Interpretation and Use of Binary REDR Data

This document describes and illustrates extraction of values from binary files generated according to the NASA Deep Space Network (DSN) REDR Software Interface Specification (SIS). The REDR SIS is one of several documents that describe open loop radio science raw data products created over about two decades starting in the late 1970s.

The REDR SIS describes the format and content of the most important open loop radio science files generated during the Voyager 1 and 2 encounters with Jupiter. These data were written to tape from analog-to-digital converters operating at 10 ksps. One A/D converter sampled the S-RCP receiver output sequentially, and three A/D converters sampled the X-RCP receiver output.

File and Record Formats:

Each REDR record comprises 12 bytes of header data followed by 200 16-bit samples from each of the four A/D converters (1600 bytes total), followed by 80 bytes of trailer data — totaling 1692 bytes, or 13536 bits (Table 1). A hexadecimal dump of one record from an example REDR file is shown in Figure 1. It was created using the unix-like command

```
od -t x1 vc134.dat +0. | head -106
```

Bytes in Figure 1 are shown in the physical order in which they appear in the file; they must be interpreted in that same order — most significant byte (MSB) first. Most modern computers (c. 2021) write, and expect to read, the least significant byte (LSB) first if the data are read into 2-, 4-, or 8-byte words, reversing the physical order. Reading the data into a byte array will preserve the original order.

The REDR SIS states that "all words are integer, right-hand justified, zero filled if unsigned or positive, and one filled if signed." Although this statement is correct for the header and trailer, it is incorrect for the A/D sample values. All of the even-numbered bytes in Figure 1 have value "00" suggesting that the 8-bit samples were stored in the more significant byte and the less significant byte was not used[1]. The sample value in the more significant byte is twos complement.

Example Data File:

Header and Trailer Values: The header and trailer from the first record have been unpacked in Table 2. Asterisks (*) in the right column denote status flag values. In the nine records which follow, nothing changes in the Header or Trailer except the "record second" value (bytes 6-7). In the first record it is 0, in the second record it is 2, … in the tenth record it is 18 meaning that the time tag for the ten records in the example file increases from 0.00 to 0.18 seconds in steps of 0.02 second. With 200 samples per A/D per record, the file will have captured 10000 S-band samples and 30000 X-band samples after one second.

Sample Values: Figure 1 shows the first 17 sample values (in hexadecimal); the S-band samples have been highlighted in yellow, the X-band samples in green:

```
dc  dc  f0  02  fe  d0  d9  f6  0d  ec  c5  df  ef  f8  f5  e4  dc  ...
```

[1] If 12-bit REDR files are discovered, this correction will have to be re-visited.

In decimal these are:

220 220 240 2 254 208 217 246 13 236 197 223 239 248 245 228 220 ...

Converting to twos complement gives:

-35 -35 -16 2 -2 -48 -39 -10 13 -20 -59 -33 -17 -8 -11 -28 -36 ...

And separating into S- and X-band streams:

S-band: -35 -2 13 -17 -36 ...

X-band: -35 -16 2 -48 -39 -10 -20 -59 -33 -8 -11 -28 ...

The results are shown in Figure 2. Both sample streams have a negative average value: -8.5 for the S-band values, -10.9 for the X-band values.

Table 1. REDR LOGICAL RECORDS FORMAT

Item Number	Bit Number	Length (Bits)	IBM Word	Description
1	1-8	8	1	Last Two Digits of Record Year
2	9-24	16		Record Day-of-Year
3	25-32	8		Record Hour
4	33-40	8	2	Record Minute
5	41-56	16		Record Second (times 100)
6	57-64	8		Data Validity Flag 0 = Good 1 = Bad
7	65-96	32	3	Sample Rate
8	97-112	16	4	1st AD-1 Sample (two's complement)
9	113-128	16		1st AD-2 Sample (two's complement)
10	129-144	16	5	1st AD-3 Sample (two's complement)
11	145-160	16		1st AD-4 Sample (two's complement)
12	161-176	16	6	2nd AD-1 Sample (two's complement)
13	177-192	16		2nd AD-2 Sample (two's complement)
14	193-208	16	7	2nd AD-3 Sample (two's complement)
15	209-224	16		2nd AD-4 Sample (two's complement)
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
804	12833-12848	16	402	200th AD-1 Sample (two's complement)
805	12849-12864	16		200th AD-2 Sample (two's complement)
806	12865-12880	16	403	200th AD-3 Sample (two's complement)
807	12881-12896	16		200th AD-4 Sample (two's complement)
808	12897-12898	2	404	AD-1 Receiver Number 0 = Receiver Number 1 1 = Receiver Number 2 2 = Receiver Number 3 3 = Receiver Number 4
809	12899-12900	2		AD-2 Receiver Number (0, 1, 2, or 3)
810	12901-12902	2		AD-3 Receiver Number (0, 1, 2, or 3)
811	12903-12904	2		AD-4 Receiver Number (0, 1, 2, or 3)
812	12905-12906	2		Receiver Number 1 Mode 0 = Not In Use 1 = S-Band 2 = X-Band.
813	12907-12908	2		Receiver Number 2 Mode (0, 1, or 2)
814	12909-12910	2		Receiver Number 3 Mode (0, 1, or 2)
815	12911-12912	2		Receiver Number 4 Mode (0, 1, or 2)
816	12913-12920	8		Receiver Number 1 Filter (0 to 127)
817	12921-12928	8		Receiver Number 2 Filter (0 to 127)
818	12929-12936	8	405	Receiver Number 3 Filter (0 to 127)
819	12937-12944	8		Receiver Number 4 Filter (0 to 127)
820	12945-12960	16		} Commanded Frequency - H/P*
	12961-12968	8	406	
821	12969-12992	24		Commanded Frequency - L/P*

* H/P = High Part = Variable / 10
L/P = Low Part = (Variable modulo 10) x 10^6

Table 1. REDR LOGICAL RECORDS FORMAT (cont'd)

Item Number	Bit Number	Length (Bits)	IBM Word	Description
822	12993-13016	24	407	Synthesizer Count - H/P*
823	13017-13024	8	408	Synthesizer Count - L/P*
	13025-13040	16		
824	13041-13056	16	409	Ramp Start Frequency - H/P*
	13057-13064	8		
825	13065-13088	24		Ramp Start,Frequency - L/P*
826	13089-13120	32	410	POCA Sweep Rate (two's comp. x 10^5)
827	13121-13128	8	411	POCA Status (see 820-13, RSC-11-3)
828	13129-13152	24		Time Offset (nanoseconds)#
829	13153-13184	32	412	HSDB Sample Size (8 or 12 bits)
830	13185-13216	32	413	0 (not used)
831	13217-13248	32	414	0 (not used)
832	13249-13280	32	415	0 (not used)
833	13281-13312	32	416	0 (not used)
834	13313-13344	32	417	0 (not used)
835	13345-13352	8	418	Last Two Digits of File Creation Year
836	13353-13368	16		File Creation Day-of-Year
837	13369-13376	8		File Creation Hour
838	13377-13384	8	419	File Creation Minute
839	13385-13392	8		File Creation Second
840	13393-13400	8		File Spacecraft ID Number
841	13401-13408	8		File Station Number
842	13409-13416	8	420	Last Two Digits of File Start Year
843	13417-13432	16		File Start Day-of-Year
844	13433-13440	8		File Start Hour
845	13441-13448	8	421	File Start Minute
846	13449-13456	8		File Start Second
847	13457-13464	8		Last Two Digits of File Stop Year
848	13465-13472	8	422	File Stop Day-of-Year
	13473-13480	8		
849	13481-13488	8		File Stop Hour
850	13489-13496	8		File Stop Minute
851	13497-13504	8		File Stop Second
852	13505-13512	8	423	1st PREDIK Set ID ASCII Character
853	13513-13520	8		2nd PREDIK Set ID ASCII Character
854	13521-13528	8		3rd PREDIK Set ID ASCII Character
855	13529-13536	8		4th PREDIK Set ID ASCII Character

Time Offset = [1 / (20 x Sample Rate)] x 10^9 + 460 nanoseconds

0000000	4f	00	40	10	03	00	00	00	00	00	27	10	dc	00	dc	00
0000016	f0	00	02	00	fe	00	d0	00	d9	00	f6	00	0d	00	ec	00
0000032	c5	00	df	00	ef	00	f8	00	f5	00	e4	00	dc	00	06	00
0000048	07	00	ee	00	04	00	e8	00	ef	00	ef	00	3b	00	f3	00
0000064	e8	00	02	00	1a	00	fa	00	ea	00	ea	00	d4	00	f9	00
0000080	fe	00	e2	00	c8	00	e2	00	15	00	fd	00	e8	00	02	00
0000096	da	00	fa	00	07	00	fe	00	fa	00	ff	00	ef	00	f4	00
0000112	e6	00	0e	00	d7	00	01	00	fa	00	fd	00	fb	00	e5	00
0000128	f9	00	dd	00	10	00	e7	00	e8	00	04	00	0f	00	f8	00
0000144	fb	00	ec	00	f7	00	04	00	ef	00	03	00	cc	00	f3	00
0000160	e1	00	f2	00	e1	00	e8	00	09	00	f4	00	21	00	f3	00
0000176	fc	00	f5	00	fd	00	ea	00	06	00	01	00	e1	00	e8	00
0000192	f0	00	03	00	dd	00	22	00	fb	00	f6	00	fc	00	fe	00
0000208	f4	00	e7	00	2c	00	df	00	f6	00	e5	00	f6	00	e0	00
0000224	03	00	00	00	d0	00	fa	00	e4	00	03	00	f8	00	0f	00
0000240	ed	00	e4	00	0d	00	10	00	ee	00	01	00	15	00	fd	00
0000256	e7	00	f0	00	de	00	d7	00	f3	00	00	00	e9	00	f6	00
0000272	e6	00	f6	00	14	00	0c	00	ee	00	f1	00	1d	00	f2	00
0000288	07	00	f3	00	02	00	e6	00	01	00	fa	00	c8	00	db	00
0000304	f6	00	19	00	d8	00	04	00	ef	00	05	00	13	00	f7	00
0000320	0c	00	fa	00	0a	00	24	00	f4	00	f8	00	e7	00	f5	00
0000336	ee	00	f6	00	e9	00	f2	00	ed	00	f8	00	0a	00	f2	00
0000352	ec	00	ed	00	1b	00	fe	00	ec	00	fe	00	02	00	00	00
0000368	0b	00	ea	00	d6	00	d8	00	06	00	07	00	e7	00	d5	00
0000384	fb	00	03	00	0a	00	e9	00	e5	00	0b	00	0e	00	14	00
0000400	ed	00	ea	00	08	00	ea	00	06	00	00	00	e6	00	ee	00
0000416	f7	00	eb	00	df	00	ea	00	f5	00	03	00	1d	00	e7	00
0000432	ef	00	f1	00	fd	00	f0	00	ee	00	ff	00	c6	00	fb	00
0000448	f3	00	e0	00	e5	00	ec	00	08	00	ee	00	19	00	e4	00
0000464	02	00	08	00	27	00	e8	00	d5	00	ff	00	f9	00	f3	00
0000480	f1	00	e7	00	d8	00	f9	00	f6	00	f1	00	f5	00	f6	00
0000496	03	00	f9	00	2d	00	f2	00	fe	00	0c	00	17	00	d8	00
0000512	e4	00	e3	00	d9	00	fc	00	07	00	e1	00	e1	00	ed	00
0000528	ff	00	f5	00	01	00	fd	00	ff	00	fc	00	f6	00	d9	00
0000544	f0	00	fd	00	08	00	f3	00	e8	00	fa	00	d9	00	f8	00
0000560	e9	00	e5	00	d6	00	fe	00	ef	00	ee	00	1f	00	f6	00
0000576	19	00	f2	00	14	00	e5	00	fa	00	04	00	f6	00	e8	00
0000592	f4	00	07	00	db	00	fc	00	ff	00	00	00	dd	00	05	00
0000608	fc	00	e2	00	22	00	e9	00	f4	00	f7	00	ec	00	e6	00
0000624	0e	00	0a	00	ae	00	f4	00	f7	00	fa	00	fc	00	f6	00
0000640	ee	00	eb	00	1f	00	03	00	fd	00	f9	00	0d	00	d0	00
0000656	fc	00	fd	00	ee	00	e2	00	f6	00	ec	00	cf	00	fb	00
0000672	eb	00	ed	00	03	00	16	00	f5	00	f4	00	34	00	10	00
0000688	ff	00	ec	00	16	00	f2	00	ea	00	ec	00	ce	00	ec	00
0000704	0e	00	eb	00	c8	00	04	00	ea	00	00	00	12	00	f7	00
0000720	db	00	03	00	25	00	04	00	e6	00	f9	00	f0	00	fa	00
0000736	fe	00	f6	00	d9	00	f3	00	00	00	fa	00	f8	00	0d	00
0000752	ed	00	06	00	19	00	f2	00	e0	00	e5	00	20	00	01	00
0000768	fd	00	ef	00	e7	00	f0	00	f6	00	ee	00	dd	00	f5	00
0000784	f4	00	fe	00	fa	00	f9	00	f0	00	f8	00	08	00	12	00
0000800	01	00	f8	00	f4	00	fb	00	ec	00	fa	00	d2	00	fb	00
0000816	f2	00	f7	00	f2	00	f6	00	00	00	f4	00	13	00	e0	00
0000832	eb	00	02	00	fb	00	d5	00	fc	00	cf	00	d1	00	06	00

Figure 1a. Hexadecimal dump of the first half of record 1 from binary REDR vc134. The 12-byte header is highlighted in yellow at the top.

```
0000848  08 00 ed 00 db 00 e8 00 1d 00 f7 00 15 00 de 00
0000864  00 00 0c 00 1d 00 e3 00 e6 00 f8 00 f4 00 f5 00
0000880  e8 00 f6 00 d5 00 fd 00 f0 00 e3 00 b2 00 e9 00
0000896  04 00 fb 00 f7 00 ee 00 fc 00 12 00 0e 00 dd 00
0000912  fa 00 01 00 d0 00 0c 00 ec 00 03 00 b4 00 fe 00
0000928  05 00 f6 00 fb 00 e7 00 0d 00 e9 00 24 00 ec 00
0000944  ee 00 26 00 f2 00 ec 00 d4 00 13 00 c2 00 03 00
0000960  ef 00 06 00 eb 00 05 00 fb 00 ef 00 16 00 fa 00
0000976  1b 00 f7 00 1d 00 00 00 e7 00 fc 00 09 00 e7 00
0000992  e8 00 f5 00 eb 00 0f 00 e9 00 ea 00 dd 00 fe 00
0001008  f5 00 e8 00 ee 00 f1 00 fd 00 e5 00 fa 00 e0 00
0001024  fe 00 fd 00 de 00 ce 00 e7 00 fb 00 eb 00 00 00
0001040  df 00 f8 00 23 00 18 00 03 00 01 00 1c 00 ea 00
0001056  00 00 db 00 fc 00 e0 00 04 00 08 00 d2 00 ec 00
0001072  fb 00 06 00 de 00 f9 00 f4 00 f3 00 1b 00 0c 00
0001088  fe 00 dc 00 12 00 fe 00 e8 00 de 00 e0 00 03 00
0001104  fb 00 ff 00 e5 00 ed 00 ef 00 fe 00 07 00 06 00
0001120  ef 00 ed 00 1f 00 0a 00 12 00 ee 00 11 00 13 00
0001136  0c 00 e8 00 ed 00 d2 00 fc 00 da 00 ea 00 e8 00
0001152  ee 00 fd 00 0e 00 04 00 fc 00 02 00 28 00 eb 00
0001168  fc 00 ea 00 e8 00 f4 00 ec 00 f5 00 ce 00 e5 00
0001184  03 00 05 00 fb 00 dc 00 ee 00 06 00 14 00 08 00
0001200  e6 00 fe 00 10 00 f5 00 e8 00 ea 00 e3 00 00 00
0001216  fc 00 da 00 dc 00 f9 00 ff 00 fc 00 00 00 fd 00
0001232  02 00 07 00 21 00 0d 00 fc 00 fa 00 ef 00 f3 00
0001248  fe 00 da 00 d6 00 f0 00 1a 00 f8 00 e9 00 e5 00
0001264  f2 00 f6 00 f6 00 f1 00 f2 00 06 00 00 00 f9 00
0001280  e0 00 ec 00 fc 00 03 00 e5 00 d2 00 da 00 f4 00
0001296  fa 00 ef 00 f7 00 db 00 f9 00 01 00 15 00 e4 00
0001312  e6 00 fe 00 f1 00 f9 00 ef 00 f1 00 d6 00 07 00
0001328  f1 00 cf 00 01 00 f0 00 fd 00 dc 00 18 00 e5 00
0001344  02 00 fb 00 1a 00 d7 00 e6 00 0e 00 f7 00 0e 00
0001360  fa 00 f8 00 cc 00 ff 00 ea 00 fa 00 fe 00 fe 00
0001376  fb 00 12 00 27 00 eb 00 fd 00 fc 00 ff 00 f6 00
0001392  ed 00 17 00 d4 00 e8 00 e0 00 e5 00 f5 00 ec 00
0001408  ec 00 ed 00 26 00 f1 00 f1 00 f4 00 09 00 03 00
0001424  fd 00 f7 00 c4 00 e9 00 f0 00 ed 00 c2 00 07 00
0001440  ed 00 ee 00 f5 00 07 00 d5 00 e3 00 26 00 f9 00
0001456  14 00 f4 00 13 00 e7 00 fe 00 ff 00 d6 00 d8 00
0001472  ec 00 f0 00 e0 00 f2 00 f6 00 f8 00 fc 00 0a 00
0001488  e3 00 e7 00 09 00 04 00 0d 00 04 00 0b 00 e2 00
0001504  fc 00 fd 00 ed 00 e5 00 e1 00 0c 00 db 00 ef 00
0001520  d2 00 0f 00 05 00 f2 00 f5 00 e9 00 e8 00 f2 00
0001536  f5 00 f1 00 bf 00 ed 00 dc 00 08 00 e2 00 f8 00
0001552  fb 00 02 00 fe 00 f5 00 e4 00 f5 00 14 00 f1 00
0001568  d7 00 e0 00 1d 00 14 00 04 00 ed 00 e2 00 ea 00
0001584  07 00 0e 00 e7 00 e2 00 f6 00 f7 00 11 00 02 00
0001600  f9 00 f6 00 1b 00 fd 00 f0 00 e5 00 15 60 06 06
0001616  00 00 3f 69 09 12 af 34 9c 43 6d 6e 81 cb 3f 69
0001632  09 12 af 34 00 00 28 d2 75 00 15 54 00 00 00 08
0001648  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0001664  00 00 00 00 4f 00 72 11 16 2a 1f 3f 4f 00 40 10
0001680  03 00 00 00 00 00 00 00 56 47 31 33
```

Figure 1b. Hexadecimal dump of the last half of record 1 from vc134. The 80-byte trailer is highlighted in yellow at the bottom.

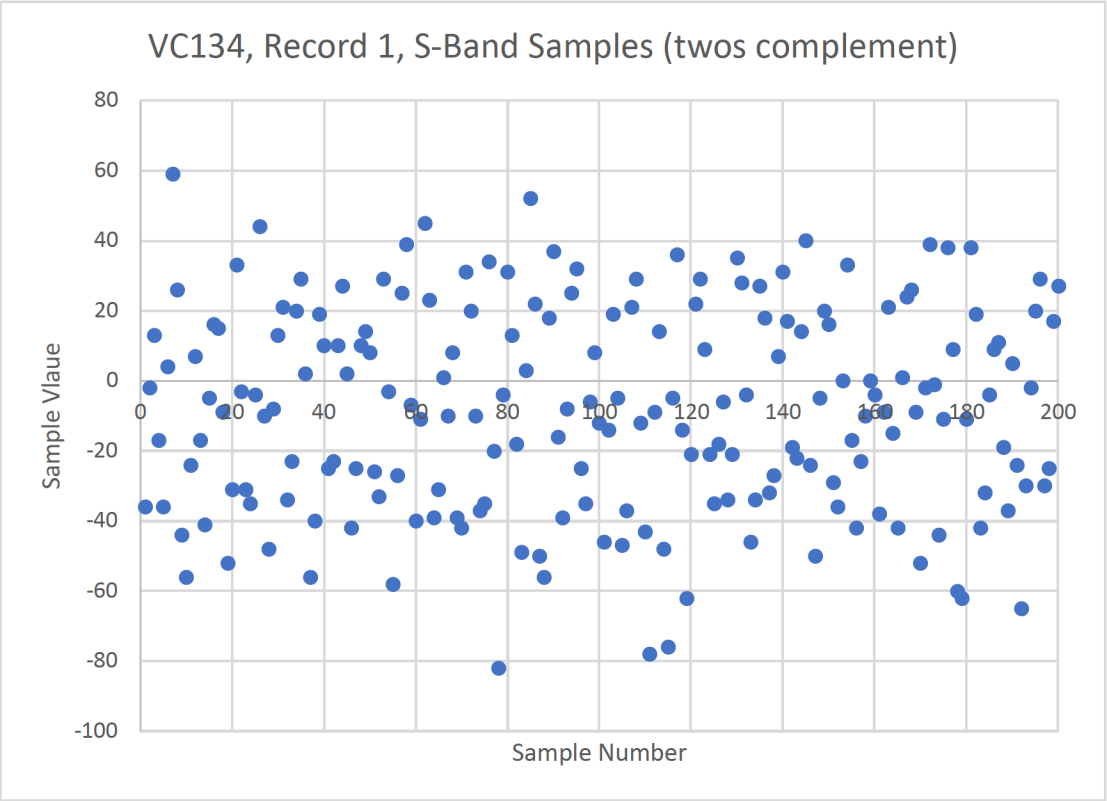

Figure 2a. S-Band samples (200) in the first record.

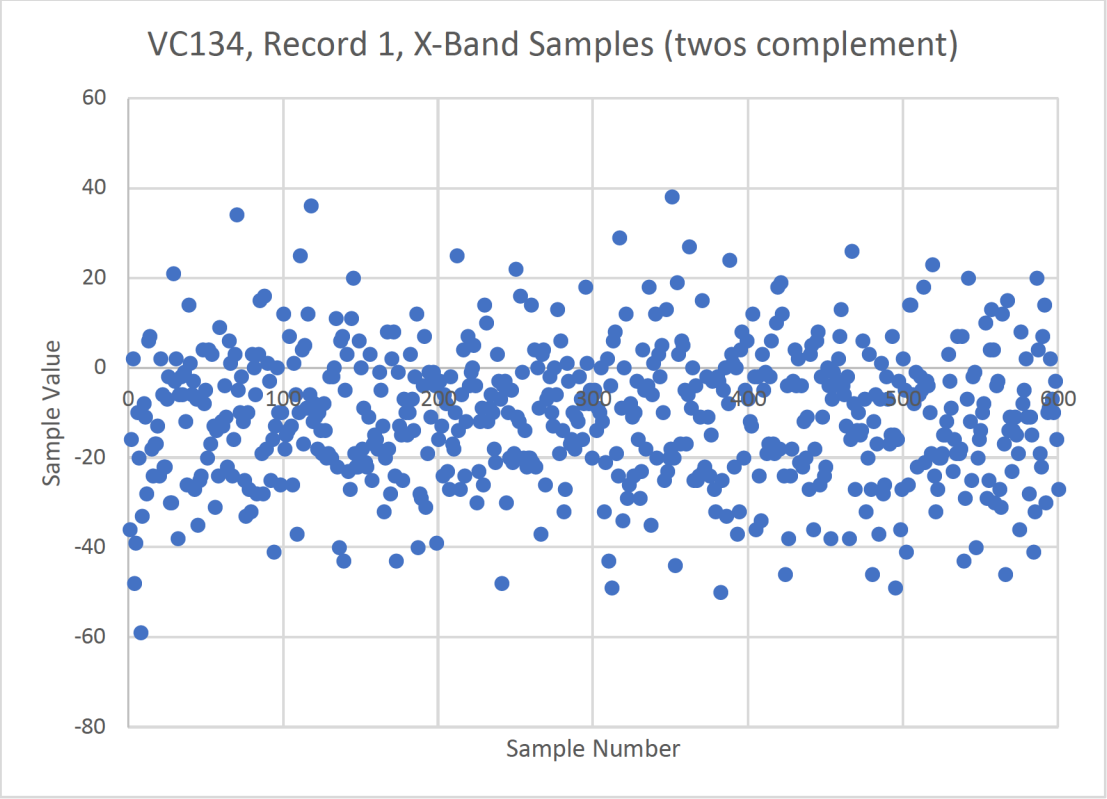

Figure 2b. X-Band samples (600) in the first record.