

Miniature Space GPS Receiver by means of Automobile-Navigation Technology

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Outline

- Introduction
- Issues and Solutions
- Performance
- Radiation Tolerance
- All-Sky GPS Antenna
- Conclusions

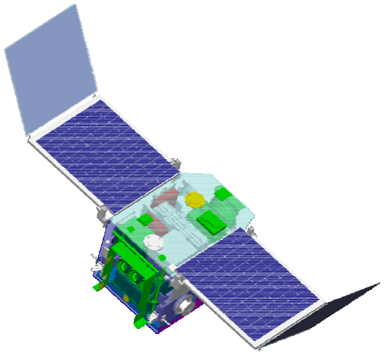
Introduction

- GPS (Global Positioning System) receivers

	Spaceborne GPS Receivers	Automobile-Navigation GPS Receivers
Weight	Several kg	< 100 grams
Power	> 10 W	< 1W
Cost	~ $ 1 million	~ $ 500

Automobile-Navigation GPS Receiver → Spaceborne GPS Receiver →

modification



INDEX satellite

Acknowledgements

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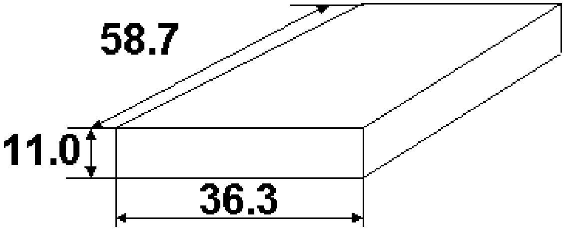
- Institute of Space Technology and Aeronautics
  Japan Aerospace Exploration Agency (ISTA / JAXA)
- NT Space
- AmTech Corporation

Specification of the selected commercial GPS receiver for automobile-navigation

Receiving Channels		8 Channels
RF input	Frequency	L1 : 1.575 GHz C/A
	Sensitivity	-132 dBm
Power supply		DC +5.0 V 180 mA
Power Consumption		0.9 W
Weight		35 g
Size		58.7×36.3×11.0 mm^3





Issues and Solutions

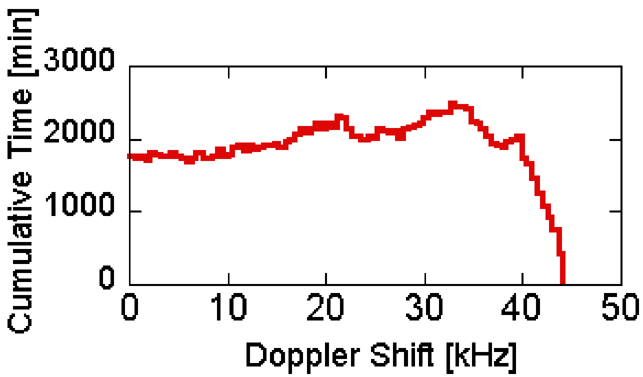
These are general issues.

- **Large Doppler Shift in Orbit**
  → **Expansion of Frequency Scanning Range**

- **Time Tag Error**
  → **Output of Accurate Time Tag**

Large Doppler Shift in Orbit

- On the ground (Automobile)
  - Doppler shift $\Delta f_d = \pm\ 7$ kHz
  - Frequency scanning range $\Delta f_s = \pm 17$ kHz
- In the low earth orbit (Satellite)
  - Doppler shift $\Delta f_d = \pm\ 45$ kHz



Altitude 690 km Polar orbit

ROM Modification : Expansion of frequency scanning range

$$\Delta f_s = \Delta f_d + \Delta f_o = (\pm 45) + (\pm 12) = \pm 57 \text{ kHz}$$



Time Tag Error

- Automobile-navigation GPS receivers
  - Output data
    - Position data with coarse time tag

- If time tag error is 0.2 sec (V × ΔT)
  - Automobile (40 m/sec) → Position error 8 m
  - Satellite (7500 m/sec) → Position error 1500 m

- Spaceborne GPS receivers require accurate time tag



Solution to Time Tag Issue

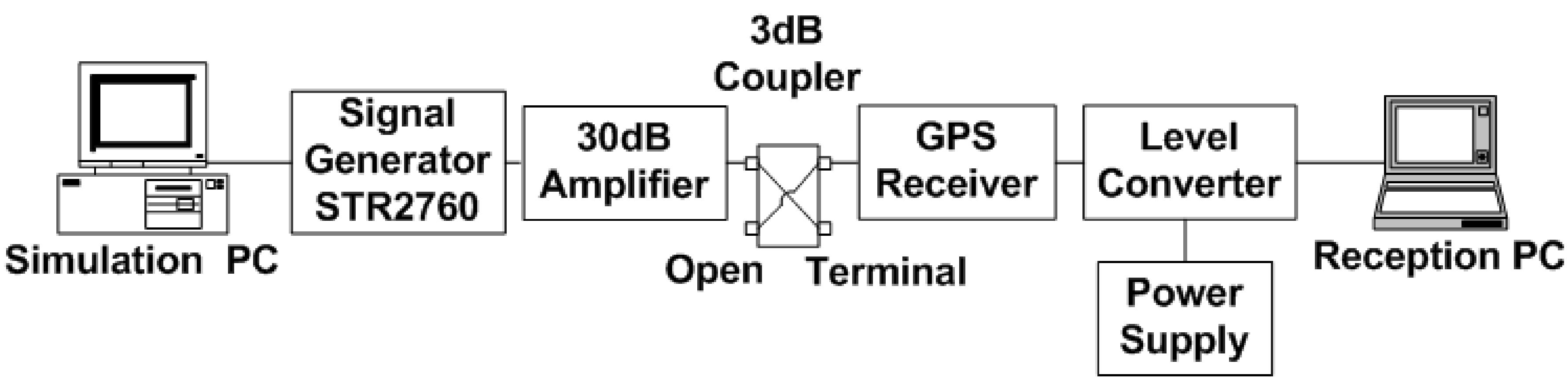
- Modification of Software in ROM
  - First Version (INDEX)
    - Pseudorange output with accurate time

    ➡ Positioning calculation by external computer

  - Second Version (on going by ISTA / JAXA)
    - Position with accurate time tag
    - Pseudorange output
    - Ephemeris output

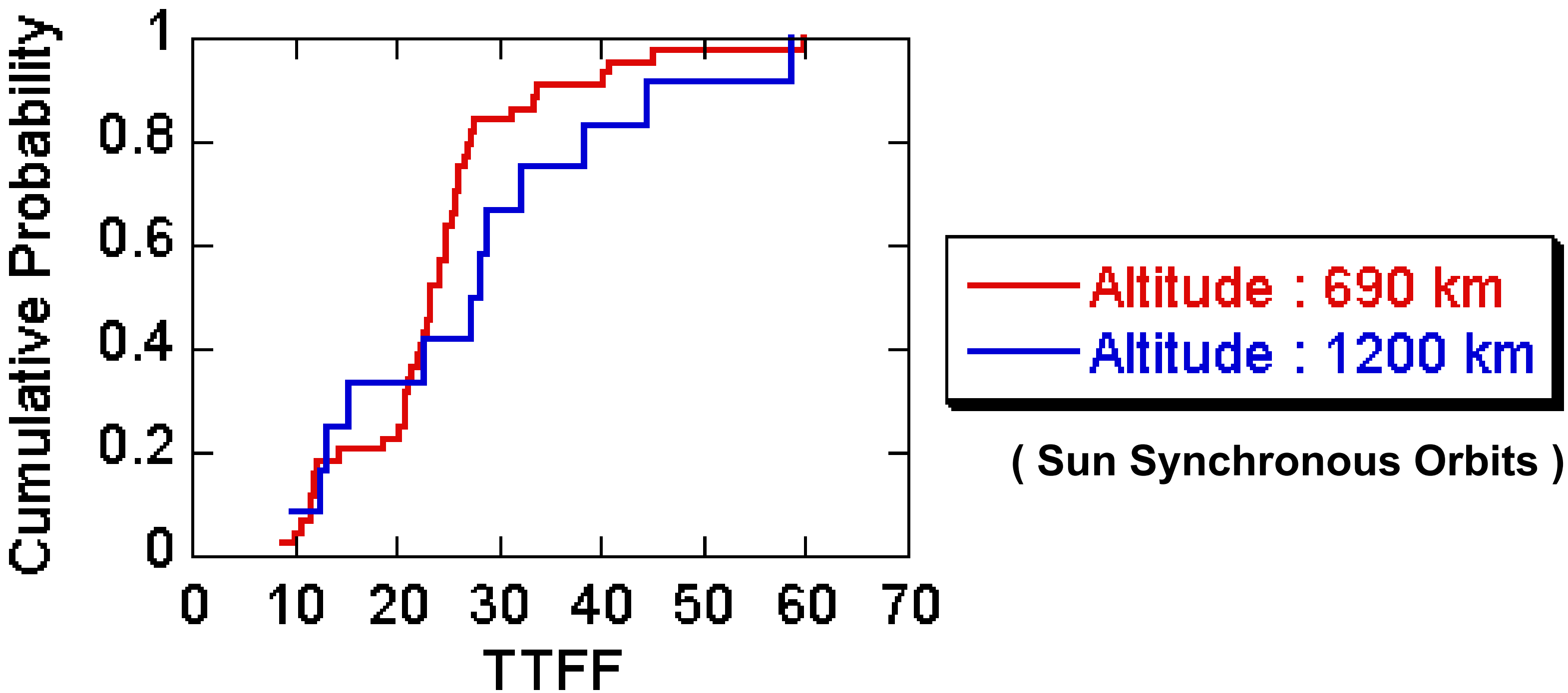
Performance tests with GPS Simulator

- GPS Simulator
  - STR2760 (SPIRENT Inc.)
    - Output Channels : 10 ch
    - Signal : L1 (1.575 GHz)





Performance of Acquisition



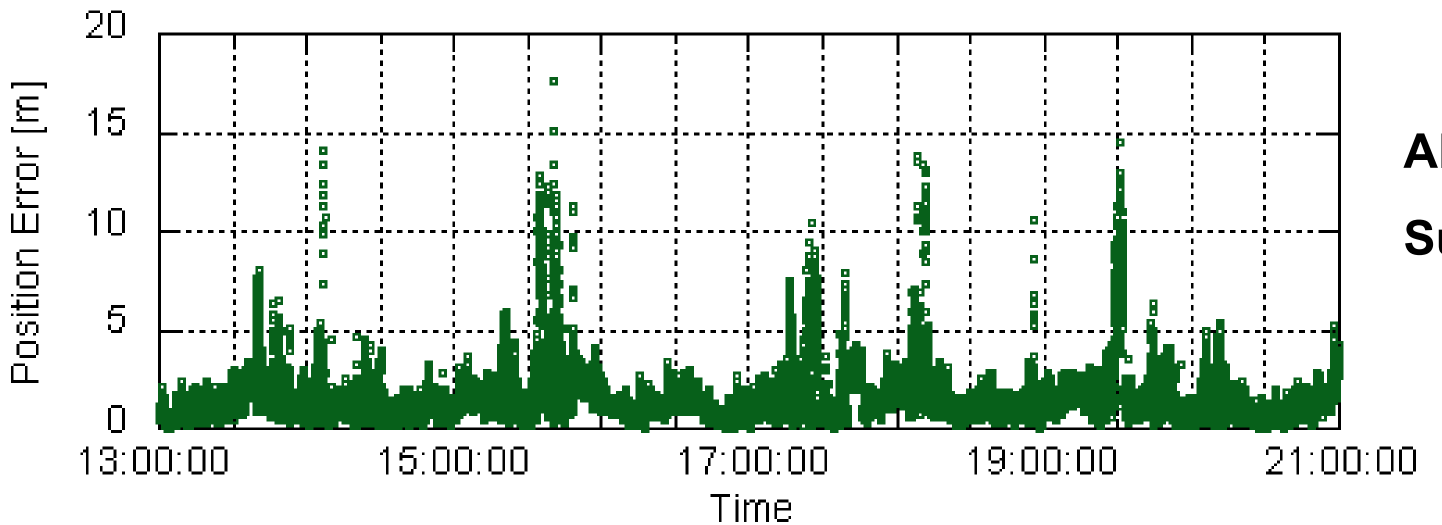
(Sun Synchronous Orbits)

Acquisition Time

TTFF (Time to First Fix) : < 60 min (Cold Start)

Position Error of Receiver Measurement in Orbit

(without error of ionosphere, ephemeris data and satellite clock, etc)



Altitude:690 km

Sun Sync. Orbit

- **Position Error of Receiver Measurement : 2 m (RMS)**
- **PDOP : 2.7 (RMS)**
- **Receiver Measurement Error : 0.8 m (RMS)**

(Position error = σ_{range} × PDOP)

Estimated Error in Orbit

Error source	Estimated error in orbit (RMS [m])
Ephemeris data	2.1*
GPS satellite clock	2.1*
Ionosphere	5.4**
Receiver measurement	0.8
Total range error	6.2

Position error (PDOP = 2.7)	16.7

* Reference : P.W. Parkinson, “Global Positioning System”

* * NATO Standard Agreement STANAG 4294 Issue 1

$$\text{Ionospheric delay} = \frac{82.1 \times \text{TEC}}{F_c^{\,2} \times \left(\sqrt{\sin^2 E + 0.076} + \sin E\right)}$$

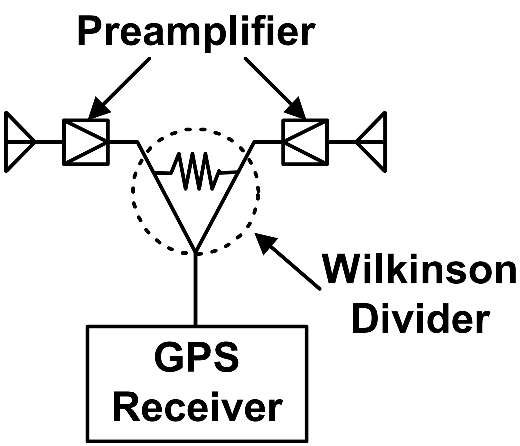
$\text{TEC} = 1.0 \times 10^{17}\ [\text{m}^{-2}]$

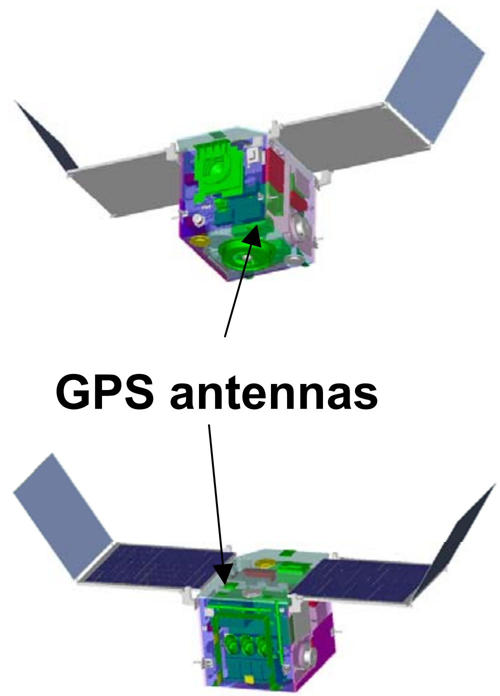
Radiation Tolerance

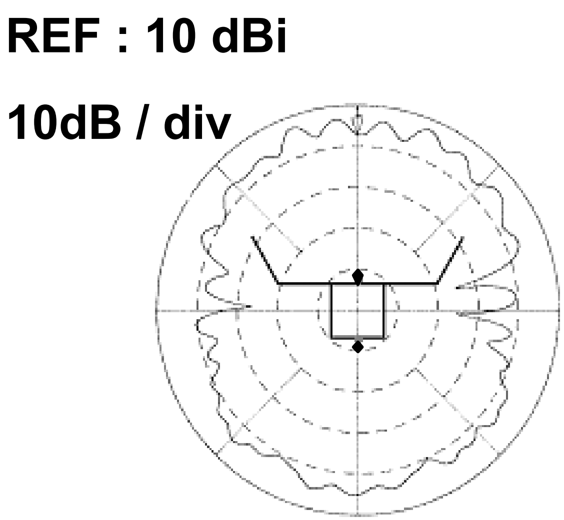
- **Total Dose Radiation test with Co60**
  20 krad

- **Radiation test with proton of 30 and 200 MeV**
  SEL-free
  SEU-Once per several days (200 MeV)

All-Sky GPS Antenna for INDEX







Conclusions:

(1) We developed a spaceborne GPS reciever based on a automobile-navigation GPS reciever.

(2) Modifications of software in ROM

- **Expansion of frequency scanning range**
- **Output of pseudorange with accurate time tag**

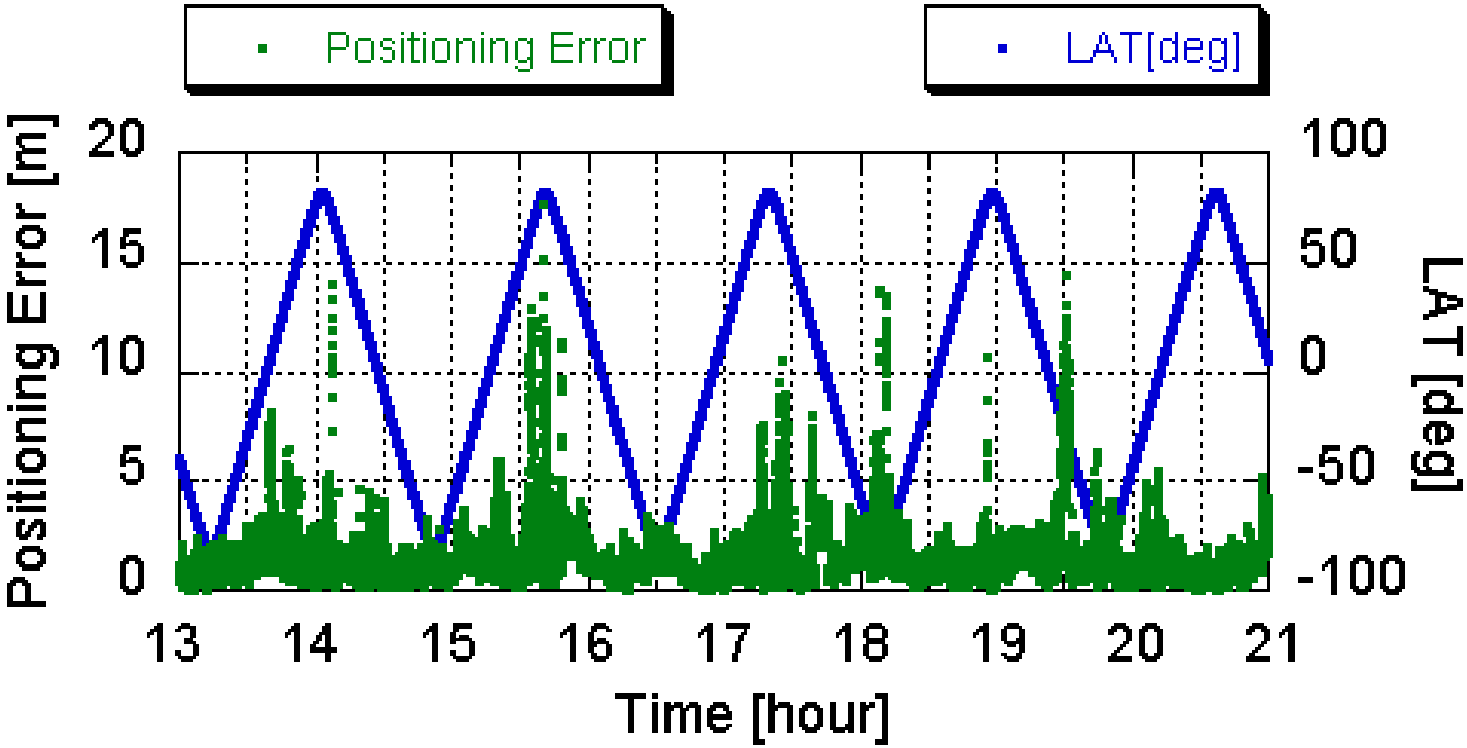
(3) This GPS receiver is able to be used in LEO.

- **Cold start acquisition : less than 60 min.**
- **Position accuracy : less than 20 m.**
- **SEL-free for 200 MeV proton.**
- **SEU once per several days.**

will be onboarded on INDEX satellite in the next year.

Thank you

Backup Slides


Positioning Error
LAT[deg]
Positioning Error [m]
20
15
10
5
0
100
50
0
-50
-100
LAT [deg]
13
14
15
16
17
18
19
20
21
Time [hour]