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Subject: **Interpretation and Use of Binary RSC-11-11 Data**

Purpose and Scope:

This document describes and illustrates extraction of values from binary files generated according to the NASA Deep Space Network (DSN) RSC-11-11 Software Interface Specification (SIS). RSC-11-11 is one of several modules within DSN 820-013 that governed open loop radio science raw data products created over about two decades starting in the 1980s. In this document, RSC-11-11 is referenced as:

[1] *Document 820-013 (Rev. A), DSN System Requirements, Detailed Interface Design, RSC-11-11, DSN Radio Science System Original Data Record (ODR) and Original Data Stream (ODS),* effective date 1 October 1992.

This document is designed to accompany the Planetary Data System (PDS) Radio Science Documentation bundle located on the Geosciences node of the PDS. The entire Radio Science Documentation bundle can be found at the following URL:

https://pds-geosciences.wustl.edu/radiosciencedocs/urn-nasa-pds-radiosci_documentation/

Introduction:

The RSC-11-11 SIS specifies the format and content of data produced by the DSCC Spectrum Processing Subsystem (DSP), using the Radio Science software of the DSP referred to as DSP-R. The digital data were recorded on 9-track tapes at densities up to 6250 bpi; copies of the original tapes were sent to the investigation team, which could copy them to files on a local computer for analysis[1]. RSC-11-11 specifies that data could be sampled at 19 different rates between 200 samples/second and 50,000 samples/second, typically at 8-bit resolution but with a 12-bit resolution option at lower sample rates.

During the Galileo mission, the DSP-R was configured to sample at 200, 1250, and 2500 samples/second per analog-to-digital (A-D) converter at 8-bit resolution, though occasionally other sample rates and 12-bit recordings were made in cruise for testing. Other missions during this era may have had alternate configurations of the DSP-R.

File and Record Formats:

Each RSC-11-11 file contains an arbitrary number of records. Each RSC-11-11 record comprises 166 bytes (83 "words") of header data (Figure 1) followed by the receiver samples. The number of bytes in the receiver sample part of the record varies with the sampling rate and bit resolution

[1] Late in the RSC-11-11 era some DSP-R data were transferred electronically. The RSC-11-11B SIS may contain a better description of those data.

of the recording. The total record length then will also vary with the sample rate and bit resolution. The record size, sample rate, and bit resolution are given in header data.

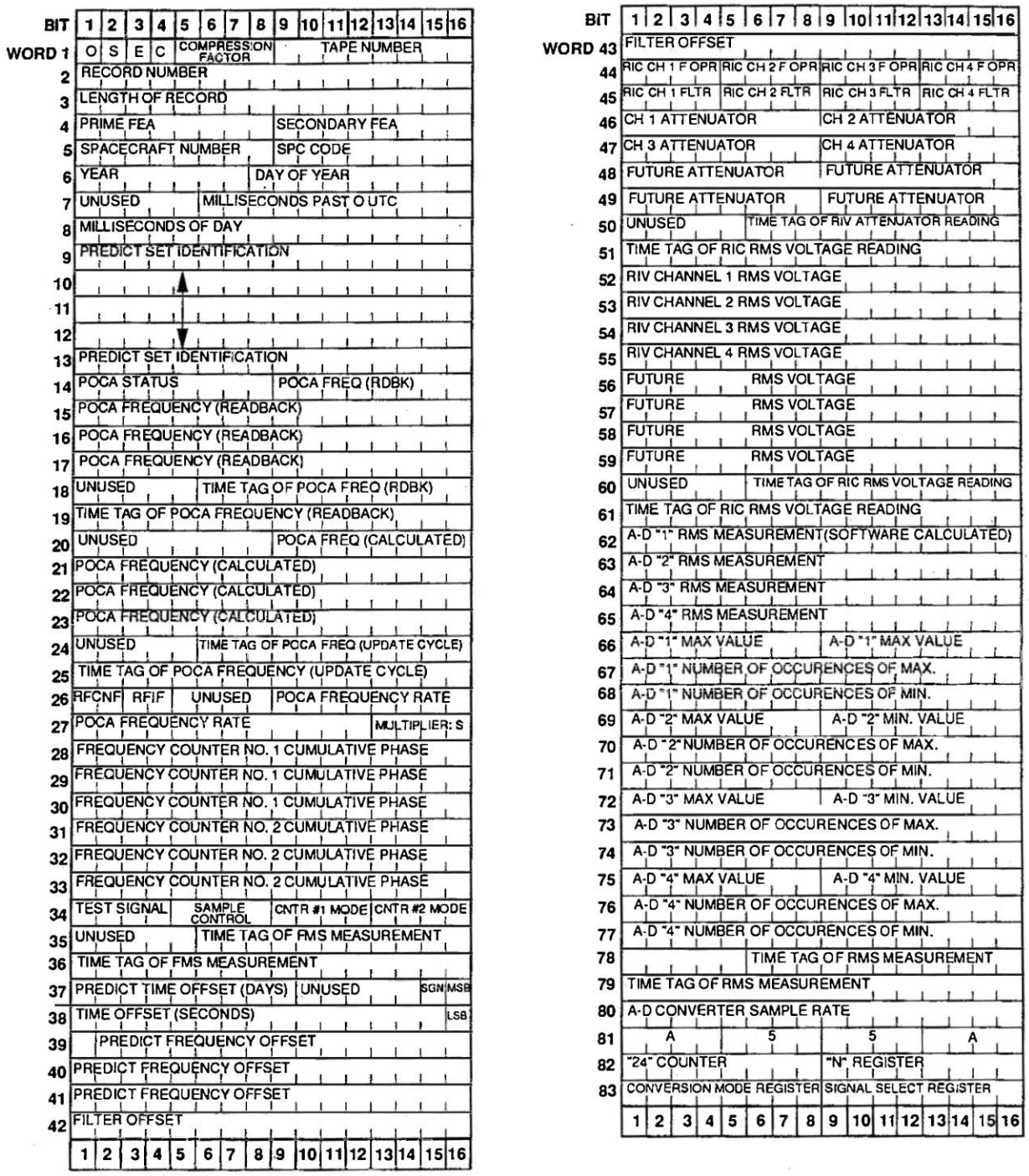

Figure 1. *RSC-11-11 record header structure. [1]*

Note that the more significant byte appears first in the tape record; most modern computers (c. 2023) write, and expect to read, the least significant byte first. Note also that receiver samples are *real* samples, not complex samples as is common in 2023.

The content and format of the record fields are described in [1]. Each header record contains crucial information for interpretation of the samples, including the time tag, DSN station information, down-conversion factors, and the analog-to-digital converter configuration.

The DSP-R down-converted the signal by a "prediction" of the expected frequency. This predicted frequency drives the Programmable Oscillator Assembly (POCA). The POCA data is given in the header with a timetag, readback (actual) frequency, calculated (commanded) frequency, and frequency rate. The interpretation of the POCA data is as a piecewise linear function of the timetags and readback frequency. The RSC-11-11 document [1] includes formulas relating S-band sky frequency and POCA frequency. X-band sky frequency was assumed to be 11/3 times the S-band frequency and receiver design made necessary conversions from the same POCA value.

The sample values directly follow the header. The structure of the sample section of the records varies depending on the bit resolution [1].

Example Data File:

An example RSC-11-11 file generated during the Galileo encounter with Ganymede has been included in the Radio Science Documentation bundle. Data were collected at DSN ground station 14 on 1997-127. The logical identifier (LID) of the example product is

urn:nasa:pds:radiosci.documentation:dsn.rsc-11-11:gll1997127sample

It includes 10 binary records (*gll1997127sample.dat*), their unpacked header values (*gll1997127sample.hdr*), and their unpacked sample values (*gll1997127sample.txt*). A hexadecimal dump of the first 400 bytes of the binary file is shown in Figure 3. The highlighted bytes are from the first 166-byte (83 word) header.

```
92 00 0f 79 05 35 0e 00 4d 0a c2 7f 03 68 7f 60
41 42 37 20 20 20 20 20 20 20 75 43 27 12 02 18
68 67 03 68 7f 60 07 43 27 12 02 20 48 83 03 68
7f 6a 11 15 57 10 e0 eb aa 09 c0 00 e0 eb aa 09
10 00 11 10 03 68 7f 60 00 00 00 00 00 00 00 00
00 00 ff ff f1 5a 33 33 33 33 77 1e 77 77 00 00
00 00 03 06 ac 4a 00 1d 00 01 00 05 00 01 20 20
20 20 20 20 20 20 21 a1 1b 7e 02 98 02 98 02 98
02 98 ab 40 00 00 00 00 ab 40 00 00 00 00 ab 40
00 00 00 00 ab 40 00 00 00 00 03 68 7b 78 04 e2
a5 5a 00 00 35 55 67 89 60 74 84 69 85 61 74 6d
6d 8e 7e 75 69 78 85 72 6b 6d 83 83 86 82 65 85
88 81 87 81 77 71 86 6b 74 85 7d 86 7d 72 5e 7b
80 7f 93 75 5a 74 72 89 64 62 7a 8b 6f 7d 6f 71
72 64 84 70 98 7a 74 75 79 67 61 78 80 78 70 55
5b 7f 88 60 73 92 87 74 75 7b 67 6e 7d 91 70 74
75 6c 77 74 66 72 86 6f 87 64 72 68 78 75 6d 77
88 81 73 8e 90 76 7b 78 7b 7c 74 86 6e 7f 66 77
6c 66 74 75 86 7e 73 7a 7b 68 7f 81 80 70 78 78
7c 87 89 6e 73 7c 90 8a 62 6e 6b 7f 6f 83 6e 76
88 7e 78 73 63 9d 74 67 74 6f 74 5a 6e 87 84 75
78 84 55 87 83 7a 7b 75 7f 71 6f 83 a2 6a 77 72
6e 6a 75 8e 50 7a 74 61 7c 84 85 7b 6c 66 75 87
69 64 7b 81 95 85 77 90 84 6e 81 6a 84 63 72 87
6a 77 81 78 5e 7e 74 66 7a 72 98 7a 75 7a 74 62
```

Figure 2. *Hexadecimal dump of the first 400 bytes in example file gll1997127sample.dat. The first 166 bytes (yellow highlighting) contain header information.*

Header Values: All header values, except those described as unused in the spec document [1], have been decoded from the first record of the sample file in Table 1. Some of the information in the header is diagnostic and not used in reconstruction of signal properties. Values which require a bit-level interpretation are parsed into the appropriate binary sequence.

Table 1. *Selected values from the header in the sample file.*

Byte Count	Hex Value	Bit Numbers	Binary Value	Description	Unpacked Value
1	92	1	1	O	1
		2	0	S	0
		3	0	E	0
		4	1	C	1
		5-8	0010	Comp Factor	0010
2	00			Tape Number	0
3-4	0f 79			Record Number	3961
5-6	05 35			Record Length (number of words)	1333 (=2666 bytes)
7	0e			Primary FEA	14
8	00			Secondary FEA	0
9	4d			Spacecraft ID	77
10	0a			Signal Processing Center ID	10
11-12	c2 7f	1-7	1100001	Year	97
		8-16	0 01111111	Day of Year	127
13-16	03 68 7f 60	1-4		Unused	
		5-32	011 01101000 01111111 01100000	Milliseconds Past Midnight UTC	57180000
17-26	41 42 37 20 20 20 20 20 20 20			Predict Set Identification	AB7
27	75	1	0	POCA Control Flag	0 (Manual)
		2	1	POCA Control Ready Flag	1 (Ready)
		3	1	POCA Synthesizer Power Flag	1 (On)
		4	1	POCA Synthesizer in Lock Flag	1 (In-Lock)
		5	0	POCA Limit Enable Flag	0 (Off)
		6	1	POCA Track Flag	1 (On)
		7	0	POCA Acquisition Flag	0 (Off)
		8	1	POCA Sweep Flag	1 (On)
28-34	43 27 12 02 18 68 67			POCA Frequency Readback (microHertz)	43271202186867
35-38	03 68 7f 60	1-5		Unused	
		5-32	011 01101000 01111111 01100000	POCA Milliseconds Past Midnight UTC	57180000
39	07			Unused	
40-46	43 27 12 02 20 48 83			POCA Frequency Calculated (microHertz)	43271202204883
47-50	03 68 7f 6a			POCA Update Cycle	57180010
51	11	1-2	00	RF Configuration of IF-video switch	00
		3-4	01	RF Configuration as reported by IF	01 (PRIME mode)

Byte Count	Hex Value	Bit Numbers	Binary Value	Description	Unpacked Value
		5-8	0001	Unused	
52-54	15 57 10	1-20	0001 01010101 01110001	POCA Rate (Hz/sec)	0.15571
		21-23	000	POCA Rate Power of 10 Multiplier	0
		24	0	POCA Rate Sign	0
55-60	e0 eb aa 09 c0 00			Frequency Counter 1 Cumulative Phase (before normalization by 2^20)	247302774702080
61-66	e0 eb aa 09 10 00			Frequency Counter 2 Cumulative Phase (before normalization by 2^20)	247302774657024
67-68	11 10	1-4	0001	FMS Test Facility Input Signal Selection	
		5-8	0001	FMS Sample Control Register	
		9-12	0001	Frequency Counter 1 Mode Register	
		13-16	0000	Frequency Counter 2 Mode Register	
69-72	03 68 7f 60	1-5		Unused	
		6-16	011 01101000 01111111 01100000	FMS Milliseconds Past Midnight UTC	57180000
73-74	00 00	1-9	00000000 0	Predict time offset in days	0
		10-14	00000	Unused	
		15	0	Sign of predict time offset in days	0
		16	0	Unused	
75-78	00 00 00 00			Predict Time Offset in seconds	0
79-82	00 00 00 00			S-band frequency offset in Hertz	0
83-86	ff ff f1 5a			Filter Offset	-3750
87-88	33 33	1-4	0011	RIC Channel 1 Filter Operator select	3
		5-8	0011	RIC Channel 2 Filter Operator select	3
		9-12	0011	RIC Channel 3 Filter Operator select	3
		13-16	0011	RIC Channel 4 Filter Operator select	3
89-90	33 33	1-4	0011	RIC Channel 1 Filter Reported select	3
		5-8	0011	RIC Channel 2 Filter Reported select	3
		9-12	0011	RIC Channel 3 Filter Reported select	3
		13-16	0011	RIC Channel 4 Filter Reported select	3
91	77			Channel 1 Attenuator Setting (dB)	119
92	1e			Channel 2 Attenuator Setting (dB)	30
93	77			Channel 3 Attenuator Setting (dB)	119
94	77			Channel 4 Attenuator Setting (dB)	119
95-98	00 00 00 00			Future Use	
99-102	03 06 ac 4a	1-5		Unused	
		6-16	011 00000110 10101100 01001010	RIV Att Milliseconds Past Midnight	50768970
103-104	00 1d			RIV Channel 1 RMS Voltage (mV)	29
105-106	00 01			RIV Channel 2 RMS Voltage (mV)	1
107-108	00 05			RIV Channel 3 RMS Voltage (mV)	5
109-110	00 01			RIV Channel 4 RMS Voltage (mV)	1
111-118	20 20 20 20 20 20 20 20			Future Use	
119-122	21 a1 1b 7e	1-5		Unused	
		6-16	001 10100001 00011011 01111110	RIC RMS Milliseconds Past Midnight	27335550
123-124	02 98			A-D 1 RMS Measurement	664
125-126	02 98			A-D 2 RMS Measurement	664

Byte Count	Hex Value	Bit Numbers	Binary Value	Description	Unpacked Value
127-128	02 98			A-D 3 RMS Measurement	664
129-130	02 98			A-D 4 RMS Measurement	664
131	ab			A-D 1 Max	171
132	40			A-D 1 Min	64
133-134	00 00			A-D 1 Max Occurrences	0
135-136	00 00			A-D 1 Min Occurrences	0
137	ab			A-D 2 Max	171
138	40			A-D 2 Min	64
139-140	00 00			A-D 2 Max Occurrences	0
141-142	00 00			A-D 2 Min Occurrences	0
143	ab			A-D 3 Max	171
144	40			A-D 3 Min	64
145-146	00 00			A-D 3 Max Occurrences	0
147-148	00 00			A-D 3 Min Occurrences	0
149	ab			A-D 4 Max	171
150	40			A-D 4 Min	64
151-152	00 00			A-D 4 Max Occurrences	0
153-154	00 00			A-D 4 Min Occurrences	0
155-158	03 68 7b 78	1-5		Unused	
		6-16	011 01101000 01111011 01111000	RMS Milliseconds Past Midnight	57179000
159-160	04 e2			A-D Converter Sample Rate	1250
161-162	a5	1-4	1010	NBOC Sync Data: A55A	A
		5-8	0101		5
	5a	8-12	0101		5
		13-16	1010		A
163-164	00 00			Unused	
165	35	1	0	NBOC converter overflow flag	0
		2	0	Not used	0
		3	1	NBOC PLL Lock flag	1 (in-lock)
		4	1	Sample rate flag	1 (kilosamples/sec)
		5	0	Test mode flag	0 (normal mode)
		6	1	Bit resolution flag	1 (8-bit)
		7-8	01	A-D Sample mode	01 (1 input signal sampled sequentially)
166	55	1-2	01	Sample Register A-D 1	01 (Channel 2)
		3-4	01	Sample Register A-D 2	01 (Channel 2)
		5-6	01	Sample Register A-D 3	01 (Channel 2)
		7-8	01	Sample Register A-D 4	01 (Channel 2)

Data Values: After the 166-byte header, each record in the sample file includes 2500 bytes of 8-bit data samples (*real* samples). In Figure 2, these begin with hexadecimal value '67' in byte 167.

The header indicates that data were sampled using 4 A-D converters sequentially. Therefore, the samples can be read sequentially from the data, in the order of A-D 1, A-D 2, A-D 3, A-D 4, etc. The time stamp in the header indicates the time of the first sample.

The full set of unpacked sample values is given in file *gll1997127sample.tab* in the example product. The first 200 samples are shown in Figure 3 below.

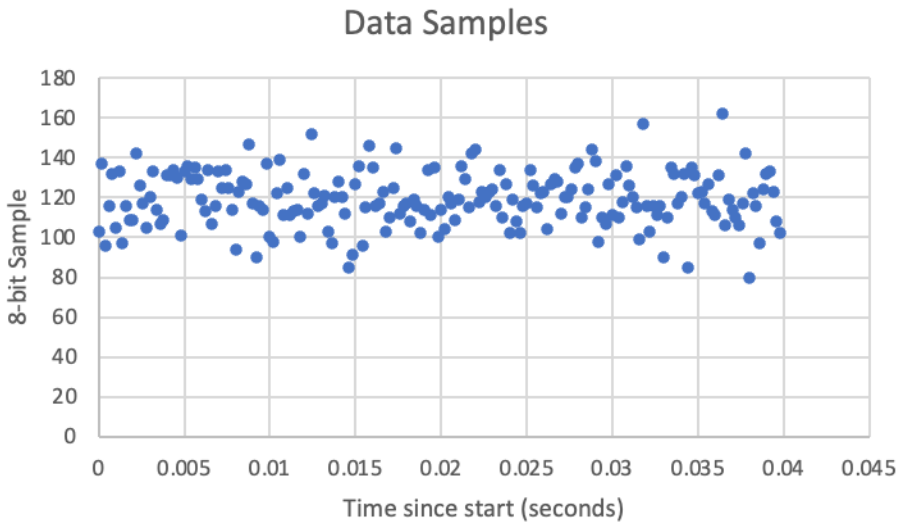

Figure 3. *First 200 samples from gll1997127sample.dat. The first sample has value 103. Values are distributed approximately symmetrically about their mean (119.3).*

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