NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

May 30, 1974

VLA COMPUTER MEMORANDUM #109

# "WHY IS ALL THAT TRASH IN GLOBAL COMMON?"

## An Exposition

Barry Clark

VLA Computer Memorandum #108 gives the layout in detail of global common. This memorandum is a companion piece, setting down a little more detail about each variable and the reasons for its existence. This memo is, however, still a programmer level document, and is not really fit for general instruction.

Memo #108 begins with a description of the block status word. Each block contains a block status word indicating the status of the devices controlled by the information in that block. There are five levels of seriousness of indications in the status blocks, as follows:

0 -- All indications within normal range.

1 -- Warning. Device requires attention, but data is believed good. Example-dewar pressure slightly too high.

2 -- Error. Device is probably malfunctioning. There is either a serious malfunction or an error in the monitor system. Example-dewar temperature above 100° K.

4 -- Severe error. Device is certainly malfunctioning. Example-Antenna pointing to wrong position under manual control.

8 -- Danger. Device may need attention to avoid damage. Example-Antenna servo motor currents at 150% of overload.

More than one error level may be set at a given time, and, indeed, one would expect that, say, a severe error would generate other error and warning indications. The status word is organized in this fashion so that the warning levels may be combined with a simple OBM (or bit in memory) command.

These flags may be set under three different conditions, and a separate set of flags is maintained for each condition. The conditions are first, normal observing conditions (error status will be set by things like system monitor points out of bounds); second, calibrator observations (error status will be set by things like unusual amplitude or non-zero phase); and third, special test runs (for example the correlator noise tests, or tests to ensure variables at the antenna are following the instructions of the DCS).

The next table in Memo #108 is the Array Control Block, which is primarily interested in keeping track of time. The VLA clocks will run on International Atomic Time, to avoid conceptual difficulties with the leap seconds which occur in UTC (which is the official US time). IAT progresses at a uniform (geocentric) rate with no jumps. At this writing it differs from UTC by 13.000000 seconds, and the current rate of the rotation of the earth is such that it is necessary to insert about 1 leap second per year. There are, however, suggestions to step IAT by 32.18 seconds to bring it into coincidence with Ephermeris Time. Therefore, by the end of the century, IAT-UTC may exceed one minute, but will almost certainly be less than two.

Modified Julian Atomic Date is a sequential day count, changing each day at $0^h$ IAT. It was 0 during the day of November 17, 1858. The last five digits coincide with those of the Julian Date during the second half of the day.

The fundamental clocking interval of the VLA is generated by the positive going zero crossings of a 19.2 Hz wave. They occur at intervals of 52.083333.... miliseconds. These clock pulses are counted to subdivide the day, and to subdivide the 10 second major cycle. There are 192 counts per 10 second cycle, and 1,658,880 counts per day. The division to convert these counts into a fraction of a day is done only every ten seconds. At the same time, the sidereal time is calculated from the formulae of VLA Computer Memoranda #103 and #105.

A status word is provided in this control block for the one-of-a-kind items in the array, e.g., the Maser LO standard and site power. A second status word is provided for those critical items which have a redundant system, like the master LO system.

The various pointers which appear in the ARACB are to be used for locating other types of blocks and for locating monitor data. Locating such things by name is a no-no. To do so would mean that each time the area was rearranged, all tasks running in the computer would have to be reassembled.

Because the calculations in the task GEOM10 are rather complicated, we can make the calculations low priority by providing a buffer area. The time and its trig functions, and the appropriate geometry for each subarray and each antenna, are calculated at leisure, and left in the buffers labled "Cosine sidereal time, next 10 second interupt", etc. Then when the 10 second major interval occurs, these precalculated quantities are moved into the corresponding "last 10 second interupt" slots by a fast program operating with very high priority, and then, once more, 10 seconds are available for filling the "next 10 second interupt" buffers. Therefore, while the "last 10 second interupt" locations will be up-to-date, the "next 10 second interupt" locations are not guaranteed.

The refraction parameters are calculated from the environmental parameters measured, using, for instance, the formula given by Saucier (Principles of Meterology)

$$\log_e P = \frac{17.27T_d}{237.3+T_d} + 1.81$$

where $T_d$ is the dewpoint (centigrade) and p is the water vapor pressure (milibars). Then, if P is the total barometric pressure and T the (Kelvin) temperature,

$$n - 1 = \frac{7.76\mathrm{x}10^{-5}}{T} (P + \frac{4810}{T} p)$$

The refraction pointing constant is, to a first approximation, $(n-1)/2\pi$. The integrated atmospheric phase path is given by the product of n-1 times a scale height. For the dry air portion, the scale height is simply $\frac{kT}{gmu}$. For the water vapor, a scale height of 2 km is about appropriate. Therefore, the atmospheric zenith phase path is, in meters, about

$$S = 0.00227\ P + \frac{750}{T^2}\ p$$

It is hoped that refraction will be sufficiently stable that these constants may be computed by INIT (which runs at least once per hour) rather than having to schedule them more frequently.

The Arm Control Block exists only to provide a home for the Arm status word, which records troubles with the waveguide, and other such components which appear in threes.

The Subarray control block contains all sorts of goodies of the sort needed to identify a particular observation -- the source name, position, etc. There is one quantity which is absent which you might expect in this block: a "scan number". When several subarrays may be active at any given time, a sequential scan number may be a rather confusing and inappropriate way to identify a particular observation. I therefore propose to identify observations by start time (specified to sufficient precision) and (if necessary) by subarray or by source name.

Because of the frequent use of things like CAS-A-1 and PICA-4 on the Green Bank Interferometer, I suggest incorporating a 15 bit numeric qualifier on the end of the source name, which would merely be not printed unless specified non-zero, thus reserving the 8 character source name field for that part of the name which must be alphabetic.

The observation mode descriptors would contain information about the type of observation--a frequency code, line/continuum, calibrator flag, pointing/standard observing procedure, etc. I envision the second word used for telling where in a cycle things are--for instance, while doing pointing observations by moving sequentially around 5 (or 6, or 9, or 10) offset points, this would be an indication of which pointing offset is in use now.

The Data surpression control would be used to surpress data recording during that time when the antennas are moving to the new source. A flag is set when the task INIT begins, surpressing data recording, and is reset when the first antenna arrives at the source (further data surpression is by way of the 'serious error' bit in the antenna status word).

Observations may be made with a single subarray on up to four different frequencies simultaneously. That is, the two 50 MHz bands may be positioned independently, and the R and L polarization outputs may be positioned independently (of course, in this case the crossed correlators, LR and RL contain no information). Therefore there are pointers to four separate IF group control blocks, and a list of four separate frequencies, which, in the most common mode, will consist of two pairs.

The true, array center alt-az coordinates will be calculated and left in the SCB every 10 seconds. The trig functions of A (azimuth) and h (altitude) appear naturally in the derivation, as do those of the paralactic angle z. (The locations are described in Memo #108 in terms of the zenith distance, $z = 90° - h$.) The ATAN2 function can then be applied to give the natural angles, which are then fixed and stored for the pointing constant routines. The trig functions of the paralactic angles are kept because, in the linear expansion, the amount moved in a time $\Delta t$ (sidereal radians) is given by

$$\Delta h = -\Delta t \cos\delta \sin \eta$$

$$\Delta A = \Delta t \cos\delta \cos \eta \sec h$$

The source coordinates and derivatives are used by GEOM10 to calculate the current source position for each 10 second interupt. The rate of change of velocity with time is also given for use with the spectral line system.

A gain code is included because, to save space, one likes to store 16 bit words of data rather than words sufficiently long to include the whole dynamic range. At any one time, the dynamic range of the instrument is limited to about 25 dB by atmospheric sidelobes and other effects. However, the strongest sources we might wish to look at have correlation coefficients greater than 0.5, whereas the noise level in a 12 hour observation is a correlation coefficient of about $4 \times 10^{-7}$ rms. The least significant bit as it comes from the correlator is a correlation coefficient of about $4 \times 10^{-6}$ in 0.3 seconds or about $10^{-7}$ after 10 seconds accumulation. This scaling is adequate for all weak sources. This, however, overflows sixteen bits for correlation coefficients greater than .003 (about one flux unit at L Band, the most sensitive case). Therefore, provision is made to shift the data right to observe the strongest sources. This gain code, included as part of the source description input to INIT, is stored in the subarray control block.

The precession matrix is included to convert the u,v coordinates (which appear more or less naturally during the phase and rate calculations) from the natural coordinate system of date to 1950 (or other reference coordinate system). This obviates the necessity of rotating maps made at different eras for accurate comparisons.

In advertently omitted from Memo #108 is the stop time, sidereal radians, E, which should occupy locations 133 and 134 of the SCB. When GEOM10 notices that this time is exceeded, it will activate INIT to update the SCB to a new source.

The information in the IF group control block is primarily for the use of the line observing programs in setting local oscillator frequencies.

The Antenna control block primarily describes the locations of the antenna. The azimuth and elevation give its pointing. The current az-el is derived by adding the change in az-el (from the SCB) to the corrdinates at last 10 sec. The quantities BX, BY, BZ give the location of the antenna in a topostationary coordinate system originating at the array center. The term given here as BA is the distance between the intersection of the axes, and is given that name rather than the traditional denomination of 'K term' to emphasize its affinity with the antenna location as being one of the 'baseline parameters'--which is to say, a parameter in a heuristic formula which describes the phase response of the instrument to a point source. A delay term is also provided to allow for the various cable lengths associated with the antenna.

The delay included in this block is the true wave delay calculated from the interferometer phase equation

$$D = \underset{\sim}{B}\cdot\underset{\sim}{S} - B_A \cos h$$

This phase appears in both a fixed point and a floating point version, as the former is most convenient for the phase calculations (for a floating multiplication by the frequency) while the latter is the most convenient for running the delay lines. (The change in delay since the last 10 sec interupt is $u \cos\sigma \, \Delta t$). The parameter $\underline{w}$ is yet a third version of the wave delay, expressed in different units and not including the cable length term.

Similarly the time derivative of phase, u, appears in both fixed and floating formats, because the former is conveniently short for including with the data and is useful for calulating current delay, while the latter is convenient for the fringe rate calculation necessary to drive the lobe rotators. The second derivative of phase is included for the use of the IF routines to estimate the lobe rotator rates during the 10 second intervals.

The pointing constants are assigned room according to the discussion of the memo Wade to Grove, February 22, 1974. It still remains my hope, however, that a simpler set of formulae will suffice to describe the antenna pointing, and that several of the constants will be either zero or duplicated. All of the pointing constants are given in fixed point turns, B-8, except for the encoder zero point offsets, which are scaled S+1. These are preserved in their full glory because, first, the antennas are rotated to go from arm to arm, and therefore the azimuth zero point will commonly be a third of a circle, and second, this is a good place for INIT to leave the result of its decision as to which turn of the cable wrap overlap to use, and whether to use a plunged elevation.

The front end control block is primarily a home for the front end status word. A separate block is necessary so that diagnostic information may be maintained on front ends not actually in use (e.g., on the upconverter during C band observations). The block also provides a home for a code telling the frequency of the K/KU first LO (C band has no first LO and the L band first LO is fixed frequency).

The preamp control block tells only the preamp status, and which front end is switched into it.

With each IF is associated a lobe rotator and a delay line. The If control block is concerned with running these devices, according to the formulae of VLA Computer Memo #103.

The terms on intrinsic IF sensitivity will deal with converting from correlator outputs (correlation coefficients) to Janskys of correlated flux. The exact manner in which this is accomplished depends to some extent on the behavior of the instrument, and is not defined now. (The questions to be answered are, chiefly, 1) are the phase terms under control, so that the correlator gain is the geometric mean of the two IF intrinsic gains, and 2) is the modulated noise source gain measurement really more stable than the system temperature itself (corrected for zenith distance effects)).

The faulty correlator control blocks will be set up as needed in a small buffer area whenever CHECK determines (by isolated extreme rms values or by the psuedo-random pattern test) that a given correlator is malfunctioning.