Ultra-Wideband Two-Cluster Tracking System Design with Angle of Arrival Algorithm

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Abstract

This paper describes a design effort for a prototype ultra-wideband (UWB) tracking system that is currently under development at NASA Johnson Space Center (JSC). The system is being studied for use in tracking of lunar/Mars rovers during early exploration missions when satellite navigation systems are not available. The UWB technology is exploited to implement the tracking system due to its properties such as high data rate, fine time resolution, low power spectral density and multipath immunity. A two-cluster prototype design using commercially available UWB products is proposed to implement the Angle Of Arrival (AOA) tracking methodology in this research effort. Simulations show that the AOA algorithm can achieve the fine tracking resolution with low noise Time Difference Of Arrival (TDOA) estimates. The outdoor tests demonstrate the UWB tracking feasibility.

Tracking Methodology and System Design

An AOA technique using TDOA information is utilized for location estimation in the prototype system, not only to exploit the precise time resolution possible with UWB signals, but also to eliminate the need for synchronization between the transmitter and the receiver. This Two-Cluster AOA tracking methodology in a two dimensional space is illustrated in Figure 1. After The UWB radio at each cluster is used to obtain the TDOA estimates from the UWB signal sent from the target, the TDOA data are converted to AOA data to find the angle of arrival assuming this is a far filed application, i.e. r1, r2 >> d. Since the distance between two clusters is known, the target position is computed by a simple triangulation.

Time Domain Corporation UWB radios P200 were chosen as transmitter and receivers for this design effort. A cross-correlation procedure has been implemented in the prototype system to estimate the time delay between the two received UWB pulses for each cluster. Cross-correlation between the two direct-path arrivals is employed to estimate the precise time delay between the signals. The maximum cross-correlation coefficient between two of the arriving signals gives the optimal (maximum-likelihood) estimate of the time delay between the two. In order to extend the tracking range, high gain (17 dB) horn antennas and low noise amplifiers are used at the receiver side to boost the received signal.

Simulation and Outdoor Test Results

In order to transform TDOA estimates to AOA data, a far field assumption (r1, r2 >> d so that the lines from the target to two antennas in each cluster are approximately parallel) is made. The simulated tracking error due to the approximation is plotted in Figure 2 for a chosen 2D semi-sphere tracking setting (a=50m, d=15m, range r=610m). A similar simulation with noisy TDOA estimates (standard derivation 10 picoseconds) is conducted and the error analysis is illustrated in Figure 3. The simulation shows that the average tracking error at range of 610 meters is 2.7595 meters, less than 0.5% of the tracking range.

Outdoor tests to track the SCOUT vehicle (a prototype Lunar/Mars rover under development at JSC) near the Meteor Crater, Flagstaff, Arizona were performed on September 12-13, 2005. Figure 4 shows the Two-Cluster baseline setting and Figure 5 shows the tracking target SCOUT vehicle with on-board UWB radio as the transmitter. The tracking performance was obtained with less than 1% tracking error at ranges up to 2000 feet. No RF interference with on-board GPS, video, voice and telemetry systems was detected. The outdoor tests demonstrate the UWB tracking capability.

Figures

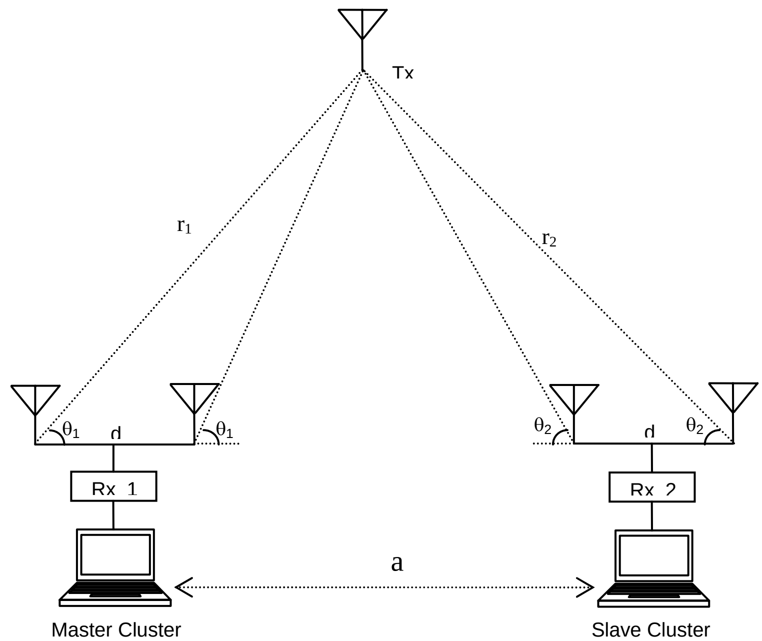

Fig. 1 Two-Cluster AOA Tracking Methodology

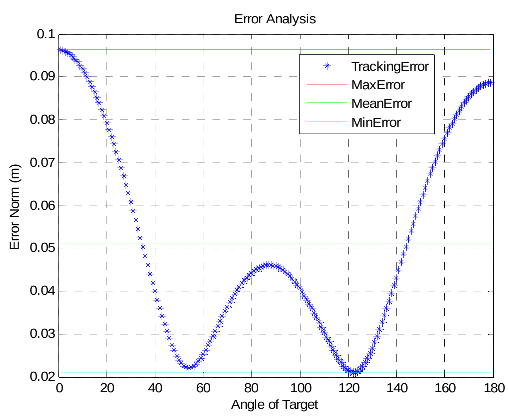

Fig. 2 Tracking error with perfect TDOA estimates

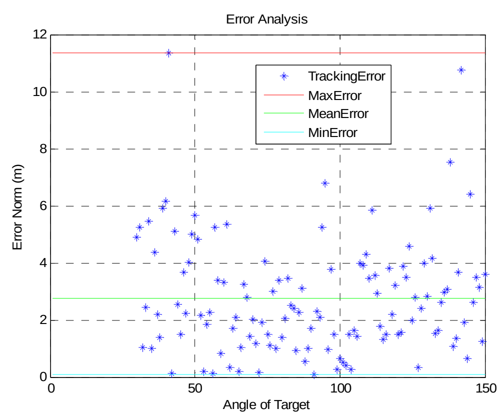

Fig. 3 Tracking error with noisy TDOA estimates

Fig. 4 Two-Cluster Tracking Baseline

Fig. 5 Tracking Target – SCOUT vehicle