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Rapid UTC: a step forward for enhancing GNSS system times

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Outline

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- Coordinated Universal Time UTC
- Rapid solution UTCr, features and quality
- UTC representations used for steering GNSS times
- Summary

Coordinated Universal Time (UTC)

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- UTC is the time-scale maintained by the BIPM, with assistance from the IERS, which forms the basis of a coordinated dissemination of standard frequencies and time signals. It corresponds exactly in rate with TAI but differs from it by an integer number of seconds (Rec. ITU-R TF.460-6);
- All standard-frequency and time-signal emissions must conform to UTC (Rec. ITU-R TF.460-6);
- The UTC frequency should be used as the ultimate reference for standard-frequency emissions and other electronic systems (Rec. ITU-R TF.486-2);
- UTC should be used to designate the time in all international telecommunication activities and in all official documents of the International Telecommunication Union (Rec. ITU-R TF.102-1/7);
- UTC is published monthly under the form of values [*UTC-UTC*(*k*)] every five days (*BIPM Circular T*).

UTC and rapid UTC (UTCr)

- Extrapolation of [*UTC-UTC(k)*] over 10-45 days is necessary to many applications;
- UTC is not adapted for real and quasi-real time applications;

More frequent publication of UTC impacts on:

- UTC contributing laboratories
  - More frequent assessing of the steering of UTC(k),
  - Better stability /accuracy of UTC(k),
  - Enhanced traceability to UTC;
- GNSS community and users
  - Better synchronization of GNSS times to UTC via improved UTC(k) predictions.

Rapid UTC (UTCr) – General features

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- Started within a BIPM pilot project in January 2012;
- Officially declared a permanent product in July 2013;
- 39 participating laboratories (out from 72 in UTC);
  - 60% of the number of clocks in UTC representing 85% of the weight
- Daily values of [*UTCr-UTC*(*k*)] are published every Wednesday before 18 h UTC at the BIPM ftp server (ftp://tai.bipm.org/UTCr/);
- 1-month instability (over 2012-2013)
  - UTCr is $4.\times10^{-16}$
  - UTC is 3.5×10^{-16}

Rapid UTC (UTCr) – Publication

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UTCr_1344
2013 NOVEMBER 06, 12h UTC

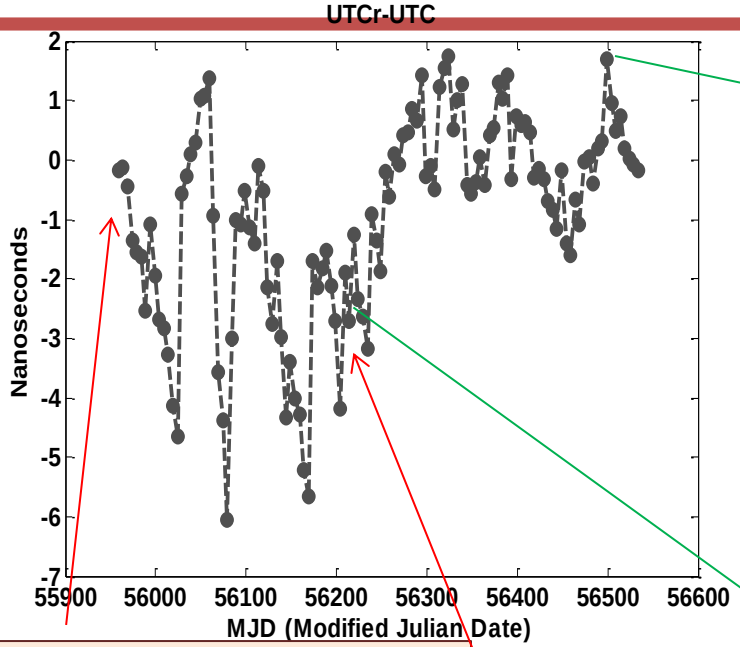
BUREAU INTERNATIONAL DES POIDS ET MESURES
ORGANISATION INTERGOUVERNEMENTALE DE LA CONVENTION DU METRE
PAVILLON DE BRETEUIL F-92312 SEVRES CEDEX TEL. +33 1 45 07 70 70 tai@bipm.org

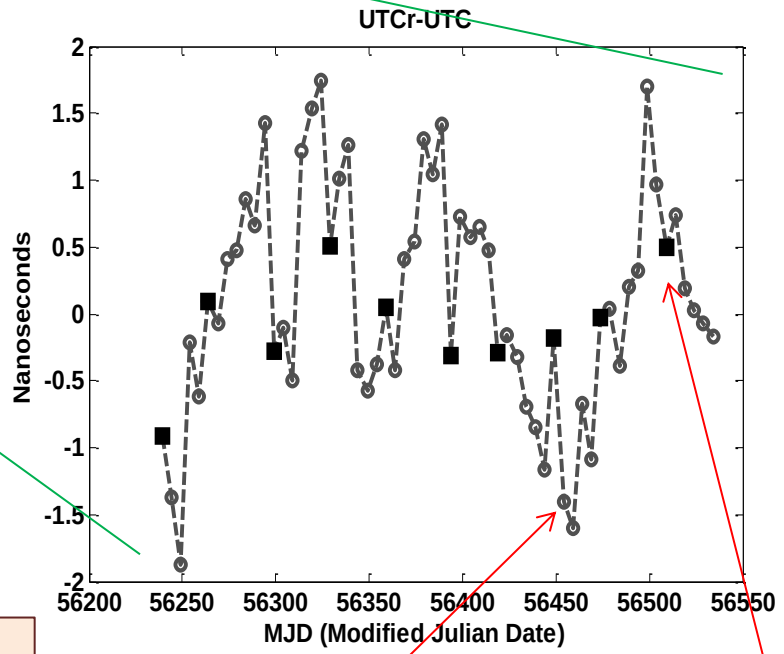
Computed values of [UTCr-UTC(k)]

Date 2013 0h UTC	OCT 28	OCT 29	OCT 30	OCT 31	NOV 1	NOV 2	NOV 3
MJD	56593	56594	56595	56596	56597	56598	56599
Laboratory k	[UTCr-UTC(k)]/ns						
AOS (Borowiec)	0.3	0.6	0.1	-0.3	-0.4	-1.2	-1.0
BEV (Wien)	-36.1	-37.0	-31.8	-25.5	-26.1	-20.5	-20.9
CH (Bern-Wabern)	-3.7	-6.4	-7.6	-8.3	-8.2	-9.1	-9.5
CNM (Queretaro)	-5.4	-6.4	-5.0	-5.8	-5.3	-5.9	-6.6
CNMP (Panama)	0.0	-1.6	-8.5	-13.2	-23.9	-17.1	-25.4
DMDM (Belgrade)	-13.1	-16.6	-17.5	-22.3	-30.5	-31.0	-29.4
DTAG (Frankfurt/M)	240.8	240.5	239.0	239.9	238.4	235.1	233.7
IFAG (Wettzell)	-863.1	-863.1	-865.7	-871.3	-875.1	-876.9	-875.4
IGNA (Buenos Aires)	4621.9	4637.8	4654.7	4669.3	4686.0	4705.1	4724.0
INTI (Buenos Aires)	62.2	61.0	61.3	60.7	67.8	75.9	73.1
IT (Torino)	-8.8	-9.2	-8.9	-9.0	-9.2	-10.3	-10.0
KRIS (Daejeon)	-16.0	-16.3	-15.8	-15.7	-15.3	-15.7	-15.0
LT (Vilnius)	410.7	402.9	393.9	396.9	391.9	389.0	382.2
MSL (Lower Hutt)	782.4	781.8	791.7	802.6	813.9	828.0	842.6
NAO (Mizusawa)	-20.3	-23.1	-23.2	-20.5	-23.4	-23.8	-25.4
NICT (Tokyo)	10.9	10.6	10.4	10.2	10.0	8.9	8.3
NIM (Beijing)	-7.8	-7.7	-7.8	-9.1	-8.5	-9.7	-9.9
NIMT (Pathumthani)	0.1	1.8	2.5	-2.1	-2.3	-1.0	0.0
NIST (Boulder)	-1.4	-1.9	-2.7	-3.5	-3.5	-4.3	-3.9
NMIJ (Tsukuba)	0.6	0.3	0.0	-0.4	-0.3	-1.1	-1.2
NMLS (Sepang)	1119.1	1104.1	1084.3	1072.6	1053.4	1037.7	1018.2
NPLI (New-Delhi)	-3.7	-3.4	-3.7	-4.2	-4.0	-3.6	-3.3
NRC (Ottawa)	-22.6	-19.6	-22.1	-20.6	-26.5	-26.6	-22.8
NRL (Washington DC)	-4.6	-4.4	-4.2	-4.1	-3.4	-2.1	-1.1
NTSC (Lintong)	-0.1	-0.2	-1.3	0.7	-2.6	-1.9	-3.6
ONRJ (Rio de Janeiro)	-11.8	-12.1	-13.0	-13.5	-14.8	-14.3	-15.0
OP (Paris)	-3.1	-2.8	-3.1	-3.3	-3.2	-3.6	-3.4
ORB (Bruxelles)	-11.4	-10.6	-10.7	-12.9	-12.4	-15.2	-17.3
PL (Warszawa)	38.2	38.8	35.7	32.6	29.9	32.5	29.1
PTB (Braunschweig)	-6.9	-6.6	-7.1	-7.7	-8.1	-8.7	-8.5
ROA (San Fernando)	0.4	0.6	0.2	-1.1	-1.8	-3.2	-4.0
SCL (Hong Kong)	33.7	35.6	27.5	34.7	29.3	32.4	28.1
SG (Singapore)	-17.2	-17.9	-19.2	-20.6	-19.2	-20.2	-19.4
SP (Boras)	-6.4	-5.7	-6.3	-6.9	-7.2	-7.6	-7.5
SU (Moskva)	-2.0	-1.7	-2.1	-2.4	-2.2	-2.6	-1.9
TL (Chung-Li)	-5.6	-6.2	-6.9	-7.4	-7.8	-8.9	-8.1
UME (Gebze-Kocaeli)	1363.3	1367.5	1369.9	1370.5	1376.8	1380.7	1379.1
USNO (Washington DC)	-3.4	-3.8	-4.2	-5.0	-5.1	-5.3	-5.5
VSL (Delft)	-23.0	-22.2	-22.0	-20.5	-18.3	-18.8	-12.9

UTC remains available from the monthly Circular T at
(http://www.bipm.org/jsp/en/TimeFtp.jsp?TypePub=publication).

Rapid UTC (UTCr) – General features





Start of pilot experiment publication (Feb 2012)

Completed algorithm and procedure (Nov 2012)

Start of official publication (July 2013)

UTCr-UTC [from Nov 2012]
min;max -1.88 ns;+1.75 ns
Mean +0.09 ns
RMS 0.83 ns

Steering to UTC after publication of *Circular T*( )

UTC(k) serving to steer GNSS times and their [*UTCr-UTC(k)*]

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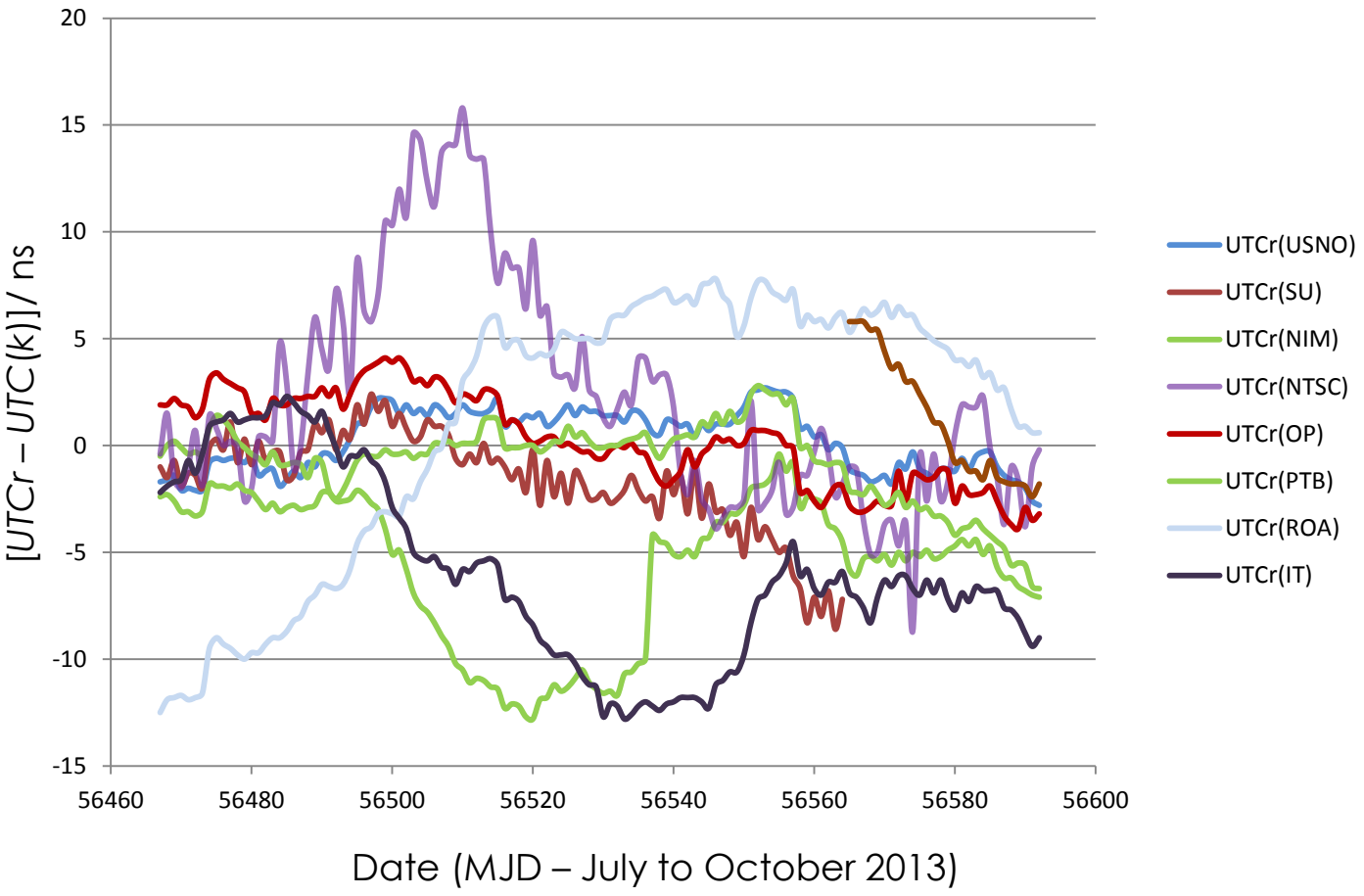

GPS time steered to UTC(USNO)
GLONASS time steered to UTC(SU)

BeiDou System time steered to UTC(NIM)/UTC(NTSC)

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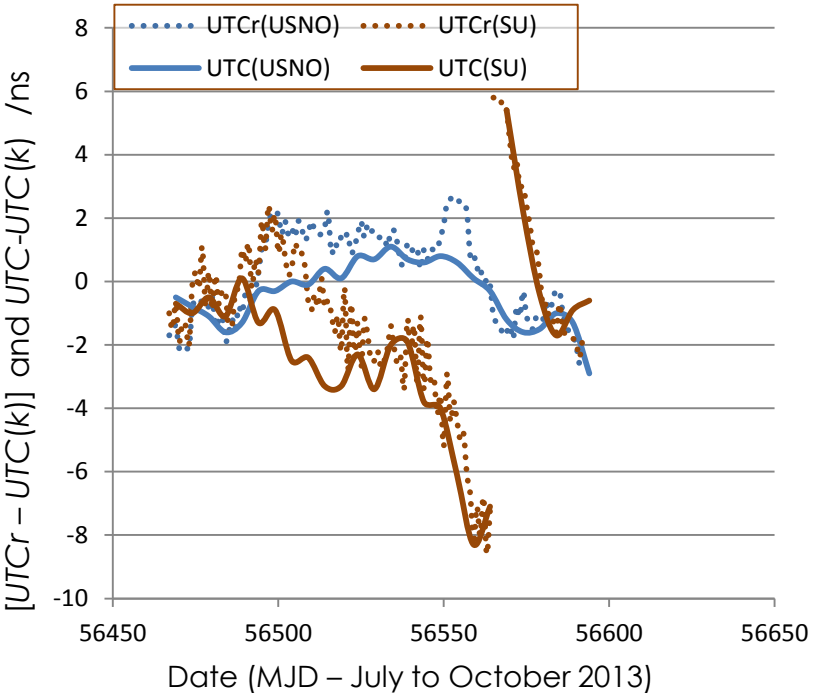
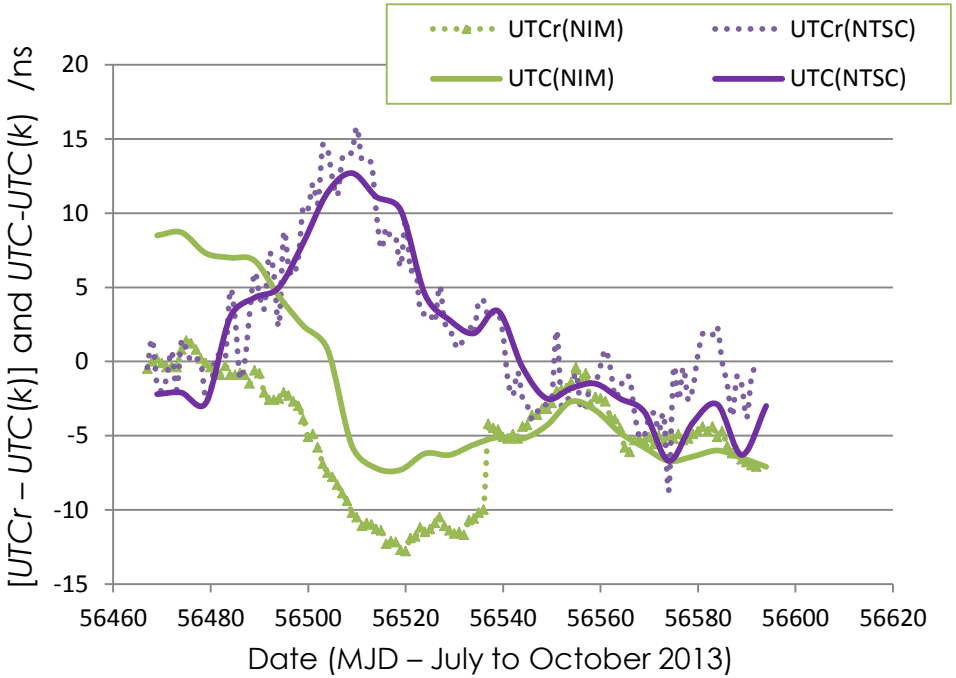
UTC(k) used for steering GPS/GLONASS times



UTC(k) used for steering BeiDou time



UTCr-UTC	USNO	SU	NIM	NTSC
mean/ns	+0.67	+0.90	-3.22	+0.48
RMS/ns	0.70	0.64	5.86	3.35
u_{CirT}/ns	3.8	2.0	5.2	4.9

GALILEO time steered to a set of European realizations of UTC (OP, PTB, ROA, IT, NPL)

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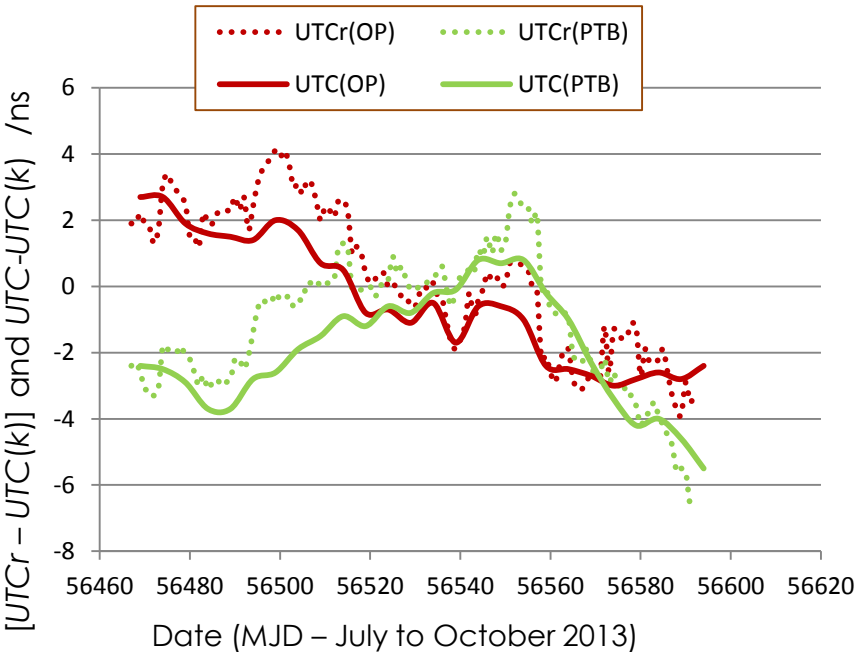
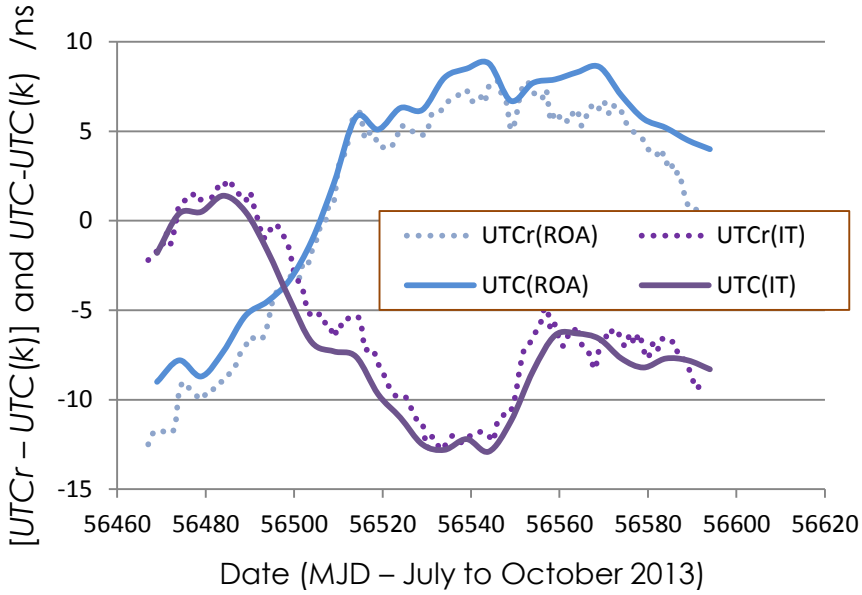
UTC(k) used for steering GALILEO time





UTCr-UTC	OP	PTB	ROA	IT
mean/ns	+0.73	+0.73	-1.40	+0.88
RMS/ns	0.85	0.65	3.22	0.22
u_{CirT}/ns	1.9	1.6	5.1	2.0

Summary

- UTCr is a BIPM official product that provides frequent access to UTC; traceability to UTC remains only through monthly *BIPM Circular T*;
- A well designed algorithm allows the provision of a rapid UTC solution with excellent metrological quality,
  - the instability of UTCr is comparable to that of UTC,
  - on average, the absolute value UTCr-UTC < 2 ns since Nov 2012,
- UTCr helps in enhancing the quality of the UTC(k);
- All UTC contributing laboratories are expected to contribute in the near future;
- UTCr is a step forward to a more frequent publication of UTC.