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SYNCHRONISATION SOURCES FOR TELECOMMUNICATION NETWORKS
GENERAL OVERVIEW

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Overview

What Is A Sync Source

Global Navigation Satellite Systems
Atomic Clocks
Sync Source Performance in Perspective
Next Generation Sync Sources
Conclusions
Attributes of Sync Sources

Sync Sources are typically Primary Reference Clocks (PRC’s) and must:

- Provide a Stratum 1 reference signal to other clocks within a network.
- Serve as a master clock for a network, network section, office or network element.
- Accurate to 1 part in $10^{11}$ (1x10⁻¹¹) or better with verification to Universal Coordinated Time (UTC).
ITU-T G.811 / G.803

Long term frequency accuracy better than $1 \times 10^{-11}$

Phase discontinuity better than $1/8$ UI
(64ns at 2048 kHz)

1 Frame slip in 72 days
Classic PRC per ITU-T G.811

3x PRS (< 10^{-11})

SSU (ITU-T G.812)

Phase discontinuity better than 1/8 UI (64ns at 2048 kHz)
Clock Source Overview

Cesium

Rubidium

GNSS Receivers
GPS, Glonass, Galileo, Compass

Loran C / eLoran Receivers
Long Range Navigation System Vers.C 90 kHz- 110kHz

Long wave Receiver
DCF77(D), MFS (UK), WWVB (US)

CDMA Receiver
Primarily USA

TDM
(Frequency)

NGN
(Frequency & Time)

Mobile BTS
(Wimax/Cellular)

DVA/DVB/DVH
SF MBMS

Power Utility
Military

2048 kHz
2048 kbps

IEEE 1588 (PTP)
NTP
DTI/UTI

1pps
10 MHz

IRIG-B
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## Global Navigation Satellite System

<table>
<thead>
<tr>
<th>GNSS</th>
<th>GPS</th>
<th>GLONASS</th>
<th>GALILEO</th>
<th>COMPASS (Beidou2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Country</strong></td>
<td>![USA]</td>
<td>![Russia]</td>
<td>![Europe]</td>
<td>![China]</td>
</tr>
<tr>
<td><strong>Orbital height</strong></td>
<td>20180 km</td>
<td>19100 km</td>
<td>23222 km</td>
<td>21500 km</td>
</tr>
<tr>
<td><strong>Orbital period</strong></td>
<td>11:58 h</td>
<td>11:15 h</td>
<td>14.05 h</td>
<td>12:35 h</td>
</tr>
<tr>
<td><strong>System Control</strong></td>
<td>Military</td>
<td>Military</td>
<td>Civil</td>
<td>Military</td>
</tr>
<tr>
<td><strong>Timing Services</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Clocks</strong></td>
<td>Cs, Rb</td>
<td>Cs</td>
<td>PHM, Rb</td>
<td>Rb</td>
</tr>
<tr>
<td><strong>TimeScale</strong></td>
<td>TAI-19</td>
<td>UTC-3 hours</td>
<td>TAI</td>
<td></td>
</tr>
<tr>
<td><strong>Time Offset transmission</strong></td>
<td>GGTO GPS/Galileo Time Offset</td>
<td>GGTO GPS/Galileo Time Offset</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Open service / 95%</strong></td>
<td>100 ns</td>
<td>100 ns</td>
<td>30ns</td>
<td>50ns</td>
</tr>
<tr>
<td><strong>Open service / 95%</strong></td>
<td>28m</td>
<td>35m</td>
<td>50m</td>
<td></td>
</tr>
</tbody>
</table>

**RNSS Regional Navigation Satellite Systems:** QZSS (Japan), IRNSS (India) and Beidou1 (China)
Pro's:
- low cost
- high quality PRS, if stable internal Oscillator used
- provides frequency, time and phase!

Con's:
- off air system, need to receive satellite information
- outdoor antenna installation required (may be expensive)
- lightning issues / protection
- system errors may cause large time offsets
  RAIM Receiver Autonomous Integrity Monitoring doesn't prevent for all errors!
- Jamming
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Cesium atomic clock  autonomous  PRS

famous 5071A Cs
80% weight in UTC

Pro’s:
- strategic independent, autonomous high quality PRS (x 10^{-12})
- up and running within 30 minutes after power on
- no external reference signals required
- no antenna installations required
- long life time tubes, warranty up to 12 years
- Cesium beam no frequency aging behavior (Rb, Maser age)
- self controlled, alarm indication

Con’s:
- expensive compared to GNSS Receiver
- Cs beam tube needs to be replaced after 12 years typical
- ToD outputs require initial time synchronization
Rubidium Atomic Clocks
Almost a Primary Reference Source

Use:  - Versatile frequency source for many commercial, telecommunication & aerospace applications
      - first atomic clock in space
      - meets lifetime mobile basestation holdover
      - perfect Osc. inside GNSS & SSU systems

Pro’s:  - small, light, low cost, low power atomic clock
        - fast warm up (7 minutes)
        - excellent retracibility
        - unlimited lifetime (physics doesn’t limit lifetime)
        - self controlled, alarm indication
        - 3-6 weeks network holdover
        - very good short term stability

Con’s:  - doesn’t meet PRS stability specification
        - Rubidium typical frequency aging of 1 to 5e-11/month
        - initial factory calibration / aging correction required
Other Atomic Clocks

Active Hydrogen Maser (AHM)
- Uses intrinsic properties of the hydrogen atom.
- Best short term frequency stability
- Frequency stability is ~40X superior to cesium
- Relatively large, complex and expensive
- Used for maximum stability (Master Ground Stations for GNSS, National standards, radio ground stations, and very long baseline interferometry).

Passive Hydrogen Maser (PHM)
- Uses intrinsic properties of the hydrogen atom.
- The cavity is fed by an external 1420 MHz frequency (passive vs. active) that is tuned to produce the maximum output in the cavity.
- Frequency stability comparable to lower Cesium
- H\textsubscript{2} replenishment after 4-6 years.
- Passive Maser show frequency aging behavior, therefore is not a good standalone PRS
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Oscillator Stability versus GPS

Allan Deviation (rf/f) vs. Observation period in seconds

- TCXO
- OCXO
- CESIUM
- RUBIDIUM
- GPS (SA off)
- Free run stability

Observation periods:
- 30s
- 200s
- 1.5ks
- 30Ks
- 8h
- 500ks
- 6d
GPS PRC stability with SA on / off

TCXO based, SA active

TCXO based, SA inactive

Rubidium based, SA active

Rubidium based, SA inactive

Limits for wander at PRC outputs per EN 300 462-6-1 V1.1.1 (1998-05)

GR-2830
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NGN PRS Sync Source

NTP (Network Timing Protocol)
PTP/IEEE 1588 Sync Protocol
(1G Sync E)
G. UTI (Universal Timing Interface)

RT Categories
MSPP: Multi Service Provisioning Platform
MSAN: Multi Service Access Node
EAD: Ethernet Aggregation Device
IP DSLAM
PON
Sync Sources in the NGN Network

CORE
- Mesh
- Content Network
  - VoD
  - TV

AGGREGATION
- Hub & Spoke or Ring
- TDM/ATM

ACCESS
- 3GPP/2
  - TDM/ATM
  - WiMAX
  - Ethernet
  - DSLAM
  - xDSL
  - xPON
  - M-CMTS

SUBSCRIBER
- Mobile
- Residential
- Business
  - Self Build: Licensed/un-licensed

Network Management Software
- TimePictra
- TimeScan
- TimeMonitor

SSU 2000
- TDM signals
- NGN signals
- NTP & PTP Server
- TimeCesium

TP 1100 w/NTP
- TP5000 PTP Master Clock
- TP 500 ext. PTP Client
- TP100 GPS Source
- PTP SoftClient Solutions

Rb-OEM Source
Live deployed network in Europe

- Sync was tested over Packet-over-SDH, 2 weeks
- Moderately loaded network ring (7 hops in one direction, 15 hops in the other)
- Meeting G.823 sync mask + 1ppb with large margin
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- **Cesium**
  - Until mid 90s Cesium was the choice as PRS
  - Today Tier 1 and national operators use Cs as PRS for strategic / political reasons

- **GPS**
  - since beginning 90s continuously stable open service, the last years w/o SA
  - deregulated telecom market generated high demand on PRS’s, due cost reasons
    GPS disciplined PRS became very popular !
  - By now the most deployed PRS in Telecom Networks
    ( at the beginning NO trust in GPS, today too much trust !!)

- **GNSS**
  - GPSIII, Glonass, Galileo, Compass provide many Satellites to choose from
  - new signals, more accuracy, integrity information, higher signal strength
  - interoperability

Interoperable multi GNSS Receiver will become the ultimate PRS Sync Source

Timing protocols like PTP will provide virtual sync sources throughout the IP NGN
Thank You For Your Time …

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