Ultra-Wideband Time-Difference-Of-Arrival Two-Point-Tracking System

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Outline

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- TDOA Tracking Methodology
- Analytical Tracking Resolution
- Fine Time Resolution of UWB Pulses
- Lab Tests of the Prototype System
- Summary
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Motivation

- UWB TDOA high resolution proximity Tracking System (developed at JSC) provides sub-inch tracking resolution for Honeywell’s robotic control system [1].
- This system can be enhanced with two-point-tracking capability and applied to the docking process of the Lunar rover Chariot for the battery charging.
Time Difference of Arrival (TDOA)

Hyperbola: \( b^2 x^2 - a^2 y^2 = a^2 b^2 \)
Time Difference of Arrival (TDOA)

Rx1
(x1, y1)

Rx2
(x2, y2)

Rx3
(x3, y3)

Tx
(x, y)
Advantages of TDOA

- No synchronization between Tx and Rx
- Simplex (one-way) data estimation
- TDOA estimates can be obtained through Cross-Correlation plus Peak Detection (CCPD)
Proximity High Resolution [1]

\[
\text{MSE} \approx 4c^2 \sigma^2
\]

\[
\bar{\varepsilon} = 2c\sigma
\]

\[
c = 3 \times 10^8 \text{ m/s}
\]

\[
\sigma = 10^{-9} \text{ s} = 1 \text{ ns}, \quad \bar{\varepsilon} = 0.6 \text{ m}
\]

\[
\sigma = 10^{-11} \text{ s} = 10 \text{ ps}, \quad \bar{\varepsilon} = 0.006 \text{ m}
\]
A ultra wideband device is defined as any device where the fractional bandwidth is greater than 0.20 or occupies 500 MHz or more of spectrum.
Why UWB?

- Immunity to interference from narrow band RF systems due to ultra-wide bandwidth
- Low impact on other RF systems due to extremely low power spectral densities
- Capable of precise tracking due to sub-nanosecond time resolution
- Robust performance in multipath environments
- High data rate communication (100 Mbps and higher)

Sinusoidal, Narrowband

Impulse, Ultra-Wideband

Resolving between direct vs. multipath components is possible with extremely narrow UWB pulses

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System Configuration

UWB TDOA Two-Point-Tracking System Configuration

Docking Port

Mobile Rover Transmitter

Omni Antenna 1

LNA

UWB "B"

UWB "A"

P210 UWB XNTR

4-way Combiner

P210 UWB RCVR Radio

Omni Antenna 2

LNA

802.11

Laptop 1

Laptop 2 Tranceiver Processor

Hub

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TDOA Proximity Tracking (1Rx4A set-up)
TDOA Estimate (from 8 pulses)
Docking Process Guided by Two-Point-Tracking
Summary

- A UWB TDOA Two-Point-Tracking System has been conceived and developed at JSC.
- This system can provide sub-inch tracking capability of two points on one target.
- This capability can be applied to guide a docking process in a 2D space.
- Lab tests demonstrate the feasibility of this technology.
Future Work

Future work includes expanding the tracking area to the size of Chariot docking site and test the docking process with the actual dimension of the Chariot battery charging station.