Interpretation and Use of Binary RSC-11-10A Data

This document describes and illustrates extraction of values from binary files generated according to the NASA Deep Space Network (DSN) RSC-11-10A Software Interface Specification (SIS). In this document, RSC-11-10A is referenced as:

[1] *Document 820-013 (Rev. A), DSN System Requirements, Detailed Interface Design, RSC-11-10A, Voyager Neptune ODR Agreement,* effective date July 1988 (PDS logical identifier urn:nasa:pds:radiosci.documentation:dsn.rsc-11-10a:1988-07-01)

RSC-11-10A 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-11-10A specifies the format and content of the open loop radio science files collected using the 70-m NASA Deep Space Network antenna near Canberra, Australia, during the Voyager 2 encounter with Neptune. Variations of this format, used for collection of data during the same encounter at Parkes Observatory (Australia) and the Usuda Tracking Station (Japan), are described separately.

Data Overview:

Digital open loop data were the primary inputs for the study of radio occultations by the neutral atmosphere and ionosphere of Neptune and by the ionosphere of Triton[1].

The 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 Neptune encounter, S- and X-band receiver outputs in right-circular polarization (RCP) from the 70-m antenna (DSS-43) at the DSCC near Canberra, Australia, were written to tape at 100,000 8-bit (real) samples per second from each of the two receiver channels. The X-RCP receiver output was sampled alternately by analog-to-digital converters (ADCs) AD1 and AD3. The S-RCP receiver output was sampled alternately by AD2 and AD4. Each ADC operated at 50,000 samples per second; AD2 and AD4 were delayed by 10 μs relative to AD1 and AD3, yielding an effective rate of 100,000/s for each receiver.

Table 1 shows the Neptune occultation timeline, significant events, and corresponding tape numbers (column 6). Table 2 provides the same information with events before, during, and after the Triton occultation.

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 computer. Subsequent handling has exclusively used the electronic (laptop) files. Throughout, [1] has remained the descriptive document of the Canberra data.

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[1] G. L. Tyler, D. N. Sweetnam, J. D. Anderson, S. E. Borutzki, J. K. Campbell, V. R. Eshleman, D. L. Gresh, E. M. Gurrola, D. P. Hinson, N. Kawashima, E. R. Kursinski, G. S. Levy, G. F. Lindal, J. R. Lyons, E. A. Marouf, P. A. Rosen, R. A. Simpson, and G. E. Wood. Voyager Radio Science Observations of Neptune and Triton, *Science*, **246**, 1466-1473, 1989.

Event Time (UTC)	Event	Tape Start (s)	Tape State (UTC)	Tape Stop (UTC)	Tape NC	Notes
		09302	02:35:02	02:38:03	0590	Test
		09722	02:42:02	02:50:00	0591	Test
		11522	03:12:02	03:20:02	0592	Test
		12002	03:20:02	03:28:01	0593	Test
06:40:02	Begin recording of Neptune occultation	24002	06:40:02	06:48:02	0594	
		24482	06:48:02	06:56:02	0595	
06:59:09 07:01:02 07:02:02	Inbound ring plane crossing S-band telemetry OFF X-band telemetry OFF	24962	06:56:02	07:04:02	0596	
07:06:02 07:11:25	Start roll to Canopus End roll to Canopus	25442	07:04:02	07:12:02	0597	
07:14:52	Begin Mini-ASCAL	25922	07:12:02	07:20:02	0598	
07:22:53 07:26:03	End Mini-ASCAL TWNC OFF	26402	07:20:02	07:28:02	0599	
		26882	07:28:02	07:36:02	0600	
07:42:03	TWNC ON	27362	07:36:02	07:44:02	0601	
		27842	07:44:02	07:52:02	0602	
		28322	07:52:02	08:00:02	0603	
08:07:57	Begin limbtrack maneuver	28802	08:00:02	08:08:02	0604	
		29282	08:08:02	08:16:02	0605	
		29762	08:16:02	08:24:02	0606	
		30242	08:24:02	08:32:02	0607	
		30722	08:32:02	08:40:02	0608	
		31202	08:40:02	08:48:02	0609	
		31682	08:48:02	08:56:02	0610	
08:56:54	End limbtrack maneuver	32162	08:56:02	09:04:02	0611	
		32642	09:04:02	09:12:02	0612	
		33122	09:12:02	09:20:02	0613	
09:20:59 09:24:30	Outbound ring plane crossing Begin Mini-ASCAL	33602	09:20:02	09:28:02	0614	
09:32:30	End Mini-ASCAL	34082	09:28:02	09:36:02	0615	
09:38:04 09:39:04 09:39:54 09:43:42	X-band telemetry ON S-band telemetry ON Begin IMC End IMC	34562	09:36:02	09:44:02	0616	
09:51:40	Begin roll to Alkaid	35042	09:44:02	09:52:02	0617	
10:00:00	Return to normal subreflector focusing	35522	09:52:02	10:00:02	0618	
10:02:24 10:05:16 10:06:61	End roll to Alkaid Real-time TWNC OFF Begin IMC	36002	10:00:02	10:08:02	0619	
		36482	10:08:02	10:16:02	0620	
		36962	10:16:02	10:24:02	0621	
10:30:04	TWNC ON	37442	10:24:02	10:32:02	0622	
10:32:28 10:36:06	End IMC Begin NIMC	37922	10:32:02	10:40:02	0623	
		38402	10:40:02	10:48:02	0624	
10:55:01	End recording of Neptune occultation	38882	10:48:02	10:55:01	0625	

Table 1. Voyager 2 Neptune occultation time line with open loop data tape numbers (column 6).

Event Time (UTC)	Event	Tape Start (s)	Tape State (UTC)	Tape Stop (UTC)	Tape NC	Notes
12:20:02	Begin recording of Triton occultation	44402	12:20:02	12:28:02	0626	
		44882	12:28:02	12:36:02	0627	
		45362	12:36:02	12:44:02	0628	
		45842	12:44:02	12:52:02	0629	
		46322	12:52:02	13:00:02	0630	
		46802	13:00:02	13:08:02	0631	
		47282	13:08:02	13:16:02	0632	
		47762	13:16:02	13:24:02	0633	
13:28:45 13:29:45	S-band telemetry OFF X-band telemetry OFF	48242	13:24:02	13:32:02	0634	
		48722	13:32:02	13:40:02	0635	
13:45:26	Begin Triton occultation	49202	13:40:02	13:48:02	0636	
13:48:26	End Triton occultation	49682	13:48:02	13:56:02	0637	
		50162	13:56:02	14:04:02	0638	
14:05:46 14:06:46	X-band telemetry ON S-band telemetry ON	50642	14:04:02	14:12:02	0639	
		51122	14:12:02	14:20:02	0640	
		51602	14:20:02	14:28:02	0641	
		52082	14:28:02	14:36:02	0642	
		52562	14:36:02	14:44:02	0643	
		53042	14:44:02	14:52:02	0644	
		53522	14:52:02	15:00:02	0645	
		54002	15:00:02	15:08:02	0646	
		54482	15:08:02	15:16:02	0647	
		54962	15:15:02	15:24:00	0648	
		55442	15:24:02	15:32:02	0649	
		55922	15:32:02	15:40:02	0650	
		56402	15:40:02	15:48:02	0651	
		56882	15:48:02	15:56:02	0652	
		57362	15:56:02	16:04:02	0653	
		57842	16:04:02	16:12:02	0654	
		58322	16:12:02	16:20:02	0655	
16:28:02	End recording of Triton occultation	58802	16:20:02	16:28:02	0656	
		59282	17:00:00	17:05:00	0657	Test
		59762	17:10:00	17:15:00	0658	Test

Table 2. Voyager 2 Triton occultation time line with open loop data tape numbers (column 6).

File and Record Formats:

A typical tape contains a 32-byte tape header followed by 8 minutes of data in 24000 data records of 4166 bytes each. Each data record comprises 166 bytes of header data (Figure 1) and 4000 8-bit receiver samples (Figure 2). An example of RSC-11-10A binary data accompanies this document in the PDS4 archive; also included are translations of the binary to ASCII.

Important: RSC-11-10A binary data were written in “most significant byte” (MSB) first order. Most contemporary computers (ca. 2025) store and read numbers in “least significant byte” (LSB) order, so it is important to handle original RSC-11-10A data at the byte level to prevent corruption of values by unintentional “byte swapping”.

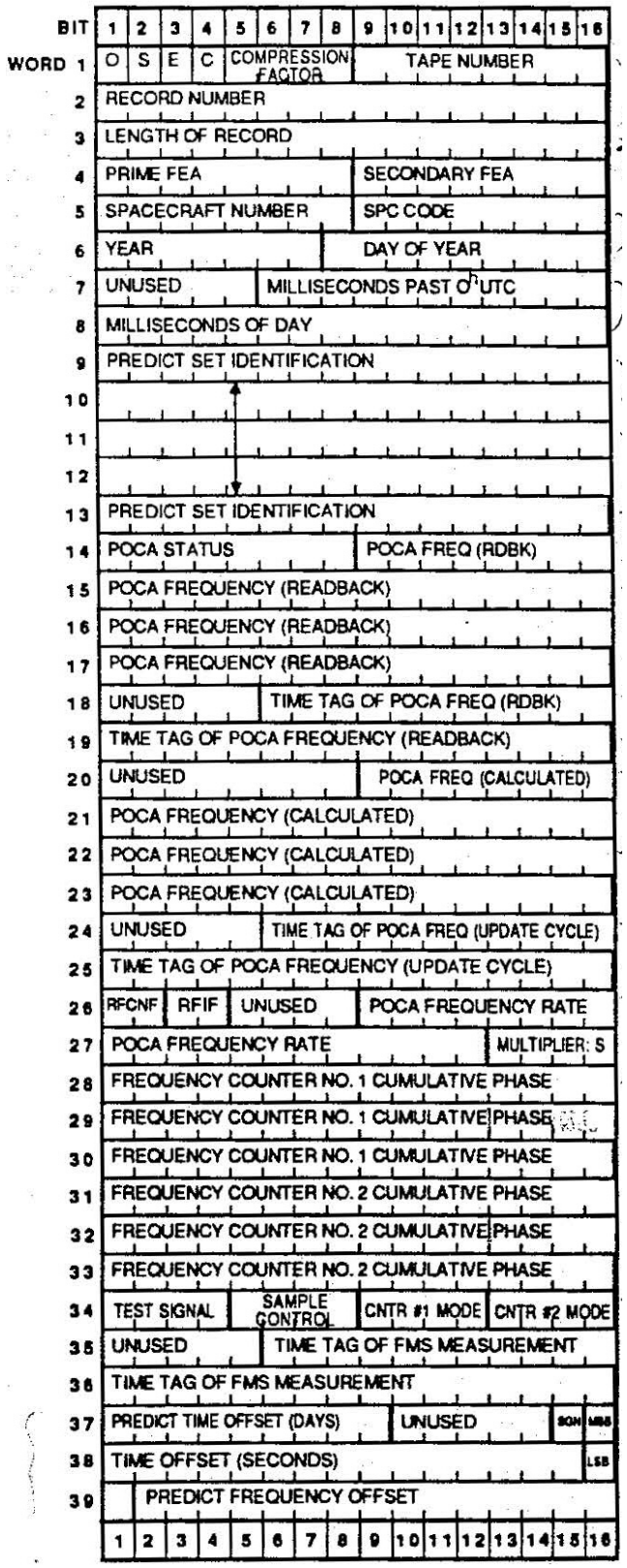

Figure 1a. Structure of RSC-11-10A record header (Words 1-39).
One 16-bit word (left margin) is two 8-bit bytes.

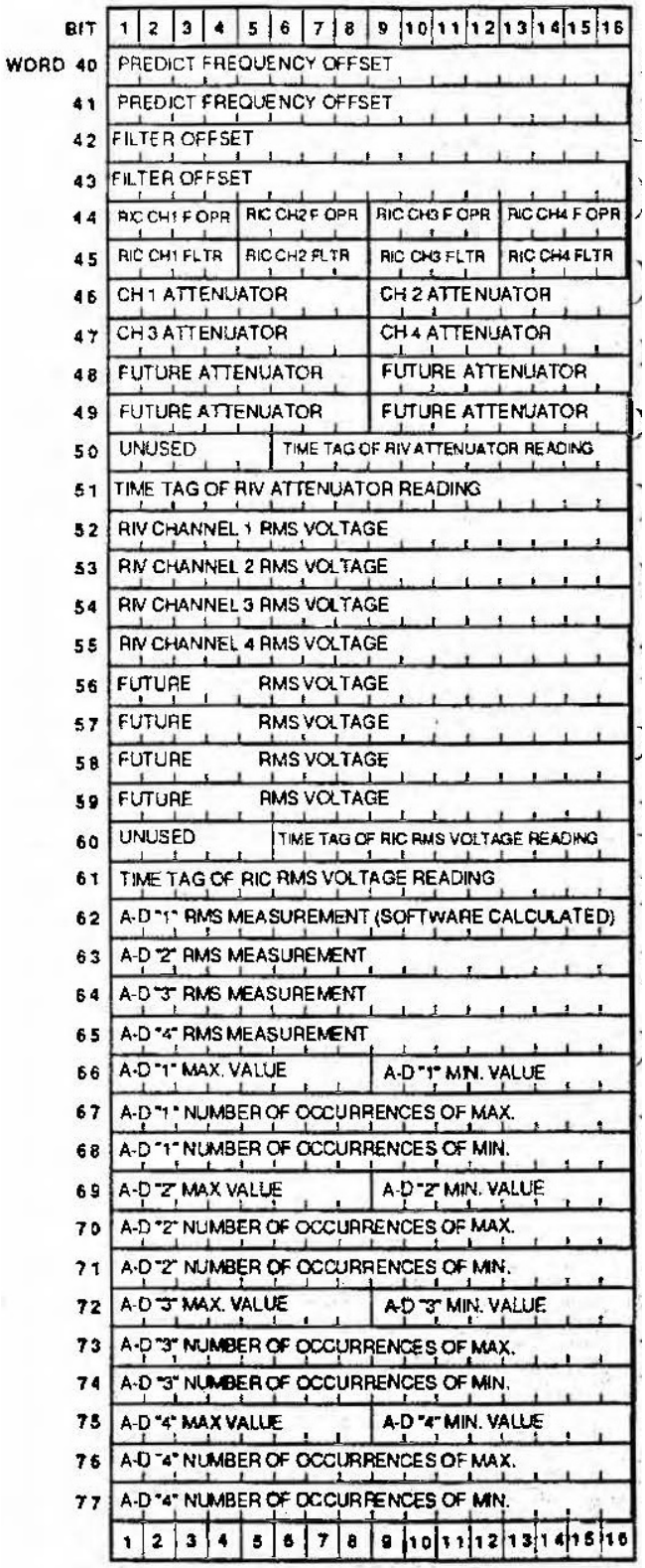

Figure 1b. Structure of RSC-11-10A record header (Words 40-77).
One 16-bit word (left margin) is two 8-bit bytes.

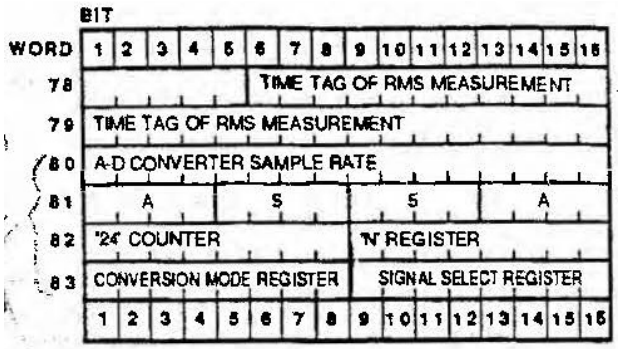

Figure 1c. Structure of RSC-11-10A record header (Words 78-83).
One 16-bit word (left margin) is two 8-bit bytes.

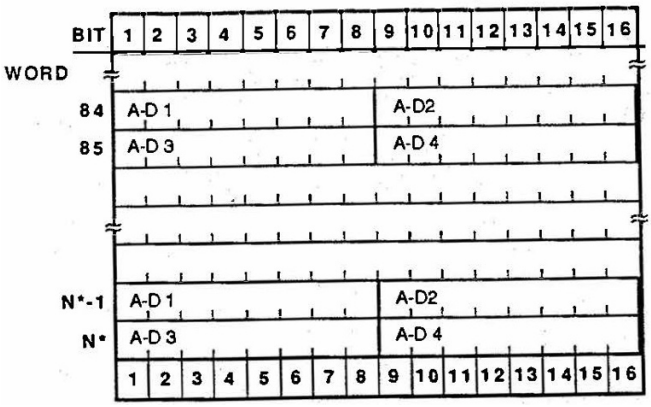

Figure 2. Structure of the data portion of RSC-11-10A records. The record header ends at Word 83 For Voyager 2 at Neptune, receiver samples were 8-bits and N=2083. Each 16-bit word (left margin) is two 8-bit bytes.

Example Data File:

An example of RSC-11-10A data (*nc0590a.dat*) generated at Canberra during the Voyager 2 encounter with Neptune accompanies this document. The example file is a truncated version of original file *NC0590*, shown starting at 02:35:02 in Table 1. Figure 3 shows the first 240 bytes in hexadecimal format from the unix-like command

od -t x1 nc0590a.dat +0. | head -15

```
0000000   44  53  50  52  2d  35  32  30  35  2d  4f  50  2d  44  2d  56
0000016   37  2e  31  33  00  00  00  00  00  00  00  00  00  00  00  00
0000032   d1  01  00  01  08  23  28  00  20  28  b2  ed  00  8d  ef  f0
0000048   54  45  53  54  2a  31  20  20  41  20  75  43  29  79  11  84
0000064   84  84  00  8d  ec  08  00  43  29  79  11  84  84  84  00  8d
0000080   ec  26  00  00  00  01  79  3d  bc  ce  50  00  69  3d  bc  cc
0000096   50  00  11  10  00  8d  ef  fa  00  00  00  00  00  00  00  00
0000112   00  00  ff  fe  d9  bb  33  33  33  66  30  30  6f  75  00  00
0000128   00  00  00  8d  8c  f4  01  dd  03  2a  00  02  00  05  00  00
0000144   00  00  00  00  00  00  00  8d  8c  f4  05  6b  04  48  05  87
0000160   04  7b  f1  1b  00  01  00  01  d8  2f  00  01  00  01  e9  16
0000176   00  01  00  01  db  28  00  01  00  01  00  8d  ec  08  c3  50
0000192   a5  5a  0e  fa  36  11  49  8f  72  50  a8  9c  83  67  39  6f
0000208   78  89  98  67  95  79  2c  85  86  81  a3  75  99  96  8b  9b
0000224   7b  93  84  67  bc  b9  73  67  51  78  89  75  9a  7a  80  67
```

Figure 3. Hexadecimal dump of the first 240 bytes from file *nc0590a.dat*. The byte counter along the left margin is in decimal. The first 32 bytes (yellow highlighting) contain the tape header, the next 166 bytes (green highlighting) contain the first record header. The first data sample is in byte 199.

A full hexadecimal dump of the example file is available (with annotations) in *nc0590a.hex.pdf*

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

```
DSPR-5205-OP-D-V7.13
```

followed by 12 ASCII null characters (0x00).

Record Headers: The first record header may be unpacked as shown in Table 3; see [1] for interpretations. Headers from all five data records are given in accompanying file *nc0590a.hdr*. If *nc0590a.hdr* were read into a spreadsheet (such as Microsoft Excel), file *nc0590a.txt* provides field titles which can be added to the spreadsheet.

Table 3. Unpacked Record Header from Data Record 1 (nc0590*a.dat*)

Bit Field	Byte Location	Bit Location (from start of record)	Value (b = binary) (h = hexadecimal)	Description	Unpacked Value
1	1	1	1_b	Time tag and configuration flag	1
2	1	2	1_b	Start of recording flag	1
3	1	3	0_b	Error flag	0
4	1	4	1_b	Sample resolution	0
5	1	5-8	1_h	Compression factor	1
6	2	9-16	01_h	Tape number	1
7	3-4	17-32	0001_h	Record number	1
8	5-6	33-48	0823_h	Record length (words)	2083
9	7	49-56	28_h	Prime front end area (FEA)	40
10	8	57-64	00_h	Secondary FEA	0

11	9	65-72	20_h	Spacecraft number	32
12	10	73-80	28_h	Signal Processing Center (SPC)	40
13	11	81-87	1011001_b	Year (last two digits)	89
14	11-12	88-96	ed_h	Day of year	237
15	13	97-101	00_h	Unused 1	0
16	13-16	97-128	$8deff0_h$	Time of first sample (milliseconds past 0h UTC)	9302000
17	17-26	129-208	$544553542a3120204120_h$	Predict set ID	TEST*1 A
18	27	209	0_b	POCA status (source of control)	0
19	27	210	1_b	POCA status (readiness)	1
20	27	211	1_b	POCA status (synthesizer power)	1
21	27	212	1_b	POCA status (synthesizer lock status)	1
22	27	213	0_b	POCA status (limit enable)	0
23	27	214	1_b	POCA status (track)	1
24	27	215	0_b	POCA status (acquisition)	0
25	27	216	1_b	POCA status (sweep)	1
26	28-34	217-272	43297911848484_h	POCA readback frequency (BCD, μHz)	43297911848484
27	35	273-277	00_h	Unused 2	0
28	35-38	273-304	$8dec08_h$	FTS readback time (msec past 0h UTC)	9301000
29	39	305-312	00_h	Unused 3	0
30	40-46	313-368	43297911848484_h	POCA calculated frequency (BCD, μHz)	43297911848484
31	47	369-373	00_h	Unused 3	0
32	47-50	374-400	$8dec26_h$	Diagnostic POCA time tag (msec past 0h UTC)	9301030
33	51	401-402	0_b	Antenna configuration code (selected)	0
34	51	403-404	0_b	Antenna configuration code (reported)	0
35	51	405-408	0_h	Unused 4	0
36	52-54	409-428	00000_h	POCA frequency rate (BCD, tenths of Hz/s)	0
37	54	429-431	000_b	Power of 10 multiplier for POCA frequency rate	0
38	54	432	1_b	Sign for frequency rate (0=negative, `1=positive)	1
39	55-60	433-480	$793dbcce5000_h$	One-second accumulated phase #1 (2^-20 cycles)	133306067603456
40	61-66	481-528	$693dbccc5000_h$	One-second accumulated phase #2 (2^-20 cycles)	115713881427968
41	67	529-532	0001_b	FMS test facility input signal selection	1
42-45	67	533-536	0001_b	FMS sample control register	1
46	68	537-540	0001_b	Frequency counter 1 mode register	1
47	68	541-544	0000_b	Frequency counter 2 mode register	0
48	69	545-549	00_h	Unused 5	0
49	69-72	550-576	$8deffa_h$	FMS counter time tag (msec)	9302010
50	73-74	577-585	000000000_b	Predict time offset	0
51	74	586-590	00_h	Unused 6	0
52	74	591	0_b	Sign of predict time offset (1=negative, 0=positive)	0
53	74-76	592-608	00000_h	Predict time offset (sec)	0
54	77-82	609-656	000000000000_h	S-band predict frequency offset (2^-20 Hz)	0
55	83-86	657-688	$fffed9bb_h$	S-band filter offset (Hz)	-75333
56	87	689-692	3_h	RIC filter for Channel 1 (selected)	3
57	87	691-696	3_h	RIC filter for Channel 2 (selected)	3
58	88	697-700	3_h	RIC filter for Channel 3 (selected)	3
59	88	701-704	3_h	RIC filter for Channel 4 (selected)	3
60	89	705-708	3_h	RIC filter for Channel 1 (reported)	3
61	89	709-712	3_h	RIC filter for Channel 2 (reported)	3
62	90	713-716	6_h	RIC filter for Channel 3 (reported)	6
63	90	717-720	6_h	RIC filter for Channel 4 (reported)	6
64	91	721-728	30_h	RIV attenuator setting for Channel 1 (dB)	48
65	92	729-736	30_h	RIV attenuator setting for Channel 2 (dB)	48
66	93	737-744	$6f_h$	RIV attenuator setting for Channel 3 (dB)	111
67	94	745-752	75	RIV attenuator setting for Channel 4 (dB)	117
68	95	753-760	00_h	RIV attenuator for future use	0
69	96	761-768	00_h	RIV attenuator for future use	0
70	97	769-776	00_h	RIV attenuator for future use	0

71	98	777-784	00_h	RIV attenuator for future use	0
72	99	785-789	00_h	Unused 7	0
73	99-102	790-816	$8d8cf4_h$	RIV attenuator time tag (msec)	9276660
74	103-104	817-832	$1dd_h$	RIC RMS voltage, Channel 1 (mv)	477
75	105-106	833-848	$32a_h$	RIC RMS voltage, Channel 2 (mv)	810
76	107-108	849-864	2_h	RIC RMS voltage, Channel 3 (mv)	2
77	109-110	865-880	5_h	RIC RMS voltage, Channel 4 (mv)	5
78	111-112	881-896	0	Future RMS voltage #1	0
79	113-114	897-912	0	Future RMS voltage #2	0
80	115-116	913-928	0	Future RMS voltage #3	0
81	117-118	929-944	0	Future RMS voltage #4	0
82	119	945-949	0	Unused 8	0
83	119-122	950-976	$8d8cf4_h$	RIC RMS voltage time tag (msec)	9276660
84	123-124	977-992	$56b_h$	Software calculated RMS voltage, Channel 1 (mv)	1387
85	125-126	993-1008	448_h	Software calculated RMS voltage, Channel 2 (mv)	1096
86	127-128	1009-1024	587_h	Software calculated RMS voltage, Channel 3 (mv)	1415
87	129-130	1025-1040	$47b_h$	Software calculated RMS voltage, Channel 4 (mv)	1147
88	131	1041-1048	$f1_h$	Maximum ADC value, Channel 1	241
89	132	1049-1056	$1b_b$	Minimum ADC value, Channel 1	27
90	133-134	1057-1072	0001_h	Number of occurrences of value in byte 131	1
91	135-136	1077-1088	0001_h	Number of occurrences of value in byte 132	1
92	137	1089-1096	$d8_h$	Maximum ADC value, Channel 2	216
93	138	1097-1104	$2f_h$	Minimum ADC value, Channel 2	47
94	139-140	1105-1120	0001_h	Number of occurrences of value in byte 137	1
95	141-142	1121-1136	0001_h	Number of occurrences of value in byte 138	1
96	143	1137-1144	$e9_h$	Maximum ADC value, Channel 3	233
97	144	1145-1152	16_h	Minimum ADC value, Channel 3	22
98	145-146	1153-1168	0001_h	Number of occurrences of value in byte 143	1
99	147-148	1169-1184	0001_h	Number of occurrences of value in byte 144	1
100	149	1185-1192	db_h	Maximum ADC value, Channel 4	219
101	150	1193-1200	28_h	Minimum ADC value, Channel 4	40
102	151-152	1201-1216	0001_h	Number of occurrences of value in byte 149	1
103	153-154	1217-1232	0001_h	Number of occurrences of value in byte 150	1
104	155	1233-1237	0	Unused 9	0
105	155-158	1238-1264	$8dec08_h$	Time tag of max-min samples (msec)	9301000
106	159-160	1265-1280	$c350_h$	Single ADC sample rate (samples per second)	50000
107	161-162	1281-1296	$a55a_h$	NBOC sync code	A55A
108	163	1297-1304	$0e_h$	“24” counter	14
109	164	1305-1312	fa_h	“N” register	250
110	165	1313	0_b	NBOC overflow flag	0
111	165	1314	0	Unused 10	0
112	165	1315	1_b	NBOC PLL in-lock flag	1
113	165	1316	1_b	Sample rate flag	1
114	165	1317	0_b	Operational mode flag	0
115	165	1318	1_b	Sample resolution flag	1
116	165	1319-1320	10_b	Sample mode flag	2
117	166	1321-1322	00_b	AD1 assignment	0
118	166	1323-1324	01_b	AD2 assignment	1
119	166	1325-1326	00_b	AD3 assignment	0
120	166	1327-1328	01_b	AD4 assignment	1

Data Values: The first data record in the example file includes 4000 8-bit data samples. In Figure 3, receiver samples begin with hexadecimal value 0x49 (decimal 73) in byte 199. This sample as well as the fifth, ninth, etc. came from AD1; the third, seventh, eleventh, etc. came from AD3. Together, they provide the sample stream that represents the output from the Channel 1 (X-RCP) receiver. The second, fourth, sixth, etc. samples are from AD2 and AD4; they

combine to represent the output from the Channel 2 (S-RCP) receiver (see accompanying files *nc0590x.tab* and *nc0590s.tab* respectively). Figure 4 shows histograms of the sample values from the two receivers.

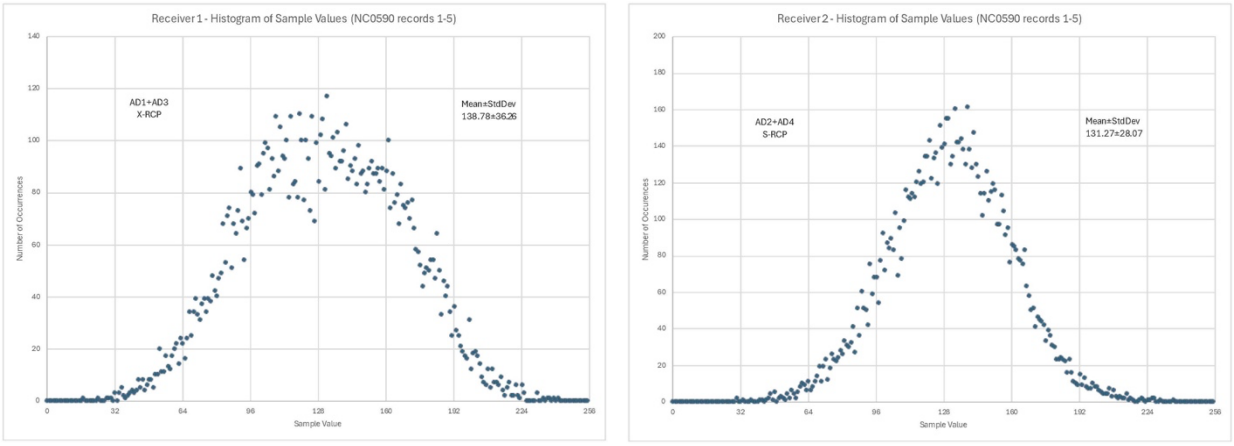

Figure 4. Histograms of the samples from each receiver in data records 1-5 of the example file (10000 samples in each histogram). Receiver 1 (X-RCP, left) is represented by samples from AD1 and AD3; Receiver 2 (S-RCP, right) is represented by samples from AD2 and AD4.