Submillimeter Array Technical Memorandum

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Reference frame corrections due to Polar motion

Introduction

It is well known that the axis of rotation of the Earth does not coincide with the axis of maximum moment of inertia (symmetry axis). As a result, the Celestial Ephemeris Pole (normal to the true equator) as determined by observations of astronomical sources, wobbles around the "pole" defined according to terrestrial reference frame. This is the so called Chandler wobble. (S. C. Chandler discovered in 1891, the period of this wobble to be about 430 days, which is greater than the expected value of 305 days, which is calculated neglecting the elasticity of the Earth[1,2]). Since the Polar motion amplitude is of the order of 0.3" in amplitude, it is important to include this effect in the calculations of the apparent positions of sources for the SMA. The Polar motion results in a variation of the latitude and longitude of a particular point on Earth as a function of time, around their mean values, over time scales of days, according to the following equations [3],

$$\delta\phi = x\ cos(\lambda_m) - y\ sin(\lambda_m) \tag{1}$$

$$\delta\lambda = (x\ sin(\lambda_m) + y\ cos(\lambda_m))tan(\phi_m) \tag{2}$$

where λ_m and ϕ_m are the mean values of the latitude and longitude and x and y are the angular deviations of the "true" pole with respect to the terrestrial pole, measured in arcseconds.

The values of x and y offsets of the pole are published by the International Earth Rotation Services (IERS) periodically, as Bulletin-A [4]. The Coordinated Universal Time (UTC) as read from the GPS by *Hal*, is corrected for the change in longitude, according to equation 2, resulting in 'UT1'. An additional correction, accounting for the non-uniformity in Earth's rotational rate (due to tidal effects etc.) needs to be applied. This correction in time is typically of the order a few-tenths of a second. To keep this correction within 0.7 seconds, the IERS occasionally announces an integral second correction to UTC (the leap-second), at the end of June or December. This announcements are also made in Bulletin-A. Daily values of DUT=UT1-UTC are also tabulated along with the values of x and y. It is easy to obtain the Bulletin-A electronically from their FTP server. In this memo, I document the software that retrieves the values of x, y and DUT. These numbers are also updated in Reflective Memory locations for use by other processes.

Software

The following Perl code gets the Polar motion numbers from the IERS FTP server. This code will be executed by SMARTS each time it is started up to track astronomical sources. The code will be executed at least once daily, but never during a track. The FTP connection is made only if a new file is available (updated weekly, every Friday, 0h UT). Otherwise, a previously retrieved text file called *ser7.dat* is parsed for the current date of observations. The parsed values of x, y and DUT are appended to another ascii file called *results.ser7*. To ensure that there is no error in parsing (due to say, a change in the file format at in the IERS Bulletin), the present values are compared with the previous day's values. If there is an error that is greater than 0.1" in either x or y, and 0.1 seconds in DUT, then an alarm is sent by email. A flag can also be set in the Diagnostics and Error Reporting System. In this event, the previous days values are used in the pointing calculations.

```
#!/usr/local/bin/perl

# File: polar.pl
# Author: Nimesh A. Patel
# Date: 15 December 1994
# Assumptions: 1) Executed by  cron or the tracking program through
#  SMARTS.   2) Previous files ser7.dat and results.ser7
# are in the present area, if not, change the paths accordingly in the
# open statements.
#
# Modifications(20 May 1998): 1) Use Perl5.004 (and FTP module instead
# of shell script to do ftp). 2) Take care of year 2000.
#
# This program gets the ser7.dat file from IERS
# by anonymous ftp and reads it to extract the
# x and y offsets of the pole (in arcseconds)
# and the value of (UT1-UTC) for the current date.
# These numbers are appended to a file: results.ser7
# See http://maia.usno.navy.mil/bulletin-a.html
# for details on the IERS Bulletin.

# Load the ftp module.
use Net::FTP;

# If today is a Friday, then
# get the file by anonymous ftp....

if ((localtime)[6] eq 4) {
$ftp=Net::FTP->new("192.5.41.22"); # ftp connection to the IERS server.
die "Could not connect: $!" unless $ftp;
$ftp->login('anonymous','npatel@cfa.harvard.edu');
$ftp->cwd('/ser7');
$ftp->get('ser7.dat');
$ftp->quit();
}

# Use gmtime to get the GMT string.

$d=(gmtime)[3];
$month=(Jan,Feb,Mar,Apr,May,Jun,July,Aug,Sep,Oct,Nov,Dec)[(gmtime)[4]];
$year=(gmtime)[5];

# gmtime returns only the hundreds of years, we need to add the century.
# Postpone the year-2000 problem to 2098!

if($year<98) { $year+=2000;}
else {$year+=1900;}

# add 1 because the array index for month goes from 0 to 11.
$mn=1+(gmtime)[4];

#debug
#print "$d,$mn,$year\n";
```

```
# Using Eqn. 12.92-1 from the Explanatory Supplement
# to the Astronomical Almanac to calculate JD from the given
# gregorian calendar  date in terms of day number, month number
# and year number. Need to do integer arithmetic.

$term1=int((1461*int(($year+4800+int(($mn-14)/12))))/4);
$term2=int((367*($mn-2-12*(int(($mn-14)/12))))/12);
$term3=int((3*int(($year+4900+int(($mn-14)/12))/100))/4);
$JD=$term1+$term2-$term3+$d-32075;

# subtract 1 to take care of noon..., subtract 2400000 to get MJD.

$MJD=$JD-1-2400000;

#debug
#print "$term1\n$term2\n$term3\n";
#print "Julian Day= $MJD\n";

open(INFILE,"ser7.dat") || die "Could not find the file ser7.dat\n";

@eachline=<INFILE>;
close(<INFILE>);

# finding the line number after which the relevant data appears....

for($i=0;$i<=$#eachline;$i++)

{

        $_=$eachline[$i];

        if (/ MJD       x\(arcsec\)    y\(arcsec\)    UT1-UTC\(sec\)/)

                {
                        $linenum=$i;
                        last;
                }
}

for($i=$linenum;$i<=$#eachline;$i++)
{
        $_=$eachline[$i];
        if (/$MJD/) {

# counting the number of words on this line ...

        @words=split(' ',$_);
        $wordnos=$#words+1;

# ... index accordingly...

# This stuff is to avoid confusing ourselves the line with
# the current MJD happens to have printed a leading date
```

```
        $index=$wordnos - 3;

# Now pull out xoffset, yoffset and dut....

        @pars=split(' ',$_);

        $x=$pars[$index];
        $y=$pars[$index+1];
        $dut=$pars[$index+2];

        print "x=$x, y=$y, dut=$dut\n";

        &results ;
        exit 0;


        };
}
sub results
{

        # Open the results file and check its last line— see if the
        # current values are way off; if so, send an alarm and exit
        #(alarm for now== email to my beeper; later this will be among
        # other alarms of the Diagnostics and Error Software.

        open(OUTFILE,"results.ser7") || die "Could not find the file results.ser7\n";
        while(<OUTFILE>){($MJDp,$xp,$yp,$dutp)=split(' ',$_);}
        close(OUTFILE);

        open(OUTFILE,">>results.ser7") || die "Could not find the file results.ser7\n";

        $dif_x=($x-$xp);
        if($dif_x lt 0.0) { $dif_x=-$dif_x;}
        $dif_y=($y-$yp);
        if($dif_y lt 0.0) { $dif_y=-$dif_y;}
        $dif_dutp=($dut-$dutp);
        if($dif_dutp lt 0.0) { $dif_dutp=-$dif_dutp;}

        if(($dif_x ge 0.1) || ($dif_y ge 0.1) || ($dif_dutp ge 0.1)) {&alarm};

                print OUTFILE "$MJD    $x    $y    $dut\n";
        close (OUTFILE);
        exit 0;

}

sub alarm
{
        open(MAIL,"|mail npatel\@cfa.harvard.edu");
        print "Alarm!";
        print MAIL "Alarm! IERS script failed.
```

```
        Please check the reading of ser7.dat manually.\n";
        close(MAIL);
        # send email to alphanumeric pager
        open(MAIL,"|mail npatel\@alphame.com");
        print "Alarm!";
        print MAIL "Alarm! IERS script failed.
        Please check the reading of ser7.dat manually.\n";
        close(MAIL);
        exit 0;
}
```

Figure 1: Polar wobble recorded during a period of approximately one year

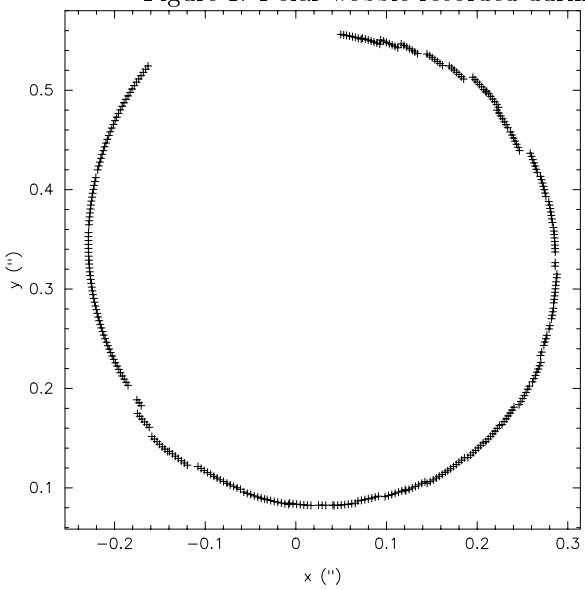
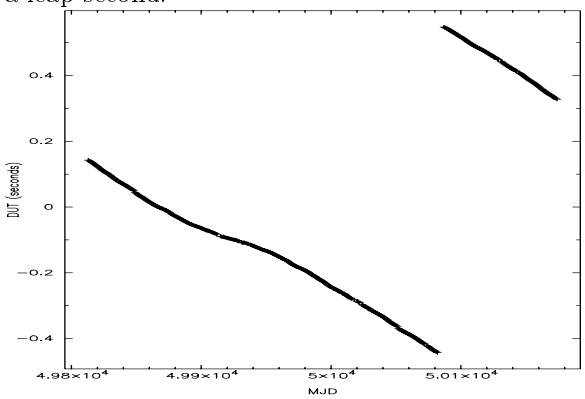


Figure 2: (UT1-UTC) recorded during the same period as above. The discontinuity corresponds to a leap-second.



References

1. Classical Mechanics, H. Goldstein, Second Edition, Addison-Wesley, Chapter 5.
2. Physics of the Earth, F. D. Stacey, John Wiley, Chapter 2.
3. Explanatory Supplement to the Astronomical Almanac, U.S. Naval Observatory, University Science Books, Chapters 3 & 4.
4. URL: http://maia.usno.navy.mil/bulletin-a.html