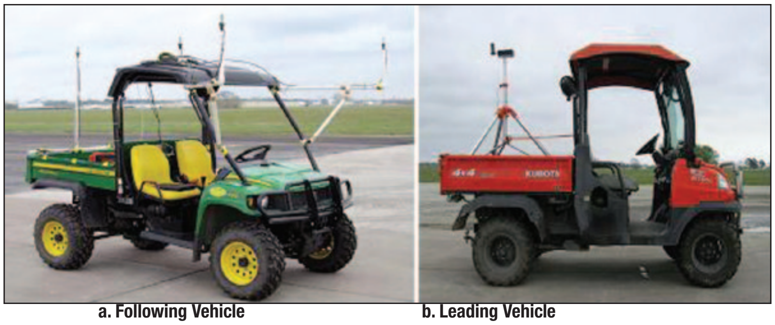
Ultra-Wideband Tracking System Design for Relative Navigation

Jianjun (David) Ni, *Johnson Space Center*
Dickey Arndt, *Johnson Space Center*
Phong Ngo, *Johnson Space Center*
Kent Dekome, *Johnson Space Center*
John Dusl, *Johnson Space Center*
Jodi Graf, *Johnson Space Center*

This report briefly discusses a design effort for a prototype Ultra-Wideband (UWB) Time-Difference-of-Arrival (TDOA) Tracking System that is currently under development at NASA Johnson Space Center (JSC). The system is being designed for use in localization and navigation of a rover in a Global Positioning System-deprived environment for surface missions. In one application enabled by the UWB tracking, a robotic vehicle carrying equipments can autonomously follow a crewed rover from work site to work site such that resources can be carried from one landing mission to the next, thereby saving up-mass. The UWB Systems Group at JSC has developed a UWB TDOA High-Resolution Proximity Tracking System that can achieve sub-inch tracking accuracy of a target within the radius of the tracking baseline. A tracking system is being designed and tested to enable relative navigation between two vehicles for surface missions by extending the tracking capability beyond the radius of the tracking baseline.



a. Following Vehicle b. Leading Vehicle

Fig. 1. *Ultra-Wideband Time-Difference-of-Arrival Tracking System configuration for relative navigation.*

System Design

In a general mission operation scenario, the crewed rover is the leading vehicle and the robotic equipment rover is the following vehicle. To autonomously follow the leading vehicle, the following vehicle needs the accurate relative position information of the leading vehicle with an adequate update rate according to the relative velocity between two vehicles.

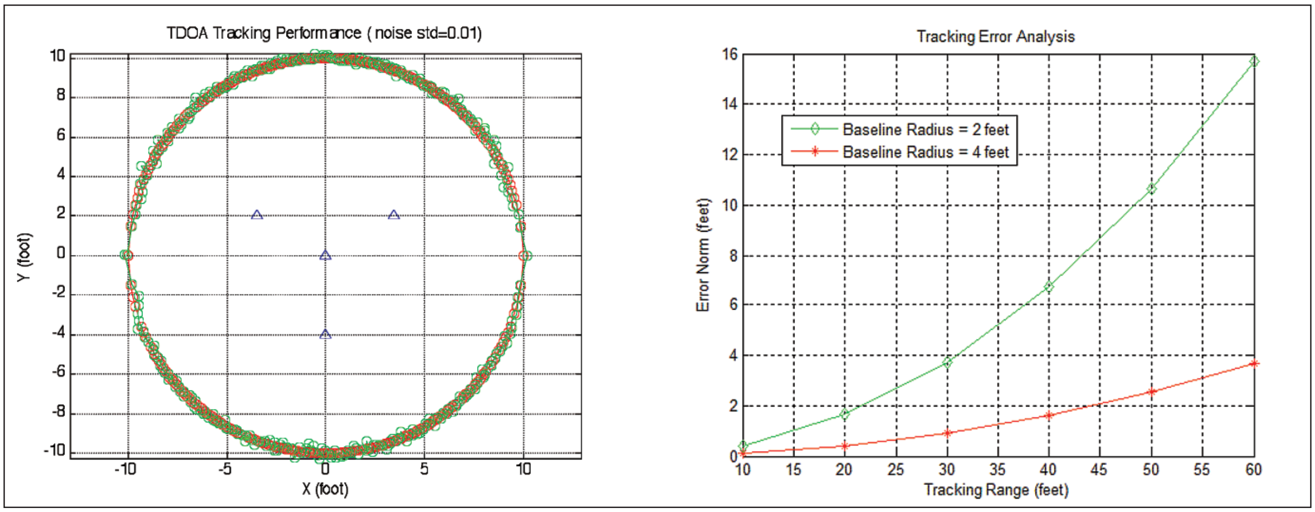
For this prototype design (figure 1), one UWB P210 transmitting radio with an omni antenna is mounted on the leading vehicle; a one-radio, four-antenna configuration is used on the following vehicle to eliminate the synchronization issue among receivers. Four receiving antennas are connected to one UWB radio receiver through a power combiner. A TDOA tracking algorithm is adopted to avoid the synchronization between transmitter and receiver. A signal processing technique—Cross-Correlation plus Peak-Detection—was developed to enable robust TDOA estimate in a noisy multipath environment. With received signals processed using the TDOA estimation algorithm, the position of the leading vehicle can be tracked. The tracking data are used by the following vehicle for autonomous control.

Performance Analysis

The UWB TDOA High-Resolution Proximity Tracking System can achieve sub-inch tracking accuracy of a target within the radius of the tracking baseline. To analyze the tracking error behavior and gain some insight regarding achievable tracking resolution when the target is outside of the baseline, the group performed simulations using the same TDOA tracking algorithm with tracking range greater than the baseline radius. The simulation results in figure 2 show that the TDOA tracking error is proportional to the square of the ratio (R/r), where "R" is the tracking range and "r" is the radius of baseline. By choosing the baseline radius of 1.2 m (4 ft), a tracking error about 1.16 m (~3.8 ft) can be achieved at range of 18 m (60 ft) while a tracking error about 0.03 m (~0.1 ft) can be achieved at range of 3 m (10 ft). Hence, this tracking performance behavior (more accurate when two vehicles get closer) is feasible for the application of vehicle following.

Ultra-Wideband Tracking System Design for Relative Navigation

continued



a. Tracking Scenario **b. Tracking Error Analysis**

Fig. 2. *Ultra-Wideband Time-Difference-of-Arrival Tracking System performance outside of baseline.*

Field Test

The field test of this tracking prototype system has been conducted at the antenna range behind Building 14 at JSC. The tests show that the UWB Tracking System at the following vehicle can track the leading vehicle in real time with a update rate of 1 Hertz (Hz) by running the experimental code. It is anticipated that the update rate can be improved greater than 5 Hz with immigrants to the application code.

Conclusion

A prototype UWB TDOA Tracking System has been designed, implemented, tested, and proven feasible for relative navigation of robotic vehicles. Future work includes testing the system with the application code to increase the tracking update rate, and evaluating the linear tracking baseline to improve the flexibility of antenna mounting on the following vehicle.