EGNOS timing performances as evaluated by SPMS

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The views expressed in this presentation are those of the authors and do not necessarily reflect the official position of the GSA/EC
Outline

1. Introduction to EGNOS and ENT
2. EGNOS timing performances
3. WAAS timing performances
4. Conclusions
EGNOS overview

EGNOS = European Geostationary Navigation Overlay Service
GPS SBAS over Western Europe

EGNOS services currently broadcast by 2 GEO:
PRN 120 and 136 (operational)
PRN 123 (to come)

EGNOS Open Service: October 2009
EGNOS Safety-Of-Life service: March 2011
EGNOS Network Time (ENT)

- EGNOS system time = ENT
- ENT is computed from differences between clocks in the EGNOS ground stations (obtained by GPS Common-View)
- ENT is steered to GPST
  \[ \text{ENT} - \text{GPST} < 50 \text{ ns (5 } \sigma \text{)} \] – cf. EGNOS SRD
- ENT is described in the ICG WG-D timing template available on the ICG web site

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Link between ENT and UTC in Message Type 12 (MT12)

- Offset between UTC [or one UTC(k)] and SBAS system time
- Max update time: 300 s
- Validity time: 86400 s

EGNOS requirement

ENT – UTC(OP) accuracy < 10 ns (3 \(\sigma\))

<table>
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<tbody>
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<td>UTC(CRL)</td>
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<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>UTC(USNO)</td>
</tr>
<tr>
<td>3</td>
<td>UTC</td>
</tr>
<tr>
<td>4</td>
<td>European UTC(k)</td>
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<td>5-6</td>
<td>Reserved for future use</td>
</tr>
<tr>
<td>7</td>
<td>Not provided</td>
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(see MOPS Annex A)
ENT and UTC(OP)

An EGNOS station at Observatoire de Paris

- Physically connected to UTC(OP)
- Time delays within this station
  - calibrated in real time through the use of dedicated GPS-like signals
  - transmitted to EGNOS system

ENT-UTC(OP) comes as output of the composite clock algorithm
(but UTC(OP) is not used to form ENT)

MT12 is uploaded to the EGNOS satellites and broadcast in each EGNOS PRN navigation frame

The EGNOS user shall be aware that applying EGNOS corrections to its GPS measurements will turn its time reference from GPST to ENT and therefore to UTC(OP) if MT12 is used
CNES awarded in 2015 by GSA of the Service Performance Member State Support (SPMS) grant:
- CNES leads a consortium of 8 state bodies from 7 countries
- Main objective = EGNOS performance monitoring

One WP is devoted to the EGNOS time function monitoring. It involves:
- the Italian Istituto Nazionale di Ricerca Metrologica (INRIM)
- the laboratory Systèmes de Références Temps-Espace (LNE-SYRTE) of Observatoire de Paris
- the Royal Observatory of Belgium (ROB)
- CNES
ENT perfo monitoring

To monitor EGNOS timing function, these time offsets are computed:
- ENT – ENT\textsubscript{user}
- ENT – UTC
- ENT – GPST

ENT\textsubscript{user} is the time scale obtained when applying EGNOS corrections on the GPS measurements of a given receiver.

The chosen approach is to have different computation methods and/or data with a view to:
- cross-checking results
- easing investigations in case of discrepancies
ENT – ENT_{\text{user}}

\[ \text{ENT} - \text{ENT}_{\text{user}} = \text{ENT} - \text{UTC(\text{OP})} - \text{ENT}_{\text{user}} - \text{UTC(\text{OP})} \]

Broadcast in MT12

**Computed by 3 different methods:**

1. Applying EGNOS corrections to a calibrated GPS rx (OPMT) connected to UTC(\text{OP})

2. Applying EGNOS corrections on BRUX (ORB GPS calibrated receiver)

3. Applying EGNOS corrections on IENG (INRIM GPS calibrated receiver)

**Circular T**

**TWSTFT**

ICG-11 : EGNOS timing performances as evaluated by SPMS
ENT – ENT\textsubscript{user} via INRIM
ENT – ENT\textsubscript{user} via ORB
ENT – ENT\textsubscript{user} via OP

ENT – ENT\textsubscript{user} via ORB using P3 iono-free combination (instead of C1 + iono corrections)
The different methods provide consistent results.

Missing results are due to absence of MT12 (e.g. Nov 2015)

The bias between ENT and $\text{ENT}_{\text{user}}$ increased from $\sim 7$ ns to $\sim 11$ ns following the interruption in Nov 2015.
ENT – UTC

\[ \text{ENT – UTC} = \text{ENT – UTC(OP)} + \text{UTC(OP) – UTC} \]

**Computed by 3 different methods:**

1. **Circular T**

2. \[ = \text{UTC(OP) – UTC(ORB)} + \text{UTC(ORB) – UTC} \]

3. \[ = \text{UTC(OP) – UTC(IT)} + \text{UTC(IT) – UTC} \]

- **Broadcast in MT12**
- **PPP**
- **TWSTFT**
The different methods provide consistent results. Missing results are due to absence of MT12 (e.g., Nov 2015).

Same code color as for ENT - ENT_user.
ENT – GPST

\[
\text{ENT} - \text{GPST} = \text{ENT} - \text{UTC(OP)} + \text{UTC(OP)} - \text{GPST}
\]

Broadcast in MT12

Computed by 3 different methods:

1. \[
\text{UTC(OP)} - \text{UTC} + \text{UTC} - \text{GPST}
\]

Circular T

2. \[
\text{UTC(OP)} - \text{UTC(ORB)} + \text{UTC(ORB)} - \text{GPST}
\]

PPP

Using BRUX CGGTTS files

3. \[
\text{UTC(OP)} - \text{UTC(IT)} + \text{UTC(IT)} - \text{GPST}
\]

TWSTFT

Using IENG CGGTTS files
The different methods provide consistent results. Missing results are due to absence of MT12 (e.g. Nov 2015).

Same code color as for ENT - ENTuser.
WNT_{user} - UTC

WAAS Network Time is also monitored using IGS station USN7

\[ WNT_{\text{user}} - UTC = WNT_{\text{user}} - UTC(USNO) + UTC(USNO) - UTC \]

Applying WAAS corrections on USN7

Circular T

\[ 2 \text{ ns} \]

\[ 50 \text{ d} \]
\( \text{WNT}_{\text{user}} - \text{GPST} = \text{WNT}_{\text{user}} - \text{UTC(USNO)} + \text{UTC(USNO)} - \text{GPST} \)

Applying WAAS corrections on USN7

Using USN7 CGGTTS files

\[ \text{Time difference [ns]} \]

\[ \text{Modified Julian Day} \]

\[ 5 \text{ ns} \]

\[ 50 \text{ d} \]
Conclusions

The SPMS consortium provides an assessment of the EGNOS timing function

The MT12 (that contains ENT – UTC(OP)) has a small bias w.r.t. our estimations of $\text{ENT}_{\text{user}} – \text{UTC(OP)}$ of ~11 ns as of now

ENT is close to UTC (and GPST) at the level of a few ns

This performance is comparable to $\text{WNT}_{\text{user}}$
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