UNIVERSAL TIME DERIVED FROM VLBI, SLR AND GPS

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Universal Time solution combined by IERS from individual series is mainly based on VLBI inertial techniques. Although satellite methods like SLR or GPS have reached a remarkable precision, they do not give access to a highly accurate non-rotating reference frame, which restricts the possibility of determining directly UT1 from their data processing. This is mainly due to uncertainties in the even zonal harmonics of the gravity field and in various models (ocean tides). We show here that it is still possible to combine the high-frequency fluctuations contained in GPS "UT1" series with the long-term variations in the VLBI solution to derive a mixed UT1(VLBI+GPS) solution of great interest for its accuracy, time resolution but also for its economic advantage.

INTRODUCTION

By 1988, GPS had shown its ability to monitor polar motion. As a result IERS decided to include this technique as a part of its activities. After IGS'92 campaign extending from June through September 1992, five analysis centers continued their work on a routine basis. IERS has recently begun to incorporate these data in its regular analyses. In addition to the pole components estimation some analysis centers, CODE, JPL, ESOC and EMR [1,2] are also computing an internal "UT1" series or a derived quantity (*e.g* the excess to 86400 s of the length of the day, LOD). Due to the fact that satellite methods are not inertial the celestial reference system they define is not stable over long periods of time; this prevents the satellite technique to accurately determine long-term UT1 variations. We show in the present paper that their high-frequency signal is still valuable when associated to the long-term variations of UT1 VLBI series.

DATA USED IN THE ANALYSES.

Four GPS analysis centers currently derive UT1-UTC (or LOD values). The present sudy is only concerned by UT1 for Earth orientation purposes, consequently, LOD series given by JPL and ESOC have been integrated to give a "UT1" series. Because of missing values or gaps in some series, interpolation was required to derive continuous and homogeneous "UT1" series. Due to large jumps in the data, the analysis was made on a restricted interval for EMR. The characteristics of each series are listed on table 1. Other operational series used in the analyses and/or in the comparisons are also listed.

	int. (d)	sampl. (d)	1992 June	Sept.	1993 Jan.	March
GPS						
EOP(CODE) 92 P 04	1	1	::::::::::	::::::::::	::::::::::	::::::::::
EOP(JPL) 92 P 02	1	1	::::	::::::::::	::::	
EOP(JPL) 92 P 03	1	1			::	::::::::::
EOP(ESOC) 92 P 02	1	1			::::::::::	::::::::::
EOP(EMR) 92 P 04	1	1			::::::::	::::::::::
VLBI						
EOP(NOAA) 93 R 01	3	1	::::::::::	::::::::::	::::::::::	::::::::::
EOP(NOAA) 93 R 03	1	0.1	::::::::::	::::::::::	::::::::::	::::::::::
SLR						
EOP(CSR) 91 L 01	3	3	::::::::::	::::::::::	::::::::::	::::::::::

Table 1 - GPS, VLBI and SLR Universal Time available at IERS/CB as of 15 March 1993

Differences between the "UT1" series for each GPS center and an external reference like the IERS combined solution (EOP (IERS) C 04) show a wide range of errors (Fig. 1) mainly linked to inaccuracy in the celestial frame defined in orbit computation. Fig.2 shows the geometrical configuration of the satellite orbit relatively to the various reference frames implied. Due to mismodeling in the even zonal harmonics of the gravity field, to ocean tides and also to atmospheric gravitational effects linked to pressure variations, the node longitude and consequently UT1 (hour angle, reckoned from the prime meridian, of a point on the celestial equator)[3] are affected by long-term errors. This prevents the satellite technique to accurately determine long-term UT1 variation. Some analysis centers like CSR have solved this problem by using external a-priori VLBI values in their computations[4].

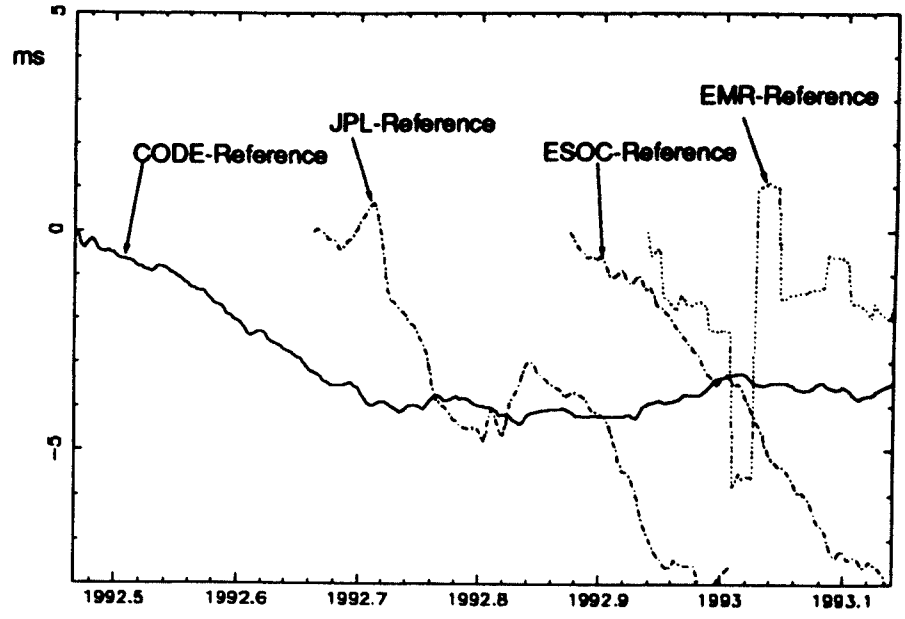

Fig. 1 - Raw "UT1" (or integrated values of LOD for JPL and ESOC) derived from GPS analysis present large systematic low-frequency errors relatively to external series (IERS combined solution) which prevents their direct use in current analyses. The plotted differences are arbitrarily set to zero at the start of the time series.

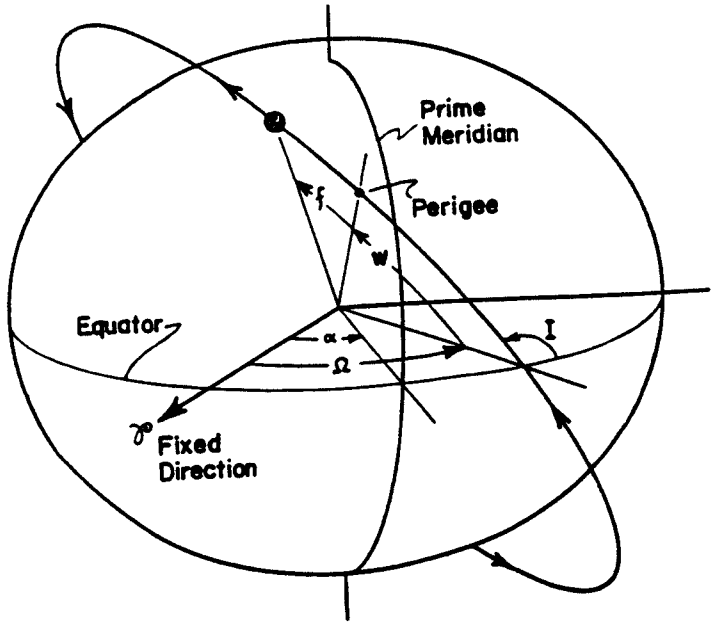

Fig. 2 - Representation of the orbit configuration relative to various reference frames. α : angle proportional to UT1 is obviously correlated to Ω, longitude of the ascending node of the satellite orbit; its determination suffers from mismodeling of Ω.

CONSTRUCTION OF A UT1 SERIES BASED ON GPS AND VLBI SOLUTIONS

We want to set up a procedure of constructing a mixed UT1 series involving long-term VLBI variations of EOP(NOAA) 93 R 01 associated to high-frequency variations given by GPS analysis *e.g.*UT1(VLBI+GPS) the most simple possible for clarity of the process. High frequency terms are removed in VLBI series while they are kept for internal GPS "UT1" series. The critical point concerns the threshold determination within which the high-frequency information contained in the GPS series is valuable. The criteria we have chosen is the following:

Parallel periodograms are made for CODE, JPL and the VLBI solutions. Depending on the analysis center (CODE or JPL) the agreement is fair until a specific period (respectively about 80 and 30 days) which is the threshold corresponding to the optimal filtering (Fig.3). This analysis could not be done for ESOC and EMR because of the relatively short data interval available.

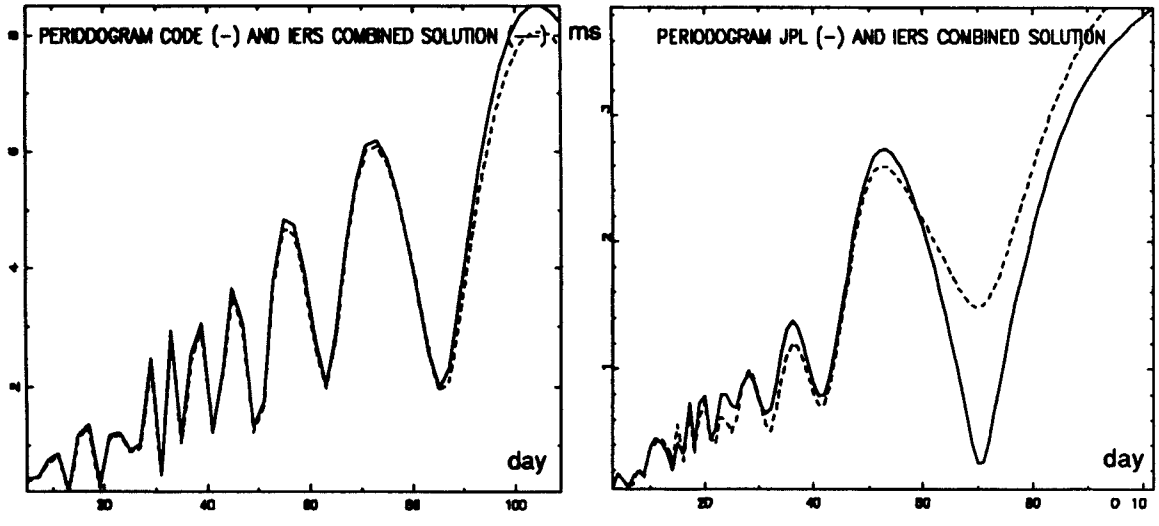

Fig. 3 - Periodograms of raw "UT1" GPS series compared to those of EOP(NOAA) 93 R 01. This analysis gives the threshold for smoothing characteristics determination

COMPARISONS OF UT1(VLBI+GPS) WITH VLBI AND SLR SERIES

In order to estimate the precision of the obtained mixed UT1(VLBI+GPS) solution comparisons with various series have been made. Fig. 4 shows its difference with NOAA and CSR solution; the rms differences of the three series are of the same order. Fig. 5 shows the differences between the mixed UT1(VLBI+GPS) solution and VLBI (EOP(NOAA) 93 R 01) and SLR (EOP(CSR) 91 L 01).

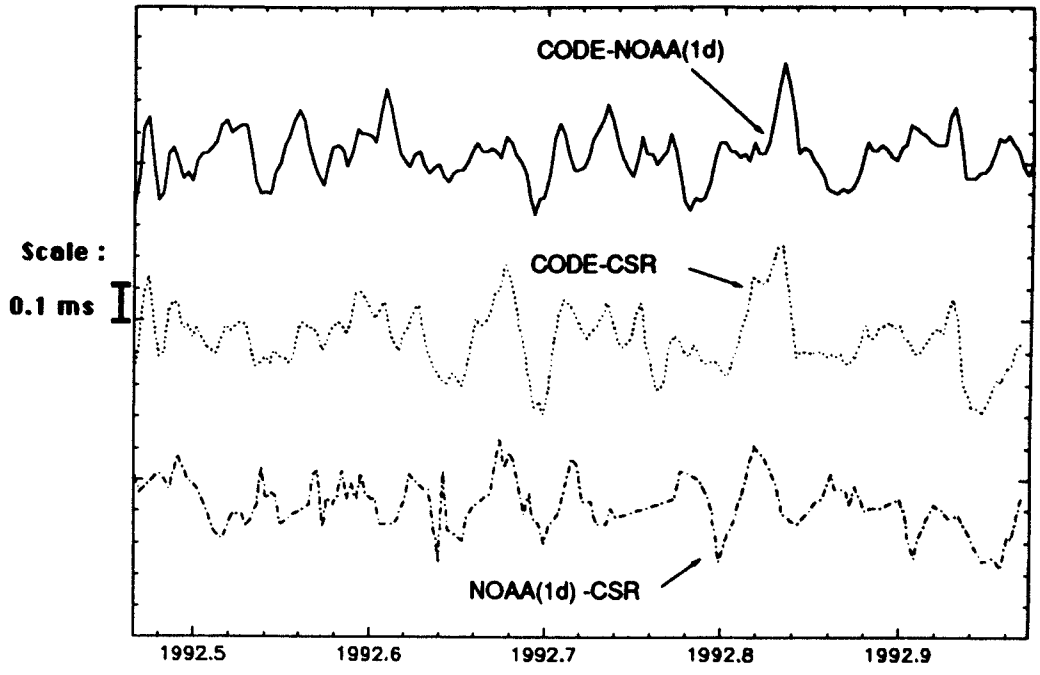

Fig. 4 - Differences between UT1(NOAA+CODE) solution with respectively EOP(NOAA) 93 R 01 and EOP(CSR) 91 L 01. RMS of the three series give estimation of the precisions.

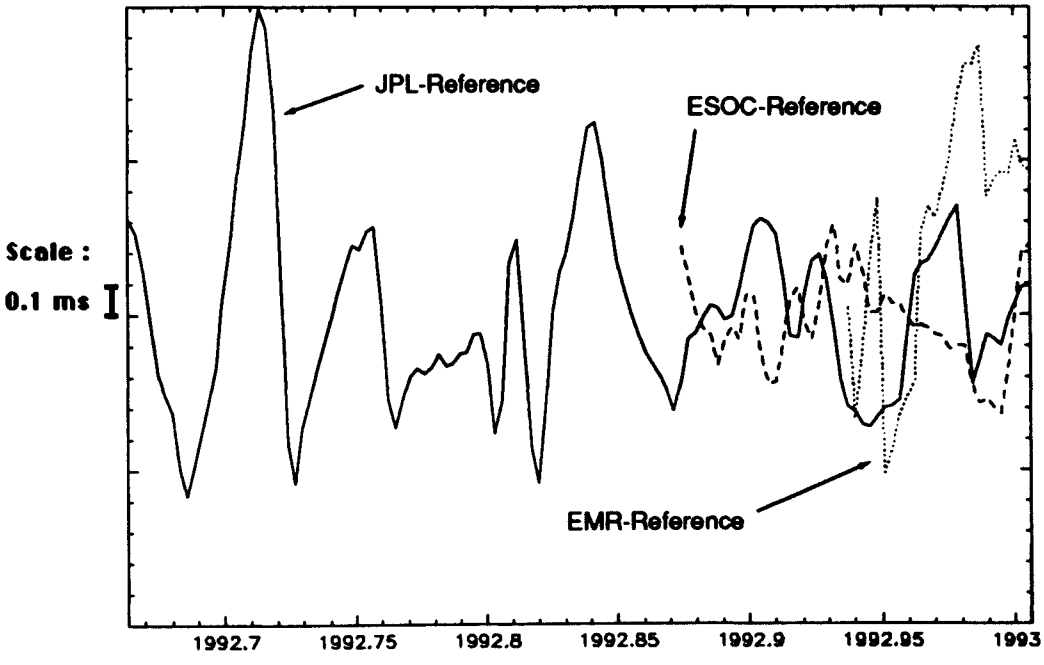

Fig. 5 - Differences between UT1(GPS+NOAA) solutions with an external reference (here EOP(IERS) 90 C 04).

Table 2 gives an estimation of the precision of each series by comparison to EOP(IERS) 90 C 04. These values are only indicative, the combined IERS solution being dependant on VLBI and SLR series.

Series		UT1 (0,0001s)
GPS		
	UT1(NOAA+CODE)	0.81
	UT1(NOAA+JPL)	2.80
	UT1(NOAA+ESOC)	1.47
	UT1(NOAA+EMR)	3.87
VLBI		
	EOP(NOAA) 93 R 02	0.41
	EOP(NOAA) 93 R 03	0.64
SLR		
	EOP(CSR) 91 L 01	0.73

Table 2 - RMS differences of various series with EOP(IERS) 90 C 04.

CONCLUSIONS

Although the internal UT1 series derived from GPS determinations are not directly usable for Earth Orientation monitoring, its high-frequency information can be used together with an external long-term calibration to derive a combined UT1(VLBI+GPS) solution which may be used both for scientific and operational purposes. Outside its high accuracy comparable to other series (NOAA, CSR) the advantage is its high sampling contribution (sub-diurnal) and also, what is not negligible its low production price due only to an additional effort in analyses. Moreover, monthly VLBI contribution seems sufficient to ensure long-term stability of the solution. Refinements of the data analyses are assumed to improve the results in a near future.

REFERENCES

[1]- Annual Report for 1991.

[2]- IGS'92 campaign, IERS Reports.

[3]- IERS Technical note 8

[4]- Aoki S.,Guinot B., Kaplan K.H.,Kinoshita H.,McCarthy D.D. and P.K. Seidelman, 1982, *Astron. Astrophys.*,105,359-361.