VLA Computer Memorandum 186

VLA Archive Data Format

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1 Overview

This memo is a revision of an unpublished note dated October 14, 1987; it succeeds and replaces all older versions. The purpose is to describe the format of the observation data written by the VLA on-line computers.

Observation data is written by the VLA on-line computers sequentially as the observations are made. The VLA may be configured to operate as up to five (more or less) independent telescopes; these are known as subarrays. At the end of each integration time, a data record (a *logical record*) for each of the active subarrays is written to the archive tape. There is no buffering or sorting. (At some future date, the restriction that all subarrays have the same integration intervals may be removed.)

Each *logical record* is completely self-contained. With the help of the rest of this document each record can be separately and completely decoded; no other information is needed.

1.1 Tape Format

The observation data is archived on magnetic tape. For historical reasons, the tapes are written with ANSI standard labels. ANSI label processing will not be discussed in this document. File marks are written occasionally. They usually represent a natural break in the observations or the end of the medium. The times at which tape marks are written are recorded in the VLA Observing Log. Since the original archive tapes are not distributed, any tape that is used as input into a post processing system will be a duplicate. Tape labels and file marks are usually not copied to the duplicate tapes.

Normally, a program reading a VLA archive tape will read and process all data records, ignoring all file marks until the double file mark which indicates the end of medium.

1.2 Record Blocking

A *logical record* contains all the data for one integration time for one subarray. The *logical record* can vary in size from about 500 bytes (for a subarray making single antenna VLBI observations) to about 900k bytes (for a subarray using all 27 antennas with each baseline producing 512 spectral channels). For convenience, the *logical record* is broken into *physical records.*

Each *physical record* written to tape is padded to be a multiple of 2048 bytes; the maximum multiple is 13, i.e., the maximum *physical record* size is

```
13 x 2048 = 26624 bytes.
```

The first two 16-bit words (four bytes) of each *physical record* are integers used for sequencing, so a *physical record* can contain up to 26620 bytes of the *logical record.*

The two integers used for sequencing are as follows:

n   is the record number of this *physical record* (starting from 1 at the beginning of each *logical record*)

m   is the total number of *physical records* in this *logical record*.

where, using integer division,

`m = [size of` *logical record* `/ 26620] + 1`

The *physical records* are written sequentially: (1,m), (2,m), ..., (m,m). If m>1, the first (m-1) *physical records* each contain 26620 bytes of the *logical record*. The final *physical record* is padded so that it contains a multiple of 2048 bytes. If m=1, the only *physical record* is likewise padded so that it contains a multiple of 2048 bytes.

The two counters can clearly be used to check for missing *physical records* on the tape and to re-synchronize after tape errors.

See Appendix A [Record Layout], page 12, for a simple pictorial representation of how the sequence of *physical records* are constructed from a *logical record*.

1.3 Logical Record Structure

Each *logical record* is divided into several data areas: the Record Control Area (RCA), the Subarray Data Area (SDA), a set of Antenna Data Areas (ADAs) and a set of Correlator Data Areas (CDAs). Each data area is by convention padded so as to be a multiple of 4 bytes. See Appendix A [Record Layout], page 12, for a simple picture of this.

2 The Data Areas

The following encoding is used in the descriptions of the data areas (RCAs, SDA, ADA):

```
AS          ASCII (NOT null-terminated; padded with blanks)
I2          2-byte integer (which is format B+15)
I4          4-byte integer (which is format S+31)
FP          4-byte ModComp floating point
DP          8-byte ModComp floating point
B+n or B-n  16-bit scaled binary integer
S+n or S-n  32-bit scaled binary integer
XX          Coded bits
```

Throughout this document the term *word* refers to 16-bit (2-byte) entities.

For further information on the ModComp integer and floating point formats, see Appendix B [ModComp Numeric Data Types], page 13.

2.1 The Record Control Area

There is one Record Control Area (RCA) which is always the first data area in the logical record. The RCA contains global information and pointers. Pointers are in units of 16-bit words and count from 0 at word 0; i.e., are offsets from the beginning of the RCA.

Word	Format	Description
0- 1	I4	Logical Record Length (words)
2	I2	Format Type (this is Format 1)
3	I2	Format Revision Level [1]
4- 5	I4	Date (MJAD)
6- 7	I4	IAT Time for the record creation
		(19.2 Hz interrupt count since IAT midnight)
8-11	AS	Control Program ID (unimplemented)
12-13	I4	Pointer to Subarray Data Area (SDA)
14-15	I4	Pointer to first Antenna Data Area (ADA)
16	I2	Length of each ADA
17	I2	Number of antennas in this subarray
18-19	I4	Pointer to First Correlator Data Area (CDA)
20	I2	Number of words in the baseline record header
21	I2	Total number of words in a baseline record (including header)
22-23	I4	Pointer to Second CDA
24	I2	Number of words in header (c.f. word 20)
25	I2	Total number of words in a record (c.f. word 21)
26-27	I4	Pointer to Third CDA
28	I2	Number of words in header (c.f. word 20)
29	I2	Total number of words in a record (c.f. word 21)
30-31	I4	Pointer to Fourth CDA
32	I2	Number of words in header (c.f. word 20)
33	I2	Total number of words in a record (c.f. word 21)
34	I2	record size/block size (The number 13 which is 26624/2048)
35	XX	(Padding)

1. See Section C.1 [Revision History], page 15.

The details of the meanings of the words 18-33 will be found in the description of the CDAs (see Section 2.4 [The Correlator Data Area], page 6).

2.2 The Subarray Data Area

There is one Subarray Data Area (SDA), which can be found through a pointer in the RCA. (At present, the SDA follows immediately after the RCA, but this should not be assumed.) The SDA contains information peculiar to each subarray, but common to all data coming from this subarray.

Word	Format	Description
0	I2	Subarray ID
1- 8	AS	Source Name
9	I2	Source Name Qualifier
10	AS	Array Configuration [1]
11- 13	AS	Observing Program ID
14	I2	Observer's AIPS Number

15	AS	Observing Mode [2]
16	AS	first byte - Calibrator code [3]
	XX	second byte - Observing Submode [4]
17	XX	Array Status Information for IFs A-D [5]
18	XX	Number of complex frequency channels per baseline for each CDA [6]
19	I2	Integration Time (19.2 Hz interrupt counts)
20- 21	FP	Stop Time (LST radians)
22- 23	FP	Start Time (LST radians)
24- 27	DP	Source RA, at standard epoch (Radians)
28- 31	DP	Source Dec at standard epoch (Radians)
32- 35	DP	Apparent RA now (Radians)
36- 39	DP	Apparent Dec now (Radians)
40- 55	DP	Signed sum of LOs for IFs A-D (GHz)
56- 71	DP	Sky Frequency at Band Center (channel 0) for IFs A-D (GHz)
72- 75	DP	IAT at end of Integration Interval (Radians)
76- 79	DP	LST at end of Integration Interval (Radians)
80- 83	DP	IAT for Geometry Calculations (Radians)
84- 85	FP	Current surface refractivity (n-1)
86- 87	FP	Estimated zenith atmospheric phase path (nsec)
88- 95	FP	Sin and Cos of elevation, azimuth
96- 99	FP	Cos and Sin of parallactic angle
100	XX	Bandwidth codes for IFs A-D [7]
101	XX	Front-end filter codes for IFs A-D [8]
102	XX	Recirculator control codes (currently same as bandwidth code)
103-104	FP	Zero Spacing Flux (Jy)
105-108	FP	UV limits for online ANTSOL (lower, upper) (nsec)
109-110	XX	Array Control Bits [9]
111-120	FP	Weather information [10]
121-136	DP	Radial Velocity for IFs A-D (km/sec) [11]
137-152	DP	Line Rest Frequency for IFs A-D (MHz) [11]
153-156	AS	Velocity Reference Frame for IFs A-D [11]
157-158	AS	Correlator Mode [12]
159-160	AS	Array Processor Options [13]
161	I2	Epoch year [14]
162-165	I2	Channel offsets for IFs A-D
166-169	I2	Channel separation codes for IFs A-D (the k in 50MHz/2**k)

1. See Section D.1 [Array Configurations], page 17.
2. See Section D.2 [Observing Modes], page 17.
3. See Section D.3 [Calibrator Codes], page 18.
4. See Section D.4 [Observing Submodes], page 18.
5. See Section D.5 [Array Status Information], page 20.
6. See Section D.6 [Channels per Baseline], page 20.
7. See Section D.7 [Bandwidth Codes], page 20.
8. See Section D.8 [Front-End Filter Codes], page 22.
9. See Section D.9 [Array Control Bits], page 22.
10. See Section D.10 [Weather Information], page 22.
11. See Section D.11 [Velocity Reference Frame], page 23.
12. See Section D.12 [Correlator Modes], page 23.
13. See Section D.13 [Array Processor Options], page 24.
14. See Section D.14 [Epoch], page 24.

2.3 The Antenna Data Area

The next structure is the Antenna Data Area (ADA). The first ADA can be found through a pointer in the RCA. (At present, the first ADA follows immediately after the SDA, but this should not be assumed.) The length of each ADA and the number of antennas in the subarray are also specified in the RCA. The ADAs follow one another sequentially. There is one for each antenna present, and their order determines the order of the correlator data.

Word	Format	Description
0	XX	first byte - Antenna ID
	XX	second byte - DCS address
1- 2	XX	Antenna Control Bits [1]
3	XX	IF Status for IFs A-D (c.f. SDA Word 17) [2]
4-11	FP	Nominal Sensitivity for IFs A-D (unitless)
12-19	FP	Peculiar Delay for IFs A-D (nsec)
20-23	B+0	Peculiar Phase for IFs A-D (turns)
24-27	DP	Total Delay at "geometry" epoch (nsec)
28-33	FP	U, V and W at center of integration for specified Epoch (nsec)
34-45	DP	Apparent Bx, By and Bz (nsec)
46-47	FP	Ba (K-term) (nsec)

1. See Section E.1 [Antenna Control Bits], page 25.
2. See Section D.5 [Array Status Information], page 20.

2.4 The Correlator Data Area

The last structure is the Correlator Data Area (CDA). The CDAs can be found through the pointers in the RCA. There are always 2 CDAs in continuum mode (except for early tapes when there was only one). In spectral line mode, there may be one to four CDAs.

The use of the four CDAs is defined based on correlator mode. The four pointers in the RCA point to the different CDA areas (see Section F.1 [CDA Pointer Definitions], page 26). A null (zero) pointer indicates that there is no data for this CDA

The natural ordering of data from the correlator is all spectra for each baseline in spectral line mode. In continuum, it is all AC data for each baseline, this for all baselines; and then all BD data for each baseline. The ordering of continuum data is preserved here, but note that the spectral line data has been re-ordered in the archive format to be all baselines for each spectrum. This is more in keeping with the way continuum data appears and is, in general, easier to deal with.

Included in the archive tape is all auto-correlation data as well as the cross-correlation data. Each CDA contains all the appropriate auto-correlation data for all antennas in this subarray, followed by all the cross-correlation data. The order of both sets of data is determined by the order of the ADAs.

The auto-correlation data is not of much use in continuum mode; it is suggested to replace it with the separately integrated crossed-hand auto-correlations which will be provided in the future.

The following pseudo-code describes an algorithm to obtain the data from the CDA.

2.4.1 CDA layout

For each CDA, the *correlator data area pointer* and the *total number of words in a baseline record* is specified in the RCA (see Section 2.1 [The Record Control Area], page 4).

The following loop will find the data associated with a given antenna or baseline:

```
ptr = (pointer to correlator data area)
nw  = (total number of words in a baseline record)

N = 0;
Do for I = 1 to (no. of antennas) by 1;

     pointer = ptr + N*nw
     Comment auto-correlation data for antenna I is located here;
     N = N + 1;

Do for I = 1 to (no. of antennas)-1 by 1;

     Do for J = I+1 to (no. of antennas) by 1;

          pointer = ptr + N*nw
          Comment cross-correlation data for the baseline between the
                  Ith and Jth antennas is located here;
          Comment the following formulae can be used to find
                  the ADAs for the Ith and Jth antennas:
                  (ADA pointer) + (I-1)*(ADA length) for I,
                  (ADA pointer) + (J-1)*(ADA length) for J;
          N = N + 1;

     End;
End;
```

For continuum, the data block looks like:

```
header
correlation of IF A of the Ith antenna with IF A of the Jth antenna.
correlation of IF C of the Ith antenna with IF C of the Jth antenna.
correlation of IF A of the Ith antenna with IF C of the Jth antenna.
correlation of IF C of the Ith antenna with IF A of the Jth antenna.
```

See Section F.2 [CDA Diagram for Continuum], page 26, for a simple diagram.

For each CDA, the *number of words in the baseline record header* is specified in the RCA (see Section 2.1 [The Record Control Area], page 4).

Each correlation mentioned above will consist of three words each containing a 2-byte integer:

```
real part.
imaginary part.
modified variance.
```

For spectral line, the *number of complex frequency channels per baseline* (see Section D.6 [Channels per Baseline], page 20) gives the number (M) of complex frequency channels that will be accumulated per baseline. The correlation data for each baseline is laid out as follows:

```
header
correlator channel 0, real part.
correlator channel 0, imaginary part.
correlator channel 1, real part.
correlator channel 1, imaginary part.
:
correlator channel M-1, real part.
correlator channel M-1, imaginary part.
```

Each correlation part is stored as a 2-byte integer in a single word. See Section F.3 [CDA Diagram for Spectral Line], page 28, for a simple diagram

2.4.2 Baseline Record Header

The header words in the baseline record are laid out as follows:

```
  Word                 Description
 (-2-n)  Bit map       (spectral line only) one bit per channel in the spectrum.
  to
  (-3)   n=1           (i.e., one word of bit map) if M<16
         n=M/16        (i.e., M/16 words of bit map) otherwise

         where M is the number of frequency channels in the baseline

   -2    Bits 0-1      a 2-bit integer describing the type of flagging
                        0       The whole baseline is bad
                        1       Some channels are bad
                        2 or 3  Some channel is bad for all baselines
         Bits 3-4      unused
         Bits 5-7      describe cause of flagging
                        5  Frequency RMS too big
                        6  Time RMS too big
                        7  Value too big (clip)
         Bits 11-15    5 bit scale factor (exponential)

   -1    Bits  0-3     (continuum only) 4-bit Bit map for flagging (AA,CC,AC,CA)
         Bits  6-10    first antenna number in this baseline
         Bits 11-15    second antenna number
```

The flagging information is to allow flagging of individual spectral channels. If bit p is set (i.e., 1), then channel p is flagged bad. The scheme outlined here is based on one suggested by Barry Clark and seems appropriate for both spectral line and continuum. However, it is not yet implemented.

At present only the scale factor and the antenna numbers are supported in the header.

2.4.3 The Scale Factor

To conserve space and to optimize precision the correlation data are stored as 16-bit integers with a block scale factor. A separate scale factor is specified for each baseline. In continuum, there is one scale factor for each half-correlator (AC or BD). In spectral line there is one for each spectrum.

When writing a baseline record, all integer values are left shifted (multiplied by 2) such that the largest value in the block has the most significant bit set; the number of places shifted is recorded in the scale factor. To reconstruct the value f (the real or imaginary part of a correlation) from the stored integer v and scale factor g (from the header):

```
f = v / 2**g
```

Appendix A Record Layout

```
      Logical record                        Physical records

 ------------------------------           -----------------
 | RCA  record control area   |           | 2 word header |
 ------------------------------           |...............|
 | SDA  subarray data area    |           |     first     |  26624 bytes
 ------------------------------           |  26620 bytes  |  13312 words
 | ADA  antenna data areas    |           |   from the    |
 ------------------------------           |  logical rec  |
 |                            |           -----------------
 | CDA  correlator data areas |
 |                            |           -----------------
 ------------------------------           | 2 word header |
                                          |...............|  26624 bytes
                                          |     next      |  13312 words
                                          |  26620 bytes  |
                                          -----------------

                                              etc. until

                                          -----------------
                                          | 2 word header |
                                          |...............|  padded to a
                                          |   residual    |  multiple of
                                          |   from the    |   2048 bytes
                                          |  logical rec  |   1024 words
                                          | plus padding  |
                                          -----------------
```

The two word header is

```
n  Sequence number (n = 1 ... m)
m  Total number of physical records in this logical record
```

Appendix B ModComp Numeric Data Types

The ModComp, like all computers, has its own individual ways of representing and storing numbers. Also, the VLA has created some new formats and conventions. Trying to link all this together has gone far to ensure that the number one computer language used on site is profanity! However, we will make the best of it and attempt to explain the differences.

The numeric types used on the ModComp's are explained below. Bit designations are from left to right, bit 0 (most significant) to bit 15 in a 16-bit word. All numbers have the sign in the leftmost bit (bit 0); negative numbers are two's complement.

Integers are either 16-bit (single-precision, the ModComp standard), or 32-bit (double-precision). Each assumes a binary point after the rightmost bit (the assumed scaling is B+15 or S+31; see scaled binary integers below).

Scaled Binary Integers are arithmetically equivalent to integers, but the binary point is not assumed to be at the far right. The convention is to call the binary point position just to the right of the sign bit (between bit 0 and bit 1) binary point position 0 and to count positively to the right. "B" represents a 16-bit (single-precision) number; "S" a 32-bit (double-precision) number. For example, given the 16-bit binary number

```
0100 0000 0000 0001
```

the following scalings would yield the following values:

```
B+0          0.100 0000 0000 0001
B+10         0100 0000 000.0 0001
B-3    00.00 0100 0000 0000 0001
B+20         0100 0000 0000 0001 0000 0.000
```

Floating Point numbers are of two basic types. *Single-Precision Floating Point* (FP) numbers have bit 0 as the sign, bits 1-9 as the exponent, and bits 10-31 as the mantissa. Note each floating point number uses two ModComp words. The binary point is assumed before bit 10. Therefore

```
0eee eeee eemm mmmm mmmm mmmm mmmm mmmm
```

decodes into

```
0.mm mmmm mmmm mmmm mmmm mmmm * 2**(eee eeee ee - 100 0000 00).
```

Floating point numbers are usually normalized, i.e., the first mantissa bit is the complement of the sign bit. *Double-Precision Floating Point* (DP) numbers are identical except that the mantissa contains 32 more bits. Therefore, DP numbers take four ModComp words with bits 10-63 as the mantissa. (Note this is not the same as the IEEE 794 standard, where double precision has more bits in the exponent than single precision.)

Appendix C RCA Details

C.1 Revision History

The following is a table containing the format revision history, with the significant changes made at each revision.

```
Revision  Date

   3     76Jun28         Initial supported revision level
   4     78Jan24         Weather information recorded.
   5     78May17         (u, v) recorded as FP of epoch.  It had earlier
                         been an integer in units of 16's of nsec of date
   6     79Apr05         Spectral line data available.
   7     82Apr01
   8     83Jun08         BD continuum available;
                         array configuration information available;
                         change from observer name to program code.
   9     83Jun17
  10     83Aug10         Additional spectral line information available:
                         radial velocity, line rest frame, velocity
                         reference frame, and channel offsets; enough
                         information to determine the channel separation
                         correctly in all cases (Hanning flag).
                         Epoch year included.
  11     84Feb16
  12     86Mar05         Radio/Optical velocity definition added.
  20     87Nov11         New format for testing only
         88Jan02         Begin commissioning of new system
                         Channel offsets omitted (set to 0)
                         Bandwidth code 8 reported incorrect channel width
  21     89Jan18         Channel offsets corrected
                         All bandwidth codes reported incorrect channel width
  22     89Apr05         All bandwidth codes except 8 now reported correctly
  23     90Feb07         auto-correlations included
                         All spectral line modes implemented
  24     90Mar28         Bandwidth code 8 finally fixed!
```

Revisions 3-12 were before the upgrade to the ModComp Classic computers. The data format was in detail very different from the one described in this document. This format is completely documented in the references by Randolph (revisions 1-3) and Sowinski (3-12) (see Appendix G [References], page 29).

However, a program to convert from the old format to the new makes it unnecessary for a person reading an archive tape to be aware of the details of the old format. Some changes between the early revision levels (3-12) are hidden by this program and are not listed here. However, it is important to note that several pieces of information available on the current format (revisions 20 and greater) were not written on the old tape, and could not be recreated. These are:

```
SDA     IAT for Geometry Calculations
SDA     Front-end filter codes
SDA     Zero Spacing Flux
ADA     Peculiar Delay
ADA     Total Delay at "geometry" epoch
ADA     Bx, By, Bz
ADA     Ba (K-term)
```

Appendix D SDA Details

D.1 Array Configurations

The word containing the VLA array configuration has two characters; the possible values are:

```
"A "
"B "
"C "
"D "
"AB"
"BC"
"CD"
```

D.2 Observing Modes

The word containing the observing mode has two characters; the possible values are:

```
"  "    standard observing
"D "    delay center determination mode
"H "    holography raster mode
"I*"    interferometer pointing mode, where * = "A", "B", "C", or "D" (IF)
"J*"    JPL mode, where * = "A", "B", "C", or "D" (IF)
"P*"    single dish pointing mode, where * = "A", "B", "C", or "D" (IF)
"S "    solar observing configuration
"SP"    solar observing with low accuracy ephemeris for the sun
"TB"    test back-end and front-end
"TE"    tipping curve
"TF"    test front-end
"VA"    self-phasing mode for VLBI phased-array mode
"VS"    single dish VLBI
"VX"    applies last phase update from source line using VA mode
```

D.3 Calibrator Codes

The byte containing the calibrator code has a single character specifying the quality of the source:

```
"A"    astrometric quality (position known to within 0.001 arcsec)
"B"    near astrometric quality (position known to within 0.01 arcsec)
"C"    not astrometric quality (position known to within 0.05 arcsec)
"T"    point source; flux and position badly determined
"P"    an assumed calibrator for pointing observation
"V"    an assumed calibrator for phased array observation
" "    not a calibrator
```

D.4 Observing Submodes

The byte containing the observing submode has an 8-bit integer describing the VLA submode for those observing modes that step through different phases.

In normal observing mode (`" "`) and in holography mode (`"H"`), when things are not constant during an entire scan, a non-zero observing submode is used to indicate a new configuration. In normal observing mode, this represents *survey mode*; a new observing submode indicates a new phase reference position. In holography mode, the submode represents a new pointing position on the current raster. This mechanism may be extended to other quantities in the future.

The following table gives the other meanings of the submodes:

Submode	Observing Mode P*	I*	D
1	-	-	-
2	ON	ON	+14
3	-	-	-
4	+EL	+EL	-14
5	-	-	-
6	-EL	-EL	-7
7	-	-	-
8	+AZ	+AZ	0
9	-	-	-
10	-AZ	-AZ	+7
11	-		
12	OFF		
13	-		
14	ON		
15	-		
16	OFF		
17	-		
18	OFF		

```
where

 -     invalid data during move to next phase

ON     antennas pointing to nominal on-source position
+/-AZ  antennas pointing off source by a half beamwidth in azimuth
+/-EL  antennas pointing off source by a half beamwidth in elevation
OFF    antennas pointing off source by +2.5 beamwidths in azimuth

 0     antenna delays set to their nominal values
+/-n   antenna delays stepped by n*2**(bandwidth code) nsec
```

No other observing submodes should occur for these observing modes. During all other observing modes the submode is always zero.

D.5 Array Status Information

The word containing the array status information is divided into four 4-bit areas, one for each IF, "A", "B", "C", and "D" respectively:

```
  A    B    C    D
xxxx xxxx xxxx xxxx
```

Each set of 4 bits contains a flag indicating IF status; the further left the bit appears, the worse the quality of data; the following hold for each set:

```
xxxx = 0000 = 0      ==> OK
xxxx = 0001 = 1(int) ==> warning
xxxx = 0010 = 2(int) ==> not so good
xxxx = 0100 = 4(int) ==> bad
xxxx = 1000 = 8(int) ==> extremely bad
```

(These bits may be combined; i.e., 0101 is possible)

D.6 Channels per Baseline

The word containing the number of complex frequency channels per baseline is divided into four 4-bit areas, one for each CDA area:

```
CDA1 CDA2 CDA3 CDA4
xxxx xxxx xxxx xxxx
```

Each set of 4 bits represents an integer k, where the number of complex frequency channels per baseline is 2**k.; e.g.,

```
CDA1
xxxx = 0101 ==> 1st CDA contains 2**5 = 32 channels per baseline
```

This word applies to spectral line data only; for continuum data, the word contains zeroes.

D.7 Bandwidth Codes

The word containing the bandwidth codes is divided into four 4-bit areas, one for each IF, "A", "B", "C", and "D" respectively:

```
  A    B    C    D
xxxx xxxx xxxx xxxx
```

Each set of 4 bits contains a 4-bit integer representing the following:

	Spectral Line		Continuum
4-bit integer	Bandwidth analyzed	maximum # of channels*IF	Bandwidth
0	50 MHz	16	50 MHz
1	25 MHz	32	25 MHz
2	12.5 MHz	64	12.5 MHz
3	6.3 MHz	128	6.3 MHz
4	3.1 MHz	256	3.1 MHz
5	1.5 MHz	512	1.5 MHz

6	0.8 MHz	512	0.8 MHz
7	0.8 MHz	512	0.2 MHz
8	0.2 MHz	256	-
9	0.2 MHz	512	-

Integers 10-15 should not occur.

More precise information can be found in the references by Hunt and Rots (see Appendix G [References], page 29).

D.8 Front-End Filter Codes

The word containing the front-end filter codes is divided into four 4-bit areas, one for each IF, "A", "B", "C", and "D" respectively:

```
  A    B    C    D
xxxx xxxx xxxx xxxx
```

Each set of 4 bits contains a 4-bit integer representing the following:

```
 4-bit          front-end
integer          filter

  0              50   MHz
  1              25   MHz
  2              12.5 MHz
  3              "wire"               no filter inserted
  4              "open"               input and output not connected!
```

Integers 5-15 should not occur.

D.9 Array Control Bits

The 2 words containing the array control have 32 bits. If a bit is set (i.e., 1), the condition is true; if unset (i.e., 0), false. The bit numbering is from the left (most significant bit) starting with 0; Only the most significant 6 bits are currently defined.

```
bit #   description                encoding

  0     deicers on
  1     weather station broken
  2     correlator self test disabled
  3     Socorro Electric Co. is not providing power
  4     correlator is gated for pulsar observation
  5     weather information is generated from operator-supplied data,
             not from a computer generated model
```

(bit 5 is applicable only if bit 1 is set; i.e., the weather station is broken)

D.10 Weather Information

The 10 words containing the weather information have five floating point numbers as follows:

```
Wind speed                  m/sec
Wind direction              degrees from North (through East)
Surface temperature         degrees Celsius
Barometric pressure         millibars
Dew point temperature       degrees Celsius
```

D.11 Velocity Reference Frame

The 4 words containing the velocity reference frame are divided into pairs of characters, one pair for each IF.

There are two conditions. Either

```
"*F" or "* "  the baseband synthesizers have been explicitly set by the
              observer (* is any character)
```

otherwise Doppler correction was applied using the following criteria:

```
"Tx"    Topocentric rest frame; velocity in km/s, rest frequency in MHz
"Gx"    Geocentric rest frame; velocity in km/s, rest frequency in MHz
"Bx"    Barycentric rest frame; velocity in km/s, rest frequency in MHz
"Lx"    LSR rest frame; velocity in km/s, rest frequency in MHz

where "x" represents the velocity switch and can be one of the following:

"O"     Offset frequency
"Z"     Doppler correction using the Optical definition
"V"     Doppler correction using the Radio definition
```

For each IF, the observing frequency was determined using this field together with the Radial Velocity (RV - km/s) and the Line Rest Frequency (LRF - MHz) as follows:

```
LRF (MHz) * DCE * DCS

where DCE = 1/(1 + VE/c)        optical
      DCS = 1/(1 + RV/c)

where DCE = (1 - VE/c)          radio
      DCS = (1 - RV/c)

  and VE (km/s) is the component of the Earth's velocity in the
                direction of the source in the specified velocity
                reference frame, determined at the beginning of the
                current "scan".
```

More extensive information can be found in the reference by Rots (see Appendix G [References], page 29).

D.12 Correlator Modes

The 2 words containing the correlator mode have 4 characters; the possible values are:

```
"    "          continuum mode; all other modes are spectral line
"1A  "          single IF mode, IF "A"
"1B  "          single IF mode, IF "B"
"1C  "          single IF mode, IF "C"
"1D  "          single IF mode, IF "D"
"2AB "          dual IF mode, IFs "A" and "B"
"2AC "          dual IF mode, IFs "A" and "C"
"2AD "          dual IF mode, IFs "A" and "D"
"2BC "          dual IF mode, IFs "B" and "C"
```

```
"2BD "          dual IF mode, IFs "B" and "D"
"2CD "          dual IF mode, IFs "C" and "D"
"4   "          four IF mode
"PA  "          polarization mode, IFs "A" and "C"
"PB  "          polarization mode, IFs "B" and "D"
```

D.13 Array Processor Options

The 2 words containing the array processor options have four characters. The following characters may appear in any combination and in any order:

```
"H" - Hanning smoothing
"B" - Band pass normalization
"L" - Lag spectrum (raw correlator output)
```

D.14 Epoch

This 2-byte integer represents the epoch of the coordinates of observation. This parameter is typically 1950 or 2000. The value -1 is used to indicate epoch of date.

Appendix E ADA Details

E.1 Antenna Control Bits

The 2 words containing the antenna control bits have 32 bits. If a bit is set (i.e., 1), the condition is true; if unset (i.e., 0), false. The bit numbering is from the left (most significant bit) starting with 0:

```
bit #   description

  0     transfer switch set
  1     this antenna is a reference antenna
  2     reference antenna (same as bit 1 currently)
  3- 4  unused
  5     round trip phase correction disabled
  6     antenna off source
  7     antenna elevation "over-the-top"
  8     phase switching disabled
  9     unused
 10     antenna shadowed by another at source change time
        (this includes shadowing by antennas not in this subarray)
 11     real-time pointing correction applied
 12     solar cal activated
 13     solar attenuator inserted
 14-15  (for controlling auxiliary front-end switches 3 and 4 which are
        currently unused)

The following bits are flagging conditions:

 16     source change in progress
 17     sub-reflector not in position
 18     antenna off source
 19     L6 module not locked
 20     L8 module not locked
 21     back-end filters misset
 22     back-end total power out of range
 23     antenna flagged bad by Operator
 24     Tsys fluctuating
 25     first LO not locked
```

Appendix F CDA Details

F.1 CDA Pointer Definitions

Each entry in the table below describes what data is pointed to by each of the four pointers in the RCA for each of the possible correlator modes.

```
0    denotes that there is no data for this CDA
()   denotes an IF pair in continuum
/    denotes one of the mixed line and continuum modes
```

Only two CDAs are used for continuum; up to four for spectral line.

Correlator Mode	1st Ptr	2nd Ptr	3rd Ptr	4th Ptr
Continuum	(AC)	(BD)	0	0
"1A "	AA	0	0	0
"1B "	0	BB	0	0
"1C "	0	0	CC	0
"1D "	0	0	0	DD
"2AB "	AA	BB	0	0
"2AC "	AA	0	CC	0
"2AD "	AA	0	0	DD
"2BC "	0	BB	CC	0
"2BD "	0	DD	0	BB
"2CD "	0	0	CC	DD
"4 "	AA	BB	CC	DD
"PA "	AA	CC	AC	CA
"PB "	BB	DD	BD	DB
"1A/C"	AA	(BD)	0	0
"1B/C"	(AC)	BB	0	0
"1C/C"	0	(BD)	CC	0
"1D/C"	(AC)	0	0	DD
"2AC/C"	AA	(BD)	CC	0
"2BD/C"	(AC)	BB	0	DD

NOTE: the last six entries in the table are for future expansion, and are currently undefined ("/C" indicates "continuum").

F.2 CDA Diagram for Continuum

The following is diagram of the CDA for continuum data:

```
                     Body                              Each correlation block

             --------------------------             ----------------------
---
             |           Nant           |         /\  |   Header (see below)   |
             |    Auto-correlations     |          |  |........................|
             |..........................|          |  |                        |
             |                          |          N  |          Data          |
```

```
         |    Nant * (Nant-1)/2    |           |  |                        |
         |    Cross-correlations   |           |  |       (12 words)       |
         |                         |          \/  |                        |
         |     (see at right)      |              -----------------------
---
         |                         |
         --------------------------
                                                           Header
     H = 2, N = 14                                    -----------------------
---
                                              /\  |       0       | Scale  |
                                               H  |........................|
     Flag map is for AA, CC, AC, CA           \/  | Map |     Baseline     |
     Baseline is two 5-bit antenna numbers        -----------------------
---

     The 12 words are:
           for AA, CC, AC, CA
               (real part, imaginary part, modified variance)
where
     Nant is the number of antennas (from RCA)
```

F.3 CDA Diagram for Spectral Line

The following is a diagram of the CDA for spectral line data:

```
                 Body                             Each correlation block

       ---------------------------              -----------------------
---
       |           Nant           |         /\  |   Header (see below)   |
       |    Auto-correlations     |          |  |........................|
       |..........................|          |  |                        |
       |                          |          N  |          Data          |
       |    Nant * (Nant-1)/2     |          |  |                        |
       |    Cross-correlations    |          |  |      (M * 2) words     |
       |                          |         \/  |                        |
       |     (see at right)       |             -----------------------
---
       |                          |
       ---------------------------
                                                         Header
     H = 2 + max (1, M/16)                      -----------------------
---
     N = H + M * 2                          /\  |                        |
                                             |  |   max (1, M/16) words  |
                                             |  |        Flag map        |
                                             |  |   (currently not set)  |
    Baseline is two 5-bit antenna numbers    H  |                        |
                                             |  |........................|
                                             |  |       0       | Scale  |
                                             |  |........................|
                                            \/  |  0  |     Baseline     |
                                                -----------------------
---
where
     Nant is the number of antennas (from the RCA)
     M is the number of complex frequency channels per baseline
          (from the SDA)
```

Appendix G References

General:

A.R. Thompson, B.G. Clark, C.M. Wade, and P.J. Napier, "The Very Large Array," ApJS 44 p151, 1980

P.J. Napier, A.R. Thompson, and R.D. Ekers, "The Very Large Array: Design and Performance of a Modern Synthesis Radio Telescope," Proc. IEEE 71 p1295, 1983

R.M. Hjellming (ed.), "An Introduction to the NRAO Very Large Array" (also known as "The Green Book"), 1983

Local oscillators and spectral line:

G.C. Hunt, "Concerning VLA Local Oscillator Settings," VLA Computer memo 148, 1978

A.H. Rots, "A Short Guide for VLA Spectral Line Observers," Edition 8.0, 1990

Previous documents:

W.E. Randolph, "Data Format from Synchronous System," VLA Computer memo 126, 1975

K.P. Sowinski, "Synchronous System Data Formats," VLA Computer memo 185, 1986

Table of Contents