NATIONAL RADIO ASTRONOMY OBSERVATORY
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VLA COMPUTER MEMORANDUM #103

B. G. Clark

VLA GEOMETRY SUBROUTINES SPECIFICATION CONSIDERATIONS

1. Introduction

This memo does not consider the Ephermeris routines, but merely the geometric equations which will be executed on a routine basis throughout the observation. They are concerned with the lobe rotators (both phase and rate), the delay lines, and the antenna tracking.

In order to understand the discussion below the hiararchy of calculations must be kept in mind. That is, each device is connected to a given IF (except the antenna position, which governs 4 IF's), which in turn is connected to a given antenna (4 IF's to the antenna), which is connected to a subarray (0-27 antennas/subarray), which is finally connected to global variables, such as the time. With this convention, subscripting may be made implicit, and is not shown explicitly below.

In order to free the array from operator intervention at the time of the leap seconds, I propose to make IAT the fundamental time of the array. Each time a subarray is initialized for a new source, an Ephermeris routine will be called in which will initialize OUT1 and DUT1 such that at any new subsequent IAT time T

$$UT1 = T + OUT1 + T * DUT1.$$

The operator inputs of these constants will eventually be in the form UT2-IAT, but this consideration is a part of the Ephermeris routine and need not concern as here. The Ephermeris routine will also make available the sidereal time at midnight UT1, LSTM, the equation of the equinoxes, EEQ, and its derivative, DEEQ.

For each source, that is, for each subarray, the Ephermeris routines are presumed to leave the right ascention and declination in trig function form (i.e. CRA is cos(RA), SDEC is sin(dec)). It will also leave derivatives of the source positions, DRA and DDEC. These will enable us to both account for the precession (up to about 50 miliarcsec per hour) and to observe the sun and planets (up to about 7' per hour).

The geometric calculations are handled in two stages. A milestone routine will be executed every 9.6 seconds, and will calculate the device control quantities exactly. Then, at the service interval for each device, the quantity is extrapolated to the current time.

In the descriptions below the precision to which each block of equations must be evaluated is given to the right of the first equation, in units of eight bit bytes.

2. The milestone routines

2.1 The global calculations.

These calculations are done only once. First, the time T is read from the clock, and converted to convenient units. then:

```
UT1 = T + OUT1 + T * DUT1                              (5)
MLST = LSTM + UT1 * 1.002737811908
ALST = MLST + EEQ + DEEQ * T
CT = Cos (ALST)
ST = sin (ALST)
```

2.2 For each subarray.

Hour angle and declination:

```
CDECS = CDEC - DDEC * SDEC * T                         (5)
SDECS = SDEC + DDEC * CDEC * T
CRAS = CRA - DRA * SRA * T
SRAS = SRA + DRA * CRA * T
CH = CT * CRAS + ST * SRAS
SH = ST * CRAS - CT * SRAS
```

Zenith distance and azimuth:

```
COSZ = SINLAT * SDECS + COSLAT * CDECS * CH            (3)
SINZ = SQRT (1 - COSZ * COSZ)
COSA = (SDECS - SINLAT * COSZ)/(COSLAT * SINZ)
SINA = CDECS * SH/SINZ
SETA = SINA * COSLAT
CETA = SINLAT * SINZ - COSLAT * COSZ * COSA
Z = ACOS (COSZ)
(or Z = ATAN2 (SINZ, COSZ))
A = ATAN2 (SINA, COSA)
```

2.3 For each antenna.

The baseline parameters are its location in the rectangular earth coordinate system (BX, BY, BZ), and a constant term, BC, compounded of cable lengths, the instrumental LO phase, and the infamous K term. The fact that no baseline derivatives are included implies neglect of baseline deformations due to variations of earth tides within the observation, a maximum effect of about 0.4 mm. A rough estimation of earth tides (1.5 mm maximum) as well as the calculations of the baseline parameters from constants referred to the Conventional International Origin will be performed by the Ephermeris routines. First, the geometric delay.

Equatorial portion:

```
DEQ = BX * CH + BY * SH                                  (5)
```

Total:

```
DG = DEQ * CDECS + BZ * SDECS
DX = DG + BC
```

Derivatives:

```
U = BX * SH - BY * CH                                    (3)
V = -DEQ * SDECS + BZ * CDECS
DD = U * CD* (DRA - DEEQ - DUT1 - 1)
       + V * DDEC
```

Refraction (N is the current refractivity, H is the relative elevation of each telescope, S the total atmospheric phase path):

$$R = NH/COSZ-S*DG/(R_{\oplus} * COSZ * COSZ) \qquad (2)$$

$$D = DX + R \qquad (5)$$

Now, pointing corrections.

```
DASZ = C1 * SINZ + C2 * COSZ * COSA
     + C3 * SINA * COSZ + C4 * COSZ + C5                 (2)
DZ = D1 + D2 * COSZ + D3 * SINA + D4 * SINZ
     + D5 * SINZ/COSZ
ZA = Z + DZ                                              (3)
AA = A + DASZ/SINZ
```

2.4 For each IF:

The function FRACT takes the fractional part of the argument. The equivalent LO frequency for this IF is F. Each IF may have a peculiar phase connection, PC.

```
PHI = FRACT ( F * D) + PC                                (5)
DPHI = DD * F                                            (3)
DDPHI = DEQ * F                                          (2)
```

3. Device Updating

At entry to any routine there will be available the quantity DT, the time interval since the last 9.6 second updating.

3.1 Delay line setting - 50 ms intervals.
Each antenna:

DY = D + DD * DT (3)

Each IF adds a peculiar delay PD:

DL = DY + PD (3)

3.2 Antenna Positions 100 ms intervals.
Each subarray:

DZT = SETA * DT (2)
DAT = CETA * DT/SINZ (3)

Each antenna:

ZT = ZA + DZT (3)
AT = AA + DAT

3.3 Lobe rotator setting -1.6 second intervals.
Each IF:

PHIT = FRACT (PHI + DPHI * DT + DDPHI * DT * DT * 0.5) (3)
DPHIT = DPHI + DDPHI * DT