Scatterer and Virtual Source Detection for Indoor UWB Channels

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Outline

Intro – Motivation

Due to their large bandwidth UWB signals offer among others:

- a fine delay resolution
- robustness in harsh environments

which makes them promising candidates for e.g. indoor localization.

Indoor UWB channel:

- Multipath propagation is prevalent
- Many individual paths are recognizable and resolvable in the measurements

Localization can be done by e.g. an multipath aided indoor localization approach (Meissner et al.), which needs an algorithm for extraction of multipath components (MPCs).

Intro – Problem Definition

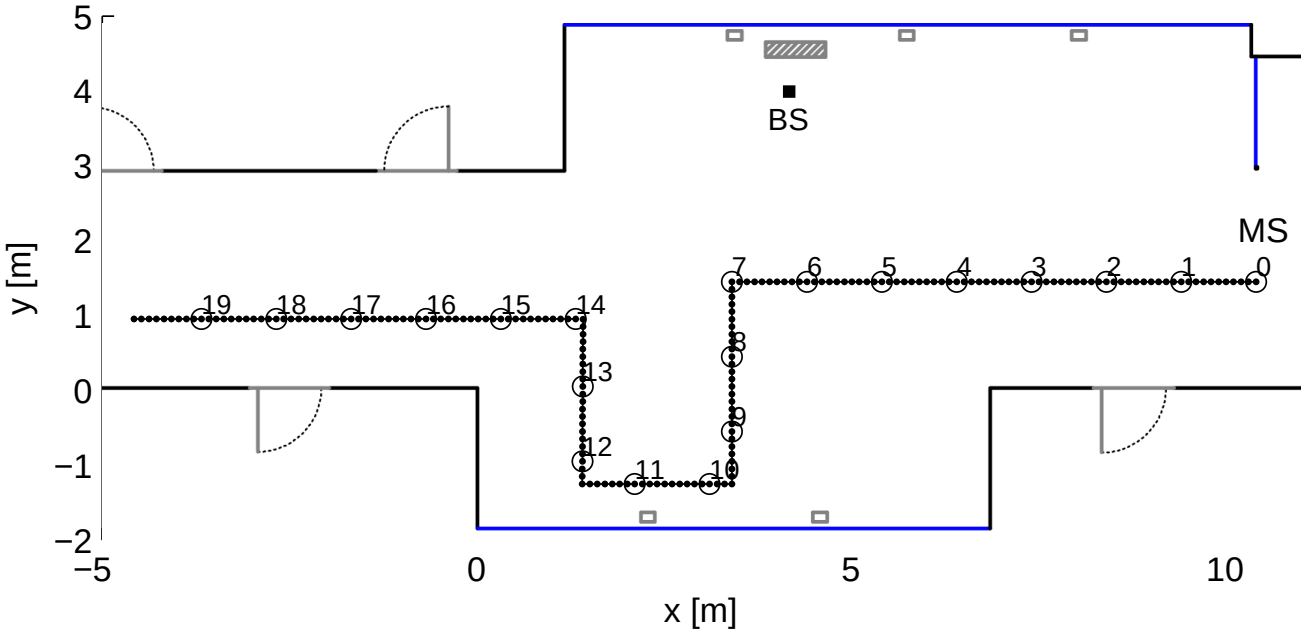
Santos et al. proposed an algorithm for MPC extraction in an outdoor environment.
MPCs are:

- Extracted from the channel impulse responses (CIRs) measured along a trajectory
- Assigned to scatterer points in spatial domain

We present:

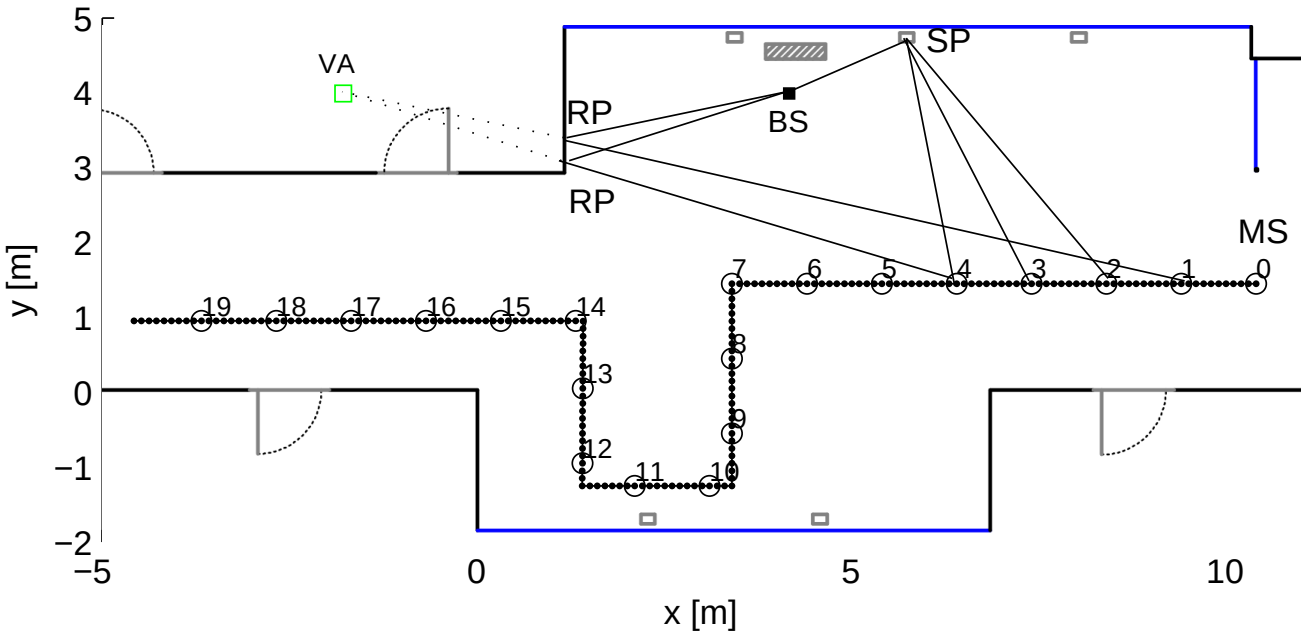
- An extension to also estimate virtual sources
- Apply it to measurement data gained in an indoor environment

Intro – Indoor Measurement Scenario



- Indoor hallway
- Frequency range of $6 - 8\mathrm{GHz}$, $1\mathrm{MHz}$ spacing
- 200 mobile station (MS) positions, $10\mathrm{cm}$ spacing

Intro – Scatterer Points and Virtual Anchors

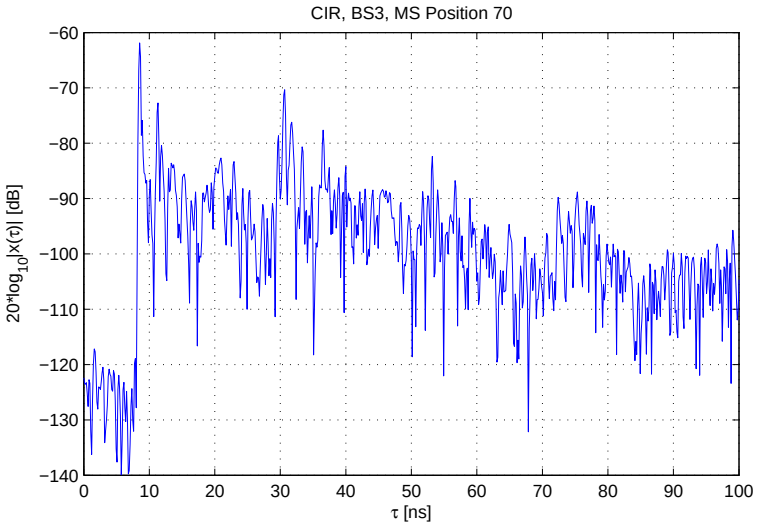


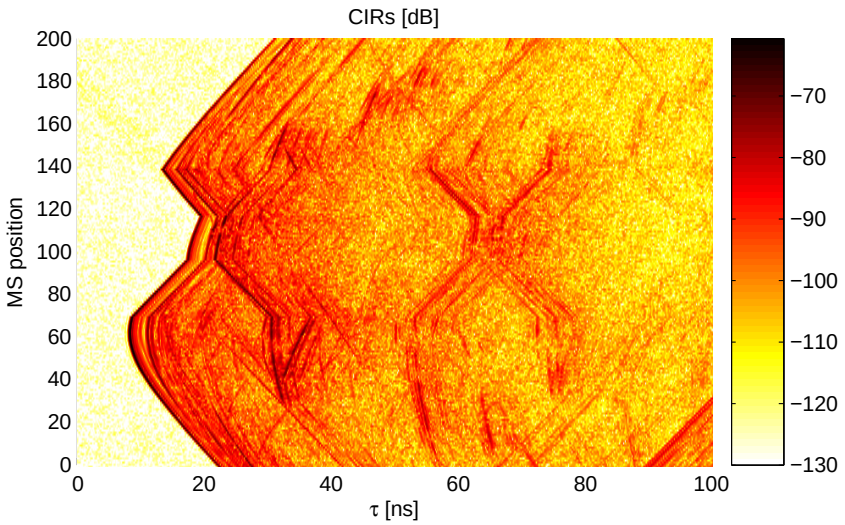
2 different delays τ:

- Scatterer Point (SP): $\tau_{l_{\mathrm{SP}}} = \frac{d(\mathrm{MS,SP})+d(\mathrm{SP,BS})}{c}$
- Virtual Anchor (VA): $\tau_{l_{\mathrm{VA}}} = \frac{d(\mathrm{VA,MS})}{c}$

Algorithm – System Model

Simplified UWB channel impulse response: $x(\tau) = \sum_{k=1}^{L} \alpha_k \delta(\tau - \tau_k)$





Algorithm tries to identify path of peaks along the MS positions and assign them to scatterer points in spatial domain.

Limitation:

- Consider single reflections only
- 2-dimensional search space

Algorithm – Method Description

3 steps:

1. High resolution peak search in time domain
2. Weighting all candidate scatterers in spatial domain
3. Detection and cancellation of strongest scatterer

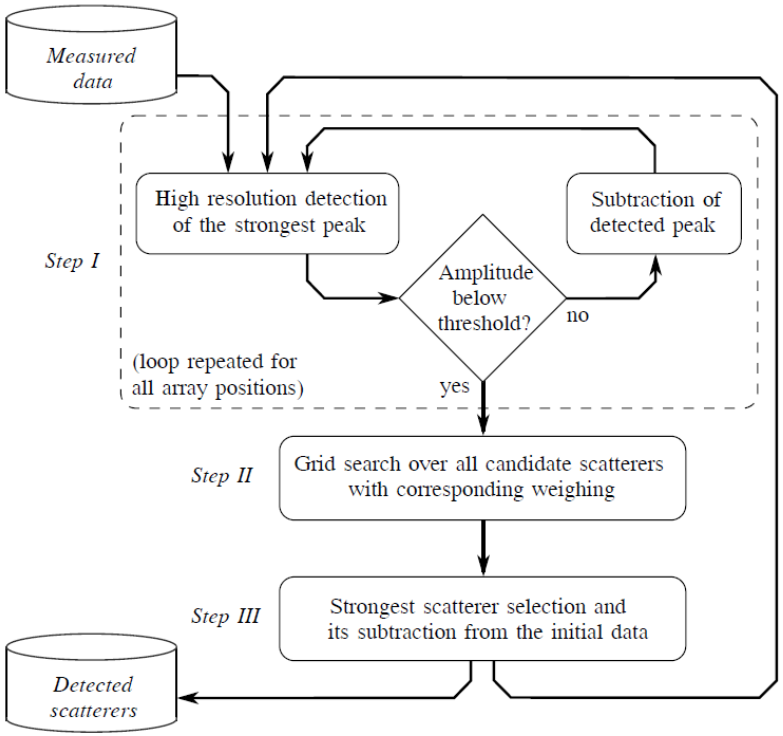


Figure: taken from [SKA+10]

Algorithm – Step II: Spatial Weighting

3 intermediate steps:

- Assign amplitude peaks to all candidate scatterers
  - Extension for Estimation VAs
- Weighting of all candidate scatterers
  - Use ASW to estimate scatterer birth and death location along MS trajectory
  - Compute weight
- Select candidate scatterer with highest weight

Algorithm – Step II: Extension for Estimation VAs

FORALL $\tau_l \in \{\tau_{l_{\mathrm{SP}}}, \tau_{l_{\mathrm{VA}}}\}$

- Assign amplitude peaks to all candidate scatterers:

  $L \ldots$ number of candidate scatterers

  $K \ldots$ number of estimated peaks in step I

  $\tau_{\mathrm{res}} \ldots$ inverse of measurement bandwidth

  FORALL $k \in K, l \in L$

  IF $|\tau_l - \tau_k| < \tau_{\mathrm{res}}$

  store amplitude according to MS position

  ENDIF

  ENDFOR

Algorithm – Step II: Extension for Estimation VAs

FORALL $\tau_l \in \{\tau_{l_{\mathrm{SP}}}, \tau_{l_{\mathrm{VA}}}\}$

- Assign amplitude peaks to all candidate scatterers:
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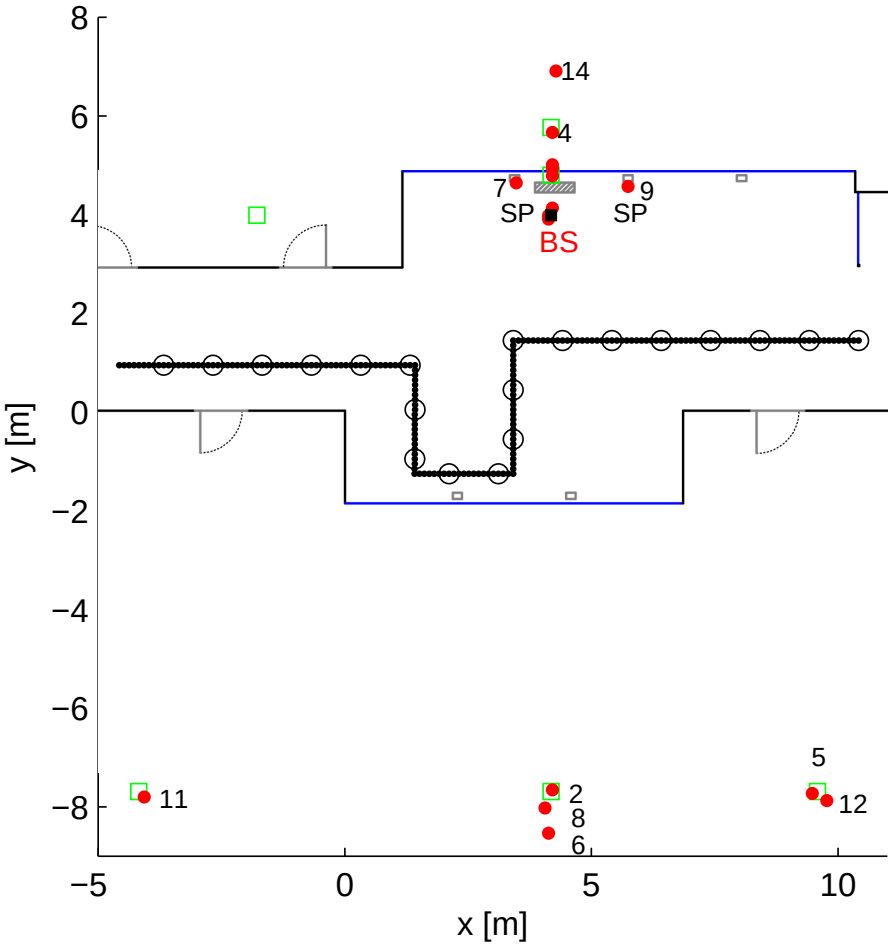
  IF $|\tau_l - \tau_k| < \tau_{\mathrm{res}}$
  store amplitude according to MS position
  ENDIF
  ENDFOR
- Weighting of all candidate scatterers

ENDFOR

- Select candidate scatterer with highest weight

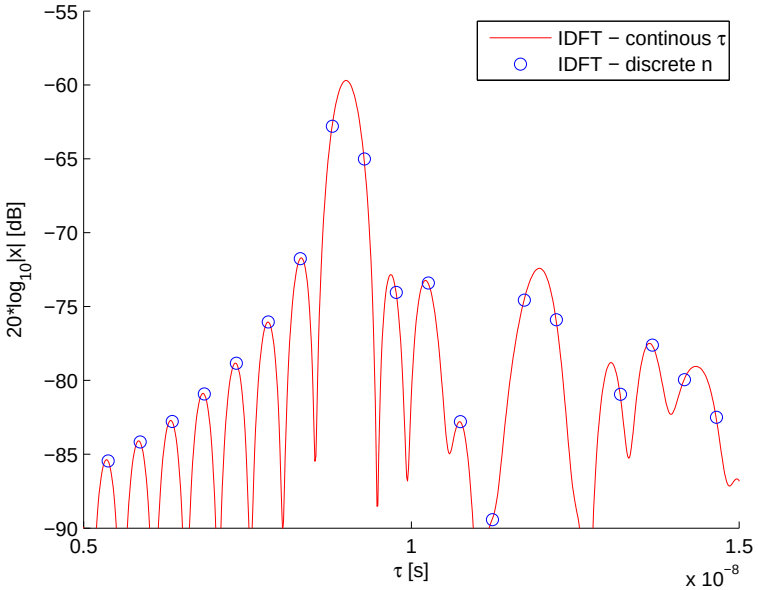
Results – Estimated Scatterer and VA Locations



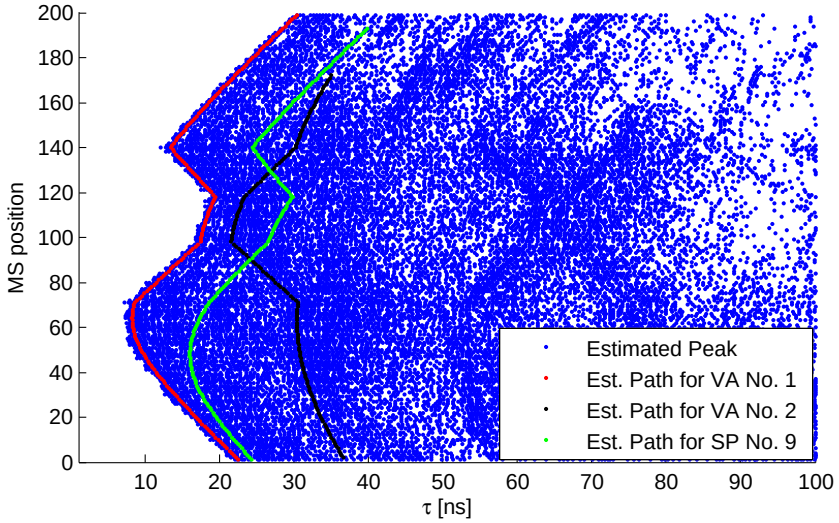
- BS, metal pillars beside the BS and the strongest VAs have been found

Results – Step I: High Resolution Peak Search

IDTFT vs. IDFT:

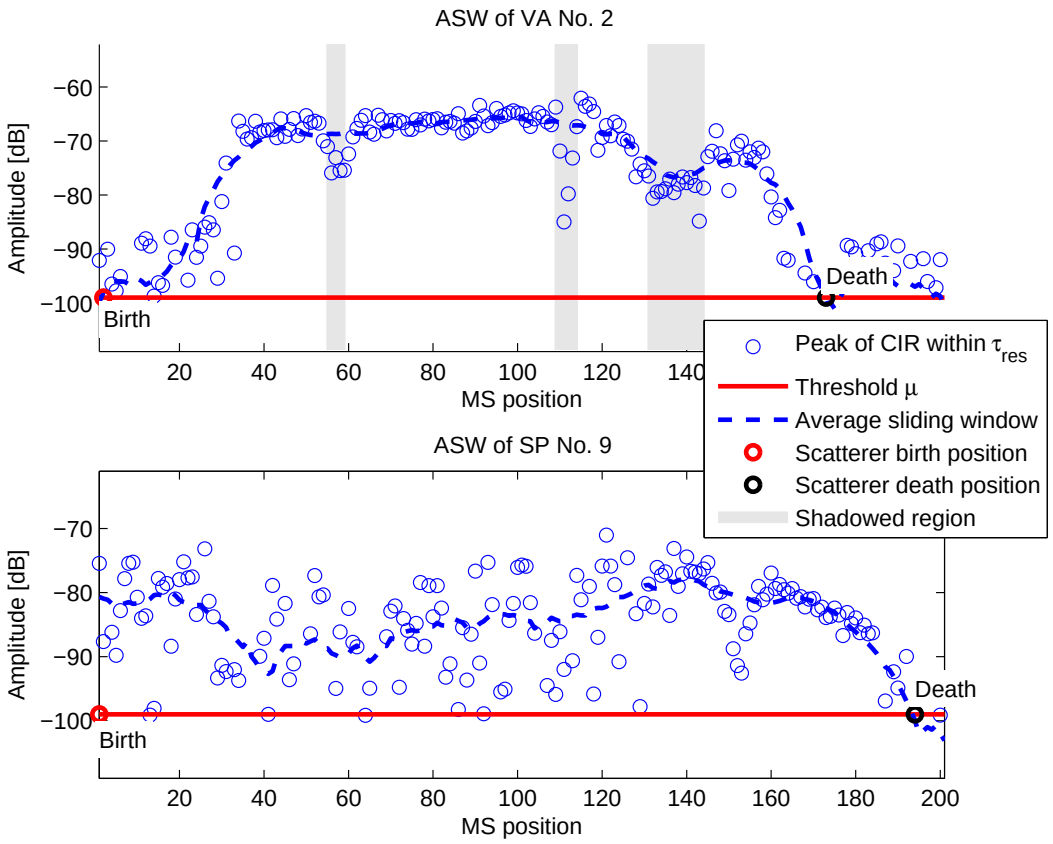


Estimated peaks above threshold $\mu = -99dB$:



- Hi-Res peak search is important in order to estimate the exact delay of a peak within a CIR
- Despite the dense multipath indoor scenario VAs have a long lifetime along MS trajectory

Results – Step II: Spatial weighting

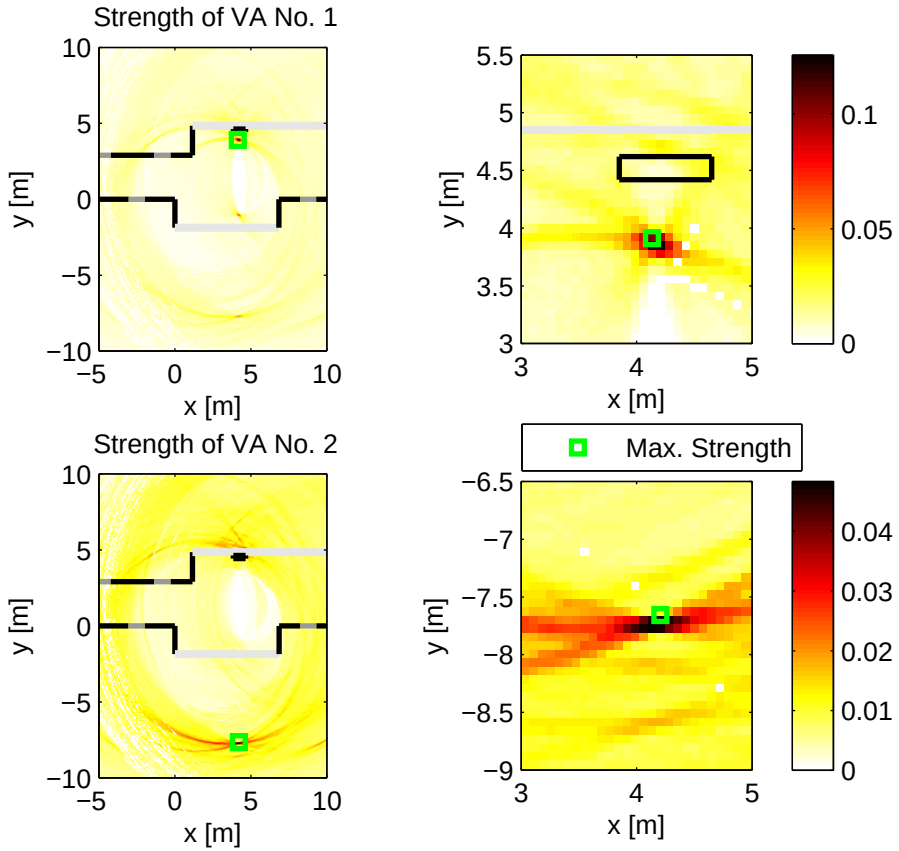


Lifetime VA:

- Geometrically:
  MS position $30 - 160$
- Algorithm:
  MS position $1 - 173$

- Estimated scatterer life-time is severely overestimated caused by the high density of scatterers in our indoor scenario or by diffuse multipath components

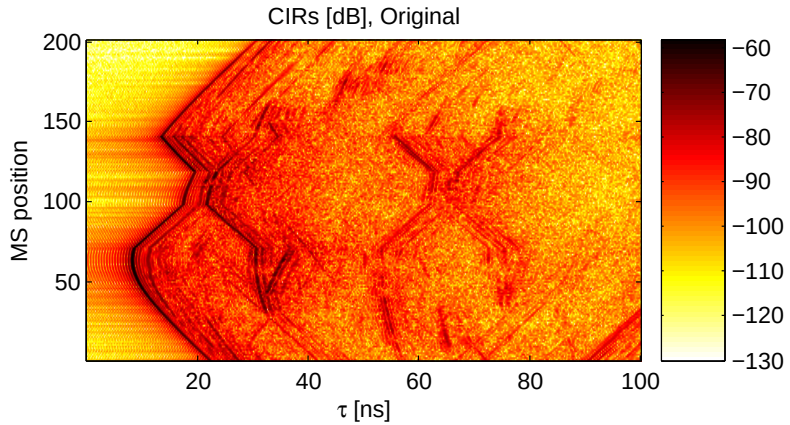
Results – Step II: Spatial weighting cont'd

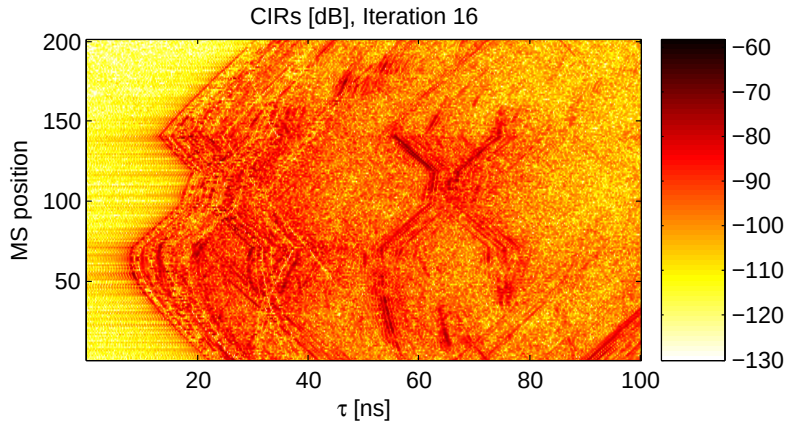


- Ambiguous point at $[4.2, -1.0]^{\mathrm{T}}$

- Ambiguous scatterer points occur if MS trajectory is a straight line, because algorithm compares its delay with the delay of the peaks exceeding the threshold in all CIRs

Results – Step III: Detection and Cancellation





LOS component:

- Highest amplitude and shortest delay
- First to be removed from the channel

Artefacts with a smaller delay than the LOS are caused by the rectangular windowing

- Paths of peaks associated with the first 16 scatterer positions are removed from the channel

Challenges

- Ambiguity of scatterer points
  - Wrong scatterer weight estimation, especially if MS trajectory is straight line
- Estimation of scatterer life-time
  - High density of MPCs
  - Exploitation of the different amplitude characteristics in blocked and visible regions
- Computational effort
  - High resolution peak search in step I
  - Grid search in step II
  - Incorporating floor plan

Conclusion

- Localization of VAs works very well
- Concept of VAs implicitly resolves higher-order reflections
- Extension to estimate virtual sources allows to apply the algorithm in scenarios with a high density of diffuse MPCs

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