One solution for a seamless positioning, IMES concept and compatibility with GNSS signals

Satoshi Kogure, Yoshihisa Kawaguchi
Japan Aerospace Exploration Agency
Kiyoshi Yajima
Lighthouse Technology and Consulting Co., Ltd.

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Are you looking for a solution for the seamless positioning?

- How many hours do you spend indoor during your daily life?
  - Most people spend their life much longer time indoor than outdoor

- Growing smart phone and LBS market require seamless positioning
  - at any condition
  - at any location
  - at any time

Indoor MEssaging System (IMES) is a powerful solution for realization of seamless positioning.
Concept of IMES

- IMES can transmit its position in three dimensions and/or ID directly
  - No pseudorange measurement and time synchronization.
- Moderate accuracy (10-20m), but stable even in deep indoor.
  - Signal reception area equals to position accuracy.
- Signal is still compatible and interoperable with GPS/QZSS signal for seamless positioning
  - The same GNSS chipset can acquire signals from satellites as well as IMES Tx without serious modifications on existing chipset software. (No change on H/W design)
- Target users are cell-phone, smart-phone and handheld receiver with low dynamics.
Seamless positioning between Indoor and outdoor with common GPS chipset

Outdoor Positioning
Need more than 4 pseudorange measurements for Position computation

Indoor Positioning
One transmitter sends position and/or ID
Just read message, don’t need pseudorange measurement

Seamless Positioning
Same handset can be used for both Indoor and outdoor locations.

GPS

IMES Tx.

GPS embedded Cell Phone

Server

Local server connection
Various info. related to users position and attribution

Com line
## IMES signal characteristics

### Signal Properties of GPS & IMES

<table>
<thead>
<tr>
<th></th>
<th>GPS</th>
<th>IMES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Center Frequency</strong></td>
<td>1575.42MHz</td>
<td>1575.42MHz +/- 8.2kHz</td>
</tr>
<tr>
<td><strong>PRN ID</strong></td>
<td>1-32</td>
<td>173-182</td>
</tr>
<tr>
<td><strong>PRN Code Chip Rate</strong></td>
<td>1.023MHz</td>
<td>1.023MHz</td>
</tr>
<tr>
<td><strong>PRN Code Length</strong></td>
<td>1ms</td>
<td>1ms</td>
</tr>
<tr>
<td><strong>Data Rate</strong></td>
<td>50bps</td>
<td>50bps</td>
</tr>
<tr>
<td><strong>Modulation</strong></td>
<td>BPSK</td>
<td>BPSK</td>
</tr>
<tr>
<td><strong>Polarization</strong></td>
<td>RHCP</td>
<td>RHCP</td>
</tr>
</tbody>
</table>

- The power of transmitter is
  - less than defined figure as Japanese radio regulation (-94.35dBW).
  - set value NOT over specified MAX receiving power strength at the user antenna input.

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5
PRN Code for IMES

- 10 PRN Codes in 210 C/A codes which the US GPS maintained its allocation table were assigned for IMES in November 2007

<table>
<thead>
<tr>
<th>PRN Signal Number</th>
<th>G2 Delay (Chips)</th>
<th>Initial G2 Setting (Octal)</th>
<th>First 10 Chips (Octal)</th>
<th>PRN Allocations</th>
<th>Orbital Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>173</td>
<td>150</td>
<td>1362</td>
<td>415</td>
<td>QZSS – IMES3</td>
<td>Ground</td>
</tr>
<tr>
<td>174</td>
<td>395</td>
<td>1654</td>
<td>123</td>
<td>QZSS – IMES3</td>
<td>Ground</td>
</tr>
<tr>
<td>175</td>
<td>345</td>
<td>510</td>
<td>1267</td>
<td>QZSS – IMES3</td>
<td>Ground</td>
</tr>
<tr>
<td>176</td>
<td>846</td>
<td>242</td>
<td>1535</td>
<td>QZSS – IMES3</td>
<td>Ground</td>
</tr>
<tr>
<td>177</td>
<td>798</td>
<td>1142</td>
<td>635</td>
<td>QZSS – IMES3</td>
<td>Ground</td>
</tr>
<tr>
<td>178</td>
<td>992</td>
<td>1017</td>
<td>760</td>
<td>QZSS – IMES3</td>
<td>Ground</td>
</tr>
<tr>
<td>179</td>
<td>357</td>
<td>1070</td>
<td>707</td>
<td>QZSS – IMES3</td>
<td>Ground</td>
</tr>
<tr>
<td>180</td>
<td>995</td>
<td>501</td>
<td>1276</td>
<td>QZSS – IMES3</td>
<td>Ground</td>
</tr>
<tr>
<td>181</td>
<td>877</td>
<td>455</td>
<td>1322</td>
<td>QZSS – IMES3</td>
<td>Ground</td>
</tr>
<tr>
<td>182</td>
<td>112</td>
<td>1566</td>
<td>211</td>
<td>QZSS – IMES3</td>
<td>Ground</td>
</tr>
<tr>
<td>183</td>
<td>144</td>
<td>215</td>
<td>1562</td>
<td>QZS1</td>
<td>A1</td>
</tr>
<tr>
<td>184</td>
<td>476</td>
<td>1003</td>
<td>774</td>
<td>Reserved (QZS)</td>
<td>TBD</td>
</tr>
</tbody>
</table>

NOTE: PRN codes are currently allowed to use only in JAPAN.
Message structure of IMES

- is defined in the annex of IS-QZSS.
  - Similar to QZSS and GPS L1C/A message structure,
    - use 30bit/word
  - Four types of IMES messages are defined currently.
    - #0 and #1; Absolute position
      - Longitude, Latitude, Floor and/or Height
      - Difference is resolution
    - #3 and #4; position ID
      - #3 for LBS managed by operators
      - #4 for local server connection
      - #0 or #1 and #3+#4 are transmitted flexible sequence
  - Four message types are reserved for future applications
Applications

- Location Based Service
  - Check in service
  - Location based Advertisement.
- Disaster Management, rescue support
  - Evacuation support, and effective rescue underground mall, huge shopping mall complex, department store and so on.
- Provide DR reference point to reset INS sensor.
  - Spot IMES transmitters are installed at revolving doors, elevator halls, entrance doors into room.
- Tracking service for children, asset, entrance control into security area, and more
Avoiding Interference to GPS

**Compatibility with GPS is Vital for IMES**
- IMES gets real power when it goes together with GPS, broadcasting signals of the same properties as the pioneer of the global navigation satellite system.
- IMES has not spared any effort to make sure **not** to give a harmful interference to GPS.

**Where GPS and IMES meet**
IMES will be operated “indoors” including by the window and building entrances. They are where the two positioning systems are expected to work seamlessly.

- **NAVSTARs**
  - “Open Sky”
  - Received Signal Strength: -158.5dBW (minimum, as specified in IS-GPS)

- **IMES Transmitters**
  - “by the Window”
  - Received Signal Strength: say, -165dBW

- **“Deep Indoor”**
  - Received Signal Strength: almost none

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Two-Step Measures against Interference

**Measure 2**
Shifting the center frequency of IMES carrier wave by +/-8.2kHz from GPS L1.
This measure is the description to raise the safety margin for high sensitivity receivers.

**Measure 1**
Specifying allowable maximum signal strength both at transmitters and receivers. According to GPS signal strength environment, different criterion is specified.

- Both measures are stated in the user interface document (IS-QZSS).
- IMES transmitter manufacturers and installers are under control of the organization of IMES stakeholders, “IMES consortium”.

Avoiding Interference
Specifying Maximum Signal Strength
Shifting Center Frequency
Measure 1: Specifying Allowable Maximum Signal Strength

- where GPS signal strength > -158.5dBW (“by the Window”)
  - Maximum allowable power at transmitters < -94.35dBW
  - Maximum allowable power at receivers < -140dBW

- where GPS signal strength < -158.5dBW (“Deep Indoor”)
  - Maximum allowable power at transmitters < -94.35dBW
  - Maximum allowable power at receivers < -150dBW

As defined in IS-QZSS Annex
Measure 2: Shifted Center Frequency from GPS L1

“I’ll be stepping aside ... just slightly.”

The center frequency of IMES carrier wave is shifted by +8.2kHz or -8.2kHz from GPS L1.

GPS 1575.42MHz

IMES 1575.4282MHz or 1575.4118MHz

Especially for high sensitivity receivers, this measure improves cross-correlation between the PRN codes of GPS and IMES by several dBs and raises the safety margin.
Measure 2: How Shifted Center Frequency work?

- Code length = 1ms

- GPS

- IMES

- df=8.2kHz = 5.2ppm
  - 1ms*df=5.2ns = 0.0053chip
  - 2ms*df=10.4ns = 0.0106chip
  - 3ms*df=15.6ns = 0.0160chip
  - 4ms*df=20.8ns = 0.0213chip

- Typical integration time used by high sensitivity receivers

- Cross-correlation for 8.2kHz-shifted signals

- Zero Doppler difference (ideal)

- Maximum Cross-correlation [dB] vs. Non-coherent Integration Time [ms]

- Worst case with a Doppler difference

- -21.1dB : worst case with a Doppler difference
Making the receiver “Cold Start” when IMES signal exists

**Examine if the receiver fixes the positioning**

- **Good ☺:** Establish positioning within 60sec.
- **NG ☹:** No positioning after 60sec.

<table>
<thead>
<tr>
<th></th>
<th>NO IMES</th>
<th>IMES with center frequency @ 1575.42MHz</th>
<th>IMES with center frequency @ 1575.42MHz +/- 8.2kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fix Rate</strong></td>
<td>100%</td>
<td>91%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Number of attempt = 50
**Experiment results – TTFF**

**Making the receiver “Hot Start” when IMES signal exists**

**Examine the time to first fix**

In “by the window” environment, no interference is confirmed, verifying the two-step measures do work effectively.

<table>
<thead>
<tr>
<th></th>
<th>NO IMES</th>
<th>IMES with center frequency @ 1575.42MHz</th>
<th>IMES with center frequency @ 1575.42MHz +/- 8.2kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTFF</td>
<td>16.6sec</td>
<td>24.8sec</td>
<td>13.1sec</td>
</tr>
</tbody>
</table>

Number of attempt = 50
GPS – IMES Compatibility Demonstration

- Demonstrations to be staged three times on 8 Sept. during:
  1) 11:00 – 11:15 JST : Morning break
  2) 13:15 – 14:15 JST : Lunch time
  3) 16:15 – 16:30 JST : Afternoon break at Reception Hall
- Using High sensitivity Rx wired with GPS simulator and IMES Tx
- Examine
  - TTFF and C/N0

<table>
<thead>
<tr>
<th>Case</th>
<th>GPS URP</th>
<th># of GPS</th>
<th>IMES URP</th>
<th>IMES PRN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open sky</td>
<td>-158.5 dBW</td>
<td>8 to 9</td>
<td>-140 dBW</td>
<td>173</td>
</tr>
<tr>
<td>By the window</td>
<td>-165 dBW</td>
<td>4</td>
<td>-140 dBW</td>
<td>173</td>
</tr>
<tr>
<td>Deep Indoor</td>
<td>-180 dBW</td>
<td>2</td>
<td>-150 dBW</td>
<td>173</td>
</tr>
</tbody>
</table>
Why should IMES Tx be controlled?

- To avoid interference between IMES signals.
- To prevent misuse on purpose or accidentally.
  - setting signal strength beyond specified value
  - transmitting wrong position

PRN#173

48° 51'29.54"N, 2° 17'39.69"E

35° 39'31.00"N, 139° 44'43.61"E

Here should be Tokyo, Why Paris?
PRN Code management(1/2)

- PRN code assignment for each Tx devise.
  - to avoid overlapping same PRN code between neighboring cells.
- Installer or Tx manufacturer should register following set of Tx configuration to get PRN code:
  - Tx product number
  - location to be installed
  - broadcasting coordinate value
  - Tx EIRP
- Broadcasting position will be registered to “Location Information code database” managed by Geospatial Information Authority in Japan (GSI), simultaneously.
PRN Code management (2/2)

- Life cycle control will be required
  - To facilitate preventing misuse
  - Tx should be traced its location and owner/manager during whole life cycle after shipment, from installation to disposal.

- JAXA is taking a role to establish the framework of IMES PRN code management and implement transiently until operational management organization is established.
  - Operating procedure for the PRN code management is now being prepared.
Further JAXA’s Works

- Finalization of technical specifications
  - Shortening of the time to read message
    - Message data rate change from 50 bps to 250 bps or more is under investigation.
    - Switching algorithms between outdoor GNSS tracking and indoor IMES tracking.
  - Message type definition
- Developing efficient management scheme and method
  - Operation procedure for PRN code management
  - Installation standard/guideline
Summary

- IMES is a solution for realization of seamless positioning.
- Two step measures are taken to avoid interference to GNSS signals
  - Specifying allowable maximum signal strength
  - Shifting the center frequency of IMES
- PRN code management procedure is being prepared by JAXA to prevent misuse on purpose or accidentally.
Thanks a lot for your attention!