Ultra Wideband Double-Directional Channel Measurements in an Office Environment

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Overview of our activities

- Channel modeling based on measured data
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• Impact of double-directional channel sounding activities with UWB signal
  1. For UWB systems:
     - Improvement of the current UWB channel models
     - Focus is to include spatial channel information
  2. For MIMO transmission:
     - Detailed investigation of the relation between MIMO capacity and physical phenomena
     - Possibility to cover wide frequency range

Final goal:
Antenna-independent channel models which are applicable both for UWB and MIMO systems with all operating frequencies
Double-directional channel

- Estimating both DOD and DOA enables us to separate antenna effects from channel model (M. Steinbauer et. al, 2001)
UWB double-directional measurements

- Measurement strategy
  - MISO/SIMO configurations = double directional meas.

**Diagram:**
- **SIMO**
  - Tx
  - Rx
  - DOA / DTOA estimation

- **MISO**
  - Tx
  - Rx
  - DOD / DTOA estimation

Connecting DOA and DOD information using DTOA
UWB channel sounding system

- Vector Network Analyzer & spatial scanner

- UWB antenna
  - Omni-directional monopole antenna
  - Flat group delay characteristics
  - Frequency sweeping from 3.1 to 10.6 GHz

- Synthetic array
  - 3-D (x-y-z) scanner and UWB antenna

- VNA

- PC
  - Data acquisition
  - Measurement control via GPIB

- Preamp (30dB)

- GPIB
Specifications of experiment

• Arrays
  – Spatial sampling: \(10 \times 10 \times 7\) points in \(xyz\) directions
  – Element spacing: 48 mm
  – Frequency range: 3.1 to 10.6 GHz
  
  \textit{Achieved 10 deg resolution of DOD / DOA azimuth angle, and 0.13 ns resolution of DTOA}

• Others
  – DOD / DOA / DTOA estimation algorithm: SAGE
  – Polarization: vertical-vertical
  – SNR at the receiver: at least 20 dB
  – Calibration: function of the VNA and back-to-back (antenna calibration)
Experiment in a meeting room

Ceiling: plaster board

Rx (1.0 m high)

Side wall: metal

Tx (2.0 m high)

Tx-Rx distance: 4.6m
The 10 strongest waves revealed that

1. Many reflected paths from the ceiling were detected
2. Multi-reflected waves were detected due to metal side walls
3. Path constitution was symmetric w.r.t. Tx-Rx line
Experiment in a meeting room

- Reflection from ceiling
  - Many metal pipes inside the plaster board
  - Metal parts of room lights
Experiment in an office

Plaster board

Tx
(2.0 m high)

Rx
(1.0 m high)

LOS is assured
Tx-Rx distance: 7.5m
Experiment in an office

- Detected waves revealed that
  1. Reflections from office desks, equipment and floor are few
  2. Reflections from windows and far wall are few
  3. The 10 strongest waves are first-order reflections on metal furniture or direct path
Observations of the results

- Initial findings from the experiment
  1. Reflection occurs on metal wall, furniture, and pipes inside the ceiling
  2. Reflection from ceiling is much stronger than those from the floor
  3. Reflections from windows are few
  4. Office environment reveals complicated propagation phenomena than residential environment due to metal structures of buildings
  5. Specular reflection contains stronger power than non-specular scattering
  6. Higher-order specular reflection still have strong power in the meeting room due to metal walls
Summary and future works

- UWB double-directional channel sounding in the meeting room and office
  - Channel sounding procedure
  - Initial findings from measurements

- Future works
  1. Quantitative analyses of channel behavior
     - Cluster analyses
     - Reflection coefficients
  2. Channel modeling based on the results
  3. Modeling of the residual components
  4. Improvement of the SAGE algorithm
     - To avoid spurious paths, search strategy and reduction of sidelobes should be considered.
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Specifications of experiment

• Signal processing of measured data
  – **SAGE** (Space-Alternating Generalized Expectation-Maximization) algorithm
  – Derivation of **DOD, DOA, DTOA** and frequency spectrum of each path

Measured data

Fourier pair

What we want

- **DOD**
- **DTOA**
- **DOA**
- **Frequency spectrum**

**Features of the SAGE**

• Maximum-likelihood based estimation (parametric channel estimation)
• Widely used in conventional wideband channel sounding, and we modified it to UWB signals
Observations of the results

• Problems

1. There are many weak paths that cannot be identified in the real environment

2. Even the 10 strongest waves, they contain only 20 to 30% of total received power