UWB Two-Cluster AOA Tracking Prototype System Design

Abstract

This presentation discusses 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 fine time resolution, low power spectral density and multipath immunity. A two-cluster prototype design using commercially available UWB radios is employed to implement the Angle of Arrival (AOA) tracking methodology in this design effort. In order to increase the tracking range, low noise amplifiers (LNA) and high gain horns are used at the receiving sides. Field tests were conducted jointly with the Science and Crew Operation Utility Testbed (SCOUT) vehicle near the Meteor Crater in Arizona to test the tracking capability for a moving target in an operational environment. These tests demonstrate that the UWB tracking system can co-exist with other on-board radio frequency (RF) communication systems (such as Global Positioning System (GPS), video, voice and telemetry systems), and that a tracking resolution less than 1% of the range can be achieved.
UWB Two-Cluster AOA Tracking Prototype System Design

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Outline

- Motivation (Tracking for Space Exploration)
- Prototype System Design Overview
- System Design Philosophy
- Key Hardware – UWB PulsON 200 Radios
- Laboratory Experiment to Test CCPD (Cross-Correlation Peak Detection)
- Methods to Increase the Tracking Range
- Field Tests with SCOUT Vehicle
- Conclusion and Future Work
Tracking for Space Exploration

- Tracking rovers and astronauts for early Lunar/Mars exploration missions when navigation satellites are not available.

- SCOUT vehicle as testbed for Lunar/Mars rover prototype.
UWB Fine Time Resolution

Sinusoidal, Narrowband

Impulse, Ultra-Wideband
Two Cluster Design

\[ c\tau_{12} \approx a \cos \theta_1 \]

\[ \theta_1 \approx \arccos \left( \frac{c\tau_{12}}{a} \right) \]

\[ c\tau_{43} \approx a \cos \theta_2 \]

\[ \theta_2 \approx \arccos \left( \frac{c\tau_{43}}{a} \right) \]

Far Field Assumption: \( r_1, r_2 \gg a \)
Advantages of Using TDOA Data

- No synchronization between Tx and Rx
- Simplex (one-way) data estimation
- Cross-correlation works well to obtain TDOA (Time Difference of Arrival)
Lab Experiments (UWB PulsON 200 Radio)

- Signal Generator
- Evaluation Kit
PRF (Pulse Repetition Frequency): 9.6 MHz
8 data rates: 75 kbps, 150 kbps, ..., 4.8 Mbps, 9.6 Mbps
Center Frequency (radiated): approximately 4.7 GHz
Bandwidth (10 dB radiated): 3.2 GHz
EIRP: -11.5 dBm
Co-exists with all US-based wireless systems (including GPS)
Superior multipath immunity as a result of UWB-physics
Fine resolution tracking
FCC Compliant - FCC 15.517, 15.209
Diamond Dipole Antenna
StrongARM TM Microprocessor for Embedded Applications Development
Lab Experiments (setup)
Lab Experiments (Four Antenna Scheme)
Two-Cluster Tracking Baseline

Cluster 1

LNA ~+33dB

Splitter -3dB

horn antennas x 4

LNA ~+33dB

I2

3Com Office Connect Hub

P200 -41dBm/MHz

Cluster 2

LNA ~+33dB

Splitter -3dB

I2

P200 -41dBm/MHz

Dell Laptop
Test Site (Arizona Meteor Crater)
Two-Cluster Tracking Baseline Set-up
Tracking Target (SCOUT)
Tracking Results (Accuracy)

Accuracy Comparison: GPS vs. UWB System

Accuracy Comparison: GPS vs. UWB System

X-Axis Distance (feet)

Y-Axis Distance (feet)
Tracking Results (Trajectory)

Trajectory: UWB System tracking the SCOUT vehicle
Conclusion

- A UWB AOA Two-Cluster tracking scheme has been established.
- The lab experiments show that CCPD technique can obtain fine TDOA estimates.
- The UWB tracking system can co-exist with other RF communication systems on-board SCOUT.
- A tracking resolution less than 1% of the range (range up to 2000 feet) has been successfully demonstrated.
- A moving target can be tracked in real time (update rate=3Hz).
- The field tests demonstrate the tracking capability of the UWB technology.
Future Work

- High data rate communications (480 Mbps) for EVA and IVA crew communications (video, voice, command, telemetry.)
- Integration of comm. and tracking system
- UWB RFID for ISS inventory tracking
- UWB Software Defined Radio Design
- Ground penetrating radar for planet exploration