NATIONAL RADIO ASTRONOMY OBSERVATORY
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VLA COMPUTER MEMO NO. 162

A BIT-LEVEL DESCRIPTION OF THE DIGITAL CONTROL SYSTEM & DCS TASK

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This memo is an update and extension of computer memo #125. It may even be complete enough to allow someone to modify the DCS task with a chance of getting it right. For an overview of the hardware refer to VLA Technical Report NO, 44.

The DCS task runs in both Monty (resident) and Bacchus (non-resident), and it is composed of three modules:

DCST	An initialization and control module
DCSCMD	Places commands in a command buffer
DCSDMX	Demultiplexes data into a monitor data base.

Additionally an interrupt handler, DCSHH, is included in the sysgens and is always resident in the computers.

The Serial Line Controller (SLC) communicates with Monty or Bacchus through an interface controller which is in the same rack as Monty or Bacchus. In the interface, four status bits are generated and these may be interrogated by the computer at any time. Commands can be sent to the controller to cause the Direct Memory Processor (DMP) to operate in synchrony with the SLC. The four status bits are:

Bit Number

15 It is monitor time. Bit stays on past the end of transfer until command time.

14 It is command time. Bit stays on past the end of transfer until monitor time.

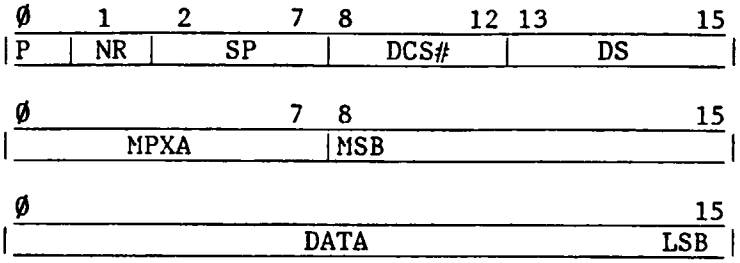
6 Busy, either a monitor or command time data transfer is in progress.

7 Interface acknowledges a read/write command. Bit in cleared when read/write is finished.

All other bits are not defined and may be Ø or 1.

When everything is operating normally, the computer is interrupted by the SLC interface four times per waveguide cycle (52.083...msec). Two of these are as a result of the end of a read/write I/O operation and are signalled by the presence of bit(s) 6 and/or 7. When recognized, these interrupts are ignored. After each of these interrupts, another interrupt occurs signifying the end of either command or monitor transfer. These cause the interrupt handler to check the just-finished operation for an error in the transfer count, check that the monitor data demuxer or command generator has finished, initializes the DMP for the next transfer, and signals a system event causing the highest priority ready task (DCS, we hope) to run. The only way of knowing whether a command or monitor transfer has just finished is to look at bits 14 & 15. The command buffer contains the waveguide cycle count for which the commands are intended. The interrupt handler compares this to the current waveguide cycle. If they do not match, it truncates the command buffer before initializing the DMP to transfer the buffer to the SLC. The interrupt routine works entirely on the basis of these four status bits. The actual data transfer is, in both directions, at the behest of the SLC and through the DMP directly into or out of core.

Monitor data received from the SLC consists of three-word message blocks or triplets:



P-Parity error
NR-no response
SP-synchronization pattern-#15 (hex)
DCS#-antenna address
DS-data set
MPXA-multiplexer address
MSB-most sig. bit of data
LSB-least sig. bit of data

Digital monitor data can use all of the 24 bit field. Analog monitor data needs only 12 bits. So, the least significant 12 bits are from the given mpxa and the most significant 12 bits are from mpxa+1. Analog monitor data is identified by mpxa between 'Ø and '177 (octal). Digital monitor data is identified by mpxa between '2ØØ and '277. Data set Ø (antenna control unit) reverses the analog data convention and put the data from the given mpxa in the most significant 12 bits.

Monitor data always comes in groups of 384 message triplets. The first triplet is from antenna Ø, data set Ø, monitor word 1. The next triplet is from antenna 1, then 2, etc... until antenna 31 (the DCS hardware thinks there are 32 antennas!). The next 32 triplets, one from each antenna, are from data set 1, the next 32 from data set 2, etc. This continues thru data set 4, then the next triplet is from antenna Ø, data set Ø, monitor word 2. This continues as above, now for monitor word 2 instead of 1. Finally, at the end are two sets of

32 triplets - one for data set 5, monitor word 1 and the other for data set 5, monitor word 2. The 384th triplet in the group is thus from antenna 31, data set 5, monitor word 2.

Commands use the same three word format, except the first byte must be #55 (Ø1Ø1Ø1Ø1 in bits) as a synchronization pattern. Any number of commands up to 128 may be sent per cycle, including none.

The DCS task relies on information strewn all about the CPU. Connected with the interrupt routine is a modified Physical Device Table (PDT) and an internal table used in communicating with the task proper.

Words used nonstandardly in the PDT are:

Word Ø:	Status at last Service Interrupt (SI).
Word 1:	If zero, interrupts are disabled and the DCS not running.
Words 7,9-14:	Are used for temporary storage at interrupt time.
Word 8:	Remembers the Transfer Address (TA) for the current operation.
Word 15:	Points to PØDCS for the first word of an internal table. This pointer makes it accessible to tasks not edited into the sysgen.
PØDCS+Ø	Monitor Control Word
+1	Transfer Initiate (TI) for reading
+2	Pointer to monitor data buffer - MBUF
+3	Transfer Count (TC) always set to -384*3
+4	Command Control Word
+5	TI for writing
+6	Pointer to command data buffer - CBUF
+7	TC, variable-number of command to sent at this time.

+8 2 words to count monitor and command timing errors

+1Ø 2 words to record differences between requested TC and actual TC

The two control words are used to synchronize the DCS task with the SLC. The monitor control word is set nonzero when a buffer has been input, and is reset to zero by the demuxer when he finishes. The command control word is set nonzero by the command generator and reset to zero by the interrupt routine after the buffer is output. If the interrupt routine finds the monitor control word still set or the command control word still reset, it declares a timing error.

In the DCS task is an idle loop which checks these two words to see when a buffer is ready to be operated upon. Commands have priority in the sense of being checked first.

Most of the buffers required for DCS are kept in various modules connected with the DCS task.

Module	Buffer	Size	Use
DCSHH	MBUF	384*3+4	Monitor Data Buffer. The four extra words are in case too many words come.
DCSHH	CRUD	8	To allow the command buffer to be written.
DCSHH	CBUF	128*3	Command Data Buffer.
DCSCMD	MANA, MANB MANC, MAND	32*3 each	Manual command buffers, 31 commands each.
DCSDMX	BF1,BF2	128 each	For MW2 data streaming.
DCST	CPCNT	1	Counts command parity errors.
DCST	MPCNT	1	Count returned monitor parity errors.
DCST	PARCNT	1	Counts monitor parity errors.

DCSDMX	PBUF	128	Cyclic parity error history buffer. The 3 error counts are summed to form a pointer (mod 16)*8 into the buffer.
DCSCMD	AUXBF	32	Boss puts commands here.

All other information is in global common and will be dealt with in connection with the command collator and the demuxer.

THE COMMAND GENERATOR

DCSCMD

The command generator executes each waveguide cycle generating a buffer of command triplets. Only four commands can go to an antenna each cycle. The commands that need to go to all antennas during normal operation are divided up and sent at specific waveguide cycles.

The command generator starts by creating a dummy command with the current waveguide cycle count written in the data field. This is then put in the command buffer as the first command. The interrupt handler checks this cycle count against the then current count and truncates the command buffer if they do not match. (It is better to say nothing than speak the truth at the wrong time.)

For each antenna there are four logical command sources, called for the sake of simplicity, Word A, Word B, Word C, and Word D. Each command source may be in one of four modes: NORMal, AUXiliary, MANual, or NULL. The collection of modes for each source word of an antenna describes the state of the antenna. Besides the 256 logically possible states, an antenna may be "empty" (does not exist any more) or "special" (will not be discussed here). The first 32 words of the DCS area of global common (see Appendix 1) describe the state of each of the 32 antennas.

NULL is a do-nothing for this source word.

MAN specifies fetch commands from a manual command buffer unique for this source word.

AUX is the same as NORM.

NORM depends on source word:

For Word A, generate commands on the basis of the Antenna Control Block or standbys if not observing.

For Word B, generate commands on the basis of the IF Control Block.
For Word C, send a dataset reset command to datasets. Also output commands sent from Boss (program CTL) through the CPU link.
For Word D, do nothing.

During observing the command generator creates different commands over a 24 waveguide cycle period for antennas with source words in mode norm or AUX.

Cycle	Word A	Word B	Word C
Ø	Azimuth		*Water Radiometer
1	Elevation		*Data Set 1 Reset
2	AZ		*Data Set 2 Reset
3	EL		*Data Set 3 Reset
4	AZ		*Data Set 4 Reset
5	EL		*Data Set 5 Reset
6	AZ		*Data Set 6 Reset
7	EL		*Data Set 7 Reset
8	AZ		
9	EL		
1Ø	AZ		
11	EL		
12	AZ		
13	EL		
14	AZ		
15	EL	Phase Reversal	
16	AZ	Cal Synch.	
17	EL		
18	AZ		
19	EL	A Rate	
2Ø	AZ	A Phase	
21	EL	C Rate	
22	AZ	C Phase	
23	EL	Rate-Phase Strobe	

*Sent only during first 24 cycle period each 1Ø second major VLA cycle.

The command generator has a special, 32*3 word buffer indentified to the CPU link under the name of 'AUX'. The first 3 words are as follows:

1st word - number of antennas to be placed in Word C auxiliary mode.

2nd word - number of commands

3rd word - address, in Boss, of aux-mode buffer image.

These 3 words are followed by a list of antennas whose Word C's were to be changed. This no longer done. The first word of this buffer is now only tested for nonzero once per cycle before generating any commands. If it is nonzero, command triplets will be read from Boss and stored in this buffer starting at the 4th word. The command generator will then place these commands into the command buffer, CBUF, if the antenna indicated in the command has its word C in NORM or AUX mode. The program will then zero the first location of 'AUX' and a busy bit in Boss is zeroed by sending a zero word to the array 'AUX' in BOSS.

There is a 32*3 word manual command buffer associated with each source. The 2nd thru 5th words of the DCS Task contain pointers to the A, B, C, and D manual command buffers. The first 3 words of each buffer are as follows:

1st word - command pointer, zero if buffer empty

2nd word - end of buffer pointer

3rd word - number of times the command pointer has been reset to start of buffer.

Each command pointer points to only one command in its buffer during a cycle. The first byte of each command triplet is used to control how the command generator handles that command. If Bit 1 is clear, every antenna which has the source mode corresponding to this buffer set to MAN will get this command. If Bit 1 is set, only the antenna indicated in the antenna field of the command triplet will receive the command - again, only if the antenna's corresponding source mode is set MAN. The command generator

copies appropriate commands from manual buffers to the command buffer, inserting the synchronization pattern and a different antennna number if needed.

At the end of each cycle the command generator checks the first byte of each command in each buffer. If Bit 3 & 5 are both set, the command is deleted from the buffer and all other commands moved up. If Bit 3 is set and Bit 5 is clear, then Bit 5 is set to mark deletion next time. If needed the command pointer is incremented or reset to the start of the buffer.

THE DEMUXER

DCSDMX

The second 32 words of the DCS area of global common (see Appendix 1) are also indexed by antenna number and contain information of interest to the demuxer. The left byte of each word is used to signal the presence of data from each data set, bit i corresponding to data set i. The right byte is used to indicate data sets with monitor word 2 in selected mode. Bit i+8 corresponds to data set i. Before demuxing a buffer full of data, all bits are cleared. Each monitor triplet is tested for a valid synchronization pattern in the first byte. If this is not present, the word in question and the rest of the buffer is ignored. Next, the "no response bit" is examined and, if on, the word is ignored. When valid data is seen from a data set, the appropriate bit is set and this item demultiplexed. The antenna field of the DCS address is examined for legality. If illegal (greater than number of antennas), it is checked for bad parity and ignored. Otherwise, it is checked for parity and then demuxed. This is repeated for each monitor triplet in the buffer.

Parity errors are 1) kept in a cyclic buffer of length 16 for operator examination, 2) counted in the aggregate, and 3) counted individually for legal data sets in the error counter for multiplex address '2Ø1. Command parity errors reported in channel '2ØØ are counted in the error counter for address '2ØØ.

When all data has been demuxed, the data set bits are examined. For any bit set, the appropriate word will be gotten from the buffer, checked for errors and streamed to logical file MDO. To try

to avoid loss of data when the number of monitored points is large, this operation is double-buffered. To read such data there is a subroutine READMO which fills a buffer passed to it with data. Documentation is in the program listing on LIB.

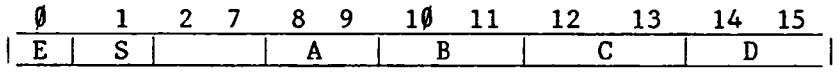
The next 16 words of the DCS area (see Appendix 1) are pointers to 8 digital demux control word pair lists and 8 analog demux control word pair lists, or zero to indicate a nonexistent data set. The first word of each list is the highest defined mpxa (analog or digital) expected. This list is indexed by valid mxpa*2 to get to a pointer to the actual demux buffer and a demux control word. If the demux control word is zero, this mpxa is not defined. To access or store the data, the demux buffer in indexed by DCS number, assuming n (bits 12-15 of the control word) words per entry.

In order to accomodate 'unique' equipment at various antennas, a kludge has been added. A monitor point that fails to be demuxed will use its DS and MPX as a key to index one of 32 tables (one for each DCS number) to see if it is a candidate for translation. If so, it will get a totally new DCS address (usually antenna Ø), new data set number (usually 6 or 7) and sometimes a new mpx. We will then try once again to demux the data. The data structures to control the translation process, as well as the target DCS addresses, are defined in CBCOM.

DCS CONTROL BLOCK IN GLOBAL COMMON

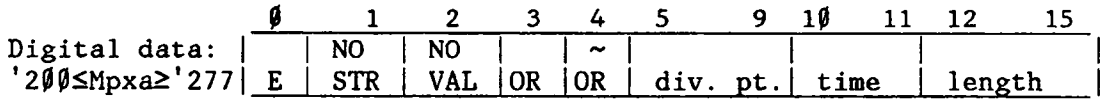
Locations Ø - 31
Command Generator Control Words (indexed by DCS#)
Locations 32-63
Data Set Response Bits (indexed by DCS#)
Left byte - monitor word 1
Right byte - monitor word 2
Locations 64-71
Pointers to Antenna Demux Control Tables - Digital (indexed by data set)
Locations 72-79
Pointers to Antenna Demux Control Tables - Analog (indexed by data set)
Locations 8Ø-87
Pointers to Antenna Ø Demux Control Tables - Digital (indexed by data set)
Locations 88-95
Pointers to Antenna Ø Demux Control Tables - Analog (indexed by data set)
Locations 96-127
Commands Received Count returned by Data Set 4 (indexed by DCS#)
Locations 128-159
Pointers to Demux Translation Tables (indexed by DCS#)

COMMAND GENERATOR CONTROL WORD



E - Empty
S - Special
A, B, C, D, = Ø Normal
1 Auxiliary
2 Null
3 Manual

DEMUX CONTROL TABLE - DIGITAL
Word 0 Maximum multiplexor address in table
Word 1 Pointer to Demux Buffer
Word 2 Demux Control Word

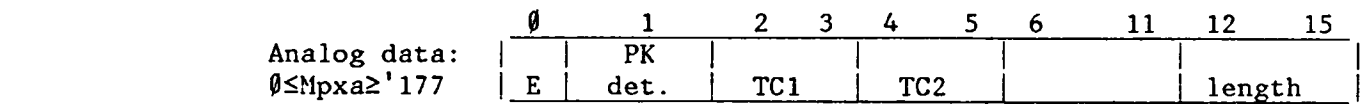


bit Ø 1 for error counter present
1 1 for no string part
2 1 for no value part
3 1 for OR strings part with previous string
4 1 for complemented string part ORed with previous string

```
    5  -  9    define division of word between string and value parts
    1Ø - 11    digital time constant
               (Ø=None, 1=2 sample times, 2=8, 3=16)
    12 - 15    define length of entry for each antenna
```

DEMUX CONTROL TABLE - ANALOG

Word Ø Maximum multiplexor address in table
Word 1 Pointer to Demux Buffer
Word 2 Demux Control Word

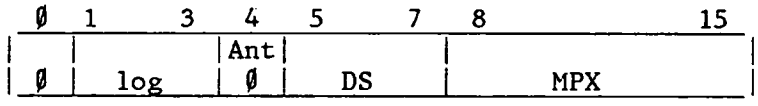



```
bit  Ø         1 for error counter present
     1         1 for peak detection
bits 2 - 3     define stage 1 time constant
               (Ø=None, 1=2 sample times, 2=8, 3=16)
     3 - 4     define stage 2 time constant
               (Ø=None, 1=32 sample tiems, 2=128, 3=512)
     6 - 11    not used
    12 - 15    define length of entry for each antenna
```

Word 1 and 2 format is repeated in both tables for each multiplexor address up to the maximum. If an address does not exist, the pointer and control word are zero. Hence, entries are indexed by multiplexor address.

DEMUX BUFFER

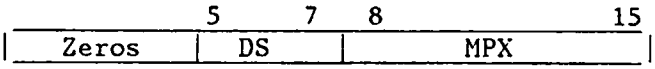
Word Ø Logging Control Word



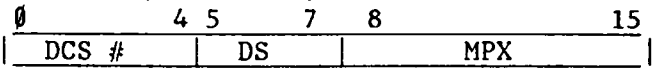

```
bit Ø        - must be zero
bits 1-3     - logging period
                  (Ø - not at all, 1-every 5 seconds, 2=2Ø, 3=8Ø,
                   4=32Ø, 5=64Ø)
bit 4        - 1 for antenna Ø
bits 5-7     - dataset
bits 8-15    - Multiplexer address
```

The length (define in demux control word) times the number of antennas is the number of words that follow in this buffer. Entries are indexed by DCS number times length.

DEMUX TRANSLATION TABLES
Word Ø Number of entries
Word 1 Old data set and MPX



Word 2 New antenna, data set, and MPX



bits 5-7 DS - dataset
bits 8-15 MPX - Multiplexer address
bits Ø-4 DCS# - antenna address

Word 1 and 2 format is repeated for the number of entries