Tag Localization in Passive UHF RFID

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This work has been funded by NXP Semiconductors and by the Austrian research promotion agency (FFG).
Outline

Introduction and Motivation

Ultra-Wideband Ranging
  Measurement Setup
  Ranging Performance

The UHF RFID Channel (Warehouse Portal)
  Ranging/Localization: Find the LOS
  Wave Propagation
  Backscatter Channel Parameters

Reducing the Bandwidth: Wideband and Narrowband Ranging
  Wideband FMCW Ranging
  Narrowband CW Ranging

Conclusion
UHF RFID Tag Localization ...
UHF RFID Tag Localization ... Why?

Intermec Technologies, Wikimedia (Kay-Uwe Rosseburg)
UHF RFID Tag Localization

Why?

1. mobile: detect + identify + localize
2. fixed (portal): read zone management
   ▶ identify false positive reads
   ▶ increase system reliability

How?
PASSIVE UHF RFID
How — Basically...

— direction finding —

- direction finding
  - direction/angle-of-arrival (AoA)
  - beamsteering (mechanically and electrically)

— range finding —

- range finding
  - time-(difference)-of-arrival (ToA, TDoA)
  - mapped to phase: phase-of-arrival
Why is it so difficult?

1. **Needed Accuracy**
   - 10 m error: airplane vs. tag

2. **System Properties**
   - constant tracking ($\geq$ min) vs. single communication (ms)

3. **Wireless Channel**
   - isolated reflection vs. dense multipath
   - clear skies vs. massive self-interference

Images: Wikimedia (Peripitus), Intermec Technologies
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Measurement Setup (Portal)

Basic Setup Description

- vector network analyzer, 0.5 – 1.5 GHz
- gain patterns and setup: UHF RFID portal
- two transmitters ("readers"), two receivers ("tags")
- metal backplanes, (absorber backplanes, no backplanes)
MEASUREMENT SETUP (PORTAL)

- backplanes (metal)
- TX1
- TX2
- tag antennas (RX)
LOCALIZATION – UWB ToA Ranging

IR-UWB ranging, \( B = 600 \text{ MHz} \) (metal backplanes):
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**CHANNEL – Localization Error**

- **required bandw.:**
  - CHANNEL
- **isolate LOS?**
  - yes
  - no
- **error [m]**
- **τ** (LOS delay)
- **B** (signal bandwidth)
- **CIR**
- **τ** (avg. group delay)

**Graphs:**
- **|CIR|^2**
  - LOS
  - delay
- **|CIR|^2**
  - LOS
  - delay

**Daniel Arnitz**

**UWB Forum**
**CHANNEL – Localization Error**

Required bandwidth:

- **CHANNEL**
- **LOS (LOS delay)**
- **grp (avg. group delay)**
- **LOS (LOS K-factor)**
- **RMS (RMS delay spread)**

(ultra-)wideband limiting: noise

narrowband limiting: multipath propagation
CHANNEL – Empty Portal

- massive multipath propagation
- multiple bounces (gate-gate)
CHANNEL – Packed Liquids

- extremely dense around LOS
- multiple bounces (pallet-gate)
**Channel – LOS Separable?**

In UHF RFID?

- on the products: $\leq 1$ cm
- ground/portal: $\approx 30$ cm

$\Rightarrow 500$ MHz UWB
CHANNEL – Backscatter Parameters

Line-of-sight K-Factor (metal backplanes, bottom-left TX)
CHANNEL – Backscatter Parameters

RMS delay spread (metal backplanes, bottom-left TX)
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Localization – Ultra-Wideband Ranging

IR-UWB ranging, $B = 600$ MHz (metal backplanes):
Localization – Wideband Ranging

FMCW ranging, $B = 150$ MHz (metal backplanes):
**Localization – Wideband Ranging**

FMCW ranging, $B = 80$ MHz (metal backplanes):

![3D plot showing localization results.](image)
LOCALIZATION – Narrowband Ranging

Phase-based CW ranging, $B = 1$ MHz (metal backpl.).
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Conclusion

Range error distribution:

- IR-UWB, 600MHz
- FMCW, 150MHz
- FMCW, 80MHz
- 2FCW, 1MHz

CDF

Absolute range error [m]

Narrowband 0  Wideband 0  Ultra-Wideband 1