Interpretation and Use of Binary RSC-11-9 (Parkes) Data

This document describes and illustrates extraction of values from binary files generated according to the NASA Deep Space Network (DSN) RSC-11-9 Software Interface Specification (SIS) that was used for radio science open loop data acquisition during the Voyager 2 encounter with Uranus in 1986 at Parkes Observatory (Australia). It may also apply to data collected during the Voyager 2 encounter with Neptune in 1989 at both Parkes and the Usuda Tracking Station (Japan). In this document, RSC-11-9 (Parkes) is referenced as:

[1] *Document 820-013 (Rev. A), DSN System Requirements, Detailed Interface Design, RSC-11-9, DSN Radio Science System Interface, Original Data Record,* effective date 1 March 1982.

RSC-11-9 is one of several modules within DSN 820-013 that documented generation of open loop radio science raw data products starting in the 1970s. Note that this version of RSC-11-9 is distinguished from the version dated 1 March 1985 [2], which governed data collection during 1986 and 1989 at NASA's Canberra Deep Space Communications Complex.

[2] *Document 820-013 (Rev. A), DSN System Requirements, Detailed Interface Design, RSC-11-9, DSN Radio Science System Interface, Original Data Record,* effective date 1 March 1985.

Document [1] may sometimes be referenced as RSC-11-9P and the data may be described as having the Parkes Original Data Record (PODR) format.

Data Overview:

PODR data were originally distributed on Computer-Compatible Tapes (CCTs). In the mid-1990s the tape data were copied to CD-ROM volumes, and in 2020 the CD-ROMs were copied to a laptop. Subsequent handling has been carried out on the electronic (laptop) files. Throughout, [1] has remained the descriptive document.

Open loop data were the primary inputs for the study of radio occultations by the neutral atmosphere, ionosphere, and rings of Uranus. These data were generated by the Spectrum Processing Assembly (SPA) of the Deep Space Communications Complex (DSCC) Spectrum Processing Subsystem (DSP), using radio science software of the DSP, designated "DSP-R".

During the Uranus encounter, X-band receiver outputs in right-circular polarization (RCP) from the 64-m antenna at Parkes Observatory were written to tape at 80000 8-bit samples per second (20000 per second sequentially from four analog to digital converters). Figure 1 shows the Uranus encounter timeline, significant events, and the corresponding tape numbers. Figure 2 lists recordings of test data.

Ground Event Time (UTC)	Event Description	1986 DOY	Tape Start (UTC)	Tape Stop (UTC)	Parkes Tape	Notes
		024	21:15:01	21:21:40	UL0304	
21:27:13	TWNC ON	024	21:21:41	21:28:20	UL0305	1
		024	21:28:21	21:35:00	UL0306	
21:41:40	S-band ranging OFF	024	21:35:01	21:41:40	UL0307	
21:45:39	Telemetry OFF	024	21:41:41	21:48:20	UL0308	
21:52:00	Begin mini-ASCAL	024	21:48:21	21:55:00	UL0309	
		024	21:55:01	22:01:40	UL0310	
22:04:00	End mini-ASCAL	024	22:01:41	22:08:20	UL0311	
		024	22:08:21	22:15:00	UL0312	
		024	22:15:01	22:21:40	UL0313	
		024	22:21:41	22:28:20	UL0314	
22:28:30	ε-ring	024	22:28:21	22:35:00	UL0315	
		024	22:35:01	22:41:40	UL0316	
22:47	4-ring	024	22:41:41	22:48:20	UL0317	
22:55	X-band to low power	024	22:48:21	22:55:00	UL0318	
22:56:02	S-band to high power	024	22:55:01	23:01:40	UL0319	
		024	23:01:41	23:08:20	UL0320	
		024	23:08:21	23:15:00	UL0321	
23:17 23:21	ionosphere Enter atmosphere	024	23:15:01	23:21:40	UL0322	
		024	23:21:41	23:28:20	UL0323	
		024	23:28:21	23:35:00	UL0324	
23:38	Enter absorption region	024	23:35:01	23:41:40	UL0325	
23:44	Exit absorption region	024	23:42:10	23:48:49	UL0326	
		024	23:48:50	23:55:29	UL0327	
		024	23:55:30	00:02:09	UL0328	
		025	00:02:10	00:08:49	UL0329	
		025	00:08:50	00:15:29	UL0330	
00:19	Enter absorption region	025	00:15:30	00:22:09	UL0331	
00:28	Exit absorption region	025	00:22:10	00:28:49	UL0332	
		025	00:28:50	00:35:29	UL0333	
		025	00:35:30	00:42:09	UL0334	
00:44	Exit atmosphere	025	00:42:10	00:48:49	UL0335	
		025	00:48:50	00:55:29	UL0336	
		025	00:55:30	01:02:09	UL0337	
01:03:14 01:04:00	S-band to low power X-band to high power	025	01:02:10	01:08:49	UL0338	
		025	01:08:50	01:15:29	UL0339	
00:19	4-ring	025	01:15:30	01:22:09	UL0340	
		025	01:22:10	01:28:49	UL0341	
		025	01:28:50	01:35:29	UL0342	
01:37:40	ε-ring	025	01:35:30	01:42:09	UL0343	
		025	01:42:10	01:48:49	UL0344	
		025	01:48:50	01:55:29	UL0345	
		025	01:55:30	02:02:09	UL0346	
		025	02:02:10	02:08:49	UL0347	
		025	02:08:50	02:15:29	UL0348	
02:16:36	Begin mini-ASCAL	025	02:15:30	02:22:09	UL0349	
02:27:17	End mini-ASCAL	025	02:22:10	02:28:49	UL0350	
02:32:04	Telemetry ON	025	02:28:50	02:35:29	UL0351	
		025	02:35:30	02:42:09	UL0352	
02:45:00	End recording	025	02:42:10	02:45:00	UL0353	

Figure 1. Significant radio science events during the Voyager 2 encounter with Uranus (as seen at Parkes). Tape start and stop times are given in columns 4 and 5; Parkes tape numbers are in column 6. Note 1: Record 4 on the original tape was short; it was padded to the correct length, and a corrected version is included in the PDS4 archive under the file name ul0305.dat.

Ground Event Time (UTC)	Event Description	1986 DOY	Tape Start (UTC)	Tape Stop (UTC)	Parkes Tape	Notes
	sinusoid at -12 kHz	024	16:18:01	16:24:40	UL0354	
	11 frequency steps of 3.5 kHz, starting at -17.5 kHz	024	17:41:01	17:47:40	UL0355	2
	3 kHz sinusoid with decreasing amplitude	024	03:35:01	03:41:40	UL0356	
	sweep?	022	18:00:06	18:02:12	UL0357	
	sweep?	022	18:06:11	18:11:05	UL0358	
	sweep?	023	17:55:09	18:01:48	UL0359	

Figure 2. Open loop test data collected before the Voyager 2 Uranus encounter. Tapes delivered to the Voyager Radio Science Team are listed in column 6 (Parkes Tape). Note 2: Record 4 on the original tape was short; it was padded to the correct length and a correct version of the binary file is included in the archive under the file name ul0355a.dat.

File and Record Formats:

A typical PODR tape contained 8000 records of 4090 bytes, representing 400 seconds of receiver output. Each data record comprised 56 bytes of header data (Figure 3), 4000 8-bit receiver samples, and 34 bytes which were undefined for the Uranus observations.

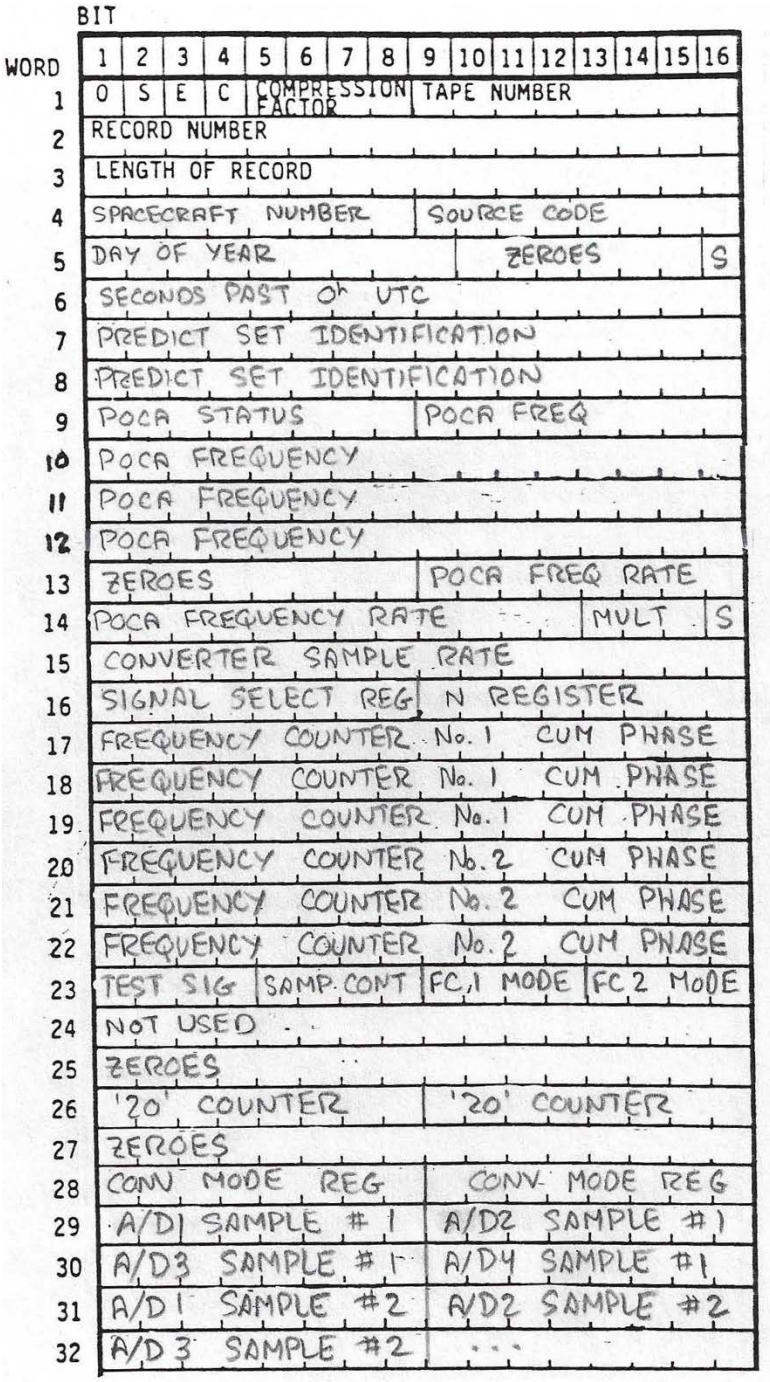

Figure 3. Structure of the PODR record; field definitions are given in [1]. One 16-bit word (left margin) is two 8-bit bytes. The record header occupies words 1-28. Receiver samples then fill the next 2000 words. The final 17 words were undefined for the Voyager 2 Uranus encounter at Parkes.

Example Data File:

The first 10 records from tape UL0305 have been archived with this document as file ul0305a.dat. A partial hexadecimal dump of the first record from ul0305a.dat is shown in Figure 4. The dump was created using the unix-like command:

od -t x1 ul0305a.dat +0.

Use of the option '-t x1' is important because most modern computers use least-significant-byte (also known as 'little endian') storage, and bytes will be displayed in reverse order if two or more bytes are displayed together.

```
0000000    81  02  00  01  07  fd  20  2b  0c  01  2c  65  50  4c  52  2a
0000016    75  45  78  99  23  00  09  30  00  00  00  01  4e  20  00  e8
0000032    ff  ff  ff  ff  ff  ff  ff  ff  ff  ff  ff  ff  00  00  00  00
0000048    00  00  17  17  00  00  45  45
           ----------^ Header 1 ^------------v Data 1 v-----------
                                             6f  77  8f  97  6e  6c  97  62
0000064    92  7a  9d  78  94  99  82  74  66  80  71  8c  72  7c  77  7f
0000080    75  7f  86  75  87  9c  9a  7f  76  6d  66  76  92  7e  98  74
0000096    73  7c  6e  87  95  85  89  7b  94  98  79  7f  7b  88  8c  76
0000112    6e  81  93  7e  9b  71  7c  81  68  7b  85  6d  82  7f  7c  61
0000128    92  8e  81  97  7a  87  82  6a  8f  7b  70  6d  85  89  68  84
0000144    95  84  86  72  84  83  6c  96  8a  94  6a  85  ac  5d  78  64
0000160    79  9b  7c  7d  7a  6f  86  8b  8c  7d  8e  96  65  6e  89  80
0000176    79  76  81  84  94  7a  84  6d  87  68  77  7c  6f  8e  78  8f
0000192    83  9c  6e  76  87  77  6b  7f  75  95  a1  8a  83  93  6d  8c
0000208    7d  74  83  85  78  71  9f  7d  77  75  91  7d  7f  7d  80  78
0000224    6e  84  71  7e  80  8a  71  85  78  75  9c  99  6e  74  95  7b
0000240    77  8b  70  86  79  89  7c  76  7d  8d  7c  72  9b  7a  72  8c
0000256    86  94  64  88  78  91  7c  77  79  94  8d  8d  9a  52  81  74
```

Figure 4. Hexadecimal dump of the first 272 bytes from file ul0305a.dat. The byte counter along the left margin is given in decimal. The first 56 bytes contain the record header; the first receiver sample (hexadecimal value '6f') is in byte 57.

The values extracted from the first record header (Figure 4) are shown in Figure 5. The hexadecimal values for some fields in Figure 5 may not be immediately recognizable in Figure 4 because of bit length differences. For example, the first five values shown in Figure 5 have hexadecimal values 1, 0, 0, 0, and 1; but the first four are single bits, so the combination has hexadecimal value '81' in Figure 4.

QUANTITY	HEXADECIMAL	DECIMAL or CHARACTER
Time and Status Validity	1	1
Sequence Flag	0	0
Error Flag	0	0
Conversion Flag	0	0
Compression Factor Type	1	1
Tape Number	02	2
Record Number	0001	1
Record Length (words)	07fd	2045
S/C ID	20	32
DSS ID	2d	43
Day of Year	18	024
Seconds of Day	12c65	76901
Predict Set ID	504c522a	PLR*
POCA Control	0	0
Control Status	1	1
Synthesizer Power	1	1
Synthesizer Lock	1	1
Limit Enable Status	0	0
Track Status	1	1
Acquisition Status	0	0
Sweep Status	1	1
POCA Frequency (microHz)	45789923000930	45789923000930.
POCA Rate (tenths of Hz/s)	00000	0
(power of ten)	0	0
(sign)	1	+
ADC Sample Rate	4e20	20000
J1 Signal Select	0	0
J2 Signal Select	0	0
J3 Signal Select	0	0
J4 Signal Select	0	0
N Counter	e8	232
Frequency Counter 1	ffffffffffff	2.814706817433590E+14
Frequency Counter 2	ffffffffffff	2.814706817433590E+14
Test Signal Select	0	0
Sample Control Register	0	0
Frequency Counter 1 Mode Register	0	0
Frequency Counter 2 Mode Register	0	0
Spares-1	0000	0
Zeroes-1	0000	0
20-Counter #1	17	23
20-Counter #2	17	23
Zeroes-2	0000	0
Word 28: Overflow Flag #1	0	0
Ones #1	4	4
Test Mode Flag #1	0	0
Short Conversion Flag #1	1	1
Sampling Mode #1	1	1
Overflow Flag #2	0	0
Ones #2	4	4
Test Mode Flag #2	0	0
Short Conversion Flag #2	1	1
Sampling Mode #2	1	1

Figure 5. Header values extracted from record 1 of file ul0305a.dat. Note that DSS ID has decimal value '43' on all tapes because the DSP-R software was written for permanent DSN stations and did not recognize '49', the Parkes ID. Also, the Ones fields in Word 28 have decimal value '4' rather than '7'. See ul0305a.hdr for ASCII conversions of all record headers in ul0305a.dat.

The first 60 data samples, converted to ASCII decimal values, are shown in Figure 6. Hexadecimal '6f' (the first data sample in Figure 4) has been converted to decimal '111'.

```
111 119 143 151 110 108 151  98 146 122 157 120 148 153 130 116 102 128 113 140
114 124 119 127 117 127 134 117 135 156 154 127 118 109 102 118 146 126 152 116
115 124 110 135 149 133 137 123 148 152 121 127 123 136 140 118 110 129 147 126
```

Figure 6. First 60 converted samples from record 1 of file ul0305a.dat.

The results from processing all records in UL0305 are shown in Figure 7. A signal appears at about 22 kHz in the last few power spectra (though partially hidden by the labeling); the average sample power also rises by about 0.45 dB at the same time. Figure 1 shows that the spacecraft went to TWNC ON at 21:27:13, meaning that the spacecraft transmitter switched from using the uplink signal from the DSN to the onboard ultra-stable oscillator as its frequency reference for downlink transmissions, moving those transmissions into the bandwidth being captured by the DSP-R.

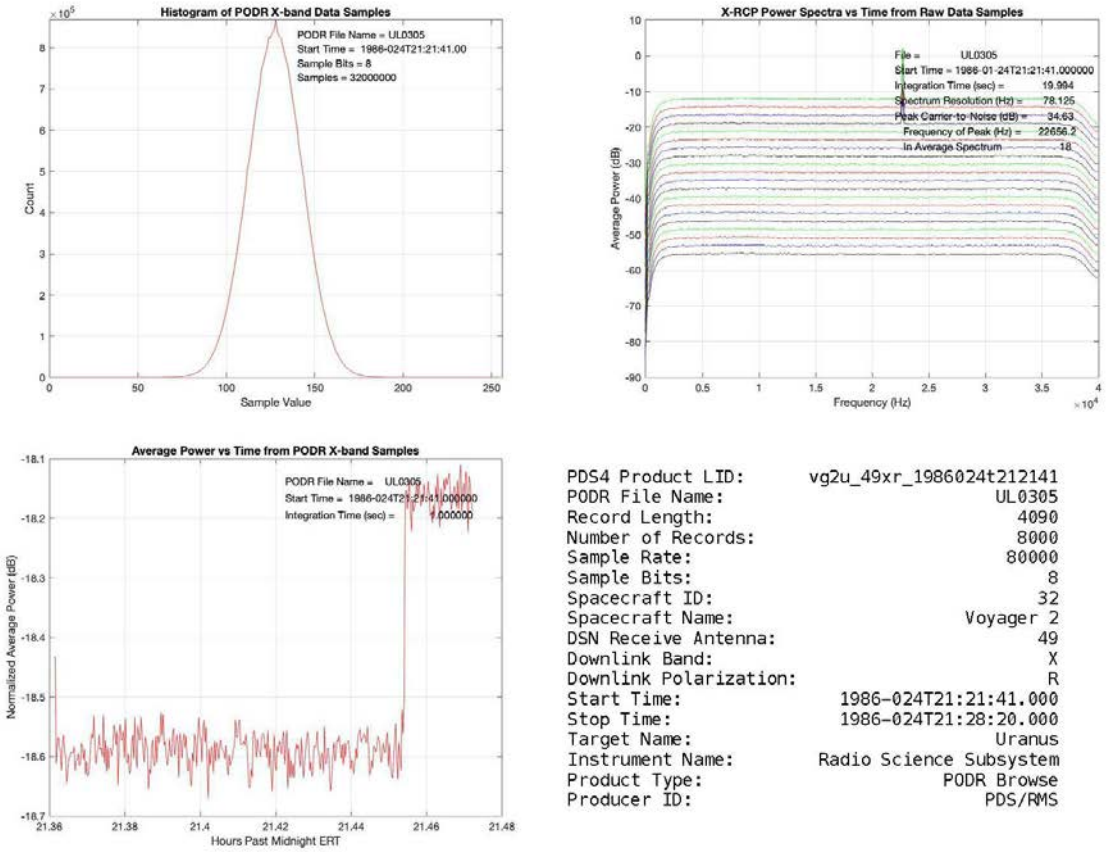

Figure 7. Results from 'quick-look' processing of all records in UL0305. Upper left: histogram of sample values. Lower left: time averaged sample power after removal of the mean. Upper right: Time averaged power spectra after removal of the mean, presented in a waterfall format with the earliest spectrum at the bottom. Lower right: An ASCII summary of the observation.