A High Performance GPS Radio Occultation Instrument

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Radio Occultation

- Probing the atmosphere and ionosphere by measuring the L1 and L2 signals from raising and setting GPS S/C
- Determining the S/C position with high accuracy to extract the atmosphere/ionosphere impact
- Method developed by JPL and Stanford, for sounding of planetary atmospheres (Mariner, Pioneer and Voyager)

Overhead Measurements
- POD
- Navigation
- Double Differencing

NPOESS Orbit
Rm=7198 km

Local Horizontal Plane

Ionospheric Occultations

Tropospheric/Stratospheric Occultations

Ionosphere

Troposphere/stratosphere

GNSS Orbit
Rg=25520 km, 26560 km
Occultation Geometry

- Carrier phase (Doppler) measurement
- Atmosphere delay
- Bending angle
- Refractivity profile
- Temperature profile
# PROGRAMMES

<table>
<thead>
<tr>
<th></th>
<th>EUROPE</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer</td>
<td>EUMETSAT</td>
<td>IPO (NOAA, NASA, DOD)</td>
</tr>
<tr>
<td>Platform</td>
<td>METOP</td>
<td>NPOESS</td>
</tr>
<tr>
<td>1:st Launch</td>
<td>2003</td>
<td>2008</td>
</tr>
<tr>
<td>No of sat</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Instrument</td>
<td>GRAS</td>
<td>GPSOS</td>
</tr>
<tr>
<td>Status</td>
<td>BB-Phase - 98</td>
<td>Risk Reduction Phase - 98</td>
</tr>
<tr>
<td></td>
<td>C/D Phase running</td>
<td>EM Phase running</td>
</tr>
<tr>
<td>Service</td>
<td>Experiment</td>
<td>Operational</td>
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</table>
Occultation Instrument Objectives

- Deliver meteorological data to the scientific and meteorological communities
- Data: temperature, pressure and electron content vertical profiles of the atmosphere and ionosphere
- 500 - 1000 profiles per day and LEO S/C
- Measurements with very high accuracy and down to a few miles altitude
- Joint program between US and Europe
Instrument Accommodation

- Two occultation antennas
- Zenith antenna for navigation (Precise Orbit Determination)
- RF units placed close to antennas for best NF
- Can accommodate long IF cables to Electronics unit

Zenith antenna coverage
Aft looking occultation antenna coverage
Forward looking occultation antenna coverage
Flight direction
# GPS System

<table>
<thead>
<tr>
<th></th>
<th>Coarse Acquisition C/A-code</th>
<th>Precision P-code</th>
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</thead>
<tbody>
<tr>
<td><strong>CDMA pseudorandom</strong></td>
<td>1.023</td>
<td>10.23</td>
</tr>
<tr>
<td><strong>BW</strong></td>
<td>±10.23</td>
<td>±10.23</td>
</tr>
<tr>
<td><strong>Frequencies</strong></td>
<td>L1=1575.42</td>
<td>L1=1575.42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L2=1227.6</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>Public</td>
<td>Encrypted (Y-code)</td>
</tr>
<tr>
<td><strong>Measurement</strong></td>
<td>Atmosphere</td>
<td>Atmosphere Ionosphere</td>
</tr>
<tr>
<td><strong>End product</strong></td>
<td>Bending angle</td>
<td>Environmental Data Records</td>
</tr>
</tbody>
</table>

Advanced Radio Technologies, Sep 8 - 10, 1999
Generic GPS Digital Receiver

- Digital down conversion
- Correlation with Early, Punctual and Late code
- Integration (despreading)
- Locked to Numerically Controlled Oscillator
Occultation Antennas

- Dual frequency fixe beam array with resonant ring elements
- Individual feed networks in suspended QFRP microstrip
- Antenna pattern shaped to earth rim
- Coverage ±50° in azimuth (captures most of the GPS satellites)
- High antenna gain 11 dBi
- Suppressed interference and noise
- Low ohmic loss, low mass
Occultation Antenna
Radio Frequency Conditioner Unit

- Very highly selective RF and IF filters
- Single stage down conversion to IF
- Common LO frequency
- Recombination of L1/L2 at IF
RFCU Functional Block Diagram

- RF L1
- RF L2
- RF LO
- Preselection Filters
- LNA Board
- LNA Board
- Power Regulator Board
- Power Regulator
- Thermistor
- Input Power
- Output Power
- Frequency
- L1: 162.92 MHz
- L2: 184.90 MHz

Advanced Radio Technologies, Sep 8 - 10, 1999

Saab Ericsson Space
RFCU Key Features

• Overall gain >85 dB
• Accommodates both GPS and GLONASS
• S&R transmitter located 20 MHz from L1 band edge
  - suppressed >95 dB
• LNA data:
  – NF < 0.9 dB
  – RL > 20 dB
  – Gain > 38 dB
RFCU L1 Preselection Filter

8-pole coaxial cavity filter

S&R transmitter suppressed 53 dB
1 Power converter
2 S/C interface
3 IF, Sampler and channel processor
4 DSP
5 Spare
6 Frequency generator

not shown: USO (Ultra Stable Oscillator)
AGGA

- Advanced GPS GLONASS ASIC
- A custom designed ASIC for space applications developed under ESA contract
- Supports C/A, P and Y(semi) code tracking
- Twelve channels
- Application:
  - S/C control; Position, Velocity, Time and Attitude
  - Support to Precise Orbit Determination, POD
  - Atmospheric sounding
  - Reference stations
## Instrument Summary

<table>
<thead>
<tr>
<th>Feature</th>
<th>Benefit</th>
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<tbody>
<tr>
<td>High S/N, low implementation losses</td>
<td>Measurements at low altitudes</td>
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<td>Wide antenna coverage many channels</td>
<td>Covers a large no of occultation</td>
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<tr>
<td>Ultra stable oscillator</td>
<td>High measurement accuracy</td>
</tr>
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<td>RFC tolerant design Distributed front ends</td>
<td>Easy to accommodate</td>
</tr>
<tr>
<td>Modular design</td>
<td>Allows redundancy and expansion</td>
</tr>
<tr>
<td>GLONASS capability</td>
<td>Prepared for GNSS-2</td>
</tr>
</tbody>
</table>
Acknowledgements

• IPO under which the GPSOS study has been conducted
• ESA under which the GRAS study has been conducted

• Reference:
  – P Sinander, P Silvestrin, Development of an Advanced GPS GLONASS ASIC, ESTEC, ESA