Update of BeiDou System and its Applications

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Outline

• Understanding GNSS
• Update of BeiDou System
• BeiDou Applications
Understanding GNSS

_Satellite_ is an object which has been placed into orbit by human endeavor.

The first Man-Made Satellite was launched by Russia in 1958.
Understanding GNSS

• Navigation Satellite
• Remote Sensing Satellite
• Earth Observation Satellite
• Meteorological Satellite
• Communication Satellite
• Direct-broadcast Satellite
• …
Understanding Beidou
Understanding GNSS

Providers

- GPS
- GLONASS
- Galileo
- BeiDou
- QZSS
- IRNSS
Update of Beidou System
1. Development Objective

- Stable, reliable and high quality service
- Serve the world, benefit the mankind

Objective:

- Meet the requirements of national security and social economic development.
- Accelerate informationization drive as well as economy development mode transformation.
- Realize social and economic benefits.
- Make contribution to international GNSS community.
2. Development Plan

1st Step

BeiDou Demonstration System

2nd Step

BeiDou Navigation Satellite System

3rd Step

BeiDou Navigation Satellite System

First initiated in 1994, BeiDou demonstration system was able to provide regional active services in 2000.
BeiDou system construction was initiated in 2004 and will provide regional passive services by 2013.
2. Development Plan

BeiDou system will be developed continuously to provide global passive services by 2020.
3. Basic Policy

- Provide continuous space-based PVT services for global users free of charge, continue maintenance and complement in order to enhance service performance.

- Formulate application industry plan and standard to push forward development of GNSS industry and promote BeiDou worldwide use.

- Strengthen international cooperation, including advocating for international GNSS Monitoring and Assessment, achieving compatibility and interoperability between BeiDou and other GNSS, ensuring BeiDou diversified applications.
4. System Description

**System Structure**

**Space segment**
- 5 GEO Satellites
- 30 Non-GEO Satellites

**Ground Control Segment**
- Master Control Station (MCS)
- Uplink Stations (US)
- Monitoring Stations (MS)

**User Segment**
- BeiDou user terminals
- Terminals compatible with other GNSS
4. System Description

Service and Performance

- Authorized service
- Wide area differential service
- Open service
- Position report service

Positioning accuracy: \( \leq 10 \) meters
Timing accuracy: \( \leq 20 \) ns
Velocity accuracy: \( \leq 0.2 \) m/s
1. System Construction

1) Satellite launch record

<table>
<thead>
<tr>
<th>Launch Time</th>
<th>Satellite Number</th>
<th>2012.2.25</th>
<th>2012.4.10</th>
<th>2012.9.19</th>
<th>2012.10.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>1</td>
<td>GEO</td>
<td>2</td>
<td>2</td>
<td>GEO</td>
</tr>
<tr>
<td>2009</td>
<td>1</td>
<td>2 MEO</td>
<td>2 MEO</td>
<td>2 MEO</td>
<td>GEO</td>
</tr>
<tr>
<td>2010</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2) Constellation status

- 14 BeiDou operational satellites in orbit.
- Constellation of 5GEOs, 5IGSOs and 4MEOs.

<table>
<thead>
<tr>
<th>Stage</th>
<th>BeiDou Navigation Satellites System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Num</td>
<td>01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16</td>
</tr>
<tr>
<td>Type</td>
<td>MEO GEO GEO GEO IGSO GEO IGSO IGSO IGSO GEO MEO MEO MEO MEO GEO</td>
</tr>
<tr>
<td>Status</td>
<td>Operational Flight test In maintenance</td>
</tr>
</tbody>
</table>
3) Ground control segment

- Construction of Master Control Station, Uplink Stations and Monitoring Stations have been accomplished.

- Employ BeiDou Time (BDT) and CGCS2000 Coordinate.
1. System Construction

4) Coverage

Service area: 55°S ~ 55°N, 55°E ~ 180°E.
5) Initial Operational Capability

- Provide Full Operational Service for China and its surrounding areas since December 27, 2012
- Publish BDS Interface Control Document (ICD) for signal-in-space
Positioning and velocity accuracy

- **Horizontal** ≤ 10m (95%).
- **Vertical** ≤ 15m (95%).
- **Velocity** ≤ 0.2m/s.
1. System Construction

6) Practical Operational Capability

Broadcast ephemeris precision

- $\text{URE} \leq 1.5\text{m.}$
- $\text{Clock bias} \leq 5\text{ns.}$
6) Practical Operational Capability

Orbit determination and time synchronization

- Orbit determination < 10 m.
- Time synchronization < 2 ns.
6) Practical Operational Capability

**Ionospheric Model**

- Ionospheric correction of Klobuchar 8 model is about 80%.
6) Practical Operational Capability

Satellite clock performance

- Frequency accuracy of the master clock is $1.62 \times 10^{-12}$.
- Drift is $3.05 \times 10^{-14}$.
- Ten thousand seconds stability is $6.59 \times 10^{-14}$.
Since IOC provision, the continuous constellation deployment, gradual improvement of service performance has

- promoted R&D of BeiDou chips and terminals.
- Implemented application demonstration in various industries and regions.
- Popularized mass market.
2. System Application

1) Fundamental Products

Chips, antennas, OEM have been launched to market.
2. System Application

2) Industry Popularization

Transportation

➢ Road transportation management.

Marine Fishery

➢ Vessel position monitoring.
➢ Emergency rescue and region alarm.
➢ Port entry and depart management.
2. System Application

2) Industry Popularization

Rescue

- rescue dispatching.
- emergency communication.
- rapid report.

Meteorology

- Meteorological sounding.
- Meteorological monitoring.
- Meteorological information gathering and release.
3) Popular Application

BeiDou chips embedded mobile phones and vehicle terminals have been in practically used.
3. International Activity

- Undertake more international responsibilities through ICG related activities.
- Cooperate with major GNSS, and popularize applications with neighbor countries.
- Promote international technical exchange.
- Promote BeiDou to merge into international standards.
3. International Activity

1) International Exchange

- World-oriented CSNC
- Academic exchange activities
- Education and training

International GNSS exchange and training center

GNSS frontier technology summer school
3. International Activity

1) International Exchange
The 4th CSNC

- Will be held on May 15-17, 2013 in Wuhan, China
- An open platform for academic exchanges
- Theme: BeiDou Application---- Opportunities and Challenges
- www.beidou.org.cn
3. International Activity

1) International Exchange

Education and training on GNSS in 2013

- MASTA Program on GNSS 2013
- 2nd BeiDou/GNSS Summer school 2013
3. International Activity

2) Coordination

Multilateral

- Deeply participate in activities of ICG as one of core system providers.
- Host the 7th meeting of ICG.
- Speed up iGMAS construction, strengthen cooperation with IGS, related organizations and other GNSS.
3. International Activity

2) Coordination

Bilateral Coordination

- Comply with radio regulations of ITU.
- carry out more than 10 rounds of bilateral and multilateral coordination to jointly share frequency and orbit resources.
3. International Activity

2) Coordination

Bilateral Coordination

- Meetings between China and Russia Satellite Navigation Cooperation to promote satellite navigation monitoring, interoperability and application.
- Satellite navigation cooperation meetings between China and Pakistan to jointly promote BeiDou/GNSS international popularization.
3. International Activity

3) BADEC

(1) Overview

- BADEC is short for BeiDou\(^+\) Application Demonstration & Experience Campaign (BeiDou\(^+\) stands for multi-GNSS including BeiDou).
- To advocate international users, to learn about and apply BeiDou/GNSS, survey and collect requirements from international users, explore new applications together, so as to provide better GNSS services to the mankind and realize mutual development of all GNSS.
3. International Activity

BADEC CONTENT

Exhibition & Propagation
- Exhibition
- Products Expo
- Website
- Video

Demonstration & Experience
- Application Demo
- User experience
- Pilot Project
- Joint Research

Discussion & Exchange
- Forum
- Symposium
- Technical Seminar
- Face-to-face Exchange

Education & Training
- Degree Education
- Short-term Training
- Workshop
- Summer School

Popularize and display the development and application achievement of BeiDou/GNSS, by applying traditional and new media forms.

Focused on typical application requirement of users, jointly conduct pilot projects and encourage the development of new innovative application.

Enhance exchange and communication among system providers, products providers and users, to promote the sustainable development of GNSS.

GNSS Application Technologies Training based on ICG regional education and training centers, or relevant education resources.
3. International Activity

3) BADEC

(3) Current and follow-up activities

- BeiDou Tour: To conduct itinerant BADEC activities majorly in the Asia-Pacific region, make detailed scheme and arrangement based on specific status and requirements of different countries.

- International projects: To jointly launch application pilot project and focus on the fields with wide application requirements, such as disaster monitoring, emergency management, transportation, marine fishery, personal LBS, etc.
3. International Activity

4) iGMAS

(1) Overview
Several GNSS monitoring activities are underway. e.g.

- preliminary experience of iGMAS,
- the long-term successful operation of IGS,
- the achievements in GNSS signal monitoring made by Stanford University, DLR, Information Analysis Center of Roscosmos, MGA and others.

Objective & tasks:

- To promote the sharing of the global monitoring resource and provide better GNSS service for users.
- to support related activities and develop proposals to optimize existing and planned capabilities, and identify additional necessary activities
- To discuss the related standards, the sharing mode of resource
- To develop the monitoring and assessment products
- To provide assessment service effectively
3. International Activity

4) iGMAS

GNSS Monitoring and Assessment Item

- Constellation Status
  - Satellite Operational Status
  - Orbit Parameters
  - DOP

- Navigation signals
  - User Received Signal Level
  - Power Spectrum
  - Ranging Code Waveform in the Time Domain
  - Modulation Error
  - Correlation Characteristics

- Navigation Message
  - Signal-In-Space User Ranging Error (SISURE)
  - Signal-In-Space Continuity
  - Signal-In-Space Availability

- Service Performance
  - Position, Velocity and Timing (PVT) Accuracy
  - Service Continuity
  - Service Availability
  - Service Integrity
3. International Activity

4) iGMAS

(2) iGMAS Progress

- Signal monitoring station, ten domestic tracking stations established.
- Cooperation intentions reached for 43 stations with 37 organizations in 23 countries.
- The specific plan of establishing stations with Russia, Pakistan and other countries is consulting.
3. International Activity

4) iGMAS

(2) iGMAS Progress

Two data centers are under construction at Wuhan University and National Time Service Center.
3. International Activity

4) iGMAS

(3) Current and Follow-up activities

- ICG Subgroup activities on International GNSS Monitoring and Assessment

- Need more countries and organizations to take part in, e.g. building stations jointly, sharing data and products with each other etc. Call for Participation! www.beidou.gov.cn

- Monitoring and Assessment Item is being under discussion.

- To support various campaign e.g. IGS M-GEX, by sharing stations, raw data and geodetic receivers with other system capabilities.
Conclusions

BDS Construction
- The second deployment step has been accomplished.
- BDS has possessed full operational capability for most Asia-Pacific area since the end of 2012

BDS Application
- ICD has been released to support industry development.
- BDS chips is matured day by day.
- Application is promoted in large scale.
Conclusions

**International Activity**

- International exchange, coordination and cooperation.
- BADEC, promote multi-GNSS applications.
- International monitoring and assessment, ensure reliable GNSS services for global users.
BeiDou Applications

GNSS is now everywhere and it can serve for everyone.

No one can address all GNSS applications, especially when users create new ones almost every day.

1) Vessel Monitoring and Management
2) Government Vehicles Management
3) Meteorological and Instrument Development
1) BeiDou Application in Vessel Monitoring and Management
Content

Background
- Situation of Vessel Monitoring at Home and Abroad
- Advantages of BeiDou in Vessel Monitoring

BeiDou and Vessel Monitoring
- Application Mode of BeiDou in Vessel Monitoring
- Services Frame Provided by BeiDou VMS
- Services Provided by BeiDou VMS

Conclusion
- BeiDou is Notably Applicable to Vessel Monitoring
Background

Situation of Vessel Monitoring at Home and Abroad

- Limited Coverage Area
- All-day Service Impossible
- Separation between Positioning and Communication

- Separation between Positioning and Communication
- Expensive

Absolute Software, AMS, Argos CLS, AST Ltd, Free Port-Eye from a sky
Advantages of BeiDou in Vessel Monitoring

**Applicability**
- Positioning and Communication Integrated
- Broad Coverage Area

**Extensibility**
- Compatible with other GNSS
- Integratability with AIS, RFID

**Reliability**
- Developed by China
- Ocean-Land-Sky Integration

**Suitability**
- Economic
- Availability in Harsh Environments
Application Mode of BeiDou in Vessel Monitoring

BeiDou Operation

GPS Constellation

COMPASS Constellation

Data Pushing by SDH or Internet, SMS & Other VAS

Monitoring Center B/S Monitoring System

VPN

Municipal Monitoring Center

Sub-Center

Internet

Shipborne Compass Navigation and Positioning Terminal

Compass Service Provider
Shanghai Ubiquitous Navigation Technologies Ltd.
Hot line: 4001008841

Shipping Enterprises
Services Frame Provided by BeiDou VMS

- Command and Dispatch
- Communication
- Transport Vessels Management
- Visualized Ship Logistics Management
- Units and Enterprise Users Management
- Position Monitoring
- 911 and Rescue

Vessel Service
Services Provided by BeiDou VMS

Inland shipping (Lancang Jiang (Mekong River)):
RS + 3D Image + BeiDou
Inland shipping (Lancang Jiang (Mekong River)):
RS + 3D Image + BeiDou
Services Provided by BeiDou VMS

Inland shipping (Lancang Jiang (Mekong River)):
RS + 3D Image + BeiDou

BeiDou Advantage: Positioning and Communication Integrated in the Remote Inland River Area

Integration Characteristics: BeiDou+RS+3D very suitable for the Environmental monitoring

Notable Benefits: BeiDou protects ship crew's life and property safety

International Corporation: BeiDou promotes the international Exchanges and Cooperation
Intelligent Ship Logistics:
BeiDou Position Service + Short Messages + Sensors Integration

Services Provided by BeiDou VMS
Services Provided by BeiDou VMS

Intelligent Ship Logistics:
BeiDou Position Service + Short Messages + Sensors Integration

Distinguish-ing Features

- BeiDou achieves the dynamic management of cargo and makes the logistics system more efficient.
- BeiDou Early Warning improves the safety of the ocean cargo transportation.
- BeiDou LBS Service offers cargo real-time monitoring (temperature, humidity, etc.) for special logistics.
- BeiDou Logistics can be integrated into Internet of Things.
More than 40,000 fishing boats are accessing to position services provided by BeiDou.
The Application of BeiDou in the Marine Fisheries
——Communicate Service
The Application of BeiDou in the Marine Fisheries
——Typhoon Warning Service
The Application of BeiDou in the Marine Fisheries

——Search and Rescue Services

Services Provided by BeiDou VMS
Services Provided by BeiDou VMS

Applications on the other Vessels

**MV Xue Long**
- Scientific Ship Monitoring
- Scientific Data Acquisition

**Sailboat**
- Competition Sailing Monitoring Service
- Personal Navigation Service

**Yacht**
- Vocation Navigation Service
- Emergency 911 Communication Service
Conclusion

BeiDou is Notably Applicable to Vessel Monitoring

- Positioning and Communication
- Various Water Environments (Inland River, Offshore, Ocean)
- Various Boats and Ships
- Autonomous Navigation
- SMS Communication
- Monitoring Management
- Intelligent Logistics
- Emergency Rescue
- Scientific Investigation

System Extensibility

Services Variability

Application Suitability
2) BeiDou Application in Government Vehicles Management
• Government Vehicles Management has become more and more important for the government to improve public service ability.
• The former management lacks effective supervision, and in urgent needs of information methods.
The management information system of Guangzhou government vehicles

- Base on combined BeiDou/GPS navigation
- Monitoring the vehicle’s route, parking places, avoiding uneconomic running, clamping down illegal government vehicle usage

One Center
Guangzhou government vehicles’ monitoring center

Three Levels’ Monitoring Platform
- City monitoring platform
- Monitoring platform of units which are directly under the city and districts and counties
- Monitoring platform of superior department

Four Major Functions
- Identity recognition
- Real-time monitoring
- Regional management
- Emergency support
### The management information system of Guangzhou government vehicles

<table>
<thead>
<tr>
<th>Monitor Objective</th>
<th>Guangzhou government vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving Area</td>
<td>Ten districts, two cities, and a few other regions</td>
</tr>
<tr>
<td>GNSS Application Mode</td>
<td>Positioning</td>
</tr>
<tr>
<td></td>
<td>Velocity Measurement</td>
</tr>
<tr>
<td>Positioning Mode</td>
<td>BeiDou+GPS</td>
</tr>
<tr>
<td>(could be set)</td>
<td>BeiDou</td>
</tr>
<tr>
<td></td>
<td>GPS</td>
</tr>
</tbody>
</table>
System Architecture

Central Management Platform

Vehicle Terminal
Vehicle Terminal

- BeiDou/GPS compatible receiver

- Identity recognition device
Key features and specifications

1. Vehicle status and road tracking control
2. Mileage statistics
3. Acousto-optic reminder
4. Remote upgrade
5. Remote setting
6. Communication backup
7. Road tracking compensation
8. Emergency alarm and abnormal alarm
9. Low voltage protection and alarm
10. Low power mode
11. Emergency shutdown

Accuracy Index

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
<td>Accuracy: 0.1 m/s</td>
</tr>
<tr>
<td>Combined Positioning Accuracy</td>
<td>Level: 10m, Altitude: 10m</td>
</tr>
<tr>
<td>Positioning velocity update rate</td>
<td>1times/s</td>
</tr>
<tr>
<td>Time index</td>
<td>Cold Start: 37s</td>
</tr>
<tr>
<td></td>
<td>Warm Start: 1s</td>
</tr>
<tr>
<td></td>
<td>Loss of lock catch: 1s</td>
</tr>
</tbody>
</table>

Signal system and working mode

| Input Signal                  | B1:1561.098MHz, C Code; L1: 1575.42MHz, C/A Code |
|                              | BeiDou positioning: Support            |
|                              | GPS positioning: Support              |
|                              | Dual positioning: Support             |
The Five Implementation of the management of government vehicles

1. The vehicles tracing and user management
2. Holiday vehicle management
3. The approval of unofficial use
4. The usage publicity
5. Illegal usage management
Identity Recognition

Reminder of forgetting to Plug in the Card
Real-time vehicle tracking
History query

Electronic fence
cross-border alarm
Vehicle Application Process

A need for vehicles → Application → For private use → For public use → 

- Fill in an application form
- Scheduling vehicles
  - Y → Approval from apartment leader
  - N → N

- dispatch a car
  - Y → Fill in the receipt of using the vehicles
  - N → Demand End

- Fill in the mileage of destination

Demand End
  - Y → Approval from apartment leader
  - N → Approval from unit director

Clear the usage

signature confirmation from the user
- vehicles’ status
- abnormal usage
- payment
- mileage
- ……
The Achievement of the Project

- 8440 government vehicles have been fitted with BeiDou/GPS monitoring device
- The system has been running for one year, showed reliable performance and got satisfied feedback
- Not only did vehicle management improve, cases of personal usage markedly decreased
- Reduced the cost, Improved the efficiency

![Average Mileage Saving](chart.png)

- 2012.02
  - Average Mileage Saving: 28.5%
- 2012.06
  - Average Mileage Saving: 36.5%
Project's Social Impact

- Achieved volume applications of BeiDou in the field of civilian vehicles monitoring
- Got praise from China Satellite Navigation Office, government, and industry experts
- Got media attention, and follow-ups
## GNSS Application Effect

### Static Test

**Location:** Guangzhou Science City, Roof of the 6th floor

**Test Environment:** Broad Vision with no obstructions

### Test Environment

<table>
<thead>
<tr>
<th>Test Group</th>
<th>Test date and the weather</th>
<th>Positioning Module/Positioning Mode</th>
<th>HDOP</th>
<th>Number of visible satellite</th>
<th>Positioning accuracy availability (10m, 95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>Aug.4: cloudy 11:04:11 ~ 13:19:30 Data set N=10845</td>
<td>T-Module BeiDou</td>
<td>2.181</td>
<td>7.04</td>
<td>90.8%</td>
</tr>
<tr>
<td>Group B</td>
<td>Aug.4: cloudy 10:28:07 ~ 13:26:05 Data set N=10715</td>
<td>U-Module BeiDou+GPS</td>
<td>0.784</td>
<td>15.99</td>
<td>100%</td>
</tr>
<tr>
<td>Group D</td>
<td>Aug.7: Clear 13:33:12 ~ 16:35:48 Data Set N=10958</td>
<td>H-Module BeiDou</td>
<td>1.39</td>
<td>8.04</td>
<td>100%</td>
</tr>
<tr>
<td>Group E</td>
<td>Aug.8: Clear 16:46:58 ~ 18:29:49 Data Set N=6172</td>
<td>U-Module BeiDou</td>
<td>1.43</td>
<td>7.29</td>
<td>97.7%</td>
</tr>
<tr>
<td>Group F</td>
<td>Aug.8: Clear 16:46:43 ~ 18:29:58 Data Set N=6182</td>
<td>H-Module BeiDou</td>
<td>1.77</td>
<td>6.6</td>
<td>100%</td>
</tr>
<tr>
<td>Group I</td>
<td>Aug.9: Clear 8:30:16 ~ 20:31:34 Data Set N=42662</td>
<td>H-Module BeiDou+GPS</td>
<td>0.74</td>
<td>15.41</td>
<td>100%</td>
</tr>
<tr>
<td>Group J</td>
<td>Aug.9: Clear 8:30:16 ~ 20:31:34 Data Set N=40141</td>
<td>T-Module BeiDou</td>
<td>2.42</td>
<td>7.45</td>
<td>94.7%</td>
</tr>
</tbody>
</table>

GNSS Application Effect

Dynamic Test
Aug. 29, 2012, Guangzhou Science City, open area

BeiDou Positioning Mode
Dual Positioning Mode

In Guangzhou Area, the application of GPS is fine, BeiDou is usable, BeiDou+GPS has better effect.

Aug. 29, 2012, Urban area test, Dual Positioning Mode
Aug. 29, 2012, Urban area test, BeiDou Positioning Mode

Note: Red line means failed be positioned, belonging to the linear prediction linear.

## User Experience Index Questionnaire of Guangzhou Government Vehicle Project

<table>
<thead>
<tr>
<th>Index</th>
<th>Sum</th>
<th>Average</th>
<th>Degrees of Satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning Tracing Accuracy</td>
<td>973</td>
<td>88.5</td>
<td>Satisfied</td>
</tr>
<tr>
<td>Positioning Tracing Coherence</td>
<td>960</td>
<td>87.3</td>
<td>Satisfied</td>
</tr>
<tr>
<td>Positioning Result Stability</td>
<td>1017</td>
<td>92.5</td>
<td>Very Satisfied</td>
</tr>
<tr>
<td>Total Score</td>
<td>2950</td>
<td>268.2</td>
<td>Satisfied</td>
</tr>
</tbody>
</table>


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**User experience index survey**

**Date:** Aug. 2012  
**Location:** Guangzhou  
**Target:** 120 vehicles  
Choose one unit from each of the ten districts and two cities, totally 12 units, and 10 cars from each unit  
**Pattern:** Dynamic Test  
**Index:** Positioning Tracing Accuracy, Positioning Tracing Coherence, Positioning Results Stability

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**GNSS Application Effect**

![Reference: Evaluation Report of Guangzhou government vehicles project users, 2012.9](image-url)
Guangzhou government vehicle project verified the availability of the BeiDou system

The multi-system can effectively improve the availability of satellite navigation positioning

The mature application of BeiDou in Guangzhou government vehicle system played a good demonstration effect in the industry

Strengthen international technical exchanges, technical cooperation and project cooperation, and jointly promote the GNSS industry booming
3) BeiDou Application
in Meteorological and Instrument Development
Contents

- Introduction to the GNSS/MET for BeiDou
- The development of the BeiDou radio-sonde system
- The development of the GNOS for BeiDou occultation on FY-3
Introduction to the GNSS/MET for BeiDou

In 2011, China meteorological administration implemented an application – the demonstration project of the atmosphere and marine sounding based the BeiDou navigation system and its meteorological application.

It aims to enhance the 3D observation for the local severe weather over the focused area, to increase the ability of data gathering for the weather forecast, and to better the service of the weather warning over the remote and undeveloped region.
Introduction to the GNSS/MET for BeiDou

The BeiDou radio-sonde system

The coastal wave and wind sounding by GNSS-R

The Beiou continuous operational reference system

The severe weather warning with BeiDou DCP
Development of the BeiDou radio-sonde system

- Construction of the BeiDou radio-sonde system
Development of the BeiDou radio-sonde system

- Radio-sonde
- Surface receiving system
  1. receiver
  2. computer and processing software
  3. radio-sonde antenna
  4. reference differential receiver and antenna
Development of the BeiDou radio-sonde system

- The BeiDou wind sounding module is the CC50 BeiDou/GPS receiver by Beijing oriental navstar science Co. Ltd.
- The BeiDou antenna is a ceramic active microstrip antenna.
Development of the BeiDou radio-sonde system

- The system experiments was conducted in 2010 and 2011.

- In 2010, the BeiDou radio-sonde was compared with the international GPS radio-sonde.

- In 2011, the BeiDou radio-sonde was used for the evaluation of the operation test for BeiDou.
Development of the BeiDou radio-sonde system

- Exp 1—static test
  - The static performance of positioning and velocity measurement

<table>
<thead>
<tr>
<th>Model</th>
<th>CEP50 (m)</th>
<th>horizontal STD (m)</th>
<th>Elevational STD (m)</th>
<th>Velocity STD(m/s)</th>
<th>Average PDOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>2.10</td>
<td>2.67</td>
<td>5.49</td>
<td>0.02</td>
<td>1.8</td>
</tr>
<tr>
<td>BeiDou</td>
<td>4.91</td>
<td>6.06</td>
<td>13.12</td>
<td>0.02</td>
<td>2.6</td>
</tr>
<tr>
<td>GPS+ BeiDou</td>
<td>2.18</td>
<td>2.8</td>
<td>6.33</td>
<td>0.02</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Test time: 2012-09-12, 2012-09-18, 2012-09-20
Development of the BeiDou radio-sonde system

- **Exp 2—Field experiment**
  - Compare the performance of positioning and velocity measurement with the BeiDou radio-sonde and the reference GPS radio-sonde tied to the same balloon.
  - The BeiDou radio-sonde uses 3 models for positioning and velocity measurement:
    - BeiDou Satellites only
    - GPS satellites only
    - GPS and BeiDou Satellites
  - The reference GPS radio-sonde is Vaisala GPS R92.
Development of the BeiDou radio-sonde system
Development of the BeiDou radio-sonde system

**Statistical result**

<table>
<thead>
<tr>
<th>Precision</th>
<th>Wind Speed (m/s)</th>
<th>Wind Direction (degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BeiDou only</td>
<td>0.60</td>
<td>4.8</td>
</tr>
<tr>
<td>GPS only</td>
<td>0.54</td>
<td>4.0</td>
</tr>
<tr>
<td>Bending with GPS and BeiDou</td>
<td>0.50</td>
<td>4.0</td>
</tr>
</tbody>
</table>

The precision demand of current wind sounding is 1 m/s in speed and 5 degrees in direction. It suggests that the module can meet the operational demand of upper air wind sounding with 3 models to measure the wind.
Development of the BeiDou radio-sonde system

- The high precision GNSS receiver is needed for the application of the remote sensing of IPW and TEC. Launched on the satellite, such receiver even adapted to the circumstance of very high speed.

- The GNOS (GNSS Occultation Sounder) will be first launched on China FY-3 /02 (launched in 2013).

- The Occultation application demands high technique of receiver manufacturing and processing of high precision of positioning and remote sensing.
Development of the BeiDou radio-sonde system

The GNOS receives the earth limb occultation BD/GPS signal, refracted passing through the atmosphere, retrieving the atmospheric profile of temperature, humidity, and ionospheric profile of TEC, by very high measurement of the path bending and the phase amplitude change.
Development of the BeiDou radio-sonde system

- GNOS receiving both the GPS and the BeiDou signal with 8 positioning channels and 8 occultation channels.
- It is consisted of 3 RTF units, a DSP unit and 3 antenna for the forward/backward occultation and the zenith positioning.
- It adopts the open loop tracking technique in the occultation receiving.

GNOS manufactured by The space technique and application research center of CSA
With GPS, about 500 occultation events can be detected.

With BeiDou orbit of 5GEO/3IGSO/4MEO and 4GEO/3IGSO/2MEO, 320 and 640 events can be detected respectively. (Simulated right)
Development of the BeiDou radio-sonde system

In 2012, CMA and CSSA jointly conducted the first surface test—the mountain based BeiDou occultation experiment.


The GNOS was set up on the mountain top of the Mount Wuling (117.478°E, 44.598°N, 2083.28m) with its antenna facing the southeast and covering azimuth of 180 and elevation angle of -35 to +35.
Total 55 BeiDou occultation events were received, with 14 of MEO11 and 12, and 41 of IGSO.
Comparison of the retrieval from BeiDou (PRN 12) and GPS (PRN14) at 6:00 in 2012-9-23. The result shows less than 3% of reflectivity exist between the GPS and the BeiDou.

PS:  
black for JAVAD/L1C retrieval  
Blue for GNOS with close loop retrieval  
Green for GNOS with L1C open loop retrieval  
Red for GNOS BeiDou retrieval  
Purple for CIRA86 computation  
Light blue for MSIS90 computation
Conclusions

- The successful development of the BeiDou radio-sonde system is a trademark for the demonstration and construction of China’s next upper air sounding system.
- The GNOS occultation application will enhance the technique of high precision receiver manufacturing and positioning and remote sensing, and deepen and widen the BeiDou scientific application.
Summary

• Understanding GNSS
• Update of BeiDou System
• BeiDou Applications
Thanks for Your Attention!

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