Septentrio Welcome!
Topics

Background
Over View of Core Modules
Overview of Survey and Machine Control Products
Reference Station Products
Polarx5
Polarx5S
Nice to meet you
So what is our company name?

SEP-10-TRIO

| sep'tentriːəʊ | with stress on the 2nd syllable
Why Septentrio?

Navigation ....

Polaris \(\rightarrow\) PolaRx

\(\alpha\sigma\tau\eta\rho\) (Aster) \(\rightarrow\) AsteRx
Mijn thuis is waar mijn Stella staat
Company history

2000  Septentrio is founded as a spin-off from IMEC, world’s premier semiconductor research center and still a strong partner & shareholder.

2002  ESA selects Septentrio as development partner for Galileo programs. Many firsts on Septentrio receivers, both IOV and FOC, including PRS.

2006  Altus is founded in Torrance, CA focusing on high end survey applications

2008  Veripos selects Septentrio receivers for its worldwide augmentation services.

2014  Antoon De Proft hired as new CEO, full acquisition of Altus.

2015  Selected by Unavco for its reference stations and scientific applications.
Altus Merges into Septentrio – Jan 2015

Altus Positioning Systems was formed in 2007
  Survey receivers based on Septentrio RTK Boards
  Manufactured in Torrance, previous location
Sold around 5000 receivers
  largest destination → China
Second Largest Customer Base is Western Canada
Altus brand name remains for Survey / GIS products
Septentrio leadership

**Septentrio NV**  
**Leuven, Belgium**  
- Corporate HQ  
- R&D, Operations, Sales, Support

**Antoon De Proft - President & CEO**  
Dr. Bruno Bougard – R&D Director  
Jan Van Hees - Business Development  
Jan Leyssens – Product Manager, Commercial Products  
Ingrid Velghe – Operations Manager  
Dirk Werquin – Manager, Avionics & Defense

**Septentrio Americas**  
**Torrance, California**  
- Americas Sales  
- Applications Engineering  
- Technical Support

**Neil Vancans – Vice President, Americas**  
Mo Kapila – Director of OEM Sales  
Dr. Francesca Clemente – Manager, Technical Support  
Eric Albrecht – Sales Manager  
David Feng – Applications Engineer  
Satish Mittal – Support Engineer

**Global Resources**  
- 60+ Engineers  
- ~100 Direct Staff  
- Europe, NA, Asia

**Antoon De Proft – Septentrio NV**  
**President & CEO**  
- IMEC Chairman, 2005 –  
- ADP Vision Managing Dir., 2000 –  
- ICOS Vison Systems CEO, 2002-09

**Neil Vancans – Septentrio Inc., Vice President**  
- Leica GPS President, 1996-2002  
- Thales Navigation GM, 2002-04  
- University College London, Masters Land Surveying

Septentrio in Confidence
Our Products

**PolaRx**
Reference receivers for science and networks

**Altus**
Smart antennas for GIS and survey

**AsteRx**
Rover Receivers and OEM boards for automation and machine control
Septentrio Technology Leadership

**Lowest Power Consumption** in its class:
- Single Frequency GNSS - 300 mW
- Dual Frequency GNSS - 600 mW
- Shutdown - 10 µW

**AIM+ Advanced Interference Monitoring**
- Built-in spectrum analyzer identifies interference
- Adaptive notch-filter suppresses CW interferers
- Pulse-blanking suppresses pulsed interferers
- GLO L2 remapping prevents loss of GPS L2 in cases with severe GLO L2 interference

**APME+ A Posteriori Multipath Estimation / Mitigation**
- Mitigates both code and carrier short-delay multipath
  - Short-delay is most prevalent and damaging form of multipath
- Identifies amount of multipath present and can simultaneously provide unaltered data as well as with multipath eliminated

Septentrio in Confidence
Septentrio Technology Leadership (cont.)

**Best-in-class** Measurement Quality

- High signal-to-noise ratio (SNR), Low Cycle Slips, High Availability

  See UNAVCO GNSS Receiver Evaluations 2012
  (http://facility.unavco.org/kb/questions/742/GNSS+Receiver+Evaluations+2012)

- Provides L1P and “real” raw data (no MP/ smoothing)

**Lock+**: Superior Tracking Robustness

- Strong vibrations can severely impact tracking continuity, which is lethal for precision RTK (ex: grade control)

- Special algorithms implemented to maintain lock even during heavy vibrations
Unique Value: Robust for Iridium Interference

Satellite based correction delivery sensitive to Iridium interference

(independent report from Chevron)

No interference problems with Septentrio receivers due to special RF design of both GNSS and L-band receiver

Septentrio in Confidence
Septentrio markets: Machine control

Marine  Construction  Mining

Logistics  Agriculture  Autonomous driving
Septentrio Markets: Survey/Mapping/GIS

Survey

GIS

Mobile Mapping

Unmanned Systems
Septentrio markets: Aerospace and Defense

Aerospace

Defense
Septentrio Markets: Reference Stations and Scientific Applications

Reference Receivers

Space Weather

Timing Receivers
Septentrio is the World Leader in Galileo Receivers

- Prime Contractor to ESA since 2004
  ➢ Most important Belgian company on Galileo
- World’s first Galileo receivers Septentrio-made
- Septentrio leadership recognized worldwide
- Two critical milestones for Galileo realized with Septentrio receivers
Core Modules
AsteRx4 OEM Board

- All frequencies/signals as in 2020
  - GPS/GLO/GAL/BDS/QZSS

- Built-in
  - Dual channel L-band receiver
  - Ready for GALILEO E6 CS

- Unique interference robustness
  - Incl resilience to chirp jammers.

- 1.4W in GPS/GLO L1/L2 mode,
- Most advanced multi-constellation RTK, PPP and Heading
  - GPS+GLO+BDS+GAL RTK

- Ready for triple carrier RTK
  - GAL E1/E2/E6
  - BDS B1/B2/B3
  - GPS L1/L2/L5

- 50Hz RTK + Heading
AsteRx-m: Ultra-low Power

- Ultra-compact OEM board for battery-operated applications, such as buoys and AUV

- Ultra-low power consumption
  - GPS/GLONASS L1: 300 mW
  - GPS L1/L2: 450 mW
  - GPS/GLONASS L1/L2: 600 mW
  - Shutdown: 10 µW
Integrate Simplicity AsteRx-m UAS

- 6-30V Power input
- Onboard data logging
- 3 serial ports of which one is compatible with pixhawk & Ardupilot
- Event marker for camerashutter synchronisation
What do customers need to order?

For Accurate Navigation applications that require CM in realtime (for inspections, automated landing...):

- AsteRx-m UAS C
- Altus-NR2 BASE UAS (corrections to be forwarded by customer application via telemetry upload)
- AA_ANT_NM_DF_L

Alternative:
Maxtena M1227HCT-A2-SMA Helical L1/L2 GPS/GLO antenna (can be bought online via Farnell for €200-300 Euro – Farnell partnumber: 2281614)
AsterRx 4 Tracks and Uses All Signals in the Sky as in 2020

GPS L1CA, L1C, L2P, L2C, L5
Survey/GIS Product Overview

APS-3
Dual-Frequency RTK/Terrastar Receiver

APS-NR2
Multi-Frequency Network Rover with 3.5G, WiFi, BT and Web Server

APS-GeoPod
Adds RTK to Mobile Computing Platforms

Septentrio in Confidence
Lock+ : Superior Tracking Robustness

- Strong vibrations can severely impact tracking continuity, which is lethal for precision RTK, PPP and heading
  - eg: grade control
- Special algorithms implemented to maintain lock even during heavy vibrations
PolaRx5

Tracks all visible GNSS signals, incl. E6
Best-in-class Measurement Quality
AIM+ Interference Monitoring
APME+ Multipath estimation & mitigation
Provides unaltered data
Low and scalable power consumption
Septentrio Ref Sta Rx’s

feature in
## IGS Network

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Coordinates</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTP</td>
<td>Concepcion</td>
<td>-36.84, -72.03</td>
<td>SEPT POLARX2</td>
</tr>
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<td>MIZU</td>
<td>Mizusawa</td>
<td>38.13, 141.13</td>
<td>SEPT POLARX2</td>
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<td>UNSA</td>
<td>Salta</td>
<td>-24.73, -66.41</td>
<td>SEPT POLARX2</td>
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<td>WTZS</td>
<td>Bad Kleinkirch</td>
<td>48.14, 12.88</td>
<td>SEPT POLARX2</td>
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<td>ZWE2</td>
<td>Zweibrücken</td>
<td>55.70, 6.76</td>
<td>SEPT POLARX2</td>
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<tr>
<td>BJNM</td>
<td>Beijing</td>
<td>40.25, 116.22</td>
<td>SEPT POLARX2</td>
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<td>NAVS</td>
<td>Hailsham</td>
<td>50.87, 0.34</td>
<td>SEPT POLARX2</td>
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<td>EPRT</td>
<td>Eastport</td>
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<td>SEPT POLARX2</td>
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<td>FAA1</td>
<td>Fa, Tahiti,</td>
<td>-17.56, -145.61</td>
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<td>Kiuru</td>
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<td>SEPT POLARX2</td>
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<td>KOPE</td>
<td>Kourou</td>
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<td>SEPT POLARX2</td>
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<td>MAL2</td>
<td>Malindi</td>
<td>-3.00, 40.19</td>
<td>SEPT POLARX2</td>
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<tr>
<td>MAS1</td>
<td>Maspalomas</td>
<td>27.78, -15.63</td>
<td>SEPT POLARX2</td>
</tr>
<tr>
<td>MGUE</td>
<td>Malargüe</td>
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<td>SEPT POLARX2</td>
</tr>
<tr>
<td>NNOR</td>
<td>New Norcia</td>
<td>-31.05, 116.19</td>
<td>SEPT POLARX2</td>
</tr>
<tr>
<td>VILL</td>
<td>Villarancha</td>
<td>40.44, -3.95</td>
<td>SEPT POLARX2</td>
</tr>
<tr>
<td>BRUX</td>
<td>Brussels</td>
<td>50.80, 4.36</td>
<td>SEPT POLARX2</td>
</tr>
<tr>
<td>RCAP</td>
<td>San Fernando</td>
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<td>SEPT POLARX2</td>
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<tr>
<td>WES2</td>
<td>Westford</td>
<td>42.01, -71.45</td>
<td>SEPT POLARX2</td>
</tr>
</tbody>
</table>

*IGS Network Map as of 2014-Jul-14 18:46:04.*
EUREF Network

 Receivers in the EUREF network

<table>
<thead>
<tr>
<th>Code</th>
<th>Receiver</th>
<th>Country</th>
<th>X-Coord</th>
<th>Y-Coord</th>
<th>SEPT POLARX</th>
<th>SEPT POLARX</th>
</tr>
</thead>
<tbody>
<tr>
<td>KUNZ</td>
<td>Kunzak</td>
<td>Czech Republic</td>
<td>49.11</td>
<td>15.20</td>
<td>703.1</td>
<td>POLARX2</td>
</tr>
<tr>
<td>DENT</td>
<td>Dentergem</td>
<td>Belgium</td>
<td>50.93</td>
<td>3.40</td>
<td>63.9</td>
<td>POLARX2E</td>
</tr>
<tr>
<td>WARE</td>
<td>Waremme</td>
<td>Belgium</td>
<td>50.69</td>
<td>5.25</td>
<td>188.0</td>
<td>POLARX2E</td>
</tr>
<tr>
<td>HERS</td>
<td>Hailsham</td>
<td>United Kingdom</td>
<td>50.87</td>
<td>0.34</td>
<td>76.5</td>
<td>POLARX3ETR</td>
</tr>
<tr>
<td>CEBR</td>
<td>Cebreros</td>
<td>Spain</td>
<td>40.45</td>
<td>-4.37</td>
<td>775.8</td>
<td>POLARX4</td>
</tr>
<tr>
<td>REDU</td>
<td>Redu</td>
<td>Belgium</td>
<td>50.00</td>
<td>5.14</td>
<td>369.9</td>
<td>POLARX4</td>
</tr>
<tr>
<td>VILL</td>
<td>Villafranca</td>
<td>Spain</td>
<td>40.44</td>
<td>-3.95</td>
<td>647.5</td>
<td>POLARX4</td>
</tr>
<tr>
<td>TERS</td>
<td>West-Terschelling</td>
<td>Netherlands</td>
<td>53.36</td>
<td>5.22</td>
<td>56.1</td>
<td>POLARX4</td>
</tr>
<tr>
<td>EIJS</td>
<td>Eijsden</td>
<td>Netherlands</td>
<td>50.76</td>
<td>5.68</td>
<td>103.8</td>
<td>POLARX4</td>
</tr>
<tr>
<td>MAS1</td>
<td>Maspalomas</td>
<td>Spain</td>
<td>27.76</td>
<td>-15.63</td>
<td>197.3</td>
<td>POLARX4</td>
</tr>
<tr>
<td>KIRU</td>
<td>Kiruna</td>
<td>Sweden</td>
<td>67.86</td>
<td>20.97</td>
<td>391.1</td>
<td>POLARX4</td>
</tr>
<tr>
<td>BRUX</td>
<td>Brussels</td>
<td>Belgium</td>
<td>50.80</td>
<td>4.36</td>
<td>158.3</td>
<td>POLARX4TR</td>
</tr>
</tbody>
</table>
Volcano monitoring

Iceland – NICE (Part of CGPS network)

The Icelandic continuous GPS network monitors Seismic activity and crustal deformation.

More info:
PolaRx5

Started supplying in January
Chosen by UNAVCO as their preferred reference Station receiver
Also chosen recently by USGS – Earthquake Early warning System in CA
Numerous Overseas
We exploit all frequencies and all constellations to maximize accuracy and dependability

- **GPS** L1CA, L1P, L2P, L2C, L5
- **GLONASS** L1CA, L2CA, L3
- **BEIDOU** B1, B2, B3
- **GALILEO** E1, E5ab, E5 Altboc, E6
- **QZSS** L1, L2, L3
- **IRNSS** L5
Best in class measurements

- High SNR, lowest amount cycle slips, highest availability
  - UNAVCO Evaluation Report:
    - X = Topcon, Y = Trimble

- Provides GPS L1P and “real” raw data (no MP/smoothing)
AIM+ Interference Mitigation

Interferences

Out-of-band

Separated filtering for all bands

In-band

Dedicated digital interference mitigation
(3 automatic notch filters, chirp jammer cancellation)
APME+: Superior Short Delay and Phase Multipath Mitigation

Multipath is caused by reflection of satellite signals on nearby Surfaces
Short delay multipath is most frequent and most damaging component
APME+

• Better against short delay multipath
• **Estimates multipath without changing tracking loops**
• Estimates multipath per satellite
• Indicates amount of multipath error
• Can be completely disabled!

---

septentrion
## Scalable Power Consumption (1.7W – 4W typ.)

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standby mode</td>
<td>250 mW</td>
</tr>
<tr>
<td>GPS + GLONASS L1</td>
<td>1.70W</td>
</tr>
<tr>
<td>GPS + GLONASS L1/L2</td>
<td>1.80W</td>
</tr>
<tr>
<td>GPS L1/L2/L5, GLO L1/L2, GAL E1/E5ab, SBAS L1/L5, BDS B1/B2</td>
<td>1.95W</td>
</tr>
<tr>
<td>All constellations and all signals</td>
<td>2.65W</td>
</tr>
<tr>
<td>Enabling ethernet</td>
<td>+650mW</td>
</tr>
<tr>
<td>Enabling WiFi</td>
<td>+450mW</td>
</tr>
<tr>
<td>Enabling REFOUT</td>
<td>+30mW</td>
</tr>
<tr>
<td>Enabling internal logging</td>
<td>+50mW (1Hz) + 150mW (10Hz)</td>
</tr>
</tbody>
</table>
PolaRx5 Interfaces

- 4x Serial RS232
- Ethernet, 10/100 Mbps
- Power-over-ethernet
- USB client and host for external disk
- Integrated Wifi

- xPPS-output (Max 100Hz)
- 10MHz reference input
- Event marker (2)

- 16 GB Internal logging
PolaRx5 – Intuitive Webinterface

Accessible via USB, Ethernet & WIFI!

http://192.168.20.1

http://192.168.3.1

http://polarx5-300123
PolaRx5 – Easily Transfer configurations from one receiver to another

Human readable (and editable) text file
PolaRx5 – A lot of debug information!

Visualise before and after interference mitigation
GNSS technology designed for easy integration

- Open architecture
- Well defined documented user interface
- Extensive and well documented command interface designed for M2M communication
- Extensive and open data structure
  - Standard open interfaces (RTCM, NMEA)
  - Septentrio Binary Format (Septentrio designed for completeness and compactness, fully documented and open)
- Common and stable hardware and software interface between different receiver models
- Multiple modes of single hardware, SW configurable
PolaRx Tracks and Uses All Signals in the Sky as in 2020

GLONASS L1CA, L2CA, L3 ready
PolaRx Tracks and Uses All Signals in the Sky as in 2020

GALILEO E1, E5a/b/AltBOC, E6

Septentrio in Confidence
PolaRx Tracks and Uses All Signals in the Sky as in 2020
The Next-Generation PolaRx

Built around AsteRx4 OEM GNSS receiver board

Key Features

- Available interfaces
  - 4 serial ports
  - USB
  - Ethernet
  - Internal memory
- USB host
- Power over ethernet
- Power monitor (voltage monitor)

Form factor same as current PolaRx4 PRO:
234 x 140 x 37 mm
(length includes connectors)

Septentrio in Confidence
The Next Generation PolaRx - Scalable Power Consumption

<table>
<thead>
<tr>
<th>Condition</th>
<th>Power *</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS/GLO L1/L2, no Ethernet, no WiFi</td>
<td>2.0W</td>
</tr>
<tr>
<td>All GNSS bands, no ethernet, no WiFi</td>
<td>2.8W</td>
</tr>
<tr>
<td>Enabling Ethernet (optional)</td>
<td>+0.6W</td>
</tr>
</tbody>
</table>

* Preliminary results – ongoing testing
Industry Leading Interference Mitigation Capability
- 3 Adaptive Notch Filters *(We learn from the field)*

Tuymen, Russia
- Unknown source

Hilversum, Netherlands
- Amateur Digital packet radio

Ostend, Belgium
- Amateur TV

Septentrio in Confidence
Septentrio Open / Transparent Interface

- Well defined documented user interface
- Extensive and well documented command interface
- Extensive and open data structure
  - Standard open interfaces (RTCM – including full MSM support, NMEA)
  - RINEX 2.x/3.x support
  - Septentrio Binary Format (fully documented and open)

<table>
<thead>
<tr>
<th>SB2Length</th>
<th>u1</th>
<th>1 byte</th>
<th>Length of a MeasEpochChannelType2 sub-block</th>
</tr>
</thead>
<tbody>
<tr>
<td>CommonFlags</td>
<td>u1</td>
<td></td>
<td>Bit field containing flags common to all measurements.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bit 0: Multipath mitigation: if this bit is set, multipath mitigation is enabled. (see the setMultipathMitigation command).</td>
</tr>
</tbody>
</table>

- Common and stable hardware and software interface between different receiver models
- Software tool suite RxTools (Linux and Windows)
- Fully configurable

**Free firmware upgrades for life**

Septentrio in Confidence
Web Interface, RxControl or Command Line
Web Interface, RxControl or Command Line
PolaRx5S

All-in-view ionosphere monitoring, incl. E6 & B3
Best-in-class Measurement Quality
AIM+ Interference Monitoring
APME+ Multipath estimation & mitigation
Provides unaltered data
Real-time TEC & Scintillation Indices output
Low and scalable power consumption
What is scintillation?

• Short-term variations of the GNSS signal amplitude and phase

• Caused by scattering and diffraction in small-scale irregular structures ("bubbles") in the ionosphere
PolaRx5S: Multi-Constellation for Maximum Observability of the Ionosphere

All GPS, GLONASS, GALILEO, BEIDOU, IRNSS, QZSS and SBAS satellites used to maximize the number of piercing points

septentrío
May 2, 2016
We exploit all frequencies and all constellations to maximize accuracy and dependability.
Scintillation Parameters

**S4** -> Amplitude variation
(Standard deviation of the raw signal power normalized to the average signal power)

**Phi60** -> Phase variation
(Standard deviation of (detrended) carrier phase)

**Available for these signals:**
- GPS: L1CA, L2C, L5
- GLO: L1CA, L2CA
- GAL: E1, E5a, E5b
- BDS: B1, B2, **B3 (new on PolaRx5S)**
- QZSS: L1CA, L2C, L5
- SBAS: L1CA, L5

**Have a look at our Insight about scintillation:**
Support of ISMR output files

- **ISMР** = Ionospheric Scintillation Monitoring Records
- Format used by old Novatel GSV400B Scintillation receiver which became the standard file format used for scintillation monitoring
- Generated by RxTools (sbf2ismr.exe):

![Image of ISMR output files]

```
<table>
<thead>
<tr>
<th>Time</th>
<th>Frequency</th>
<th>Power</th>
<th>Phase</th>
<th>Velocity</th>
<th>Ionosphere</th>
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<tr>
<td>1658.18060</td>
<td>8</td>
<td>628, 59, 46.50, 5</td>
<td>0.044, 0.030, 0.012, 0.013, 0.017, 0.018, 0.018, 0.16, 0.072, 0.079, 8.823, 0.015, 9.147, -0.011, 9.385, 0.007, 10.48C</td>
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<td></td>
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<td>9</td>
<td>628, 244, 1.38, 4</td>
<td>0.459, 0.120, nan, nan, nan, nan, nan, nan, 0.576, 0.295, 4.115, 0.252, 4.115, 0.259, 9.352, -0.153, 4.108</td>
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<td></td>
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<tr>
<td>1658.18060</td>
<td>18</td>
<td>628, 32, 7.42, 6</td>
<td>0.097, 0.074, 0.025, 0.029, 0.034, 0.035, 0.035, -1.304, 0.195, 0.340, 0.022, 2.311, 0.024, 4.396, 0.004, 3.387</td>
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<td>21</td>
<td>628, 211, 12.04, 1</td>
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<td></td>
</tr>
<tr>
<td>1658.18060</td>
<td>19</td>
<td>628, 523, 2.98, 0</td>
<td>0.800, 0.68, 0.676, 0.66, 0.68, 0.68, -9.226, 2.114, 21.582, 0.084, 30.002, 0.074, 28.650, 0.015, 10.164</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```
TEC – Total Electron Content

Output in Real-time (SBF), plot available in RxControl.

“TEC is the total number of electrons integrated between two points, along a tube of one meter squared cross section” (https://en.wikipedia.org/wiki/Total_electron_content)

(STEC = Slanted TEC)

TEC – Total Electron Content

[Graph showing Total Electron Content (TEC) over time with markers for 2pm, 10pm, and 6pm.]
Questions?
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Backup Slides
Next-Generation PolaRx with 3 Self-adaptive Notch Filters
Best in High Quality Measurements

- Consistently lowest phase noise (red = SSN)
- Consistently lowest multipath
  - Even with APME disabled
- Consistently lowest cycle slips
  - Crucial for phase processing (PPP and RTK)
IONO+ against ionospheric disturbances

Ionospheric disturbances impact both tracking (signal measurement availability) and positioning accuracy

- Scintillation: quick variation of signal amplitude and phase
- Causes loss of lock and cycle slips
- Can last for minutes or hours
- Affects all signals from (subset of) satellites

Special tracking algorithms provide tracking under difficult environments

- Result from and proven in ionosphere monitors in Brazil
IONO+
Effectiveness proven in the field

Receivers co-located at Presidente Prudente, SP, Brazil
PRU1 : State-of-the-art
PRU2 : Septentrio

Even during the post-sunset period

Septentrio in Confidence
Quality Indicators

Graphic indicators and special messages for

• Problem detection by operator
• First line trouble shooting