Miniature Autonomous Star Tracker Based on CMOS APS

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Outline

- **Introduction**
- **Optics**
- **Electronics**
- **Package**
- **Tests**
- **Conclusion**

Introduction

- **Vacuum tube based star tracker**
- **CCD based star tracker**
- **Autonomous Star Tracker (AST)**
  - **equipped with microprocessor and memory**
  - **provide attitude information directly**
  - **CCD based AST has been commercialized**

Introduction

- **APS based star tracker**
  - **manufactured using COMS technology**
  - **high integration & low power consumption**
  - **construction of small, power saving, inexpensive star tracker**

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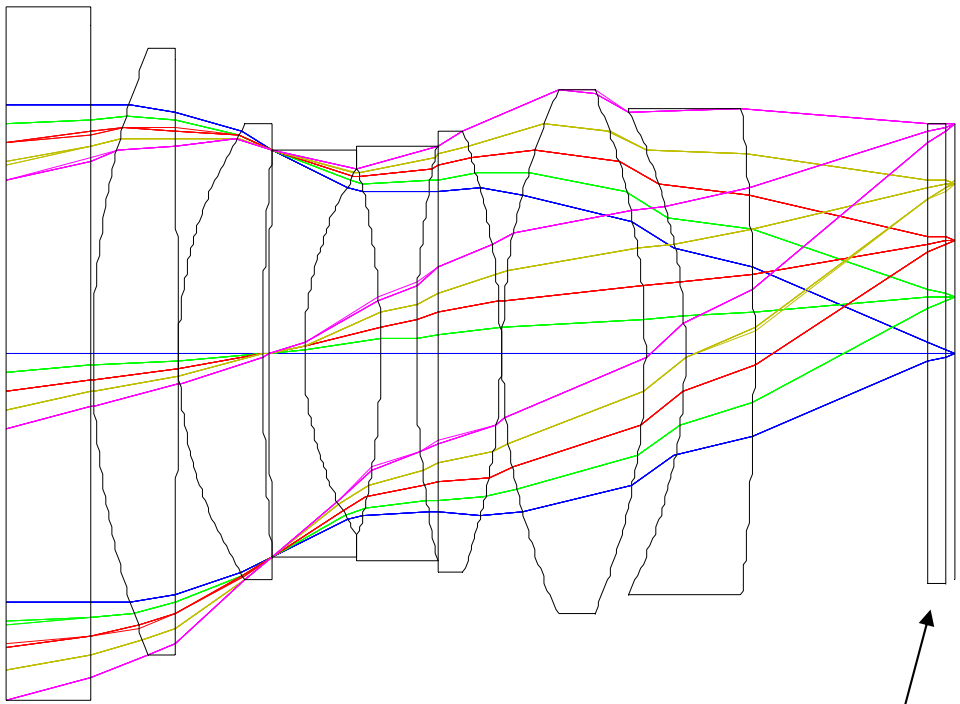
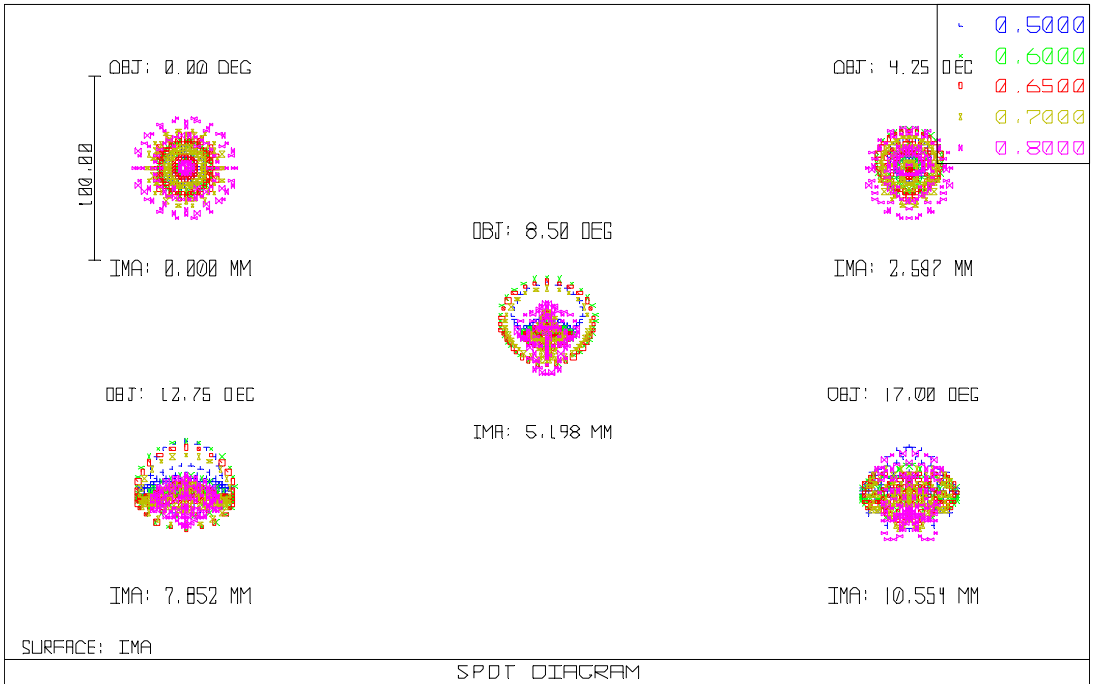
Optics



quartz protection window 7 spherical lenses detector window

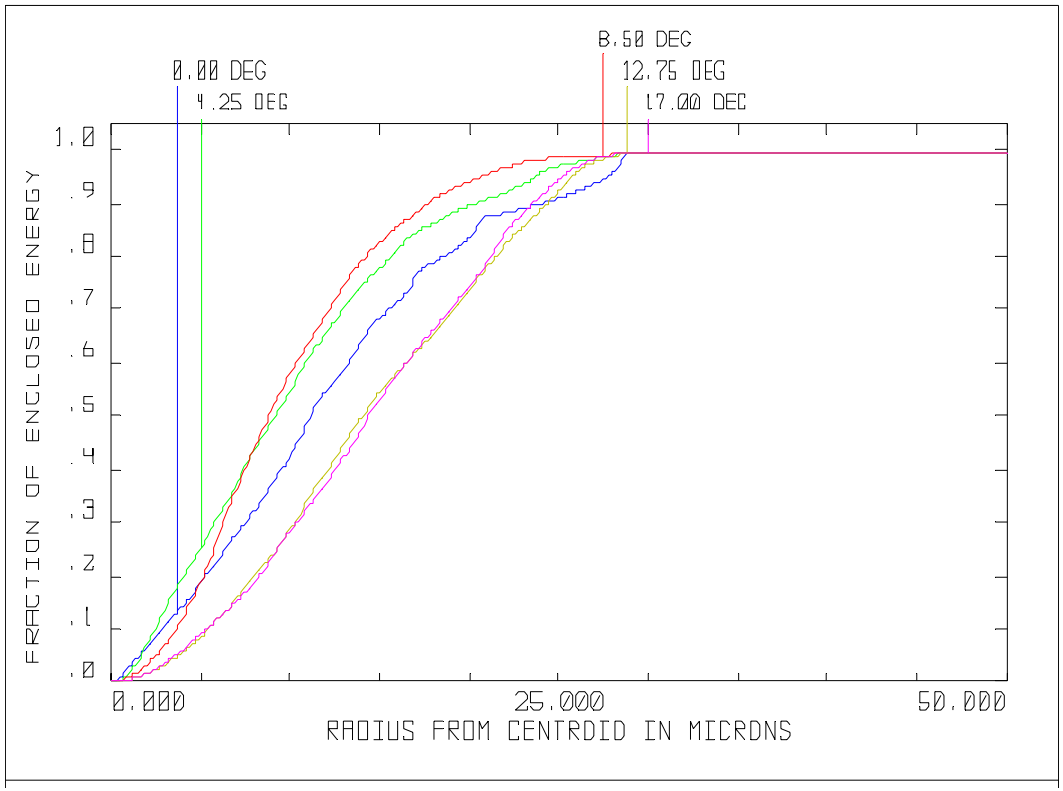
Optics

Spot Diagram



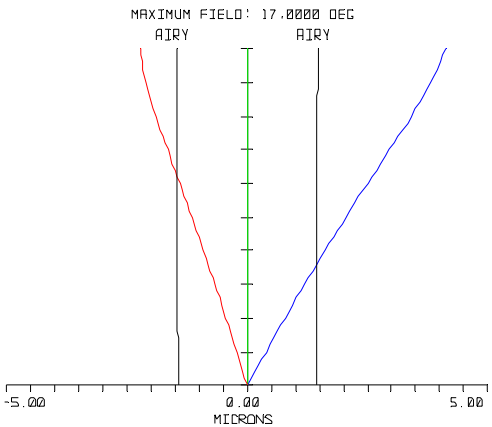
Optics

Energy Convergence

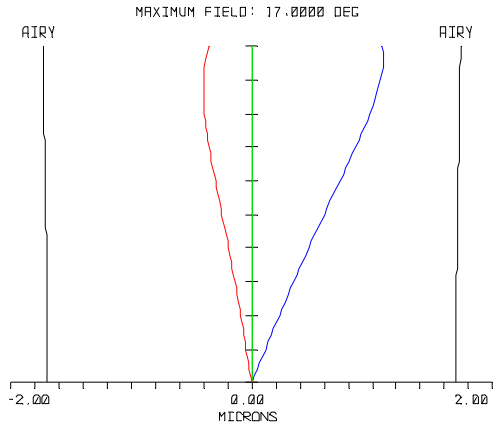


Optics

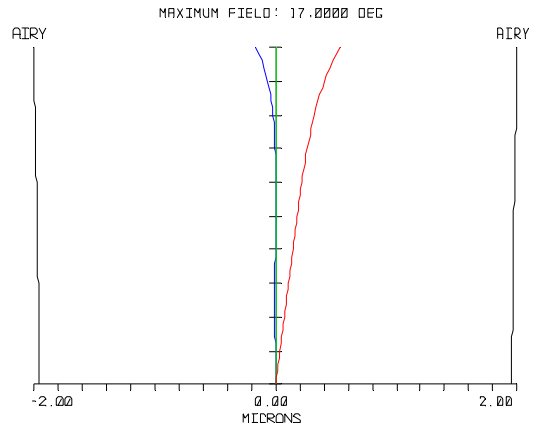
Chromatism



500~600nm



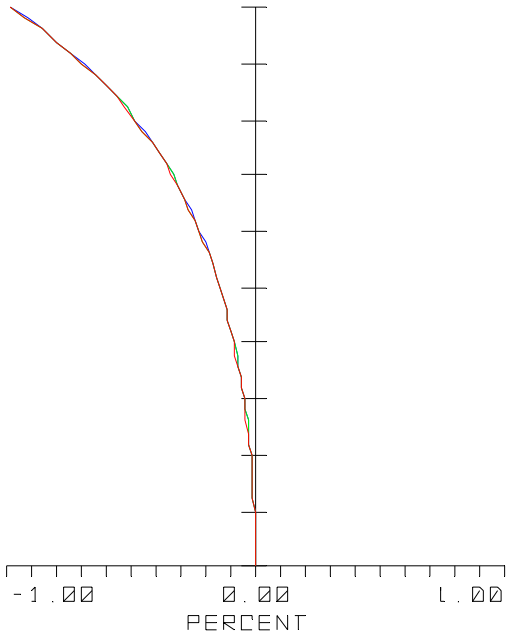
600~700nm



700~800nm

Optics

Distortion



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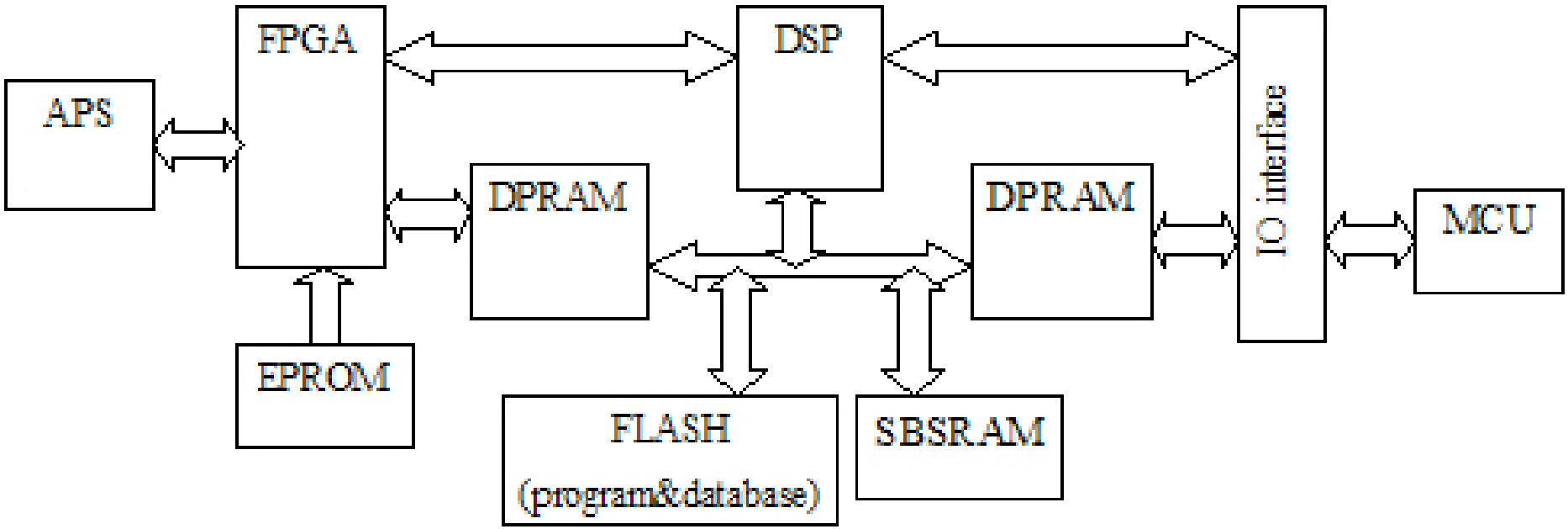
Electronics

1 : APS readout module
2 : Image filter and process module
3 : Threshold segmentation and process module
4 : Efficient data storage module
5 : Star spots data reconstruction module
6 : Star spots centroiding module
7 : Star pattern recognition module
8 : Attitude calculation module
9 : Host-computer communication module
10 : Catalog and database load module

Electronics



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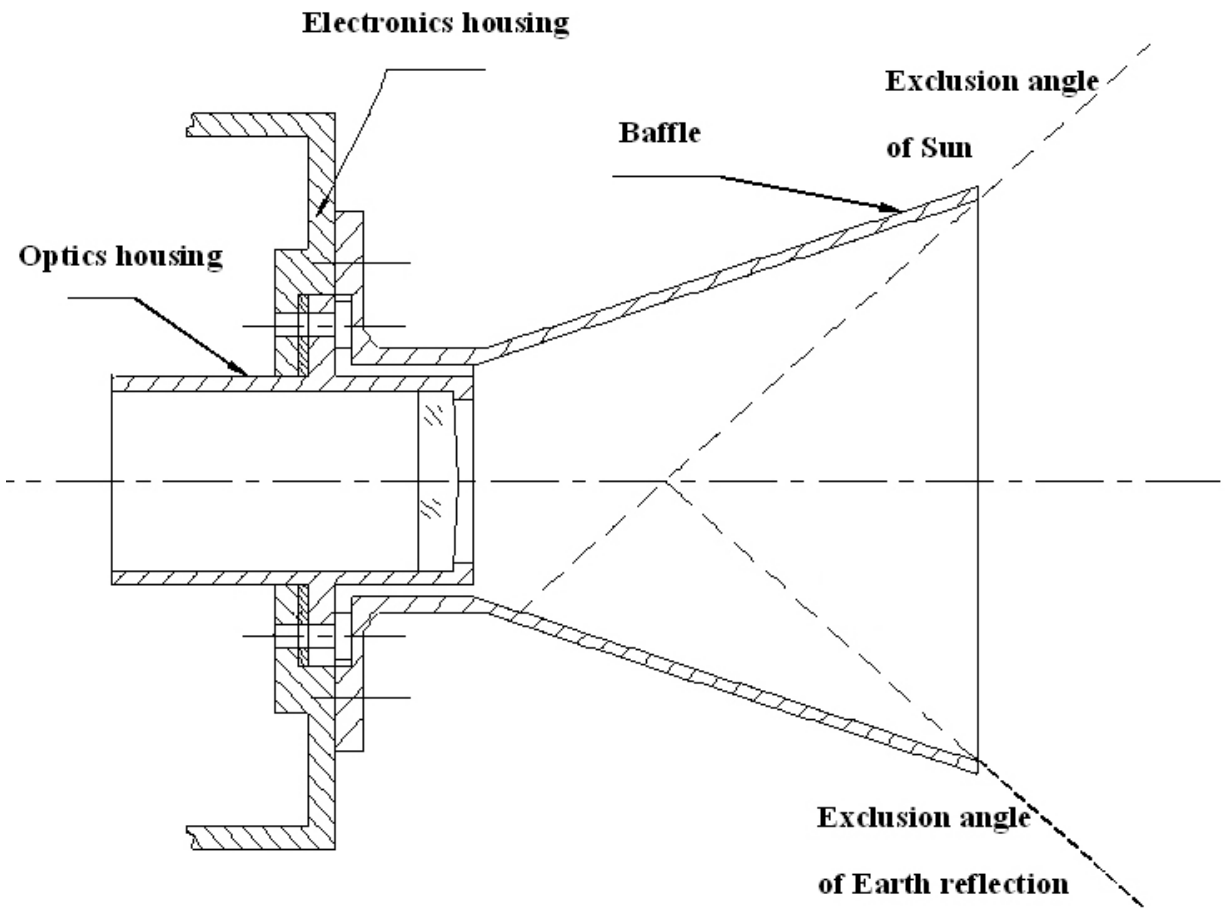
Package


Electronics housing
Exclusion angle
of Sun
Baffle
Optics housing
Exclusion angle
of Earth reflection

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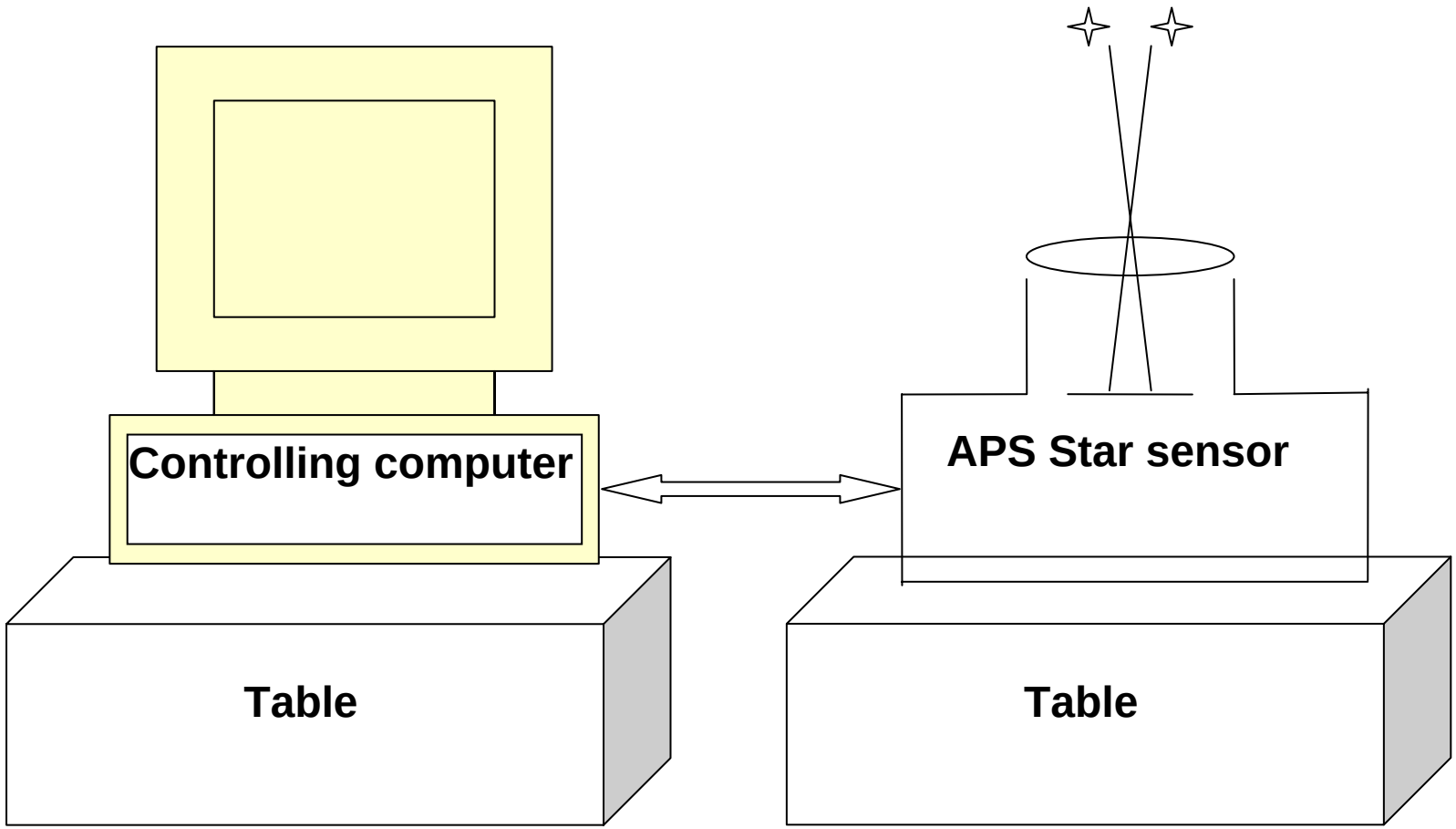
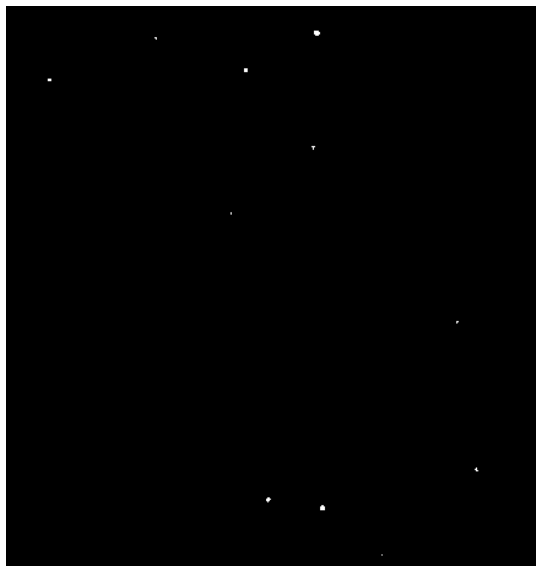
Tests

System configuration

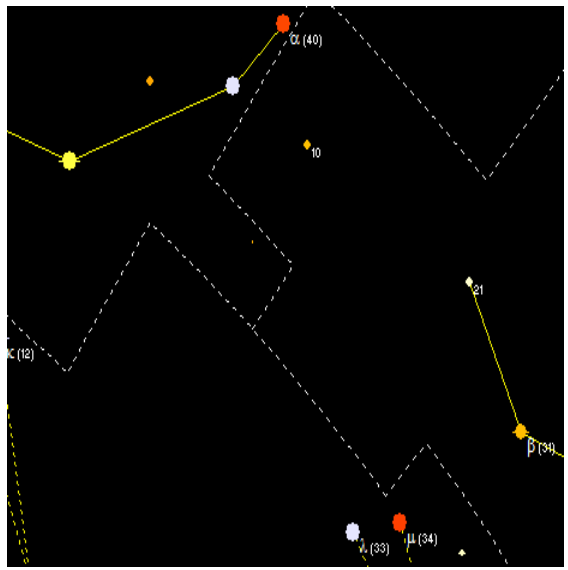


Tests

Hardware test results:



Real nigh sky image



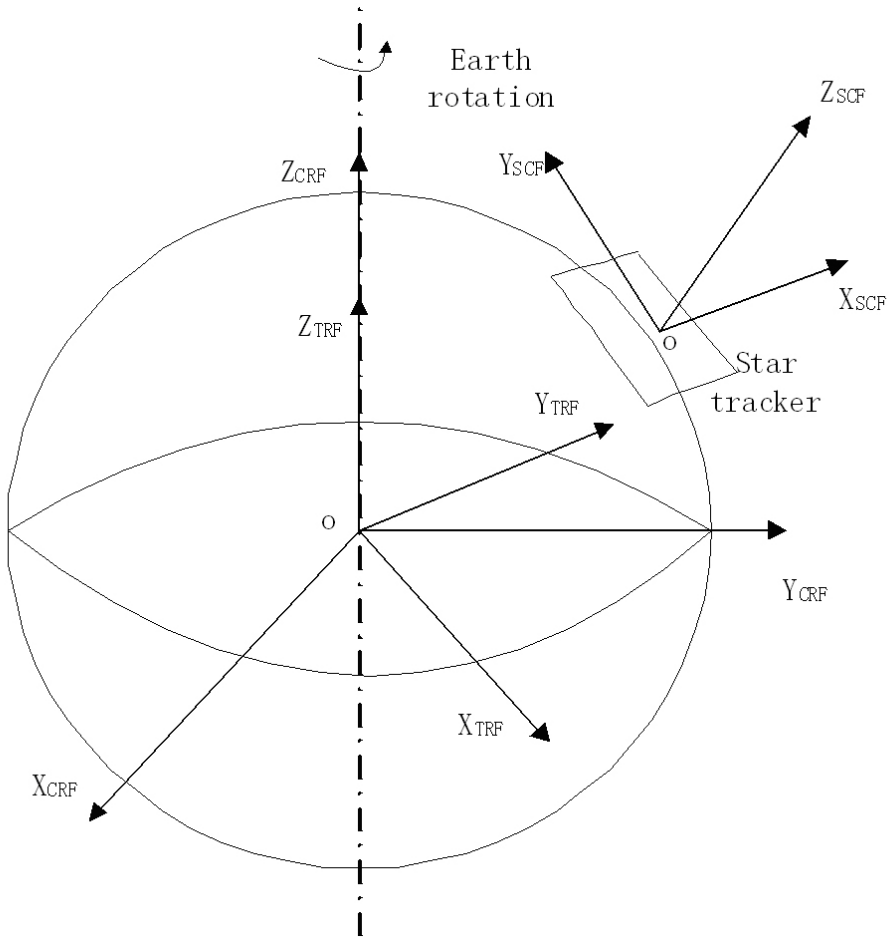
Corresponding Skymap image

5Mv magnitude sensitivity. Less than 3W power consumption. Less than 2s all sky attitude acquisition time. Up to 5Hz update rate

Tests

software test principle

$$\phi' = \arctan\left(-A_{S-C\,21} / A_{S-C\,22}\right) = \phi + \alpha$$
$$\theta' = \theta$$
$$\psi' = \psi$$



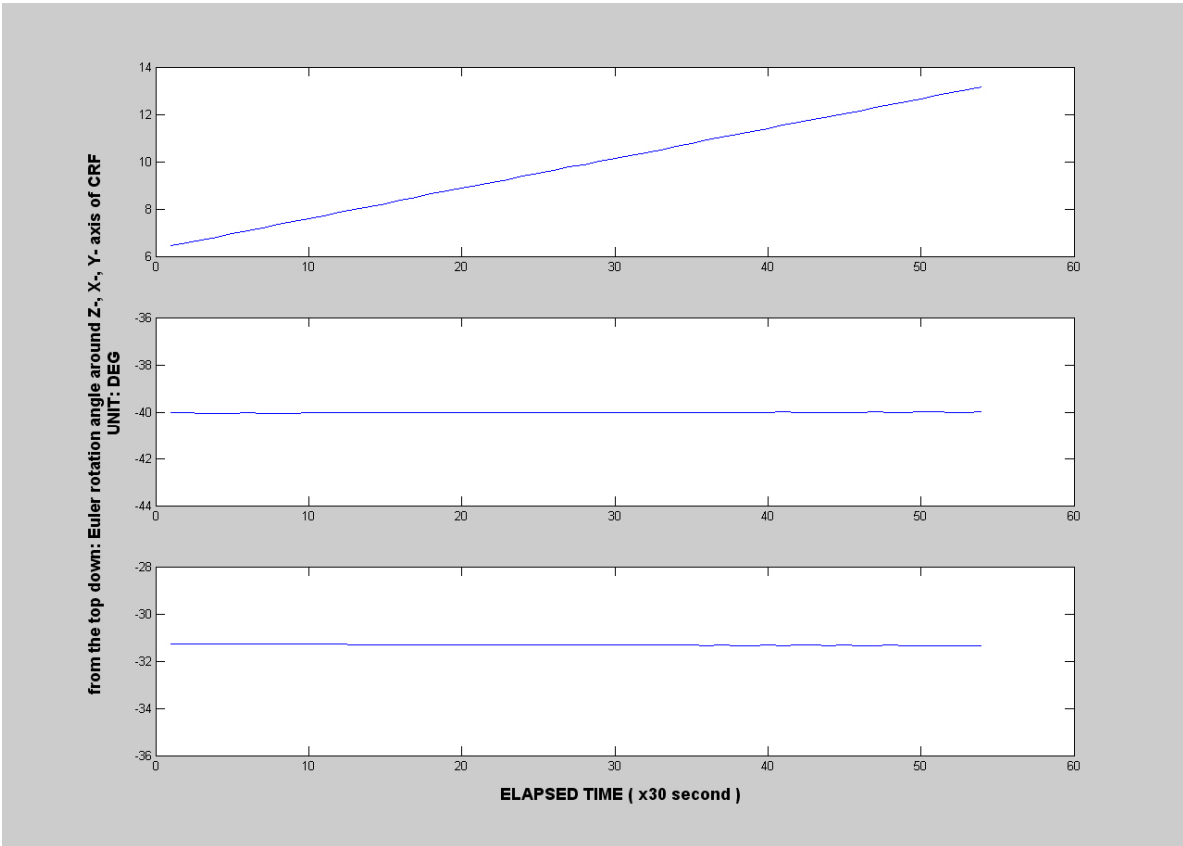
Tests

software test results

The rate of ϕ is calculated to be about 15°/hour

θ and ψ were invariable with 0.0057° and 0.0073° uncertainty

No identification failure had happened.



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Conclusion

- The concept of PSF based optical design, modularization strategy of electrical design, and compact package contribute to a small size, high rate, low power consumption and low cost star tracker
- New method of star tracker performances test uses Earth rotation as the reference instead of the expensive astronomical telescope
- Real night sky tests demonstrated that the circuit quality, magnitude sensitivity, location accuracy and sky coverage of the star tracker prototype could meet the requirements of a successful operation of autonomous star tracker