Ding Wang, Shuai Wei, Ying Wu, 2016. A performance analysis of multi-satellite joint geolocation. *Frontiers of Information Technology & Electronic Engineering*, **17**(12):1360-1387.
http://dx.doi.org/10.1631/FITEE.1500285

A Performance Analysis of Multi-Satellite Joint Geolocation

Key words: Satellite geolocation, Time difference of arrival (TDOA), Cramér-Rao bound (CRB), Calibration sources, Performance analysis

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Motivation

- Determining the position of an emitter on Earth by using a satellite cluster has many important applications, such as in navigation, surveillance and remote sensing.
- However, in realistic situations, a number of factors (such as errors in the measurement of signal parameters, uncertainties regarding the position of satellites, and errors in the location of calibration sources) are known to degrade the accuracy of target localization in satellite geolocation systems.
- A performance analysis of multi-satellite joint geolocation is needed.

Main idea

- The theoretical analysis starts with Cramér–Rao bound (CRB) derivations for four localization scenarios under an altitude constraint and Gaussian noise assumption.
- Two kinds of location mean-square errors (MSE) expressions under the altitude constraint are derived. The first location MSE provides the theoretical prediction when an estimator assumes the satellite locations are accurate but in fact have errors. The second location MSE provides the localization accuracy if an estimator assumes the known calibration source locations are precise when in fact they are erroneous.

Method

1. The performance analysis is based on the first-order perturbation analysis and Lagrange method.

2. Matrix theory is used to compare the performance.

3. Simulation results are used to verify the theoretical analysis of this paper.

Major results

- Scenario 1 In absence of satellite position errors

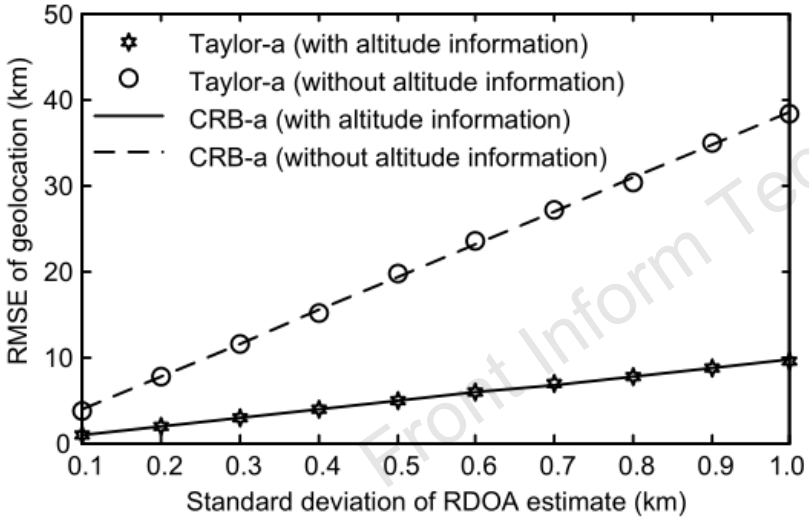

Fig. 1 RMSEs of geolocation versus standard deviations of RDOA estimates (geosynchronous satellite)

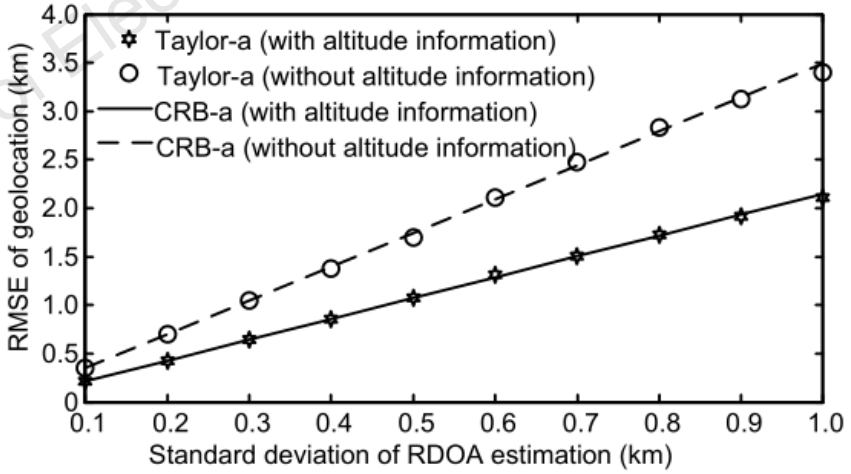

Fig. 2 RMSEs of geolocation versus standard deviations of RDOA estimates (LEO satellite)

Major results

- Scenario 2　In the presence of satellite position errors and absence of calibration sources

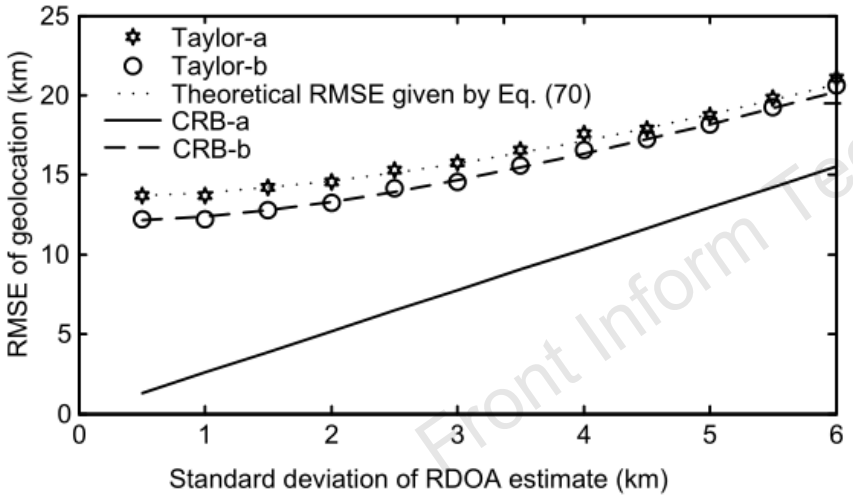

Fig. 3 RMSEs of geolocation versus standard deviations of RDOA estimates

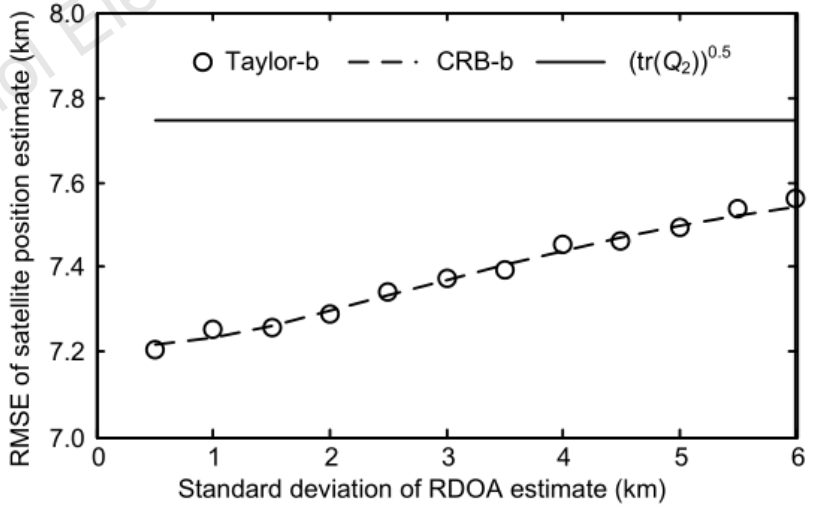

Fig. 4 RMSEs of satellite position estimates versus standard deviations of RDOA estimate

Major results

- Scenario 2 In the presence of satellite position errors and absence of calibration sources

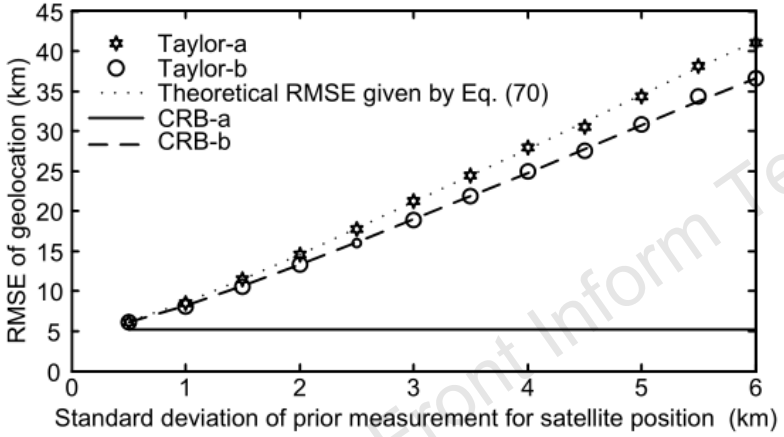

Fig. 5 RMSEs of geolocation versus standard deviations of prior measurements for satellite position

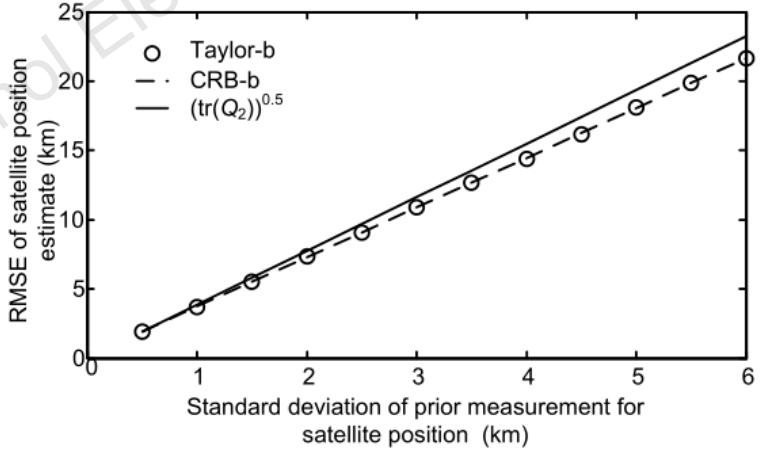

Fig. 6 RMSEs of satellite position estimates versus standard deviations of prior measurements for satellite position

Major results

- Scenario 2 In the presence of satellite position errors and absence of calibration sources

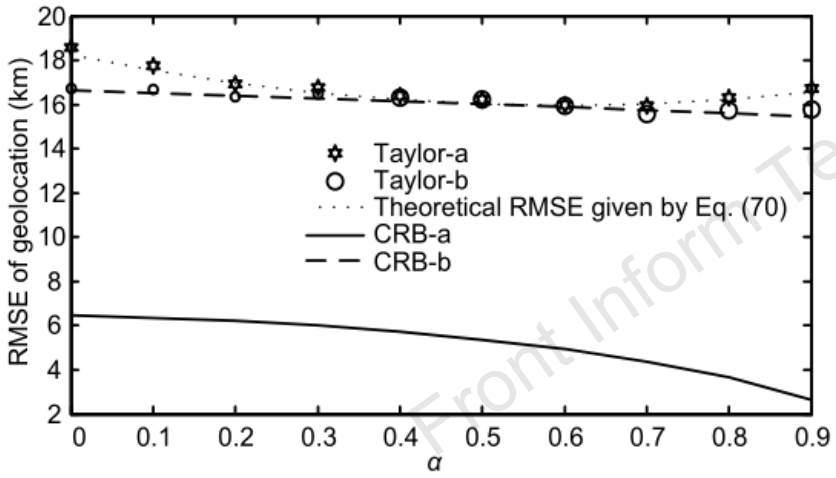

Fig. 7 RMSEs of geolocation versus α

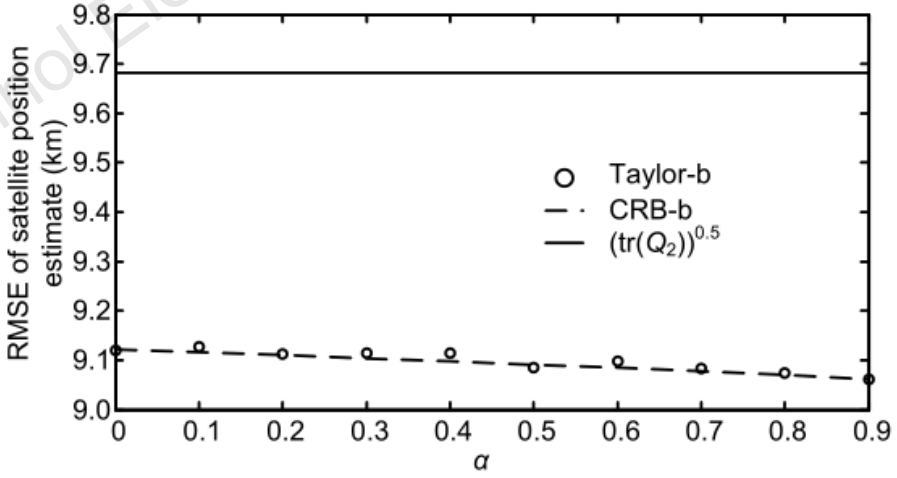

Fig. 8 RMSEs of satellite position estimates versus α

Major results

- Scenario 3 In the presence of calibration sources at accurate locations

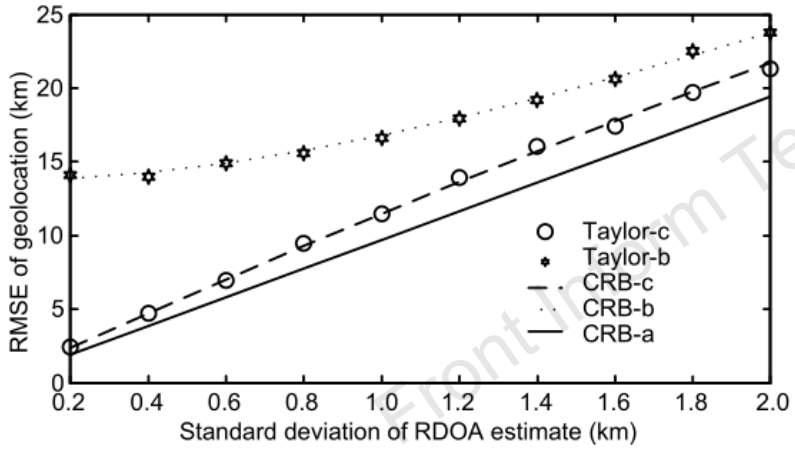

Fig. 9 RMSEs of geolocation versus standard deviations of RDOA estimates

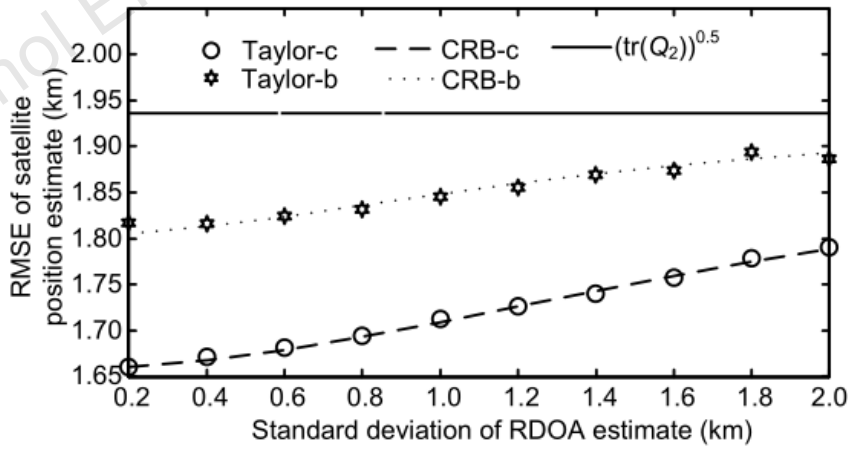

Fig. 10 RMSEs of satellite position estimates versus standard deviations of RDOA estimate

Major results

- Scenario 3 In the presence of calibration sources at accurate locations

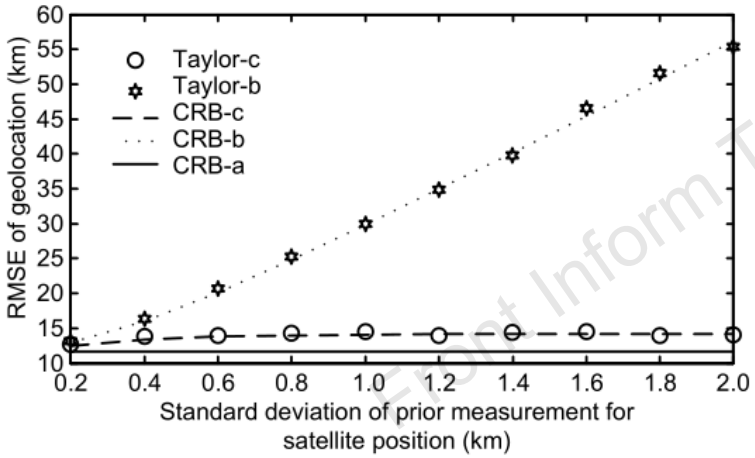

Fig. 11 RMSEs of geolocation versus standard deviations of prior measurements of satellite position

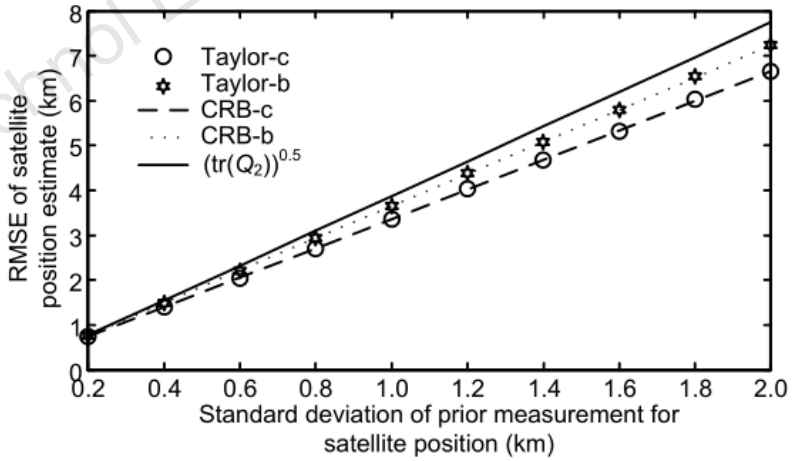

Fig. 12 RMSEs of satellite position estimates versus standard deviations of prior measurements for satellite position

Major results

- Scenario 4 In the presence of calibration sources at inaccurate locations

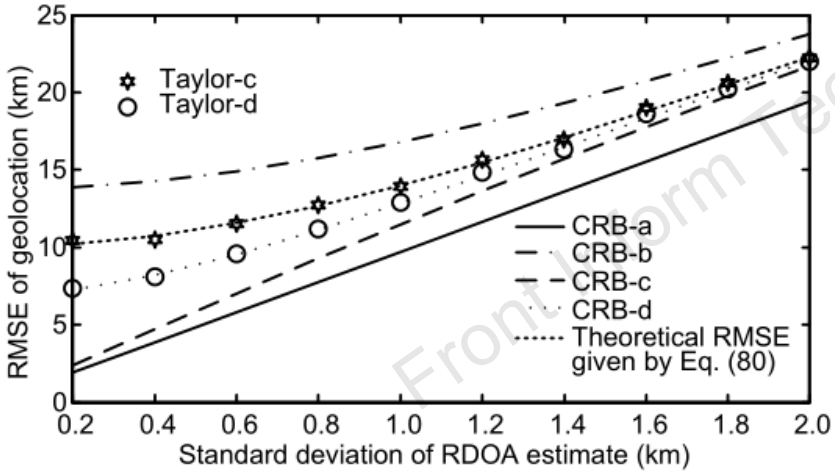

Fig. 13 RMSEs of geolocation versus standard deviations of RDOA estimates

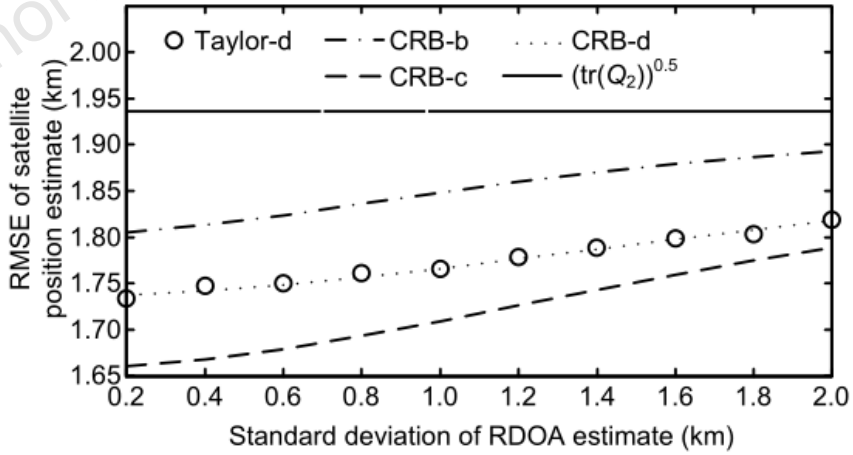

Fig. 14 RMSEs of satellite position estimates versus standard deviations of RDOA estimates

Major results

- Scenario 4 In the presence of calibration sources at inaccurate locations

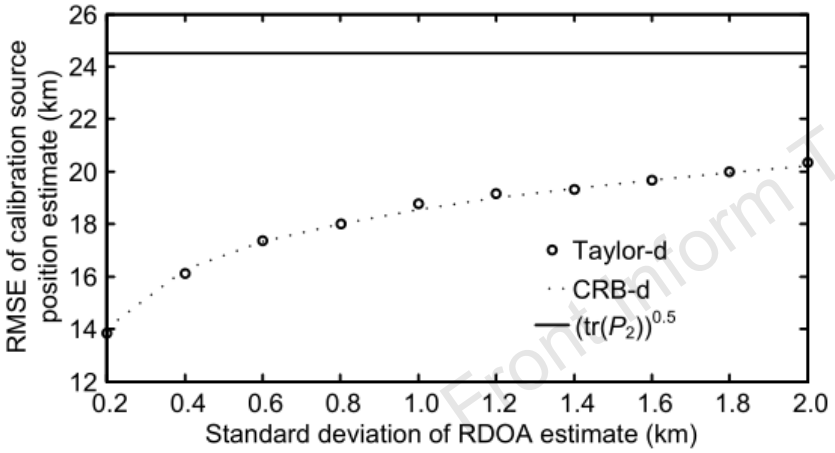

Fig. 15 RMSEs of calibration source position estimates versus standard deviations of RDOA estimates

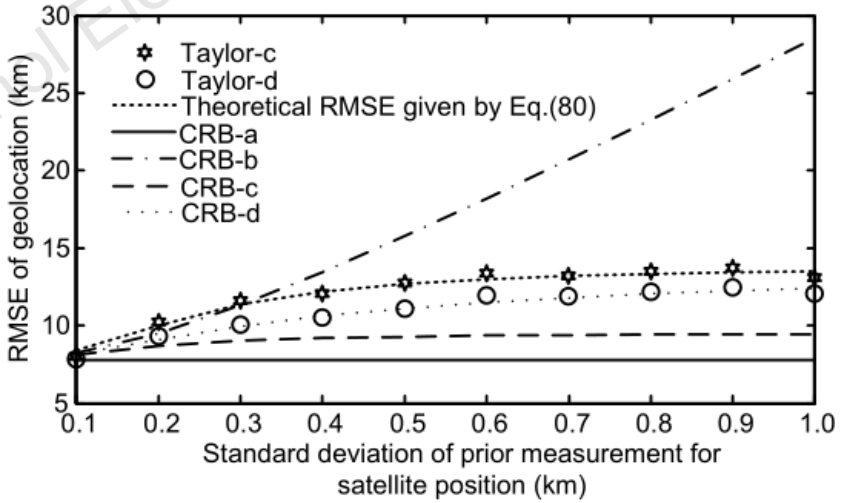

Fig. 16 RMSEs of geolocation versus standard deviations of prior measurements of satellite position

Major results

- Scenario 4 In the presence of calibration sources at inaccurate locations

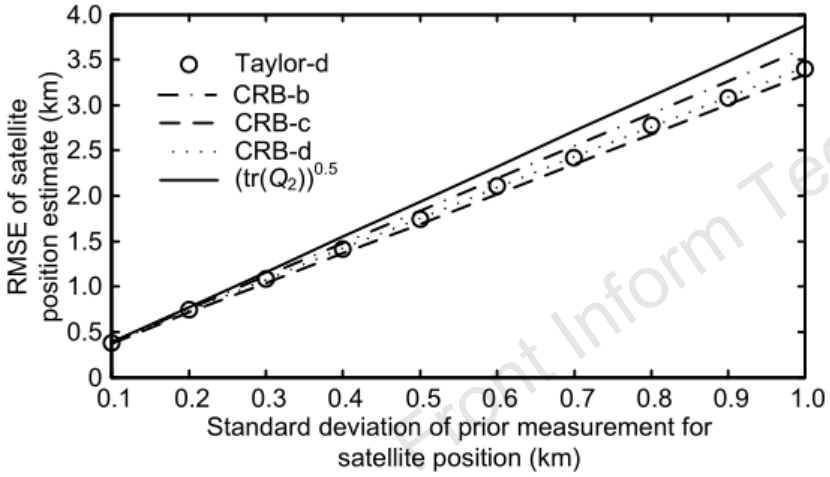

Fig. 17 RMSEs of satellite position estimates versus standard deviations of prior measurements for satellite position

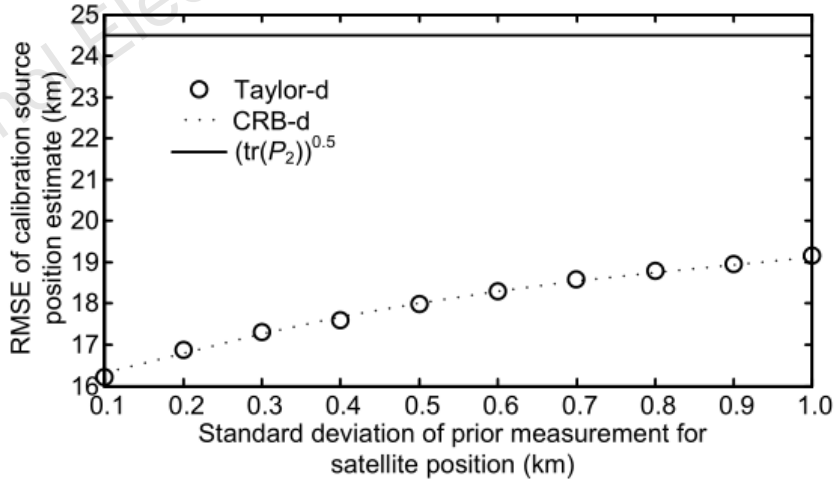

Fig. 18 RMSEs of calibration source position estimates versus standard deviations of prior measurements of satellite position

Major results

- Scenario 4 In the presence of calibration sources at inaccurate locations

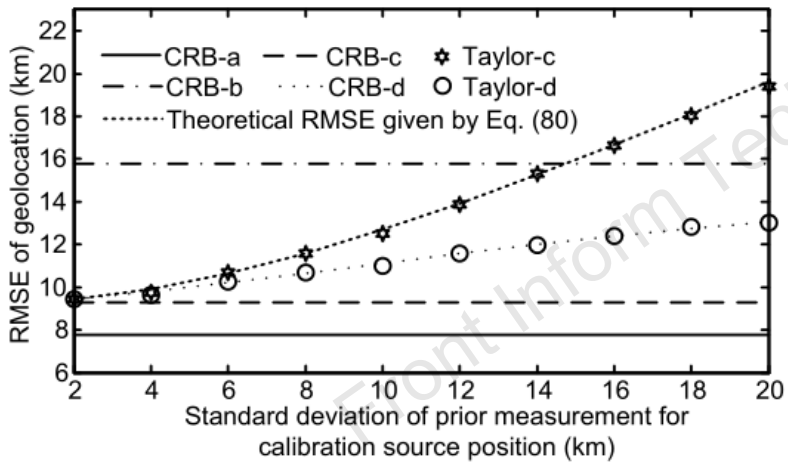

Fig. 19 RMSEs of geolocation versus standard deviations of prior measurements of calibration source position

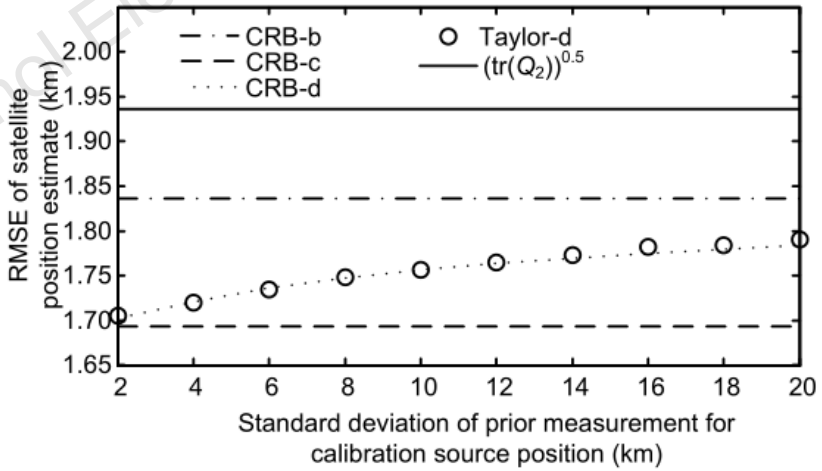

Fig. 20 RMSEs of satellite position estimates versus standard deviations of prior measurements of calibration source position

Major results

- Scenario 4 In the presence of calibration sources at inaccurate locations

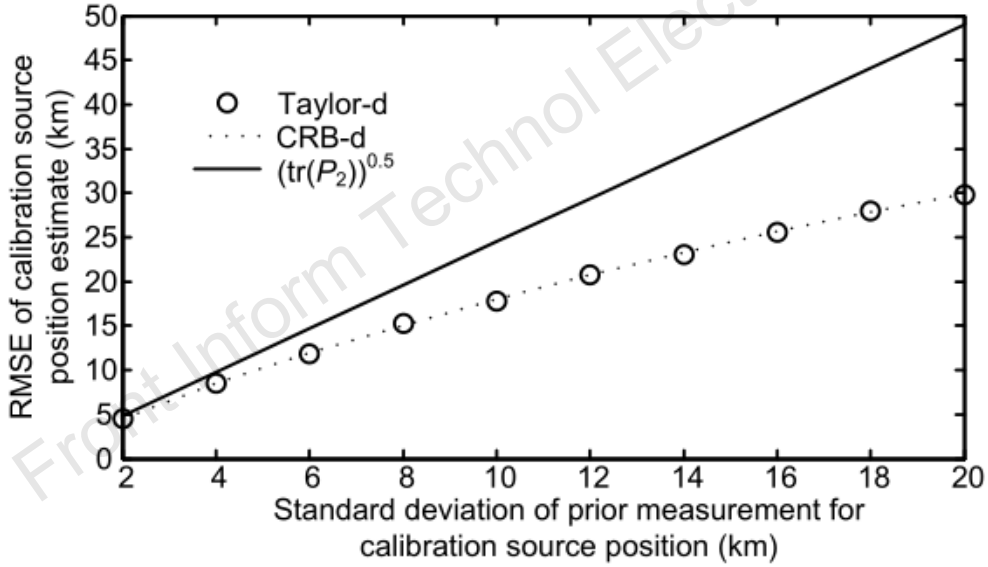

Fig. 21 RMSEs of calibration source position estimates versus standard deviations of prior measurements for calibration source position

Conclusions

- By comparing the CRBs of the four localization scenarios stated above, some insights into the effects of various error sources on localization performance can be obtained.
- The amount of reduction in accuracy of localization due to the ignorance of satellite and calibration source location errors is quantified.
- A variety of simulation experiments are reported that demonstrate the effectiveness of the theoretical analysis in this paper.