Real-Time GNSS Data Transmission
Standard RTCM 3.0

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Outline

- RTCM Overview
- RTCM SC104 DGNSS Standards
- RTCM 3.0 Standard
  - General Structure
  - Raw Data Format
    - Compression
    - Observation Types
  - Transport Protocol
- Comparison with other Formats
- General Requirements for Standard Data Formats
- Other Issues
  - Control Protocol
Radio Technical Commission for Maritime Services

RTCM SC-104: Enabling Standards that Support Emerging Positioning and Related Technologies

Rudy Kalfus (SC-104 Chairman)
Bob Markle (RTCM President)

Streaming GNSS Data Via Internet-Symposium
Frankfurt, 6 February 2006

Slides borrowed from:
www.rtcm.org
RTCM founded in 1947 as U.S. State Department Advisory Committee

Now an independent membership organization
RTCM Standards

RTCM supports development of standards and regulations of –

• International Maritime Organization (IMO)
• International Telecommunications Union (ITU)
• International Electrotechnical Commission (IEC)
• International Organization for Standardization (ISO)
RTCM Liaisons

European Telecommunications Standards Institute (ETSI)

Comité International Radio-Maritime (CIRM)

Cospas-Sarsat

International Association of Aids to Navigation and Lighthouse Authorities (IALA)

International Hydrographic Bureau (IHB)

National Marine Electronics Association (NMEA)
RTCM Members

22 Government Agencies from 7 nations

56 Manufacturers from 14 nations

41 Others:
- Associations
- Designers
- Trainers
- Service Providers
- Vessel Owners/Operators
RTCM Standards used internationally


SC109: Electronic Charts
RTCM regional Standards used in USA

SC101: Digital Selective Calling marine radios
SC110: Emergency Beacons
SC112: Radar
SC117: Electromagnetic Interference Resistance for marine radios
SC119: Maritime Survivor Locating Devices
RTCM SC-104 Differential GNSS Standards

- Originally set up in 1983 to develop standards for DGPS to achieve 5 meter accuracy navigation & positioning
- Version 1 was replaced by Version 2, when implementation problems turned up (1990)
- Version 2.1 added Real-Time Kinematic (RTK) messages to provide decimeter accuracy of short ranges (1994)
- Version 2.2 expanded differential operation to GLONASS, provided ancillary RTK messages (1998)
- Version 2.3 added several new messages to improve RTK, radiobeacon broadcasts, use of Loran-C (2001)
Inefficiency of Version 2 messages led to the development of an improved format – more efficient, higher integrity, and simplicity of development – Version 3.0 (2004)

Version 3 primarily aimed at improving RTK, supporting networked RTK

Current Working Groups: Network RTK, Internet Protocol, Coordinate Transformations, Reference Station Integrity Monitoring, GLONASS, Galileo

New Proposed Working Group: Encryption
While the Commission was originally set up to address maritime standards, DGNSS standards are applied world-wide to land and maritime positioning systems.

One strength of the SC-104 Committee is that participating companies benefit from world-wide standards, thus are motivated to develop them.

Participants include vendors, service providers and government agencies from around the world.

Standards are subjected to performance and interoperability testing prior to adoption and publication.
RTCM 3.0 General Structure

- **Scope:** OSI standard reference model
  - Application Layer (brief discussion)
  - Presentation Layer (Data Field and Message Definition)
  - Transport Layer (Message Framing, CRC)
  - Data Link Layer (no specifications, up to service providers)
    - **RTCM-NTRIP**
  - Physical Layer (no specifications, up to service providers)

- **Version 3 Database Architecture**
  - Definition of **Data Fields (DF)** (fixed length, variable length text)
    - Data Fields not on Byte Boundaries for Maximum Compression
  - Definition of **Message Types (MT)** composed of Data Fields

- Format designed for Broadcast Transmission
### RTCM3.0: DF Examples

<table>
<thead>
<tr>
<th>DF #</th>
<th>DF Name</th>
<th>DF Range</th>
<th>DF Resolution</th>
<th>Data Type</th>
<th>Data Field Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>DF003</td>
<td>Reference Station ID</td>
<td>0-4095</td>
<td></td>
<td>uint12</td>
<td>The Reference Station ID is determined by the service provider. Its primary purpose is to support multiple reference stations within a single data link transmission. It is also useful in distinguishing between desired and undesired data in cases where more than one service may be using the same data link frequency.</td>
</tr>
<tr>
<td>DF009</td>
<td>L1 Pseudorange</td>
<td>0-299792.46 m</td>
<td>0.02m</td>
<td>uint24</td>
<td>The GPS L1 Pseudorange field provides the raw L1 pseudorange measurement at the reference station in meters, modulo one lightmillisecond (299,792.458 meters). The GPS L1 pseudorange measurement is reconstructed by the user receiver from the L1 pseudorange field by: ((\text{GPS L1 pseudorange measurement}) = (\text{GPS L1 pseudorange field}) \mod (299,792.458 \text{ m}) + \text{integer as determined from the user receiver's estimate of the reference station range, or as provided by the extended data set. If DF012 is set to 80000h, this field does not represent a valid L1 pseudorange, and is used only in the calculation of L2 measurements.} )</td>
</tr>
</tbody>
</table>

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### Table 3.5-3: Contents of the Satellite-Specific Portion of a Type 1002 Message, Each Satellite – GPS Extended RTK, L1 Only

<table>
<thead>
<tr>
<th>DATA FIELD</th>
<th>DF #</th>
<th>DATA TYPE</th>
<th>NO. OF BITS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite ID</td>
<td>DF007</td>
<td>uint6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>P(Y)/CA Code Indicator</td>
<td>DF008</td>
<td>bit(1)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Reserved</td>
<td>DF001</td>
<td>bit(1)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>L1 Pseudorange</td>
<td>DF009</td>
<td>uint24</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>L1 PhaseRange – L1 Pseudorange</td>
<td>DF010</td>
<td>int20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>L1 Lock time Indicator</td>
<td>DF011</td>
<td>bit(3)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Reserved</td>
<td>DF001</td>
<td>bit(1)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Integer L1 Pseudorange Modulus Ambiguity (8 MSB’s of Pseudorange)</td>
<td>DF012</td>
<td>uint8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>L1 CNR</td>
<td>DF013</td>
<td>uint8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>72</strong></td>
<td></td>
</tr>
</tbody>
</table>
## RTCM 3.0 Message Groups, Message Types (MT)

- **Observations**
  - GPS L1  
    MT: 1001, 1002
  - GPS L1/L2  
    MT: 1003, 1004
  - GLONASS L1  
    MT: 1009, 1010
  - GLONASS L1/L2  
    MT: 1011, 1012
- **Station Coordinates**  
  MT: 1005, 1006
- **Antenna Description**  
  MT: 1007, 1008
- **Auxiliary Operation Information**  
  MT: 1013
- **Supplement # 1: (to be decided in May 2006)**
  - GPS Ephemeris  
    MT: 1019
  - GLONASS Ephemeris  
    MT: 1020
  - Network RTK (MAC)  
    MT: 1014-1017
  - Proprietary Messages  
    MT: 4088-4095
RTCM 3.0 Raw Data Messages

- **Observables (GPS, SBAS and GLONASS):**
  - Pseudorange (C/A,P1(Y),P2(Y),P2(Y) cross correlated,Correlated P/Y)
  - PhaseRange (L1,L2)
  - Carrier to Noise Ratio (L1,L2) [dB-Hz]

- **Observable Related Parameters**
  - Pseudorange Smoothing Parameters (Smoothing Interval 0…unlimited)
  - Loss of Lock: Lock Time Indicator
  - GLONASS Frequency Number

- **Compression Method**
  - L1 Pseudorange Modulo 1ms (2ms GLONASS) or Full L1 Pseudorange
  - L2 Pseudorange – L1 Pseudorange (+/- 163.82 m)
  - L1 PhaseRange – L1 Pseudorange (+/- 262.143 m + Overflow)
  - L2 PhaseRange – L2 Pseudorange (+/- 262.143 m + Overflow)
RTCM 3.0 Raw Data Messages

- **Observables**
  - MT 1001,1002,1009,1010  L1 Only
  - MT 1003,1004,1011,1012  L1+L2
  - MT 1001,1003,1009,1011 – PR Modulo 1ms, no CNO
    - Requires Receiver (or Software) **Clock Steering** (+/- 100 ns)
  - MT 1002,1004,1010,1012 – Full PR,2 Codes, 2 Carriers, 2CNO
    - **Clock Steering** required, although not necessary (atomic clocks?)
  - Transmission of **3 or more signals** (Code,Carrier,CNO) possible through **combination of messages** (1004,1002), but currently not allowed
  - Pseudoranges may be smoothed or unsmoothed
    - No simultaneous transmission of both

- **Bandwidth Requirement** (10 SVs, MT 1004)
  - 1368 Bits (171 Bytes) per Epoch

- **Maximum Data Rate:** 1000 Hz
RTCM 3.0: Antenna Description Message

- Reference Station ID (DF003)
- Antenna Descriptor (DF030)
  - IGS Naming Convention for Antenna Type
- Antenna Setup ID (DF031)
  - To be changed every time a change occurs at the station that could affect the antenna phase center variations (PCV)
- Antenna Serial Number (DF033)
  - Alphanumeric Characters, allows unique identification of individual antennas in conjunction with „Antenna Descriptor“
RTCM 3.0: Reference Station Coordinates

- Reference Station ID (DF003)
- Antenna Reference Point (ARP) Coordinates
  - ECEF-X (DF025)
  - ECEF-Y (DF026)
  - ECEF-Z (DF027)
- Antenna Height (ARP) above Marker (DF028)
RTCM 3.0 Transport Layer

- 8 Bits Preamble
- 6 Bits reserved
- 10 Bits Message Length
- 0-1023 Bytes of Data
  - (the Messages Defined in Presentation Layer)
- 24 Bits CRC
  - QualComm CRC-24Q
  - Probability of undetected errors < $2^{-24}$ for channel bit error probabilities < 0.5
### Real Time Format Features/Requirements

<table>
<thead>
<tr>
<th>Real Time Format Features/Requirements</th>
<th>RTCM</th>
<th>IGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observables for all Signals</td>
<td>Yes/No</td>
<td>x</td>
</tr>
<tr>
<td>Observables</td>
<td>Resolution</td>
<td></td>
</tr>
<tr>
<td>- Code (Pseudorange)</td>
<td>2 cm</td>
<td>?</td>
</tr>
<tr>
<td>- Phase (Phaserange)</td>
<td>0.5 mm</td>
<td>?</td>
</tr>
<tr>
<td>- Doppler</td>
<td>-</td>
<td>?</td>
</tr>
<tr>
<td>- Loss Of Lock Indicator (Lock Time)</td>
<td>LockTime</td>
<td>?</td>
</tr>
<tr>
<td>- Carrier to Noise Ratio (Standardized ?)</td>
<td>0.25 dBHz</td>
<td>?</td>
</tr>
<tr>
<td>- Channel Number</td>
<td>-</td>
<td>?</td>
</tr>
<tr>
<td>- Wavelength Factor</td>
<td>-</td>
<td>?</td>
</tr>
<tr>
<td>Time Tag Resolution</td>
<td>1 ms</td>
<td>?</td>
</tr>
<tr>
<td>Data Rate</td>
<td>&lt;1000 Hz</td>
<td>1Hz min.</td>
</tr>
<tr>
<td>Compression</td>
<td>Yes</td>
<td>?</td>
</tr>
</tbody>
</table>
## Format Comparison

<table>
<thead>
<tr>
<th></th>
<th>RTCM 3.0</th>
<th>SOC</th>
<th>BINEX 0x7f-00</th>
<th>RINEX 2.2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pseudorange</strong></td>
<td>C/A + P2(Y) or P1(Y) + P2(Y)</td>
<td>C/A + P1 + P2</td>
<td>C/A + P1 + P2</td>
<td>C/A + P1 + P2</td>
</tr>
<tr>
<td><strong>PR Resolution</strong></td>
<td>0.02 m</td>
<td>0.001 m</td>
<td>0.001 m</td>
<td>0.001 m</td>
</tr>
<tr>
<td><strong>Carrier Phase</strong></td>
<td>LA + L2 or L1 + L2</td>
<td>L1 + L2</td>
<td>L1 + L2 + LA</td>
<td>L1 + L2 + LA</td>
</tr>
<tr>
<td><strong>Carrier Phase Resolution</strong></td>
<td>0.5 mm</td>
<td>0.02 mm</td>
<td>0.0001 Cycles = 0.02 mm</td>
<td>0.001 cycles = 0.2 mm</td>
</tr>
<tr>
<td><strong>Wavelength Factor</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td><strong>Doppler</strong></td>
<td>-</td>
<td>-</td>
<td>0x7f-02</td>
<td>+</td>
</tr>
<tr>
<td><strong>CNO</strong></td>
<td>L1+L2</td>
<td>C/A + L1 + L2</td>
<td>+</td>
<td>S1,S2,SA</td>
</tr>
<tr>
<td><strong>CNO Resolution</strong></td>
<td>0.25 db-Hz</td>
<td>1</td>
<td>1.0.25 Rx Dep.</td>
<td>0.001 Rx Dep.</td>
</tr>
<tr>
<td><strong>Loss of Lock</strong></td>
<td>Lock Time</td>
<td>-</td>
<td></td>
<td>Slip Flag</td>
</tr>
<tr>
<td><strong>Time Tag Resolution</strong></td>
<td>1 ms</td>
<td>1 ms</td>
<td>100 ns</td>
<td></td>
</tr>
<tr>
<td><strong>NavTime</strong></td>
<td>Clock Steering (100 ns)</td>
<td>10 m</td>
<td>1 ns</td>
<td></td>
</tr>
</tbody>
</table>
Other Issues – Currently not Supported by RTCM3

- Is there need for a **Standardized Receiver Control Protocol**?
  - Rx Setup: (Elevation, Data Rate, …)
  - Reset
  - Data Retrieval, …
- Is there need for **Data Encryption**?
- **Kinematic and Stop and Go Support**
- **More Meta-Data**
  - Receiver Type / Serial Number / FW Versions, …
- **Support for Standardized Meteorological Data/Sensors**
- **Support for Products**
  - **State Space Parameters** (Orbits, Clocks, Biases, Iono, Tropo…)}
Summary

- RTCM3.0 provides **GNSS Raw Data in a Compressed Format**
- RTCM is the **major GNSS Standard** for Real Time Data exchange
  - Directly supported by **most Geodetic Receivers**
  - Supported by **Service Providers**
- Flexible Structure, easily extendable
- RTCM3.0 is a good choice for a Standardized Raw Data Format
  - IGS requirements not fulfilled yet, may be considered by SC104
  - **IGS** should become a **member of RTCM**
- Next RTCM SC104 Meeting: May 11-12, 2006
  - 3 Meetings per Year
Thank you for your attention