Interpretation and Use of Binary RSC-11-9 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). In this document, RSC-11-9 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 1985 (PDS logical identifier urn:nasa:pds:radiosci.documentation:dsn.rsc-11-9)

RSC-11-9 is one of several modules within DSN 820-013 that governed generation of open loop radio science raw data products over about two decades starting in the late 1970s. RSC-11-9 specifies the format and content of the most important open loop radio science files collected using NASA Deep Space Network antennas near Canberra, Australia, during the Voyager 2 encounter with Uranus. A variation of this format, used for collection of data during the Voyager 2 encounter with Uranus at Parkes Observatory (Australia), is described separately. Its citation differs only in the year of the effective date.

[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 1982 (PDS logical identifier urn:nasa:pds:radiosci.documentation:dsn.rsc-11-9p)

Data Overview:

The 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 of the Canberra data.

Open loop data were the primary inputs for the study of radio occultations by the neutral atmosphere, ionosphere, and rings of Uranus. These digital 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, S- and X-band receiver outputs in right-circular polarization (RCP) from the 64-m antenna (DSS43) and the 34-m antenna (DSS42) at the DSCC near Canberra, Australia, were written to tape at 50000 8-bit (real) samples per second from each of the four receiver channels. Table 1 shows the Uranus encounter timeline, significant events, and the corresponding tape numbers. Table 2 lists recordings of test data.

Event Time (UTC)	Canberra Event	1986 DOY	Tape Start UTC (s)	Tape Start (UTC)	Tape Stop (UTC)	Original Tape (S/N)	UC Tape	Backup Tape
		024	76501	21:15:01	21:23:01	1-0451	0452	0701
21:27:13	TWNC ON		76981	21:23:01	21:31:01	2-0453	0453	0702
			77461	21:31:01	21:39:01	3-0448	0454	0703
21:41:40 21:45:39	S-band ranging OFF Telemetry OFF		77941	21:39:01	21:47:01	4-0449	0455	0704
21:52:00	Begin mini-ASCAL		78421	21:47:01	21:55:01	5-0443	0456	0705
			78901	21:55:01	22:03:01	6-0450	0457	0706
22:04:00	End mini-ASCAL		79381	22:03:01	22:11:01	7-0446	0458	0707
			79861	22:11:01	22:19:01	8-0447	0459	0708
			80341	22:19:01	22:27:01	9-0444	0460	0709
22:28:30	ε-ring		80821	22:27:01	22:35:01	10-0442	0461	0710
			81301	22:35:01	22:43:01	11-0445	0462	0711
22:47	4-ring		81781	22:43:01	22:51:02	12-0255	0463	0712
22:55 22:56:02	X-band to low power S-band to high power		82262	22:51:02	22:59:02	13-0669	0464	0713
			82742	22:59:02	23:07:02	14-0678	0465	0714
			83222	23:07:02	23:15:02	15-0660	0466	0715
23:17 23:21	Ionosphere Atmosphere (entry)		83702	23:15:02	23:23:02	16-0679	0467	0716
			84182	23:23:02	23:31:02	17-0680	0468	0717
22:38	Enter absorption region		84662	23:31:02	23:39:02	18-0661	0469	0718
22:44	Exit absorption region		85142	23:39:02	23:47:02	19-0662	0470	0719
			85622	23:47:02	23:55:02	20-0663	0471	0720
			86102	23:55:02	00:03:02	21-0657	0472	0721
		025	86582	00:03:02	00:11:02	22-0659	0473	0722
00:19	Enter absorption region		87062	00:11:02	00:19:02	23-0693	0474	0723
			87542	00:19:02	00:27:02	24-0705	0475	0724
00:28	Exit absorption region		88022	00:27:02	00:35:02	25-0664	0476	0725
			88502	00:35:02	00:43:02	26-0665	0477	0726
00:44	Exit atmosphere		88982	00:43:02	00:51:02	27-0677	0478	0727
			89462	00:51:02	00:59:02	28-0666	0479	0728
01:03:14 01:04:00	S-band to low power X-band to high power		89942	00:59:02	01:07:02	29-0686	0480	0729
			90422	01:07:02	01:15:02	30-0685	0481	0730
01:19	4-ring		90902	01:15:02	01:23:03	31-0684	0482	0731
			91383	01:23:03	01:31:03	32-0675	0483	0732
01:37:40	ε-ring		91863	01:31:03	01:39:03	33-0681	0484	0733
			92343	01:39:03	01:47:03	34-0671	0485	0734
			92823	01:47:03	01:55:04	35-0670	0486	0735
			93304	01:55:04	02:03:04	36-0668	0487	0736
			93784	02:03:04	02:11:04	37-0682	0488	0737
02:16:36	Begin mini-ASCAL		94264	02:11:04	02:19:04	38-0667	0489	0738
			94744	02:19:04	02:27:04	39-0672	0490	0739
02:27:16 02:32:04	End mini-ASCAL. Telemetry ON		95224	02:27:04	02:35:04	40-0380	0491	0740
			95705	02:35:05	02:43:05	41-0374	0492	0741
			96185	02:43:05	02:51:01	42-0375	0493	0742
02:51:01	End recording		96661					

Table 1. This table lists significant radio science events during the Voyager 2 encounter with Uranus (as seen in Australia) as a function of time. Tapes which were delivered to the Voyager Radio Science Team are listed in column 8 (UC tapes). Backup tapes, created at Stanford University, are shown in column 9. Tapes containing test data are listed in Table 2.

Event Time (UTC)	Canberra Event	1986 DOY	Tape Start UTC (s)	Tape Start (UTC)	Tape Stop (UTC)	Original Tape (S/N)	UC Tape	Backup Tape[:File]
		025	4680	01:18:00	01:19:35		86A2247	0746:0
				01:19:35	01:21:00		86A2250	0746:1
				01:21:10	01:22:45		86A2256	0746:2
				01:22:45	01:23:00		86A2257	0746:3
				01:23:03	01:31:03		Q00001	0747
				01:31:03	01:39:03		Q00002	0748

Table 2. Open loop test data collected after the Voyager 2 Uranus encounter. Tapes delivered to the Voyager Radio Science Team are listed in column 8 (UC Tape). Backup tapes, created at Stanford University, are listed in column 9. Notation mmmm:n denotes backup tape number mmmm and file number n (starting from 0).

File and Record Formats:

A typical tape contains a 32-byte tape header followed by 8 minutes of data in 24000 records of 4390 bytes each[1]. Each data record comprises 80 bytes of header data (Figure 1), 4000 8-bit receiver samples (Figure 2), 300 bytes of Precision Power Monitor (PPM) data (Figure 3), and 10 bytes of operator-entered offsets (Figure 4). An example of RSC-11-9 binary data accompanies this document in the PDS4 archive; also included are translations of the binary to ASCII.

Important: RSC-11-9 binary data were written in “most significant byte” (MSB) first order. Most contemporary computers (ca. 2024) store and read numbers in “least significant byte” (LSB) order, so it is important to handle original RSC-11-9 data at the byte level to prevent corruption of values by unintentional “byte swapping”.

[1] Tapes UC0463, UC0482, UC0486, and UC0490 contain 24050 records (one extra second). Tapes UC0451 and UC0493 are short, containing 7800 and 23750 records, respectively. Tapes with test data contain variable numbers of records.

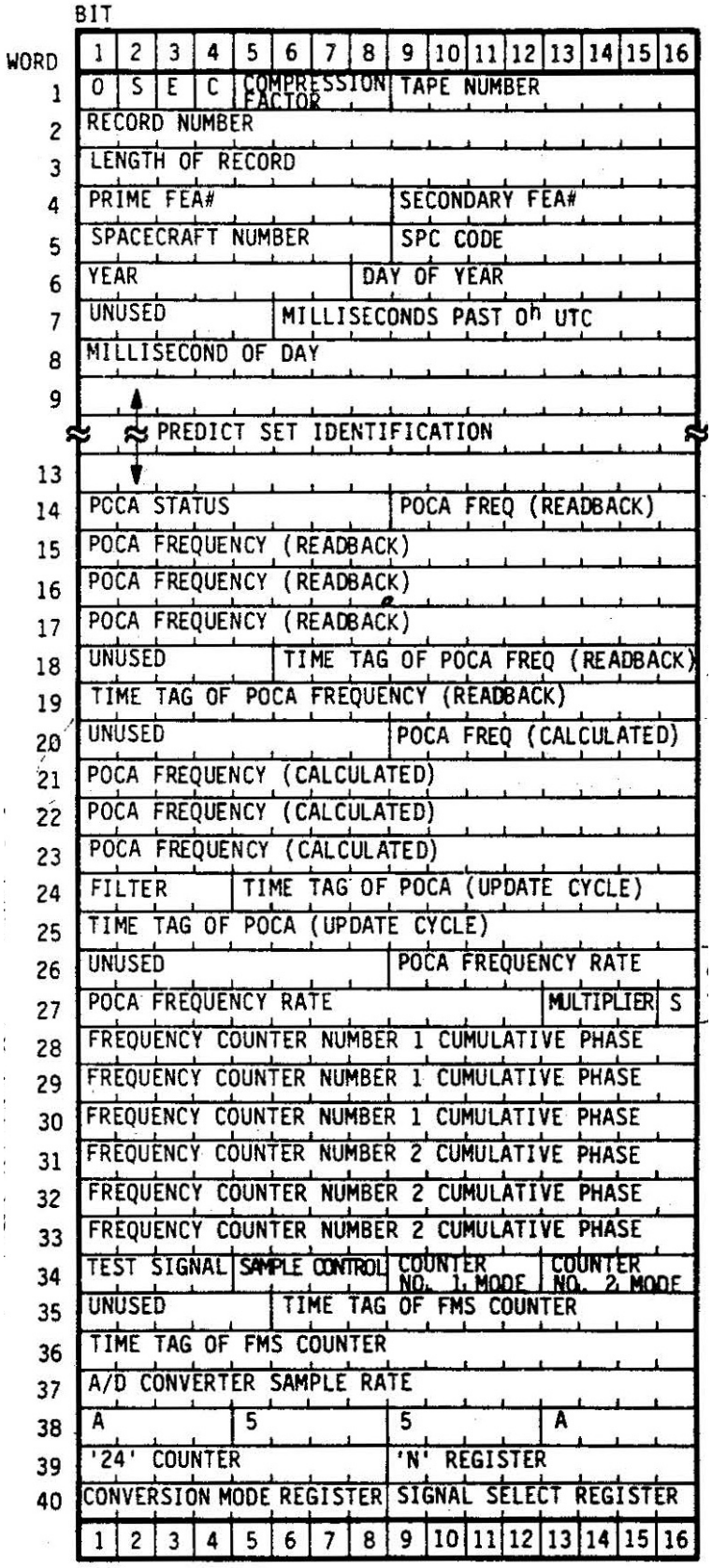

Figure 1. Structure of RSC-11-9 record header. One 16-bit word (left margin) is two 8-bit bytes.

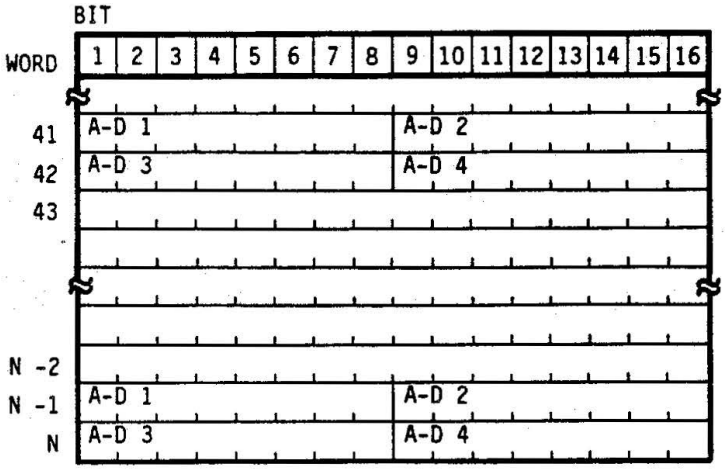

Figure 2. Structure of the RSC-11-9 data area. One 16-bit word (left margin) is two 8-bit bytes. For Voyager 2 at Uranus, the offset of the data area was N=2040 words and the analog-to-digital converter assignments were AD1=DSS-43 S-RCP, AD2=DSS-42 S-RCP, AD3=DSS-43 X-RCP, and AD4=DSS-42 X-RCP.

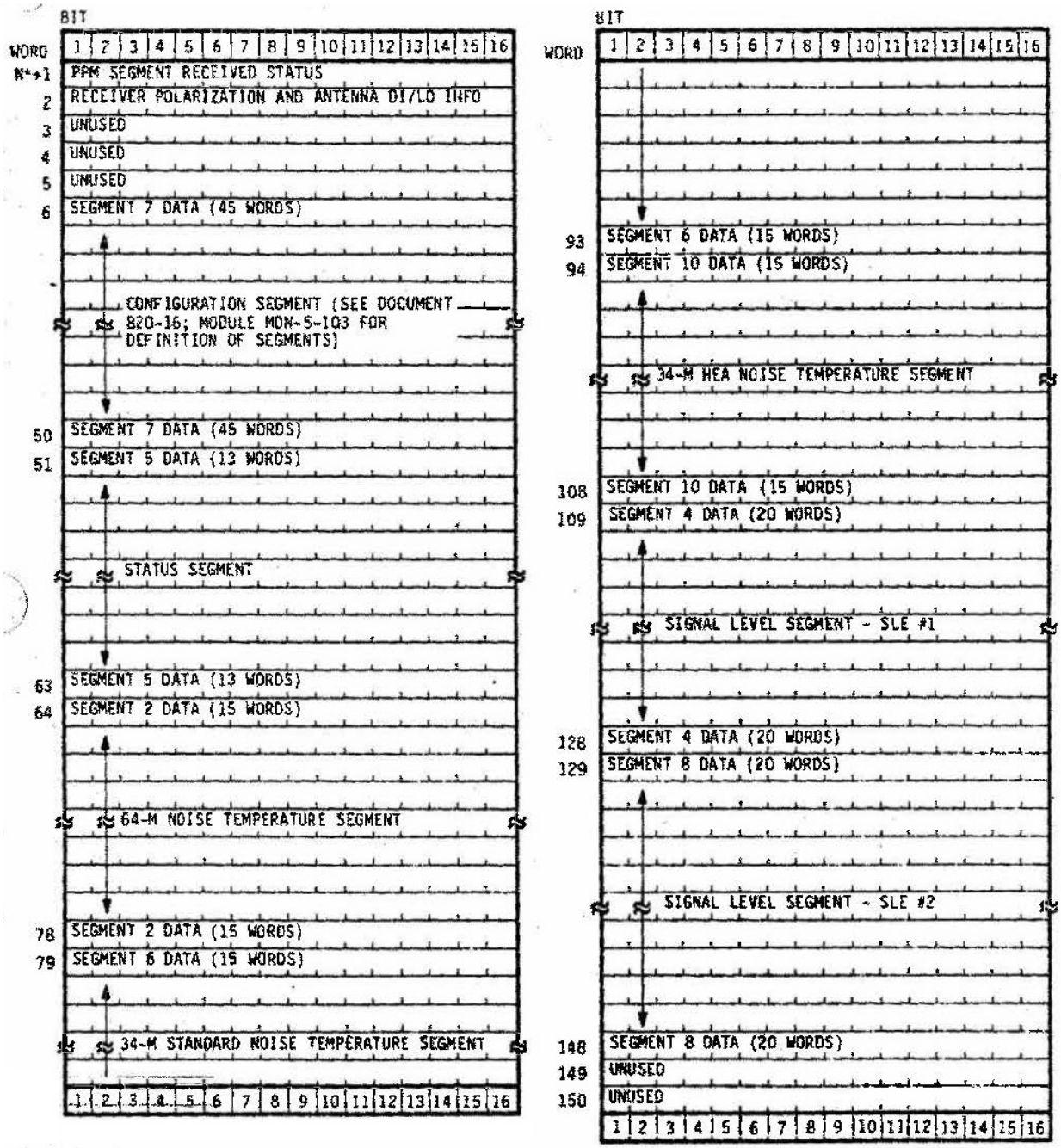

Figure 3. Structure of the RSC-11-9 PPM area. One 16-bit word (left margin) is two 8-bit bytes. For Voyager 2 at Uranus, the offset was N=2040 words.

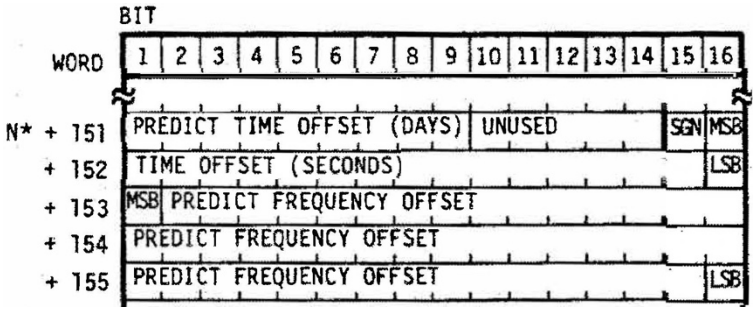

Figure 4. Structure of the RSC-11-9 operator-entered offset (OEO) area. One 16-bit word (left margin) is two 8-bit bytes. For Voyager 2 at Uranus, the offset was N=2040 words.

Example Data File:

An example of RSC-11-9 data (*uc0452a.dat*) generated at Canberra during the Voyager 2 encounter with Uranus accompanies this document in the PDS4 archive. Data were collected at the DSN ground station near Canberra, Australia, on 1986-024. The example file is a truncated version of original file *UC0452*, shown at 21:15:01 in Table 1. Figure 5 shows the first 240 bytes in hexadecimal format from the unix command

od -t x1 uc0452a.dat +0. | head -15

```
0000000    44  4d  4f  2d  35  32  30  35  2d  4f  50  2d  42  20  56  20
0000016    34  2e  33  20  00  00  00  00  00  00  00  00  00  00  00  00
0000032    c1  01  00  01  08  93  2b  00  20  28  ac  18  04  8f  50  08
0000048    5a  52  20  20  20  20  20  20  41  20  75  43  35  03  04  10
0000064    46  54  04  8f  50  08  00  43  35  03  04  10  61  02  84  8f
0000080    50  12  00  43  93  81  00  00  33  1f  1f  e5  00  00  33  1f
0000096    1f  e2  1d  10  04  8f  50  08  c3  50  a5  5a  12  f9  14  1b
0000112    8b  64  85  8a  b4  94  61  89  78  8c  70  86  7c  a5  95  81
0000128    aa  a6  90  8a  6b  7a  82  86  6c  71  90  88  91  77  8e  8a
0000144    92  8e  9f  89  89  85  a1  8a  8e  85  93  8a  80  aa  6c  8c
0000160    b2  93  7a  87  9f  8f  bb  81  77  8d  98  8c  7d  82  8f  94
0000176    7e  71  7f  8b  9c  b2  77  8a  8f  cf  9d  87  95  74  a7  88
0000192    8c  72  88  89  64  58  4f  8d  8b  82  80  86  71  a7  79  88
0000208    8f  6b  8b  84  b4  98  92  8d  7e  82  89  91  6e  7d  a2  88
0000224    98  76  8f  87  a2  99  96  8b  8f  93  95  84  84  81  7f  8e
0000240                                ...
```

Figure 5. Hexadecimal dump of the first 240 bytes from file *uc0452a.dat*. The byte counter along the left margin is given in decimal. The first 32 bytes (yellow highlighting) contain the tape header, the next 80 bytes (green highlighting) contain the first record header. The first data sample is in byte 113.

A full hexadecimal dump of the example file is available (with annotations) in *uc0452a.hex.pdf*

Tape Header: The 32-byte tape header is a string of ASCII characters, which translates to

DMO-5205-OP-B V 4.3

followed by one ASCII space character (0x20) and 12 ASCII null characters (0x00).

Record Headers: The first record header may be unpacked as shown in Table 3. Asterisks (*) in the right column denote flag values; see [1] for interpretations. Headers from all ten records are given in accompanying file *uc0452a.hdr*. If *uc0452a.hdr* were read into a spreadsheet (such as Microsoft Excel), file *uc0452a.txt* provides field headers which can be added to the spreadsheet.

Table 3. Unpacked Record Header from Data Record 1 (*uc0452a.dat*)

Bytes	Bit Numbers	Value (b = binary) (h = hexadecimal)	Description	Unpacked Value
1	1	1_b	Time tag and configuration flag	1*
1	2	1_b	Start of recording flag	1*
1	3	0_b	Error flag	0*
1	4	0_b	Sample resolution	0*
1	5-8	1_h	Compression factor	1*
2	9-16	01_h	Tape number	1
3-4	17-32	0001_h	Record number	1
5-6	33-48	0893_h	Record length (words)	2195
7	49-56	$2b_h$	Prime front end area (FEA)	43
8	57-64	00_h	Secondary FEA	0
9	65-72	20_h	Spacecraft number	32
10	73-80	28_h	Signal Processing Center (SPC)	40
11	81-87	56_h	Year (last two digits)	86
11-12	88-96	18_h	Day of year	24
13-16	97-128	$048f5008_h$	Time of first sample (milliseconds past 0h UTC)	76501000
17-26	129-208	$5a522020202020204120_h$	Predict set ID	ZR A
27	209	0_b	POCA status (source of control)	0*
27	210	1_b	POCA status (readiness)	1*
27	211	1_b	POCA status (synthesizer power)	1*
27	212	1_b	POCA status (synthesizer lock status)	1*
27	213	0_b	POCA status (limit enable)	0*
27	214	1_b	POCA status (track)	1*
27	215	0_b	POCA status (acquisition)	0*
27	216	1_b	POCA status (sweep)	1*
28-34	217-272	43350304104654_h	POCA readback frequency (BCD, μHz)	43350304104654
35-38	273-304	$048f5008_h$	FTS readback time (milliseconds past 0h UTC)	76501000
39-46	305-368	0043350304106102_h	POCA calculated frequency (BCD, μHz)	43350304106102
47	369-372	8_h	Receiver filter	8
47-50	373-400	$48f5012_h$	Diagnostic POCA time tag (milliseconds past 0h UTC)	76501010
52-54	409-428	43938_h	POCA rate (BCD, Hz per second)	43938
54	429-431	000_b	POCA rate power of ten	0
54	432	1_b	POCA rate sign	1*
55-60	433-480	$0000331f1fe5_h$	1-s Σ phase, counter 1 (scaled to 2^{-8} cycles)	857677797
61-66	481-528	$0000331f1fe2_h$	1-s Σ phase, counter 2 (scaled to 2^{-8} cycles)	857677794
67	529-532	1_h	Test signal selection	1
67	533-536	d_h[2]	Sample control register	13
68	537-540	1_h	Frequency counter 1 mode register	1
68	541-544	0_h	Frequency counter 2 mode register	0
69-72	545-576	$048f5008_h$	FMS time tag (milliseconds past 0h UTC)	76501000
73-74	577-592	$c350_h$	Single ADC sample rate	50000
75-76	593-608	$a55a_h$	NBOC sync code	$a55a_h$
79	625	0_b	NBOC overflow flag	0*
79	628	1_b	Sample rate flag	1*
79	629	0_b	Test mode flag	0*
79	630	1_b	8-bit sample flag	1*
79	631-632	00_b	ADC assignment flag	00*
80	633-634	00_b	AD1 assignment	00_b
80	635-636	01_b	AD2 assignment	01_b
80	637-638	10_b	AD3 assignment	10_b
80	639-640	11_b	AD4 assignment	11_b

[2] The expected value in this field is hexadecimal b_h or decimal 11 [1].

Data Values: The first record in the example file includes 4000 8-bit data samples. In Figure 5, samples begin with hexadecimal value 0x8b (decimal 139) in byte 113. This sample as well as the fifth, ninth, etc. came from AD1. The second, sixth, tenth, etc. samples came from AD2; the third, seventh, etc. came from AD3; and the fourth, eighth, etc. came from AD4 (Figure 2). If the data records are parsed in this way, the original sample stream can be recovered (see accompanying files *uc0452a1.tab*, *uc0452a2.tab*, *uc0452a3.tab*, and *uc0452a4.tab*, respectively). Figure 7 shows histograms of the sample values from each of the A-D converters in records 1-10 of the example file. Figure 8 shows power in AD outputs. Note that the histograms have similar shapes and the means are within 1 unit; but the distribution from AD4 is about 5 times narrower (and the histogram peak is about 5 time larger) than for the other three converters.

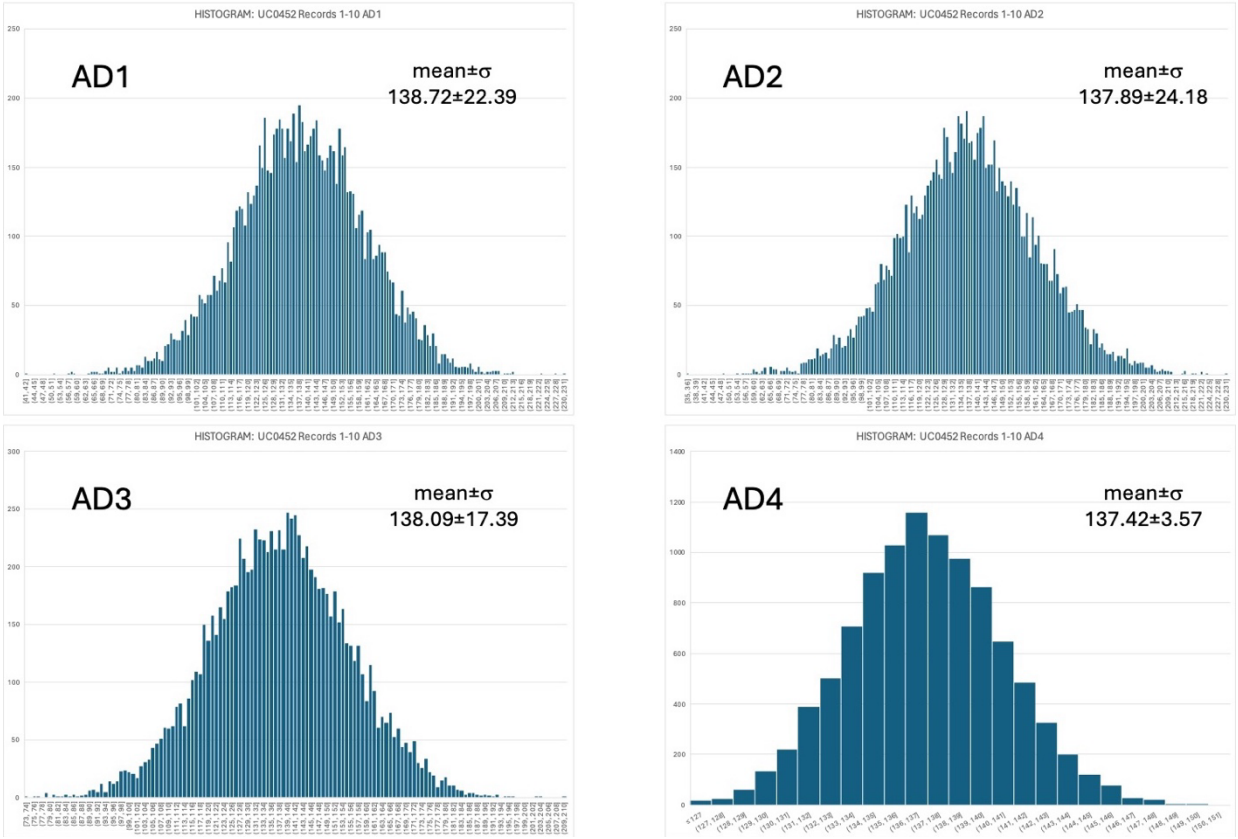

Figure 7. Histograms of the samples from each analog-to-digital converter in records 1-10 of the example file. The histograms are very similar except that the peak value for AD4 is about 5 times larger and its standard deviation is about 5 times smaller than for the other histograms.

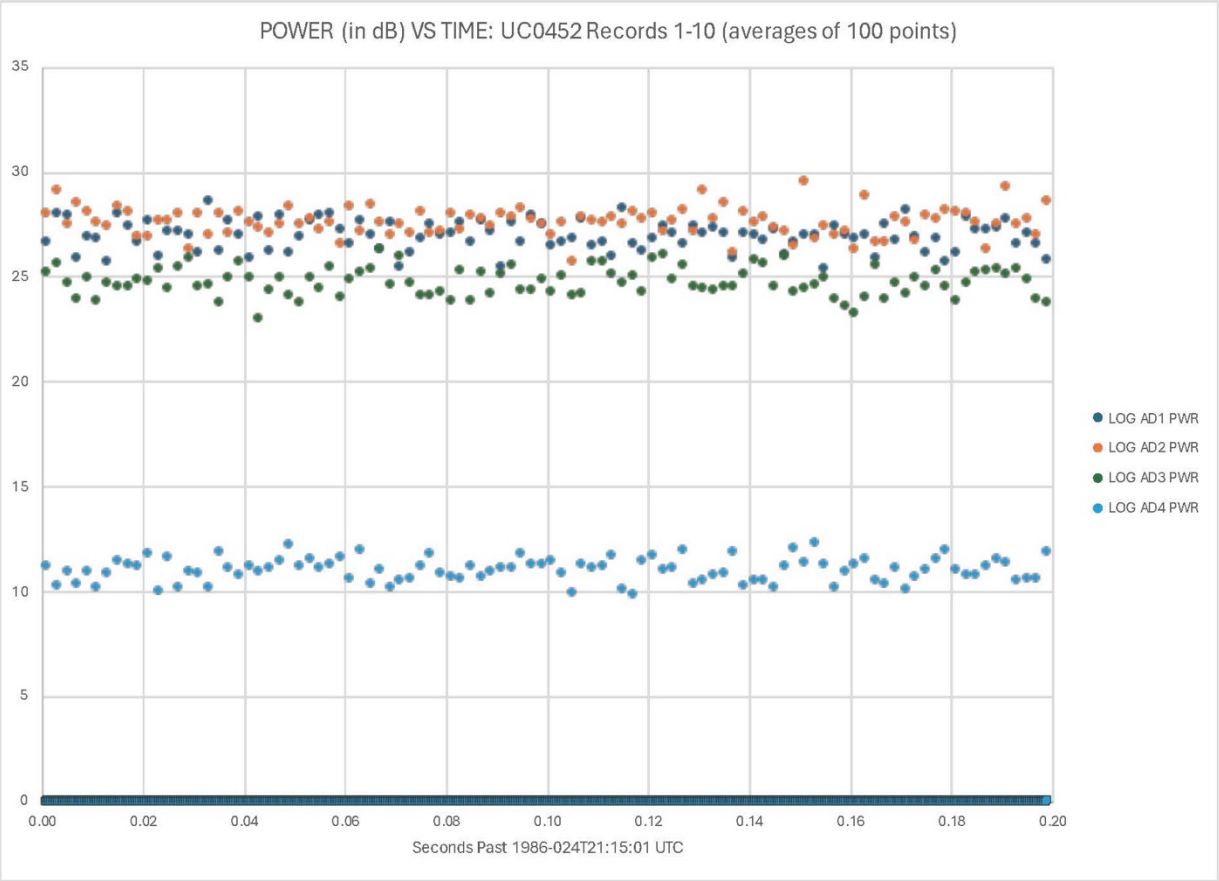

Figure 8. Power versus time in the samples from each analog-to-digital converter (ADC) versus time. Each sample value was reduced by the mean for its channel, the result was squared, and 101 such values were averaged to produce one plotted point. Sample values were extracted from the first 10 data records of UC0452*;* so there were 10000 original samples and 100 plotted points for each ADC.