4	1696		sign bits for item 111	0		0
111	i32	i	32	1728	10^-14	deta frequency/frequency -- L/P	00000000		0
112	S22	s	22	1750	0.01 ns	z-correction		0000000000000000000000	0
113	i14	i	14	1764	nanoseconds	spacecraft delay		00000000000000	0
114	i23	i	23	1787	0.01 RU	range or DRVID noise		00000000000000000000000	0
115	i1	i	1	1788		DRVID good/bad indicator; or ranging assembly status indicator		0	0
116	i1	i	1	1789		range or DRVID noise tolerance		0	0
117	i1	i	1	1790		range or DRVID power/noise tolerance		0	0
118	i10	i	10	1800		number of post acquisition DRVID points		0000000000	0
119	i8	i	8	1808		ramp controller indicator; or cause of Allan deviation report generation	04		4
120	s32	s	32	1840	10^-6 Hz/sec	programmed frequency ramp rate - H/P	00000000		0
121	S32	s	32	1872	10^-6 Hz/s; or 2^-12 DB; or seconds	programmed frequency ramp rate - L/P; or received signal strength; or ranging transmitter coder in-phase time offset	00000000		0
122	i4	i	4	1876		sign bits for item 123	0		0
123	i32	i	32	1908	10^-6 Hz/s	programmed ramp start frequency - H/P	020b9ff2		34316274
124	i4	i	4	1912		sign bits for item 125	0		0
125	i32	i	32	1944	10^-6 Hz/s	programmed ramp start frequency - L/P	35495b80		894000000
126	i1	i	1	1945		exciter frequency change flag		0	0
127	i1	i	1	1946		receiver loop lock changed flag		0	0
128	i1	i	1	1947		receiver frequency changed flag		0	0
129	i1	i	1	1948		transmitter on/off changed flag		0	0
130	i1	i	1	1949		station delay(s) change flag		0	0
131	i1	i	1	1950		ramp rate/frequency changed flag		0	0
132	i1	i	1	1951		ground mode changed flag		0	0
133	i1	i	1	1952		highest/lowest ranging component changed flag		0	0
134	i1	i	1	1953		sample year changed flag		0	0
135	i1	i	1	1954		z-correction changed flag		0	0
136	i1	i	1	1955		ramp record added flag		1	1
137	i1	i	1	1956		Doppler good/bad indicator changed flag		0	0
138	i1	i	1	1957		range good/had indicator changed flag		0	0
139	i1	i	1	1958		angles good/bad indicator changed flag		0	0
140	i28	i	28	1986	10^-6 Hz	transmitter/exciter reference frequency - H/P		0000000000000000000000000000	0
141	i30	i	30	2016	10^-6 Hz	transmitter/exciter reference frequency - L/P		000000000000000000000000000000	0
142	i32	i	32	2048		not used	00000000		0
143	i32	i	32	2080		not used	00000000		0
144	i32	i	32	2112		not used	00000000		0
145	i32	i	32	2144		not used	00000000		0
146	i32	i	32	2176		not used	00000000		0
147	i32	i	32	2208		not used	00000000		0
148	i32	i	32	2240		not used	00000000		0
149	i32	i	32	2272		not used	00000000		0
150	i32	i	32	2304		not used	00000000		0
		Total bits	2304						
		Total Bytes	288						

A. Negative Values: Although there are signed integers in record 3 (yellow highlighting), none has a negative value.

B. High Precision Values: There are H/P (high part), I/P (intermediate part), and/or L/P (low part) integers at items 30-32, 33-35, 43-44, 46-48, 49-51, 52-54, 55-57, 58-60, 61-63, 64-66, 67-69, 70-72, 120-121, 122-125, and 140-141. However, only the value at items 122-125 is non-zero. It may be reconstructed using the expression for ramp frequency at the end of Table 3-3 in [3]:

$$\text{programmed\_ramp\_start\_frequency} = (H/P) * 10^{3} + (L/P) * 10^{-6} = 34316274894.0$$

Note that reconstruction following the expression in [3] does not give the scaling required by the 'unit' column in the same table (see Appendix B, paragraph (3) of this document).

Table 4a – Extraction of Values from Record 4 (items 1-54)

Item	Pack Format	s/i	bits	cum bits	Unit	Description	hex	binary	decimal	2s comp
1	i32	i	32	32		record format	00000008		8	
2	i8	i	8	40		reserved	00		0	
3	i32	i	32	72		record type	0000005b		91	
4	i12	i	12	84	year	sample year (mod 1`900)	065		101	
5	i16	i	16	100	day	sample day-of-year	014a		330	
6	i8	i	8	108	hour	sample hour	05		5	
7	i8	i	8	116	minute	sample minute	04		4	
8	i8	i	8	124	second	sample second	27		39	
9	i20	i	20	144		reserved	00000		0	
10	i10	i	10	154		receiving station ID number		0000011001	25	
11	i8	i	8	162		receiver/downlink frequency band		00000010	2	
12	i6	i	6	168		sample data type ID		000001	1	
13	i4	i	4	172		Doppler/phase channel number	2		2	
14	i4	i	4	176		ground mode	2		2	
15	i16	i	16	192		spacecraft ID number	0052		82	
16	i8	i	8	200		range type	00		0	
17	i8	i	8	208		angles type	00		0	
18	i8	i	8	216		DRVID type	00		0	
19	i1	i	1	217		Doppler good/bad indicator		0	0	
20	s18	s	18	235	kHz 10^15 cy	Doppler bias		000000001111101000	1000	
21	i1	i	1	236		angles good/bad indicator		0	0	
22	i1	i	1	237		frequency level indicator		1	1	
23	i1	i	1	238		simulation synthesizer indicator		1	1	
24	i1	i	1	239		receiver loop lock indicator		0	0	
25	i1	i	1	240		transmitter on/off indicator		0	0	
26	i6	i	6	246		Doppler reference receiver type		000101	5	
27	i6	i	6	252		source designation/exciter type		000100	4	
28	i4	i	4	256		no process flag and cause		0000	0	
29	i32	i	32	288	0.01 s	sample interval	00000064		100	
30	i24	i	24	312	10^-6 cy	No. 1 Doppler count or downlink phase - H/P	000010		16	
31	i24	i	24	336	10^-6 cy	No. 1 Doppler count or downlink phase - I/P	431c76		4398198	
32	i24	i	24	360	10^-6 cy	No. 1 Doppler count or downlink phase - L/P	1681b8		1475000	
33	i24	i	24	384	10^-6 (RU; ns)	range- H/P (ns item 16 is 1; RU otherwise)	000000		0	
34	i24	i	24	408	10^-6 (RU; ns)	range- I/P	000000		0	
35	i24	i	24	432	10^-6 (RU; ns)	range- L/P	000000		0	
36	i8	i	8	440		lowest (last) ranging component	00		0	
37	i28	i	28	468	2^-32 cy	uplink phase - part 1	0000000		0	
38	i24	i	24	492	2^-32 cy	uplink phase - part 2	000000		0	
39	i24	i	24	516	2^-32 cy	uplink phase - part 3	000000		0	
40	i24	i	24	540	2^-32 cy	uplink phase - part 4	000000		0	
41	s24	s	24	564	0.001 deg	angle 1 (azimuth, hour angle, or X)	000000		0	
42	s24	s	24	588	0.001 deg	angle 2 (elevation, declination, or Y)	000000		0	
43	i32	i	32	620	10^-6 Hz	Doppler reference/receiver frequency - H/P	00204de7		2117095	
44	i32	i	32	652	10^-6 Hz	Doppler reference/receiver frequency - L/P	2e40d200		776000000	
45	i32	s	32	684	0.01 RU	DRVID	00000000		0	
46	i24	i	24	708	10^-6 cy	No. 2 H/R Doppler or downlink phase - H/P	000010		16	
47	i24	i	24	732	10^-6 cycles; or 10^-17; or 10^-6	No. 2 H/R Doppler or downlink phase - I/P; or 0.1 s Allan deviation - I/P; or 0.1 s smoothed noise I/P	43439a		4408218	
48	i24	i	24	756	10^-6 cy; seconds; 10^-17; 10^-6	No. 2 H/R Doppler or downlink phase - L/P; or round-trip light time; or 0.1 s Allan deviation - I/P; or 0.1 s smoothed noise I/P	2b1358		2823000	
49	i24	i	24	780	10^-6 cy	No. 3 H/R Doppler or downlink phase - H/P	000010		16	
50	i24	i	24	804	10^-6 cycles; 10^-17; or 10^-6	No. 3 H/R Doppler or downlink phase - I/P; or 1 s Allan deviation - I/P; or 1 s smoothed noise I/P	436abe		4418238	
51	i24	i	24	828	10^-6 cy; seconds; 10^-17; 10^-6	No. 3 H/R Doppler or downlink phase - L/P; or end of range acquisition time (s past 0h); or 1 s Allan deviation - L/P; or 1 s smoothed noise L/P	3fe378		4187000	
52	i24	i	24	852	10^-6 cycles	No. 4 H/R Doppler or downlink phase - H/P	000010		16	
53	i24	i	24	876	10^-6 cycles; or 10^-17; or 10^-6	No. 4 H/R Doppler or downlink phase - I/P; or 10-second Allan deviation - I/P; or 10 second smoothed noise - I/P	4391e2		4428258	
54	i24	i	24	900	10^-6 cycles; or seconds; or 10^-17; or 10^-6	No. 4 H/R Doppler or downlink phase - L/P; or T1 integration time constant; or 10-second Allan deviation - L/P; or 10 second smoothed noise - L/P	54afb0		5550000	

Table 4b – Extraction of Values from Record 4 (items 55-102)

Item	Pack Format	s/i	bits	cum bits	Unit	Description	hex	binary	decimal	2s comp
55	i24	i	24	924	10^-6 cycles	No. 5 H/R Doppler or downlink phase - H/P	000010		16	
56	i24	i	24	948	10^-6 cycles; or 10^-17; or 10^-6	No. 5 H/R Doppler or downlink phase - I/P; or 100-second Allan deviation - I/P; or 100 second smoothed noise - I/P	43b906		4438278	
57	i24	i	24	972	10^-6 cycles; or seconds; or 10^-17; or 10^-6	No. 5 H/R Doppler or downlink phase - L/P; or T2 integration time constant; or 100-second Allan deviation - L/P; or 100 second smoothed noise - L/P	69a6e0		6924000	
58	i24	i	24	996	10^-6 cycles	No. 6 H/R Doppler or downlink phase - H/P	000010		16	
59	i24	i	24	1020	10^-6 cycles; or 10^-17; or 10^-6	No. 6 H/R Doppler or downlink phase - I/P; or 1000-second Allan deviation - I/P; or 200 second smoothed noise - I/P	43e02a		4448298	
60	i24	i	24	1044	10^-6 cycles; or seconds; or 10^-17; or 10^-6	No. 6 H/R Doppler or downlink phase - L/P; or T3 integration time constant; or 1000-second Allan deviation - L/P; or 200 second smoothed noise - L/P	7ea1f8		8299000	
61	i24	i	24	1068	10^-6 cycles	No. 7 H/R Doppler or downlink phase - H/P	000010		16	
62	i24	i	24	1092	10^-6 cycles; or 10^-6	No. 7 H/R Doppler or downlink phase - I/P; or 600 second smoothed noise - I/P	44074e		4458318	
63	i24	i	24	1116	10^-6 cycles; or 0.001 volts; or 10^-6	No. 7 H/R Doppler or downlink phase - L/P; or reference (0-degree) correlation voltage; or 600 second smoothed noise - L/P	93cfd8		9687000	
64	i24	i	24	1140	10^-6 cycles	No. 8 H/R Doppler or downlink phase - H/P	000010		16	
65	i24	i	24	1164	10^-6 cycles	No. 8 H/R Doppler or downlink phase - I/P	442e73		4468339	
66	i24	i	24	1188	10^-6 cycles; or 0.001 volts	No. 8 H/R Doppler or downlink phase - L/P; or quadrature (90-degree) correlation voltage	106738		1075000	
67	i24	i	24	1212	10^-6 cycles	No. 9 H/R Doppler or downlink phase - H/P	000010		16	
68	i24	i	24	1236	10^-6 cycles	No. 9 H/R Doppler or downlink phase - I/P	445597		4478359	
69	i24	i	24	1260	10^-6 cycles; or dB	No. 9 H/R Doppler or downlink phase - L/P; or carrier suppression	25eef0		2486000	
70	i24	i	24	1284	10^-6 cycles	No. 10 H/R Doppler or downlink phase - H/P	000010		16	
71	i24	i	24	1308	10^-6 cycles	No. 10 H/R Doppler or downlink phase - I/P	447cbb		4488379	
72	i24	i	24	1332	10^-6 cycles; or n/a	No. 10 H/R Doppler or downlink phase - L/P; or highest (first) ranging component	3b6af0		3894000	
73	s4	s	4	1336		sign bits for item 74	f		15	
74	s32	s	32	1368	0.001 Hz	Doppler or downlink phase pseudo-residual	ffffc151		4294951249	-16047
75	s4	s	4	1372		sign bits for item 76	0		0	
76	s32	s	32	1404	0.001 RU	range pseudo-residual	00000000		0	
77	s18	s	18	1422	0.001 deg; or n/a	angle 1 pseudo-residual; or numerator for spacecraft turnareound ratio		000000000011110000	240	
78	s18	s	18	1440	0.001 deg; or n/a	angle 2 pseudo-residual; or dumerator for spacecraft turnareound ratio		000000000011011101	221	
79	i8	i	8	1448		exciter/uplink frequency band and input network/source ID	03		3	
80	i4	i	4	1452		angle mode	0		0	
81	i2	i	2	1454		conscan mode		00	0	
82	i1	i	1	1455		angle 1 pseudo-residual tolerance		0	0	
83	i1	i	1	1456		angle 2 pseudo-residual tolerance		0	0	
84	i1	i	1	1457		Doppler/downlink phase pseudo-residual tolerance		0		
85	i1	i	1	1458		Doppler noise tlerance		0		
86	i8	i	8	1466	percent; or 0.01 RU	percentage of data used for Allan devistion; or ranging equipment delay overflow		00000000		
87	i10	i	10	1476	cycles	total slipped cycles during count		0000000000		
88	s18	s	18	1494	0.001 Hz	Doppler noise		000000000000100111	39	
89	s18	s	18	1512	0.01 dBm	received signal strength		111111101000111101	260669	-1475
90	i24	i	24	1536	nanoseconds	exciter station delay	012cc8		77000	
91	i24	i	24	1560	nanoseconds	receiver station delay	012cc8		77000	
92	i1	i	1	1561		range modulation on/off		0	0	
93	i1	i	1	1562		prime ranging channel		0	0	
94	i1	i	1	1563		pipelining on/off		0	0	
95	i1	i	1	1564		chopper frequency on/off		0	0	
96	i1	i	1	1565		range good/bad indicator		0	0	
97	i1	i	1	1566		range calibration tolerance		0	0	
98	i1	i	1	1567		range configuration change		0	0	
99	i1	i	1	1568		range pseudo-residual tolerance		0	0	
100	i1	i	1	1569		pseudo DRVID tolerace		0	0	
101	i4	i	4	1573		amplifier type; or ramp type indcator		0000	0	
102	i1	i	1	1574		transmitter low power indicator		0	0	

Table 4c – Extraction of Values from Record 4 (items 103-141)

Item	Pack Format	s/i	bits	cum bits	Unit	Description	hex	binary	decimal	2s comp
103	i10	i	10	1584	kilowatts; or n/a	transmitter power; or ramp number		0000000000	0	
104	i24	i	24	1608	0.01 RU	ranging equipment delay	000000		0	
105	s12	s	12	1620	0.1 dB	range or DRVID power/noise ratio	000		0	
106	s4	s	4	1624		sign bits for item 107	0		0	
107	s32	s	32	1656	0.001 Hz; or 0.001 deg	average Doppler pseudo-residual; or OVLBI train axis (wedge) angle	00000000		0	
108	s4	s	4	1660		sign bits for item 109	0		0	
109	s32	s	32	1692	0.01 RU; or 10^-14	pseudo-DRVID; or delta frequency/frequency - I/P	00000000		0	
110	i4	i	4	1696		sign bits for item 111	0		0	
111	i32	i	32	1728	10^-14	deta frequency/frequency -- L/P	00000000		0	
112	S22	s	22	1750	0.01 ns	z-correction		0000000000000000000000	0	
113	i14	i	14	1764	nanoseconds	spacecraft delay		00000000000000	0	
114	i23	i	23	1787	0.01 RU	range or DRVID noise		00000000000000000000000	0	
115	i1	i	1	1788		DRVID good/bad indicator; or ranging assembly status indicator		0	0	
116	i1	i	1	1789		range or DRVID noise tolerance		0	0	
117	i1	i	1	1790		range or DRVID power/noise tolerance		0	0	
118	i10	i	10	1800		number of post acquisition DRVID points		0000000000	0	
119	i8	i	8	1808		ramp controller indicator; or cause of Allan deviation report generation	00		0	
120	s32	s	32	1840	10^-6 Hz/sec	programmed frequency ramp rate - H/P	00000000		0	
121	S32	s	32	1872	10^-6 Hz/s; or 2^-12 DB; or seconds	programmed frequency ramp rate - L/P; or received signal strength; or ranging transmitter coder in-phase time offset	fff6c7c0	11111111111101101100011111000000	4294363072	-604224
122	i4	i	4	1876		sign bits for item 123	0		0	
123	i32	i	32	1908	10^-6 Hz/s	programmed ramp start frequency - H/P	00000000		0	
124	i4	i	4	1912		sign bits for item 125	0		0	
125	i32	i	32	1944	10^-6 Hz/s	programmed ramp start frequency - L/P	00000000		0	
126	i1	i	1	1945		exciter frequency change flag		0	0	
127	i1	i	1	1946		receiver loop lock changed flag		0	0	
128	i1	i	1	1947		receiver frequency changed flag		0	0	
129	i1	i	1	1948		transmitter on/off changed flag		0	0	
130	i1	i	1	1949		station delay(s) change flag		0	0	
131	i1	i	1	1950		ramp rate/frequency changed flag		0	0	
132	i1	i	1	1951		ground mode changed flag		0	0	
133	i1	i	1	1952		highest/lowest ranging component changed flag		0	0	
134	i1	i	1	1953		sample year changed flag		0	0	
135	i1	i	1	1954		z-correction changed flag		0	0	
136	i1	i	1	1955		ramp record added flag		0	0	
137	i1	i	1	1956		Doppler good/bad indicator changed flag		0	0	
138	i1	i	1	1957		range good/had indicator changed flag		0	0	
139	i1	i	1	1958		angles good/bad indicator changed flag		0	0	
140	i28	i	28	1986	10^-6 Hz	transmitter/exciter reference frequency - H/P		0000000000000000000000000000	0	
141	i30	i	30	2016	10^-6 Hz	transmitter/exciter reference frequency - L/P		000000000000000000000000000000	0	
142	i32	i	32	2048		not used	00000000		0	
143	i32	i	32	2080		not used	00000000		0	
144	i32	i	32	2112		not used	00000000		0	
145	i32	i	32	2144		not used	00000000		0	
146	i32	i	32	2176		not used	00000000		0	
147	i32	i	32	2208		not used	00000000		0	
148	i32	i	32	2240		not used	00000000		0	
149	i32	i	32	2272		not used	00000000		0	
150	i32	i	32	2304		not used	00000000		0	
		Total bits	2304							
		Total Bytes	288							

A. Negative Values: There are 21 signed integers in record 4; they are shown in Table 4 with yellow highlighting. Only three have negative values.

(1) Item 74 is a 32-bit signed integer; interpreted as two's complement, its value is:

Doppler_pseudo-residual = -16047 mHz

since sample data type (item 12) has value '1' (high-rate Doppler).

(2) Item 89 is an 18-bit signed integer; after sign extension to 32 bits, two's complement interpretation, and assignment of "unit = 0.01 dBm" (from Table 3-3, row 89, column 3 in [3]), its value is:

received_signal_strength = -14.75 dBm

However, this value appears to be in error by a factor of 10 (see Appendix B, paragraph (2) of this document).

(3) Item 121 is a 32-bit signed integer; interpreted as two's complement, its value is:

programmed_frequency_ramp_rate = -0.604224 Hz/s

B. High Precision Decimal Values: There are H/P (high part), I/P (intermediate part), and/or L/P (low part) integers at items 30-32, 33-35, 43-44, 46-48, 49-51, 52-54, 55-57, 58-60, 61-63, 64-66, 67-69, 70-72, 120-121, 122-125, and 140-141. All are components of high precision quantities requiring more than 32 bits; most have non-zero values. The full values can be constructed by concatenating the digits as shown in Table 5 below. Application of 'unit' from column 3 in Table 3-3 of [3] provides the necessary scaling. Use of the expression following Table 3-3 [3] provides the wrong scaling (see Appendix B, paragraph (3)). An example of data plotted from the example file is shown in Figure 2.

Table 5. Construction of Numerical Values from H/P, I/P, and L/P Components

Items	Description	H/P	I/P	L/P	Value
30-32	No.1 Doppler count	16	4398198	1475000	1643981981.475
33-35	Range	0	0	0	0.0
43-44	Doppler reference frequency	217095		776000000	217095776.000
46-48	No. 2 Doppler count	16	4408218	2823000	1644082182.823
49-51	No. 3 Doppler count	16	4418238	4187000	1644182384.187
52-54	No. 4 Doppler count	16	4428258	5550000	1644282585.550
55-57	No. 5 Doppler count	16	4438278	6924000	1644382786.924
58-60	No. 6 Doppler count	16	4448298	8299000	1644482988.299
61-63	No. 7 Doppler count	16	4458318	9687000	1644583189.687
64-66	No. 8 Doppler count	16	4468339	1075000	1644683391.075
67-69	No. 9 Doppler count	16	4478359	2486000	1644783592.486
70-72	No. 10 Doppler count	16	4488379	3894000	1644883793.894
120-121	Programmed ramp rate	0		-604224	-0.604224
122-125	Programmed ramp start frequency	0		0	0.0
140-141	Transmit reference frequency	0		0	0.0

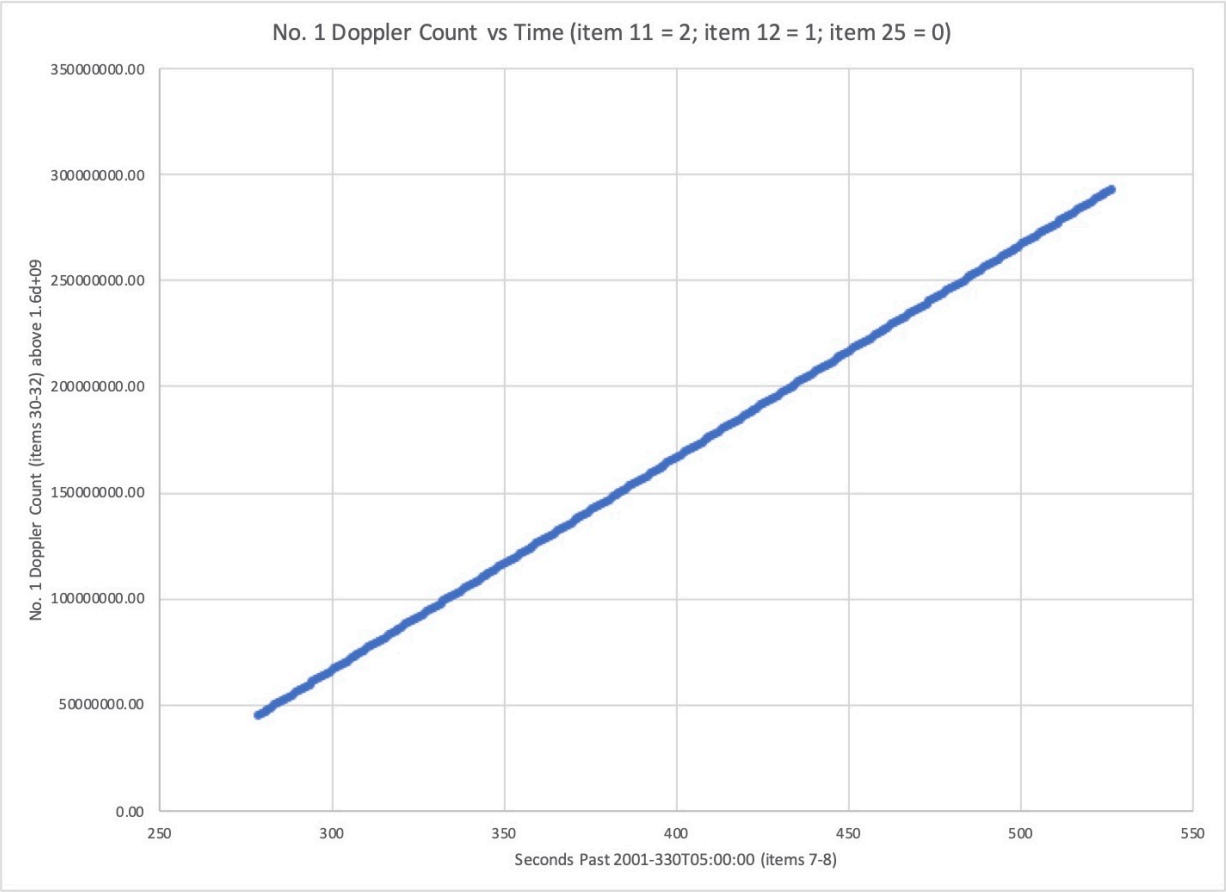

Figure 2. X-band No. 1 Doppler count from the example file plotted versus time from the example file.

C. High Precision Binary Values: The uplink_phase value is given in 4 parts (items 37-40), each having 24 bits. Whereas the "Value" in Table 5 is obtained by applying various powers of 10 to the H/P, I/P, and L/P components, the quadruple precision equation after Table 3-3 in [3] yields the final result using powers of 2 — the same result as concatenating the bits from the components into a 96-bit integer and interpreting the result in units of 2^{-32} cycles.

Other Sample Data Types:

Most records in the example data file *tdf01330.dat* contain high-rate Doppler measurements (item 12 = 1). Record 3 contains ramp data (item 12 = 6); that record is parsed in Table 3. There are two other sample data types in the example file.

Record 325 contains range data (item 12 = 5); the complete record contents are expanded below:

```
Input file tdf01330.dat:   record 325
  Item 001: Record format                                                    =          8
  Item 002: reserved0                                                        =          0
  Item 003: Record type                                                      =         90
  Item 004: Sample year, modulo 1900                                         =        101
  Item 005: Sample day-of-year                                               =        330
  Item 006: Sample hour                                                      =          5
  Item 007: Sample minute                                                    =          7
  Item 008: Sample second                                                    =         18
  Item 009: reserved31 (set to 0)                                            =          0
  Item 010: Receiving station ID number                                      =         25
  Item 011: Receiver/downlink frequency band                                 =          2
  Item 012: Sample data type ID                                              =          5
  Item 013: Doppler/phase channel number                                     =          0
  Item 014: Ground mode                                                      =          6
  Item 015: Spacecraft ID number                                             =         82
  Item 016: Range type                                                       =          7
  Item 017: Angles type                                                      =          0
  Item 018: DRVID type                                                       =          0
  Item 019: Doppler good/bad indicator                                       =          0
  Item 020: Doppler bias or overflow from Items 30-32 and 46-72              =       1000
  Item 021: Angles good/bad indicator                                        =          0
  Item 022: Frequency level indicator                                        =          1
  Item 023: Simulation synthesizer indicator                                 =          0
  Item 024: Receiver loop lock indicator                                     =          0
  Item 025: Transmitter on/off indicator                                     =          0
  Item 026: Doppler reference receiver type                                  =          5
  Item 027: Source designation/exciter type                                  =          4
  Item 028: No process flag and cause                                        =          0
  Item 029: Sample interval (0.01 seconds)                                   =          0
  Item 030: No. 1 Doppler count or downlink phase                        -  H/P =         18
  Item 031: No. 1 Doppler count or downlink phase                        -  I/P =     331138
  Item 032: No. 1 Doppler count or downlink phase                        -  L/P =    2755000
  Items 030-032: Double precision reconstruction                         =   1.803311382755000D+09
  Item 033: Range                                                            - H/P =          0
  Item 034: Range                                                            - I/P =    2970017
  Item 035: Range                                                            - L/P =    6000000
  Items 033-035: Double precision reconstruction (range units)           =   2.970017600000000D+07
  Item 036: Lowest (last) ranging component                                  =         19
  Item 037: Uplink phase - part 1                                            =          0
  Item 038: Uplink phase - part 2                                            =          0
  Item 039: Uplink phase - part 3                                            =          0
  Item 040: Uplink phase - part 4                                            =          0
  Items 037-040: Double precision reconstruction (truncated from real*8)    =   0.000000000000000D+00
  Item 041: Angle 1                                                          =          0
  Item 042: Angle 2                                                          =          0
  Item 043: Doppler reference/receiver frequency                             - H/P =    7205592
  Item 044: Doppler reference/receiver frequency                             - L/P =  128000000
  Items 043-044: Double precision reconstruction                         =   7.205592128000000D+09
  Item 045: DRVID                                                            =          0
  Item 046: No. 2 Doppler or downlink phase                                  - H/P =          0
  Item 047: No. 2 Doppler, D/L phase, 0.1-s Allan dev, or 0.1-s smoothed noise     - I/P =          0
  Item 048: No. 2 Doppler, D/L phase, 0.1-s Allan Dev, or 0.1-s smoothed noise     - L/P =       5718
  Items 046-048: Double precision reconstruction                         =   5.718000000000000D-03
  Item 049: No. 3 Doppler or downlink phase                                  - H/P =          0
  Item 050: No. 3 Doppler, D/L phase, 1.0-s Allan Dev, or 1.0-s smoothed noise     - I/P =          0
  Item 051: No. 3 Doppler, D/L phase, EoRAT, 1.0-s Allan Dev, 1.0-s smoothed noise - L/P =      18737
  Items 049-051: Double precision reconstruction                         =   1.873700000000000D-02
  Item 052: No. 4 Doppler or downlink phase                                  - H/P =          0
  Item 053: No. 4 Doppler, D/L phase, 10-s Allan Dev, or 10-s smoothed noise       - I/P =          0
  Item 054: No. 4 Dop, D/L phase, T1 integ, 10-s Allan Dev, or 10-s smoothed noise - L/P =         57
  Items 052-054: Double precision reconstruction                         =   5.700000000000000D-05
  Item 055: No. 5 Doppler or downlink phase                                  - H/P =          0
  Item 056: No. 5 Doppler, downlink phase, 100-s Allan Dev, or 100-s smoothed noise- I/P =          0
  Item 057: No. 5 Dopp, D/L phase, T2 integ, 100-s Allan Dev, or 100-smoothed noise-L/P  =         15
```

```
Items 055-057: Double precision reconstruction                          =   1.500000000000000D-05
Item 058: No. 6 Doppler or downlink phase                                  - H/P =           0
Item 059: No. 6 Doppler, downlink phase, 1000-s Allan Dev, or 200-s smoothed noise-I/P =           0
Item 060: No. 6 Dopp, D/L phase, T3 integ, 1000-s AD, or 200-s smoothed noise    - L/P =           0
Items 058-060: Double precision reconstruction                          =   0.000000000000000D+00
Item 061: No. 7 Doppler or downlink phase                                  - H/P =           0
Item 062: No. 7 Doppler, downlink phase, or 600-s smoothed noise           - I/P =           0
Item 063: No. 7 Dopp, D/L phase, ref (0-deg) corr voltage, or 600-s smoothed noise-L/P =           0
Items 061-063: Double precision reconstruction                          =   0.000000000000000D+00
Item 064: No. 8 Doppler or downlink phase                                  - H/P =           0
Item 065: No. 8 Doppler or downlink phase                                  - I/P =           0
Item 066: No. 8 Doppler, downlink phase, or quadrature (90-deg) corr voltage     - L/P =           0
Items 064-066: Double precision reconstruction                          =   0.000000000000000D+00
Item 067: No. 9 Doppler or downlink phase                                  - H/P =           0
Item 068: No. 9 Doppler or downlink phase                                  - I/P =           0
Item 069: No. 9 Doppler, downlink phase, or carrier suppression            - L/P =           3
Items 067-069: Double precision reconstruction                          =   3.000000000000000D-06
Item 070: No. 10 Doppler or downlink phase                                 - H/P =           0
Item 071: No. 10 Doppler or downlink phase                                 - I/P =           0
Item 072: No. 10 Doppler, downlink phase or highest (first) ranging component    - L/P =           4
Items 070-072: Double precision reconstruction                          =   4.000000000000000D-06
Item 073: Sign bits for item 074                                                  =           0
Item 074: Doppler or D/L phase residual                                           =           0
Item 075: Sign bits for item 076                                                  =           0
Item 076: Range pseudo-residual (0.001 range units)                               =     2097151
Item 077: Angle 1 pseudo-residual or numerator for spacecraft turnaround ratio    =         880
Item 078: Angle 2 pseudo-residual or denominator for spacecraft turnaround ratio  =         749
Item 079: Exciter/uplink frequency band and input network/source ID               =           3
Item 080: Angle mode                                                              =           0
Item 081: Conscan mode                                                            =           0
Item 082: Angle 1 pseudo-residual tolerance                                       =           0
Item 083: Angle 2 pseudo-residual tolerance                                       =           0
Item 084: Doppler downlink phase pseudo-residual tolerance                        =           0
Item 085: Doppler noise tolerance                                                 =           0
Item 086: Percent data used for Allan Deviation, or Item 104 overflow             =           0
Item 087: Total slipped cycles during count                                       =           0
Item 088: Doppler noise                                                           =           0
Item 089: Received signal strength                                                =           0
Item 090: Exciter station delay                                                   =       77000
Item 091: Receiver station delay                                                  =       77000
Item 092: Range modulation on/off                                                 =           1
Item 093: Prime ranging channel                                                   =           0
Item 094: Pipelining on/off                                                       =           0
Item 095: Chopper frequency on/off                                                =           0
Item 096: Range good/bad indicator                                                =           0
Item 097: Range calibration tolerance                                             =           0
Item 098: Range configuration change                                              =           0
Item 099: Range pseudo-residual tolerance                                         =           0
Item 100: Pseudo-DRVID tolerance                                                  =           0
Item 101: Amplifier type or ramp number                                           =           0
Item 102: Transmitter low power indicator                                         =           0
Item 103: Transmitter power or ramp number                                        =           3
Item 104: Ranging equipment delay (0.01 range units)                              =     1160350
Item 105: Range or DRVID power/noise ratio (0.1 dB)                               =         161
Item 106: Sign bits for item 107                                                  =          15
Item 107: Average Doppler pseudo-residual or OVLBI train axis (wedge) angle       =      -16043
Item 108: Sign bits for item 109                                                  =           0
Item 109: Pseudo DRVID or delta-frequency/frequency                        - I/P =         131
Item 110: Sign bits for item 111                                                  =           0
Item 111: Delta-frequency/frequency                                        - L/P =           0
Item 112: Z-correction                                                            =      -27029
Item 113: Spacecraft delay                                                        =         420
Item 114: Range or DRVID noise (0.01 range units)                                 =        6150
Item 115: DRVID good/bad or range assembly status                                 =           0
Item 116: Range or DRVID noise tolerance                                          =           0
Item 117: Range or DRVID power/noise tolerance                                    =           0
Item 118: Number of post acquisition DRVID points                                 =           0
Item 119: Ramp controller indicator                                               =           0
Item 120: Programmed frequency ramp rate                                   - H/P =           0
Item 121: Ramp rate (L/P), rcvd sig strength, or ranging tx coder in-phase time offset =        7220
Items 120-121: Double precision reconstruction                          =   7.220000000000000D-03
Item 122: Sign bits for item 123                                                  =           0
Item 123: Programmed ramp start frequency                                  - H/P =           0
Item 124: Sign bits for item 125                                                  =           0
Item 125: Programmed ramp start frequency                                  - L/P =           0
Items 122-125: Programmed ramp start frequency                          =   0.000000000000000D+00
Item 126: Exciter frequency changed flag                                          =           0
Item 127: Receiver loop lock changed flag                                         =           0
```

```
Item 128: Receiver frequency changed flag                                  =          0
Item 129: Transmitter on/off changed flag                                  =          0
Item 130: Station delay(s) changed flag                                    =          0
Item 131: Ramp rate/frequency changed flag                                 =          0
Item 132: Ground mode changed flag                                         =          0
Item 133: Hi/lo ranging component changed flag                             =          0
Item 134: Sample year changed flag                                         =          0
Item 135: Z-correction changed flag                                        =          0
Item 136: Ramp record added flag                                           =          0
Item 137: Doppler good/bad indicator change flag                           =          0
Item 138: Range good/bad indicator changed flag                            =          0
Item 139: Angles good/bad indicator changed flag                           =          0
Item 140: Transmitter/exciter reference frequency                    - H/P =          0
Item 141: Transmitter/exciter reference frequency                    - L/P =          0
Items 140-141: Double precision reconstruction                       =   0.000000000000000D+00
```

Record 512 contains Allan Deviation or Smoothed Noise data (item 12 = 8); the complete record contents are expanded below:

```
Input file tdf01330.dat:   record 512
  Item 001: Record format                                                    =          8
  Item 002: reserved0                                                        =          0
  Item 003: Record type                                                      =         90
  Item 004: Sample year, modulo 1900                                         =        101
  Item 005: Sample day-of-year                                               =        330
  Item 006: Sample hour                                                      =         15
  Item 007: Sample minute                                                    =         20
  Item 008: Sample second                                                    =         20
  Item 009: reserved31 (set to 0)                                            =          0
  Item 010: Receiving station ID number                                      =         45
  Item 011: Receiver/downlink frequency band                                 =          2
  Item 012: Sample data type ID                                              =          8
  Item 013: Doppler/phase channel number                                     =          0
  Item 014: Ground mode                                                      =          7
  Item 015: Spacecraft ID number                                             =         82
  Item 016: Range type                                                       =          0
  Item 017: Angles type                                                      =          0
  Item 018: DRVID type                                                       =          0
  Item 019: Doppler good/bad indicator                                       =          0
  Item 020: Doppler bias or overflow from Items 30-32 and 46-72              =          0
  Item 021: Angles good/bad indicator                                        =          0
  Item 022: Frequency level indicator                                        =          0
  Item 023: Simulation synthesizer indicator                                 =          0
  Item 024: Receiver loop lock indicator                                     =          0
  Item 025: Transmitter on/off indicator                                     =          0
  Item 026: Doppler reference receiver type                                  =          2
  Item 027: Source designation/exciter type                                  =          4
  Item 028: No process flag and cause                                        =          0
  Item 029: Sample interval (0.01 seconds)                                   =     323900
  Item 030: No. 1 Doppler count or downlink phase                        -  H/P =          0
  Item 031: No. 1 Doppler count or downlink phase                        -  I/P =          0
  Item 032: No. 1 Doppler count or downlink phase                        -  L/P =          0
  Items 030-032: Double precision reconstruction                 =   0.0000000000000000D+00
  Item 033: Range                                                        - H/P =          0
  Item 034: Range                                                        - I/P =          0
  Item 035: Range                                                        - L/P =          0
  Items 033-035: Double precision reconstruction                 =   0.0000000000000000D+00
  Item 036: Lowest (last) ranging component                                  =          0
  Item 037: Uplink phase - part 1                                            =          0
  Item 038: Uplink phase - part 2                                            =          0
  Item 039: Uplink phase - part 3                                            =          0
  Item 040: Uplink phase - part 4                                            =          0
  Items 037-040: Double precision reconstruction (truncated from real*8)    =   0.0000000000000000D+00
  Item 041: Angle 1                                                          =          0
  Item 042: Angle 2                                                          =          0
  Item 043: Doppler reference/receiver frequency                         - H/P =          0
  Item 044: Doppler reference/receiver frequency                         - L/P =          0
  Items 043-044: Double precision reconstruction                 =   0.0000000000000000D+00
  Item 045: DRVID                                                            =          0
  Item 046: No. 2 Doppler or downlink phase                              - H/P =          0
  Item 047: No. 2 Doppler, D/L phase, 0.1-s Allan dev, or 0.1-s smoothed noise     - I/P =          0
  Item 048: No. 2 Doppler, D/L phase, 0.1-s Allan Dev, or 0.1-s smoothed noise     - L/P =      40813
  Items 046-048: Double precision reconstruction                 =   4.0813000000000000D-02
  Item 049: No. 3 Doppler or downlink phase                              - H/P =          0
  Item 050: No. 3 Doppler, D/L phase, 1.0-s Allan Dev, or 1.0-s smoothed noise     - I/P =          0
  Item 051: No. 3 Doppler, D/L phase, EoRAT, 1.0-s Allan Dev, 1.0-s smoothed noise - L/P =       9476
  Items 049-051: Double precision reconstruction                 =   9.4760000000000000D-03
  Item 052: No. 4 Doppler or downlink phase                              - H/P =          0
  Item 053: No. 4 Doppler, D/L phase, 10-s Allan Dev, or 10-s smoothed noise       - I/P =          0
  Item 054: No. 4 Dop, D/L phase, T1 integ, 10-s Allan Dev, or 10-s smoothed noise - L/P =       1839
  Items 052-054: Double precision reconstruction                 =   1.8390000000000000D-03
  Item 055: No. 5 Doppler or downlink phase                              - H/P =          0
  Item 056: No. 5 Doppler, downlink phase, 100-s Allan Dev, or 100-s smoothed noise- I/P =          0
  Item 057: No. 5 Dopp, D/L phase, T2 integ, 100-s Allan Dev, or 100-smoothed noise-L/P  =       1103
  Items 055-057: Double precision reconstruction                 =   1.1030000000000000D-03
  Item 058: No. 6 Doppler or downlink phase                              - H/P =          0
  Item 059: No. 6 Doppler, downlink phase, 1000-s Allan Dev, or 200-s smoothed noise-I/P =          0
  Item 060: No. 6 Dopp, D/L phase, T3 integ, 1000-s AD, or 200-s smoothed noise    - L/P =          0
  Items 058-060: Double precision reconstruction                 =   0.0000000000000000D+00
  Item 061: No. 7 Doppler or downlink phase                              - H/P =          0
  Item 062: No. 7 Doppler, downlink phase, or 600-s smoothed noise               - I/P =          0
  Item 063: No. 7 Dopp, D/L phase, ref (0-deg) corr voltage, or 600-s smoothed noise-L/P =          0
```

```
Items 061-063: Double precision reconstruction                          =   0.000000000000000D+00
Item 064: No. 8 Doppler or downlink phase                                  - H/P =           0
Item 065: No. 8 Doppler or downlink phase                                  - I/P =           0
Item 066: No. 8 Doppler, downlink phase, or quadrature (90-deg) corr voltage  - L/P =        0
Items 064-066: Double precision reconstruction                          =   0.000000000000000D+00
Item 067: No. 9 Doppler or downlink phase                                  - H/P =           0
Item 068: No. 9 Doppler or downlink phase                                  - I/P =           0
Item 069: No. 9 Doppler, downlink phase, or carrier suppression            - L/P =           0
Items 067-069: Double precision reconstruction                          =   0.000000000000000D+00
Item 070: No. 10 Doppler or downlink phase                                 - H/P =           0
Item 071: No. 10 Doppler or downlink phase                                 - I/P =           0
Item 072: No. 10 Doppler, downlink phase or highest (first) ranging component  - L/P =       0
Items 070-072: Double precision reconstruction                          =   0.000000000000000D+00
Item 073: Sign bits for item 074                                                =           0
Item 074: Doppler or D/L phase residual                                         =           0
Item 075: Sign bits for item 076                                                =           0
Item 076: Range pseudo-residual                                                 =           0
Item 077: Angle 1 pseudo-residual or numerator for spacecraft turnaround ratio  =           0
Item 078: Angle 2 pseudo-residual or denominator for spacecraft turnaround ratio =          0
Item 079: Exciter/uplink frequency band and input network/source ID             =           2
Item 080: Angle mode                                                            =           0
Item 081: Conscan mode                                                          =           0
Item 082: Angle 1 pseudo-residual tolerance                                     =           0
Item 083: Angle 2 pseudo-residual tolerance                                     =           0
Item 084: Doppler downlink phase pseudo-residual tolerance                      =           0
Item 085: Doppler noise tolerance                                               =           0
Item 086: Percent data used for Allan Deviation, or Item 104 overflow           =         100
Item 087: Total slipped cycles during count                                     =           0
Item 088: Doppler noise                                                         =           0
Item 089: Received signal strength                                              =           0
Item 090: Exciter station delay                                                 =           0
Item 091: Receiver station delay                                                =           0
Item 092: Range modulation on/off                                               =           0
Item 093: Prime ranging channel                                                 =           0
Item 094: Pipelining on/off                                                     =           0
Item 095: Chopper frequency on/off                                              =           0
Item 096: Range good/bad indicator                                              =           0
Item 097: Range calibration tolerance                                           =           0
Item 098: Range configuration change                                            =           0
Item 099: Range pseudo-residual tolerance                                       =           0
Item 100: Pseudo-DRVID tolerance                                                =           0
Item 101: Amplifier type or ramp number                                         =           0
Item 102: Transmitter low power indicator                                       =           0
Item 103: Transmitter power or ramp number                                      =           0
Item 104: Ranging equipment delay                                               =           0
Item 105: Range or DRVID power/noise ratio                                      =           0
Item 106: Sign bits for item 107                                                =           0
Item 107: Average Doppler pseudo-residual or OVLBI train axis (wedge) angle     =           0
Item 108: Sign bits for item 109                                                =           0
Item 109: Pseudo DRVID or delta-frequency/frequency                        - I/P =          0
Item 110: Sign bits for item 111                                                =           0
Item 111: Delta-frequency/frequency                                        - L/P =          0
Item 112: Z-correction                                                          =           0
Item 113: Spacecraft delay                                                      =           0
Item 114: Range or DRVID noise                                                  =           0
Item 115: DRVID good/bad or range assembly status                               =           0
Item 116: Range or DRVID noise tolerance                                        =           0
Item 117: Range or DRVID power/noise tolerance                                  =           0
Item 118: Number of post acquisition DRVID points                               =           0
Item 119: Ramp controller indicator                                             =           3
Item 120: Programmed frequency ramp rate                                   - H/P =          3
Item 121: Ramp rate (L/P), rcvd sig strength, or ranging tx coder in-phase time offset =   0
Items 120-121: Double precision reconstruction                          =   3.000000000000000D+03
Item 122: Sign bits for item 123                                                =           0
Item 123: Programmed ramp start frequency                                  - H/P =          0
Item 124: Sign bits for item 125                                                =           0
Item 125: Programmed ramp start frequency                                  - L/P =          0
Items 122-125: Programmed ramp start frequency                          =   0.000000000000000D+00
Item 126: Exciter frequency changed flag                                        =           0
Item 127: Receiver loop lock changed flag                                       =           0
Item 128: Receiver frequency changed flag                                       =           0
Item 129: Transmitter on/off changed flag                                       =           0
Item 130: Station delay(s) changed flag                                         =           0
Item 131: Ramp rate/frequency changed flag                                      =           0
Item 132: Ground mode changed flag                                              =           0
Item 133: Hi/lo ranging component changed flag                                  =           0
Item 134: Sample year changed flag                                              =           0
Item 135: Z-correction changed flag                                             =           0
```

```
Item 136: Ramp record added flag                                        =          0
Item 137: Doppler good/bad indicator change flag                        =          0
Item 138: Range good/bad indicator changed flag                         =          0
Item 139: Angles good/bad indicator changed flag                        =          0
Item 140: Transmitter/exciter reference frequency                 - H/P =          0
Item 141: Transmitter/exciter reference frequency                 - L/P =          0
Items 140-141: Double precision reconstruction                  =   0.000000000000000D+00
```

Appendix A -Early Formats

Documentation describing an early version of the TDF, prepared for the Voyager Radio Science Team and dated 1997-05-19, is also included in the PDS Radio Science Documentation (RSD) bundle.

[4] *Multi-Mission Tracking Software Subsystem, Tracking Intermediate Data Record Processor/Orbit Data Editor Interface*; original dated 1977-01-20, revision 1 dated 1977-05-19.

The format is recognizable as being ATDF/TDF; each record has 288 bytes, but contents are slightly different as compared with [1-3]. There is little information on units for the various quantities in [4].

The ATDF File Identification Logical Record is described in Table 6 below (compare with Table 0 at the beginning of this document)[#].

Software expecting to find file creation year (modulo 1900) at item 004 in a recent ATDF, will find the characters 'TR' instead (decimal '855') in the same bits, making identification of the older format straightforward.

The older format allows for an ATDF Pass Summary Logical Record (record_type = 20), which does not appear in recent ATDFs. The ATDF Transmitter Logical Record format includes both Spacecraft Transponder Records (record_type = 30) and Station Transmitter Records (record_type = 31).

An example of the earlier format has been included in the PDS RSD bundle. Its logical identifier (LID) is

urn:nasa:pds:radiosci_documentation:dsn_trk-2-25:tdf79212

The label for this product was constructed by hand; it has not been extensively tested, so there may be errors.

[#] More information on the digital character set may be found in the Univac section at https://en.wikipedia.org/wiki/Fieldata

Table 6. ATDF File Identification Logical Record (1977)					
Item[β]	Pack Format	s/i	Bits	Cum Bits	Description
1	I32	I	32	32	record format (set to decimal ‘0’)
2	I8	I	8	40	reserved (set to decimal ‘128’)
4	I32	I	32	72	record type (set to decimal ‘10’)
5	I6	I	6	78	character (set to decimal ’25’ = character ‘T’)
6	I6	I	6	84	character (set to decimal ‘23’ = character ‘R’)
7	I6	I	6	90	character (set to decimal ‘06’ = character ‘A’
8	I6	I	6	96	character (set to decimal ‘08’ = character ‘C’)
9	I6	I	6	102	character (set to decimal ‘16’ = character ‘K’)
10	I6	I	6	108	character (set to decimal ‘14’ = character ‘I’)
11	I6	I	6	114	character (set to decimal ‘19’ = character ‘N’)
12	I6	I	6	120	character (set to decimal ‘12’= character ‘G’)
13	I6	I	6	126	character (set to decimal ‘05’ = character ‘ ’)
14	I6	I	6	132	character (set to decimal ‘09’ = character ‘D’)
15	I6	I	6	138	character (set to decimal ‘06’ = character ‘A’)
16	I6	I	6	144	character (set to decimal ‘25’ = character ‘T’)
17	I6	I	6	150	character (set to decimal ‘06’ = character ‘A’)
18	I6	I	6	156	character (set to decimal ‘05’ = character ‘ ’)
19	I6	I	6	162	character (set to decimal ‘11’ = character ‘F’)
20	I6	I	6	168	character (set to decimal ‘14’ = character ‘I’)
21	I6	I	6	174	character (set to decimal ‘17’ = character ‘L’)
22	I6	I	6	180	character (set to decimal ‘10’ = character ‘E’)
23	I6	I	6	186	character (set to decimal ‘05’ = character ‘ ’)
24	I6	I	6	192	character (set to decimal ‘14’ = character ‘I’)
25	I6	I	6	198	character (set to decimal ‘09’ = character ‘D’)
26	I6	I	6	204	character (set to decimal ‘23’ = character ‘R’)
27	I6	I	6	210	character (set to decimal ‘05’ = character ‘ ’)
28	I6	I	6	216	character (set to decimal ‘05’ = character ‘ ’)
29	I20	I	20	236	reserved (set to ‘0’)
30	I16	I	16	252	spacecraft ID number
32	I12	I	12	264	file creation year modulo 1900
33	I16	I	16	280	file creation day-of-year
34	I8	I	8	288	file creation hour
36	I12	I	12	300	file creation minute
37	I8	I	8	308	file creation second
38	I16	I	16	324	reserved (set to ‘0’)
			1980	2304	not used (set to ‘0’)

[β] Item numbers are from [4]. Where values are set to 0 in data records, they may have been combined with nearby items.

Appendix B — Errors in TRK-2-25 Documentation

The following corrections apply to [1-3], listed at the beginning of this document.

(1) The stated 'unit' for items 123 and 125 in Table 3-3 is '10^{-6} Hz/s'; this is incorrect. The quantity is 'programmed ramp start frequency', which should have units of Hz, not Hz/s.

(2) The stated 'unit' for item 89 in Table 3-3 is '0.01 dBm', which appears to be incorrect. Noise power density for a receiver with system temperature Tsys = 30K is -183.85 dBm. Typical carrier-to-noise ratio for a spacecraft like Cassini would be ~40 dB, equivalent to a spacecraft signal level of about -143.85 dBm. The value from the example file is -14.75 dBm (Table 4b, item 89). The correct unit for item 89 should be '0.1 dBm'.

(3) Values derived using expressions after Table 3-3 are not correct when used in conjunction with the 'unit' values listed in Table 3-3. Corrected expressions following Table 3-3 appear to be:

* double precision variable = $(H/P)*10^{14} + (I/P)*10^{7} + (L/P)$ if Doppler, downlink phase, or range

= $(I/P)*10^{7} + (L/P)$ if delta frequency/frequency

** double precision variable = $(H/P)*10^{9} + (L/P)$ if ramp frequency or rate, or reference frequency

*** quadruple precision phase = {part 1)$*2^{72}$ + (part 2)$*2^{48}$ + (part 3)$*2^{24}$ + (part 4) if uplink phase