Technische Universität Braunschweig

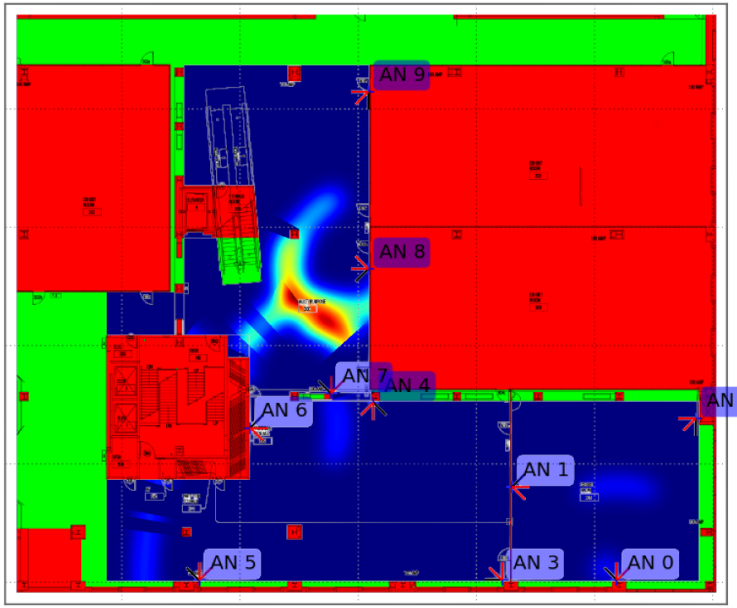
Institute of Operating Systems and Computer Networks

No-Cost Distance Estimation Using Standard WSN Radios

Georg von Zengen, Yannic Schröder, Stephan Rottmann, Felix Büsching and Lars C Wolf , April 14, 2016

Indoor localization

- Use cases:
  - Health care
  - Logistics
  - IoT
- Many systems need special hardware
- Distance estimation is a base technology for localization



InPhase

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- Utilizes phase measurement unit of *AT86RF233*
- Present in many WSNs

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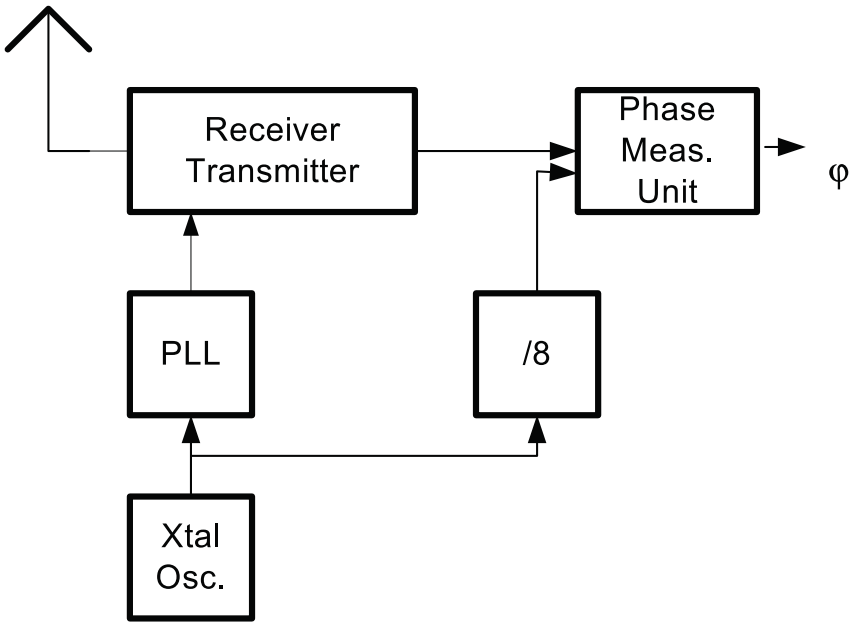
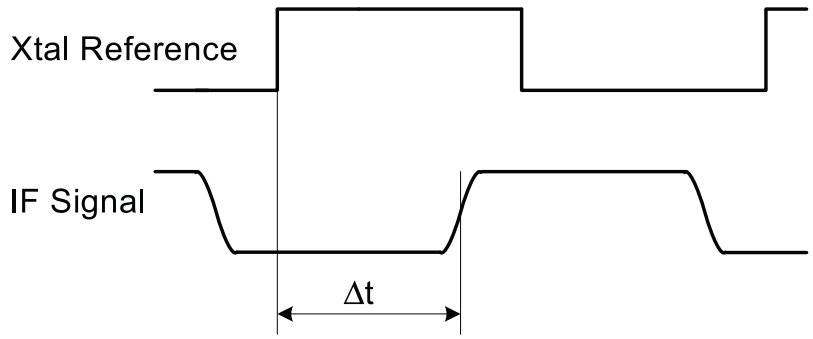
- Utilizes phase measurement unit of *AT86RF233*
- Present in many WSNs
- No additional hardware

Atmel RTB

- Reference Implementation
- Utilizes phase measurement unit of *AT86RF233*
- Closed source
- Few documentation
- No integration

Phase Measurement Unit

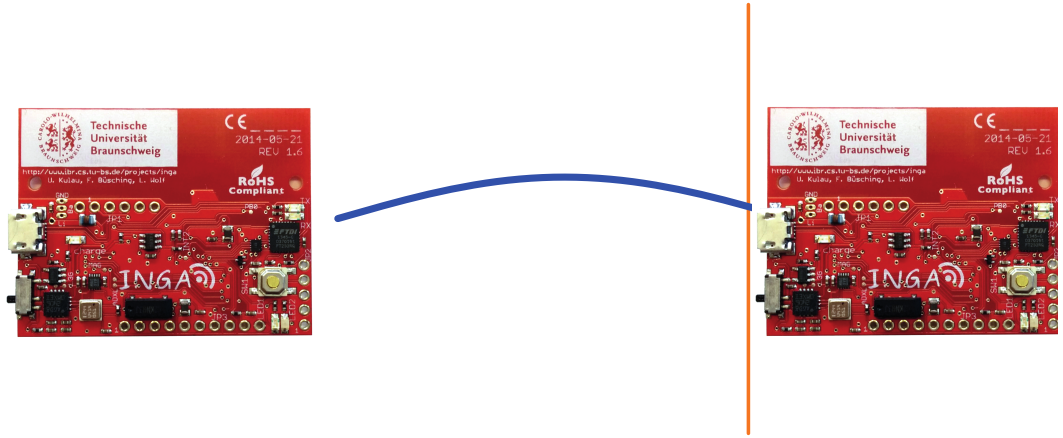




$$\varphi = 2\pi\Delta t/T$$

Atmels Active Reflector method overcomes synchronization

Basic Phase Measurement



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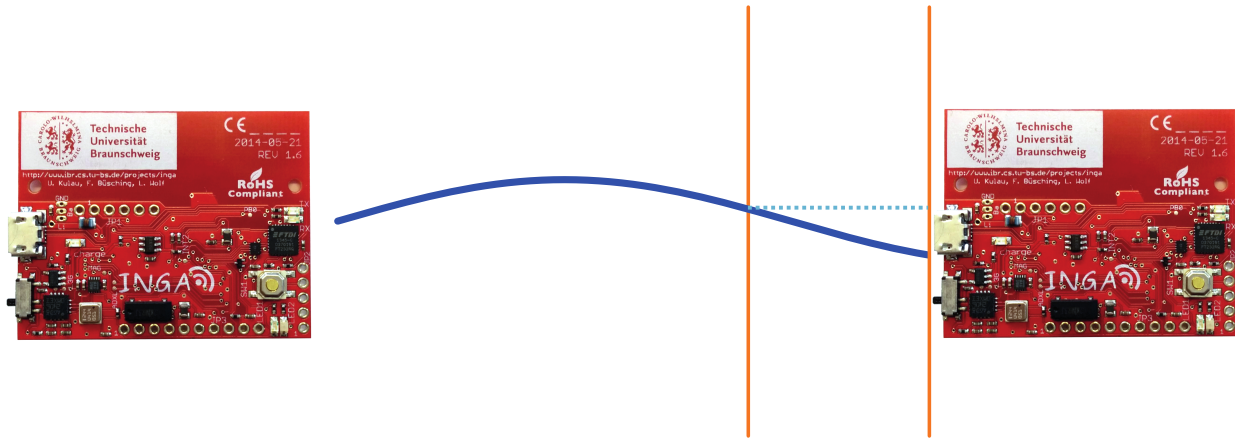

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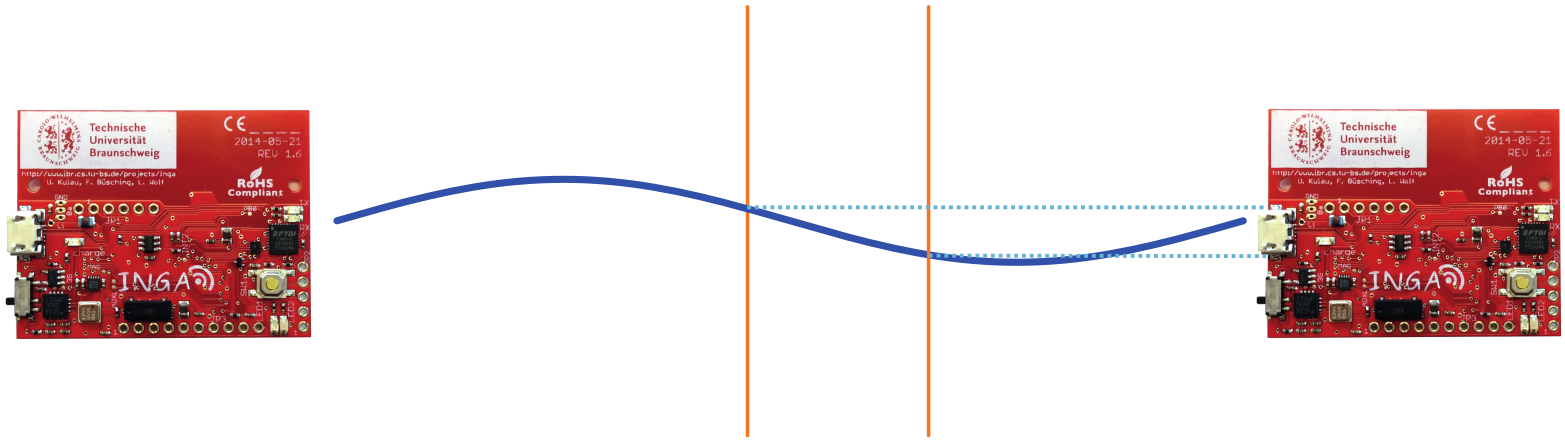
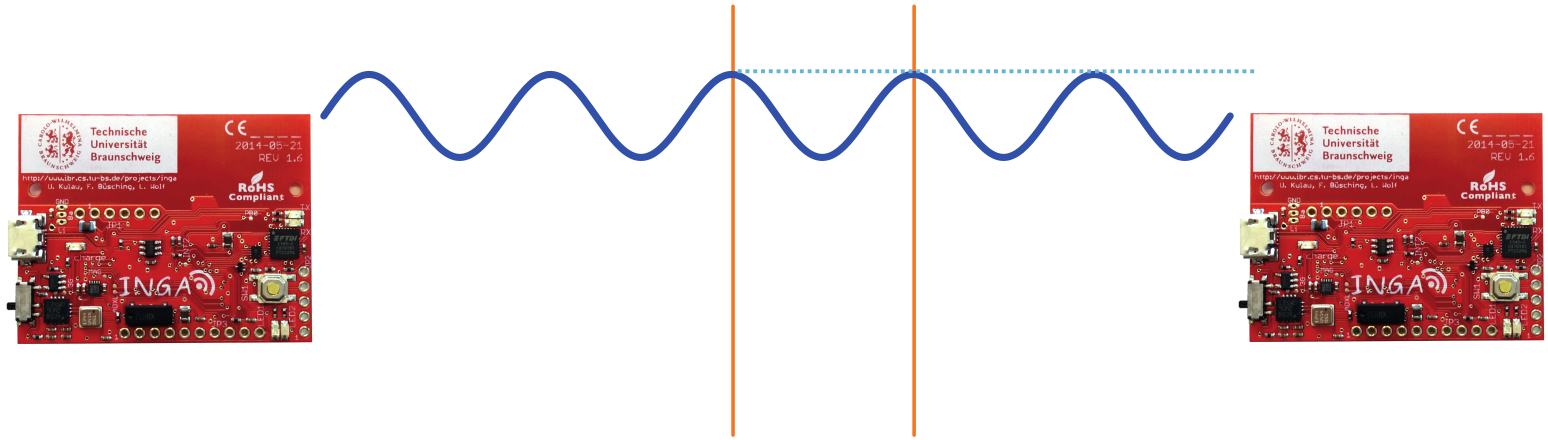
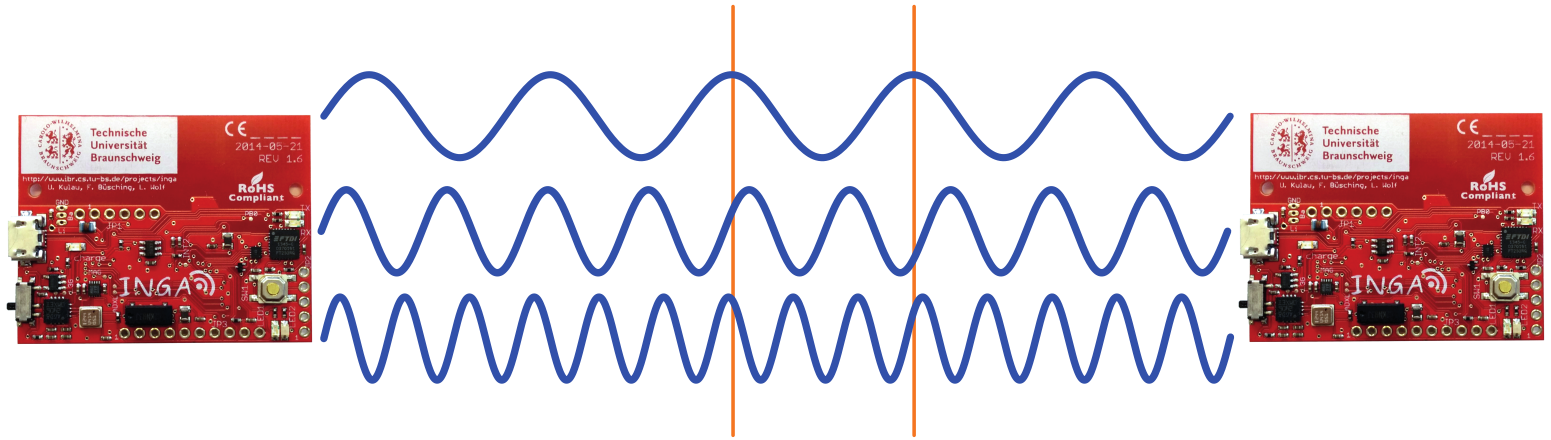


Phase Measurement at 2.4GHz



wavelength 12.5 cm at 2.4 GHz

Multiple Phase Measurements



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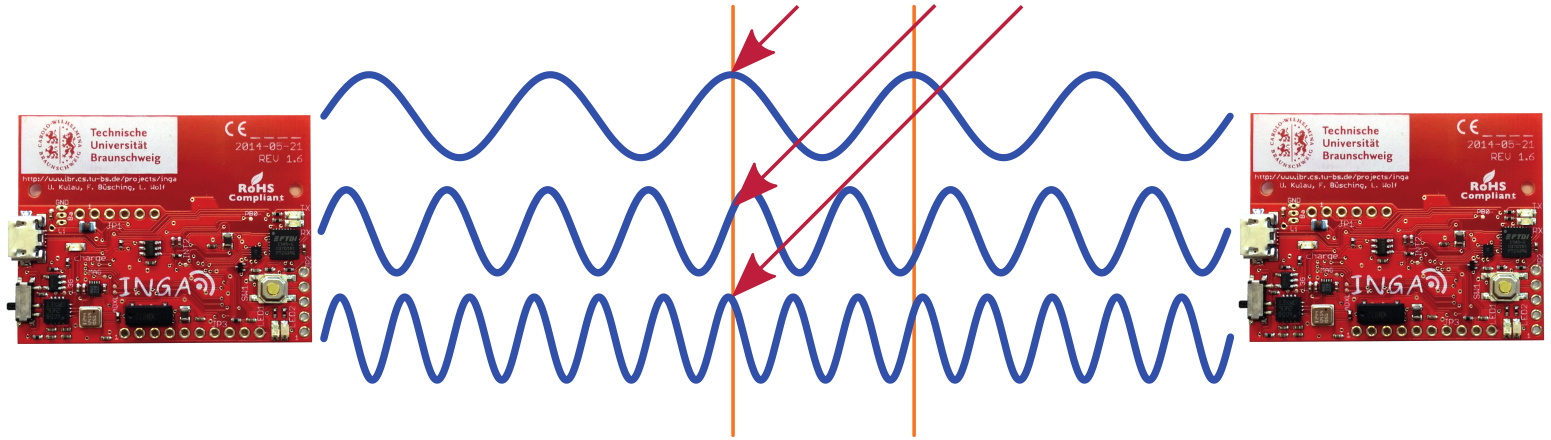
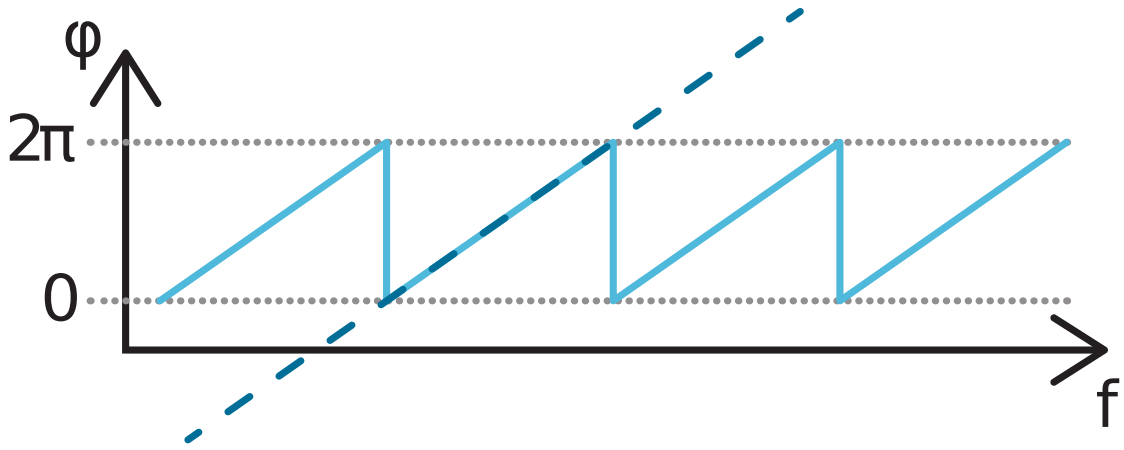
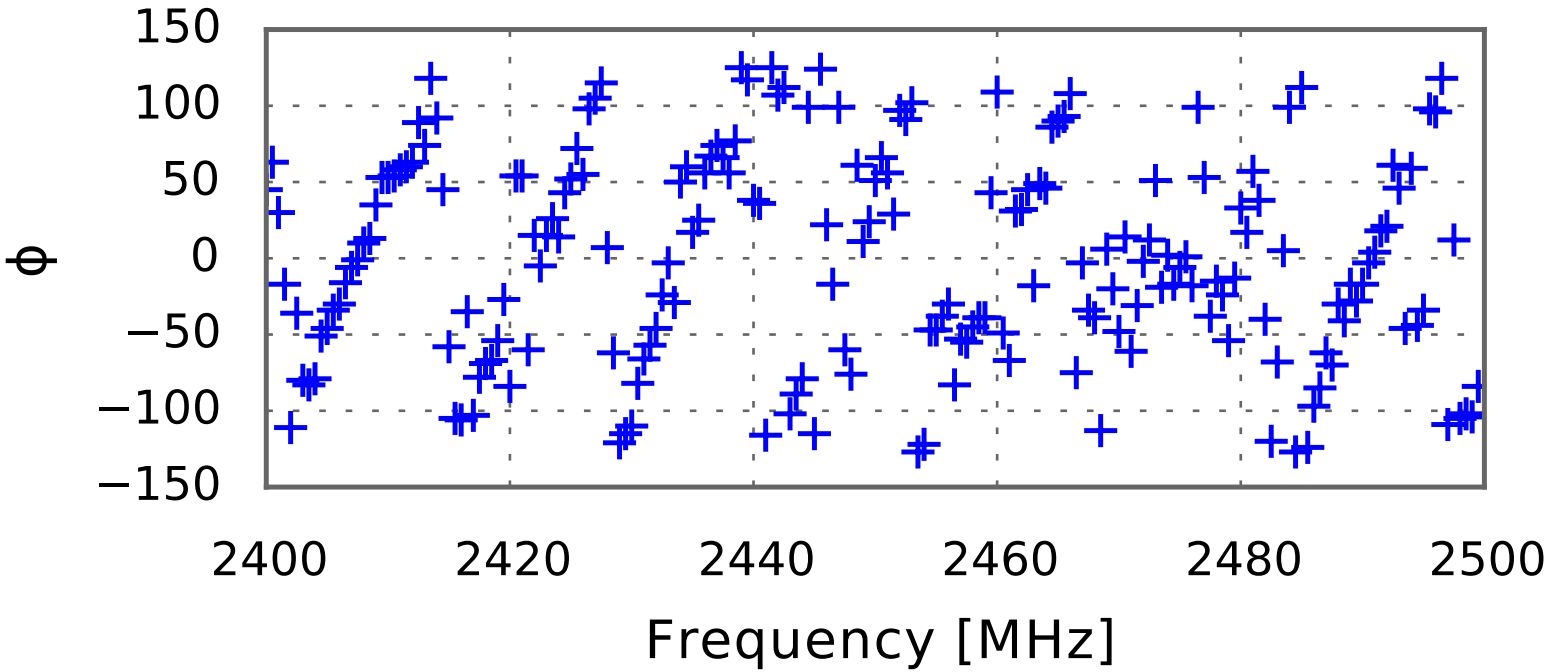


Distance Estimation on Phase Response Φ



Distance d is proportional to slope $m = \frac{\Delta\varphi}{\Delta f}$

Real Phase Response



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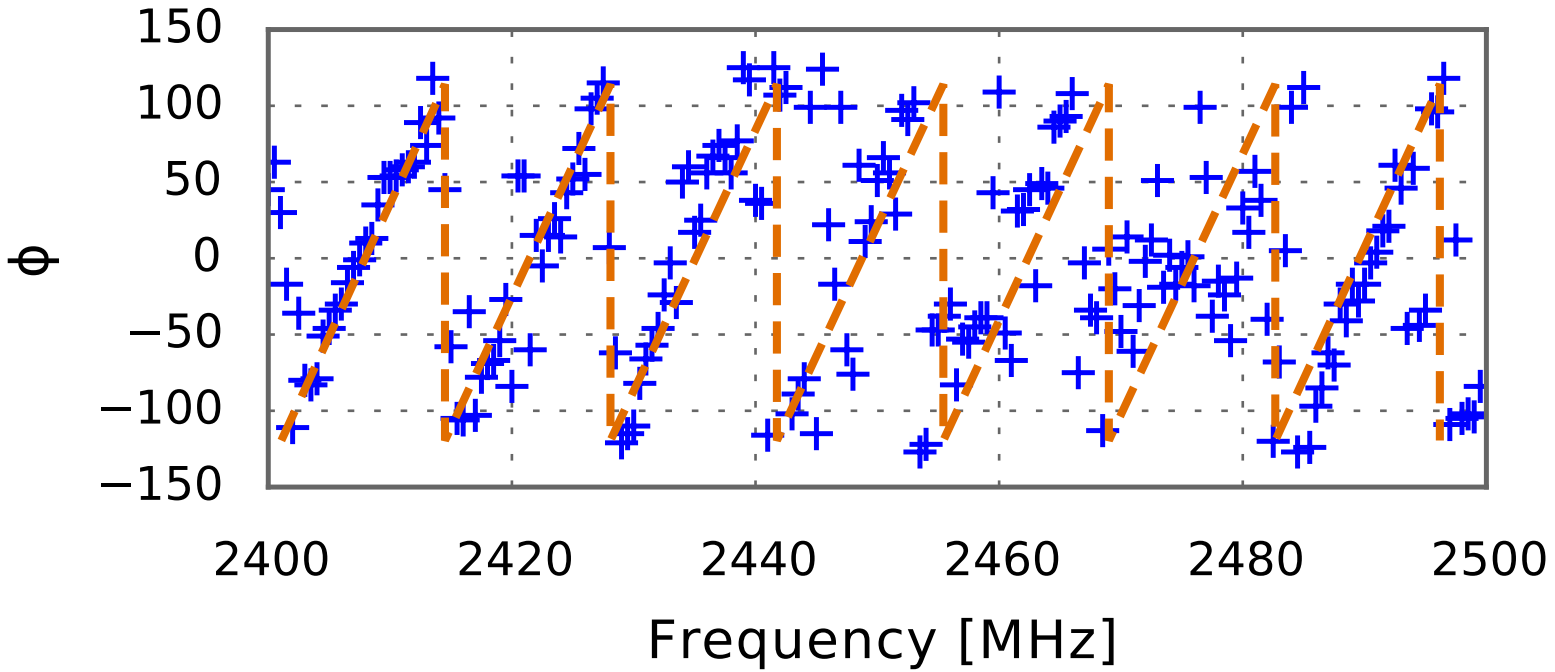

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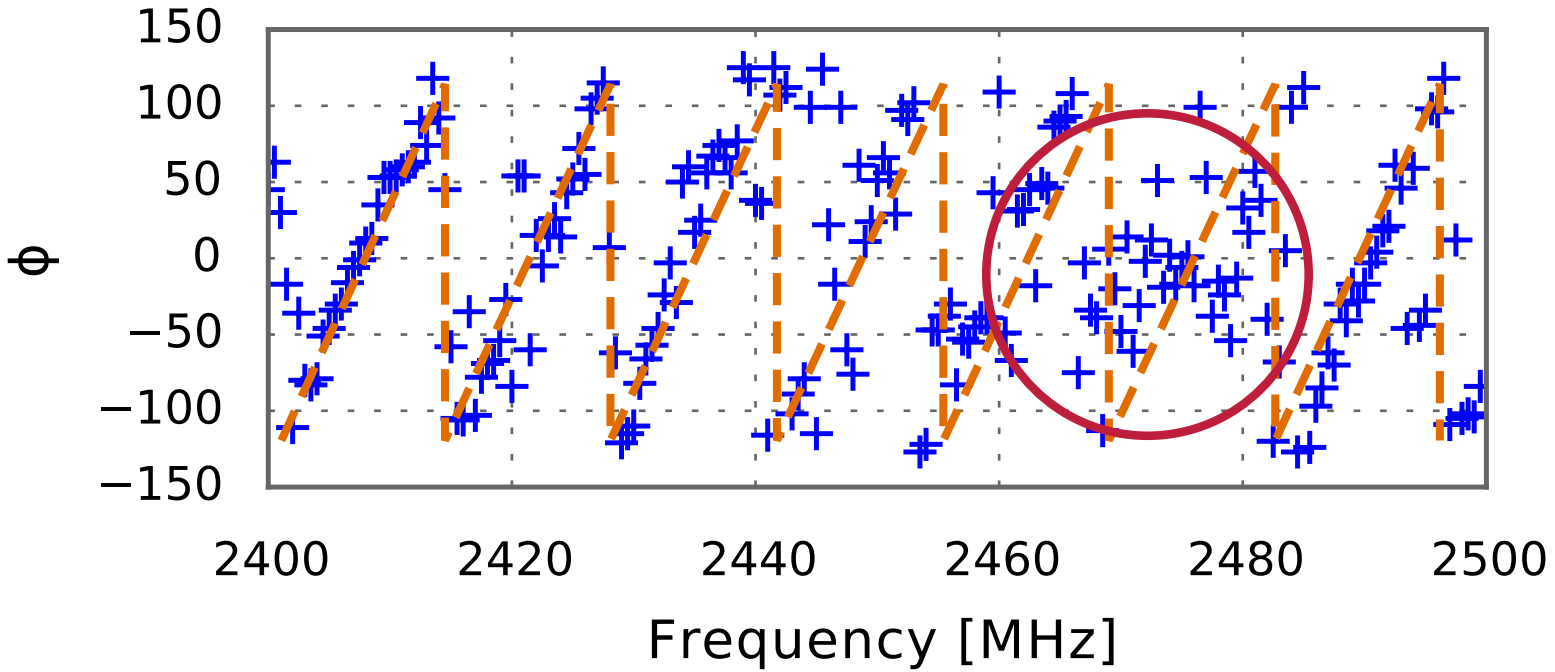

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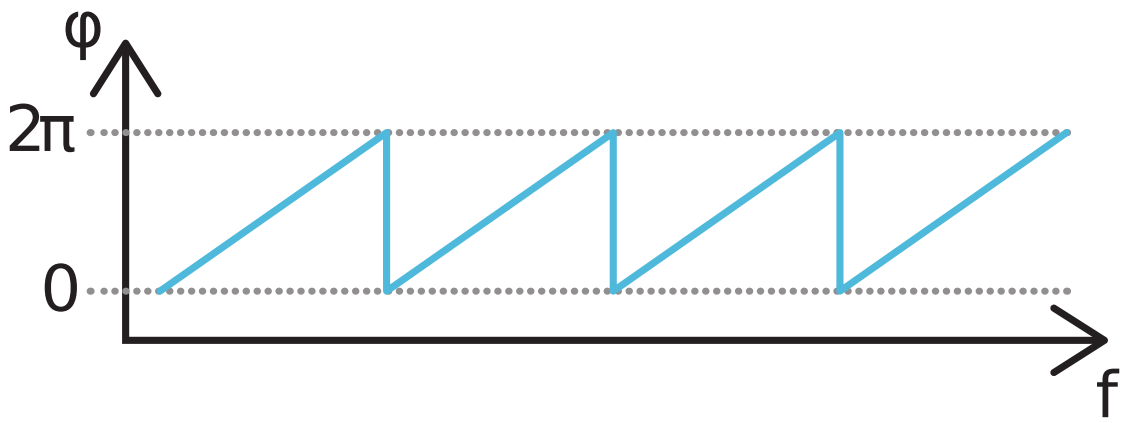

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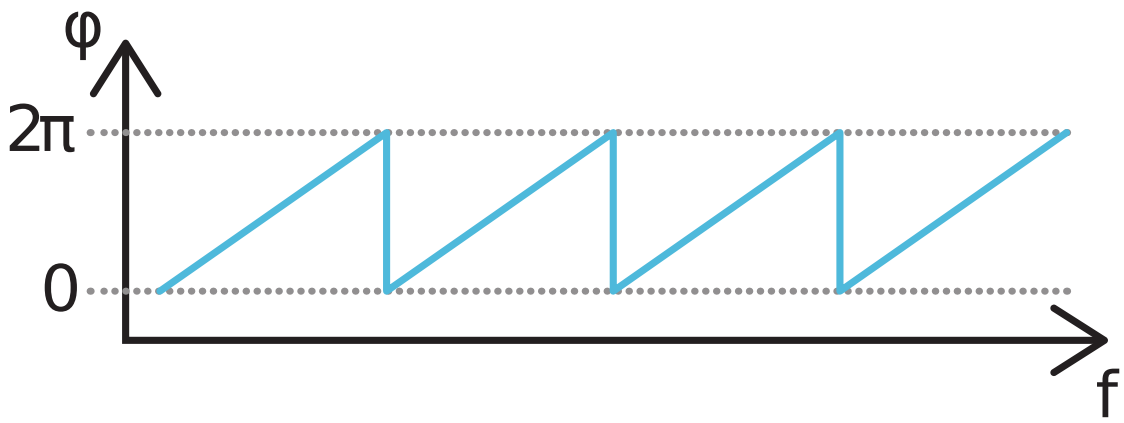

Distance *d* is proportional to frequency of phase response (f_Φ)

Determine f_Φ with Fourier transformation

The highest peak in $\mathcal{F}(\Phi)$ Fourier-transformation of Φ is f_Φ

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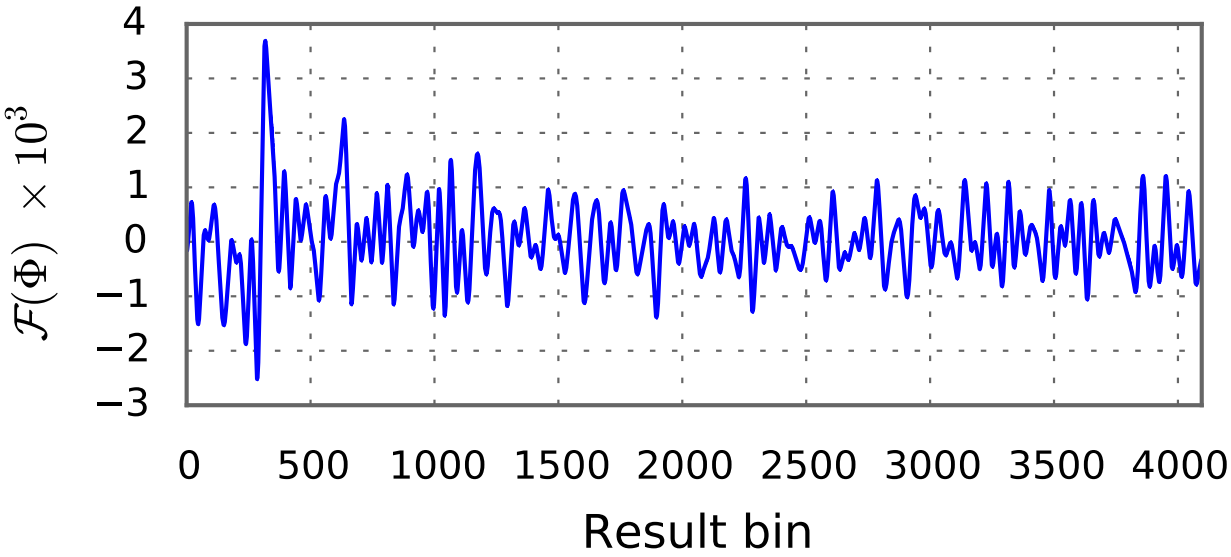
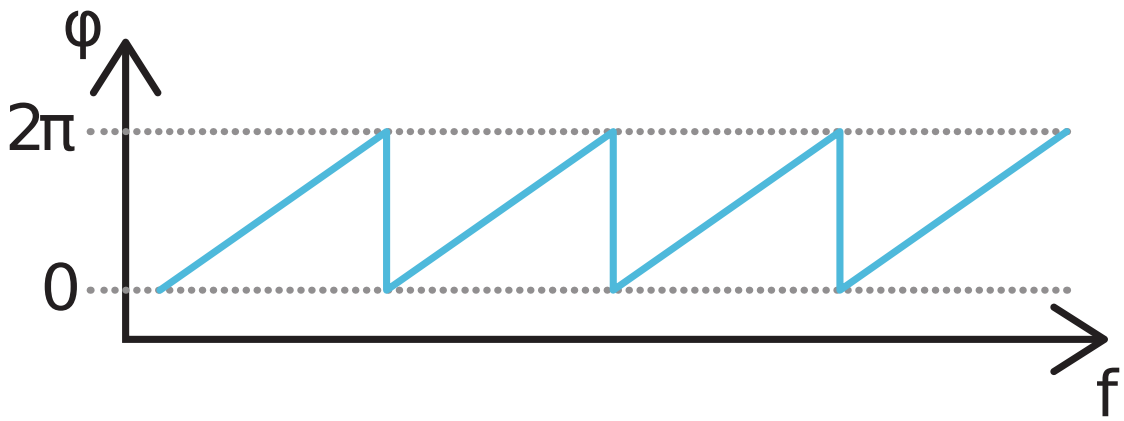


$\mathcal{F}(\Phi)$ still too noisy to find f_Φ

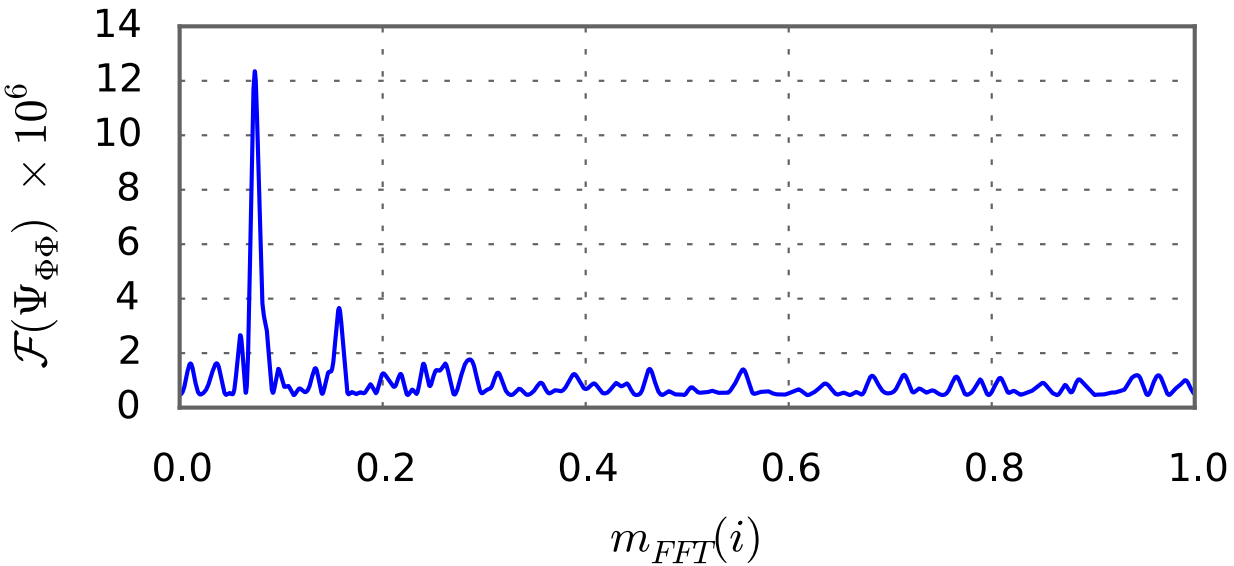
Wiener-Khintchine Theorem

Auto correlation suppresses noise in periodic signals



Determine f_Φ with Wiener-Khintchine

The highest peak in $(\mathcal{F}(\Psi_{\Phi\Phi}))$ Fourier-transformed auto correlation of Φ is f_Φ



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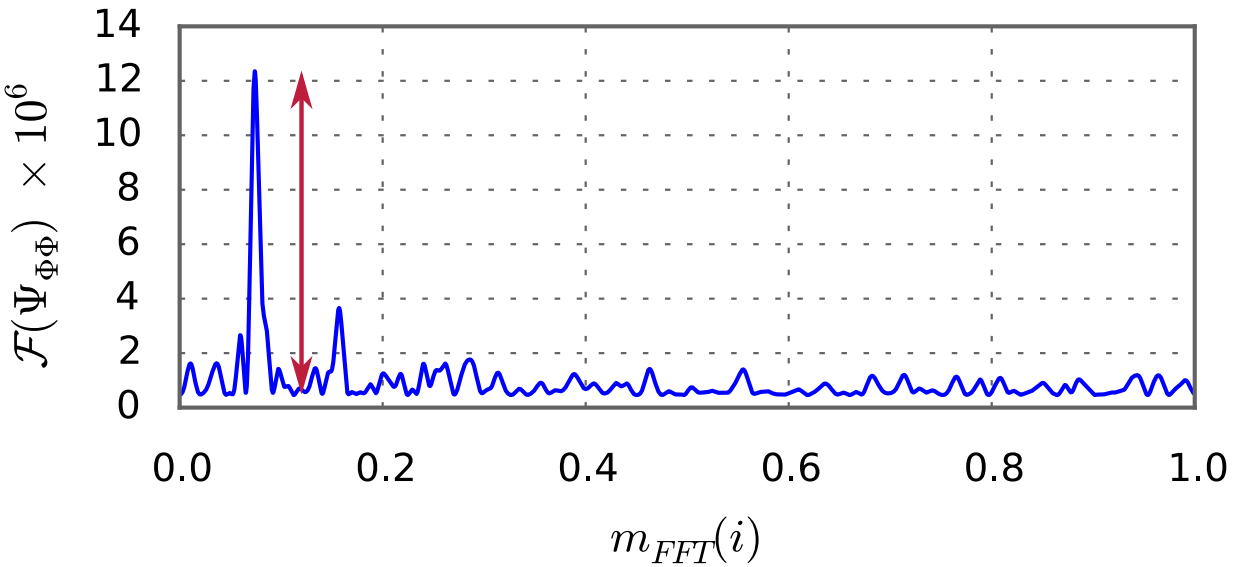

Height of peak at f_Φ is DQF

Evaluation

- Four evaluation scenarios
  - Basement
  - Park
  - Apartment
  - **Office Corridor**

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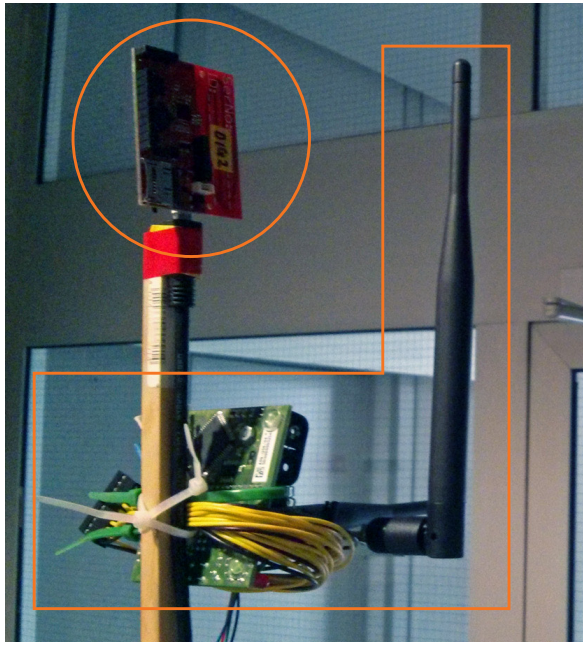
- Evaluation against Atmel RTB
- Laser distance measurement as ground truth



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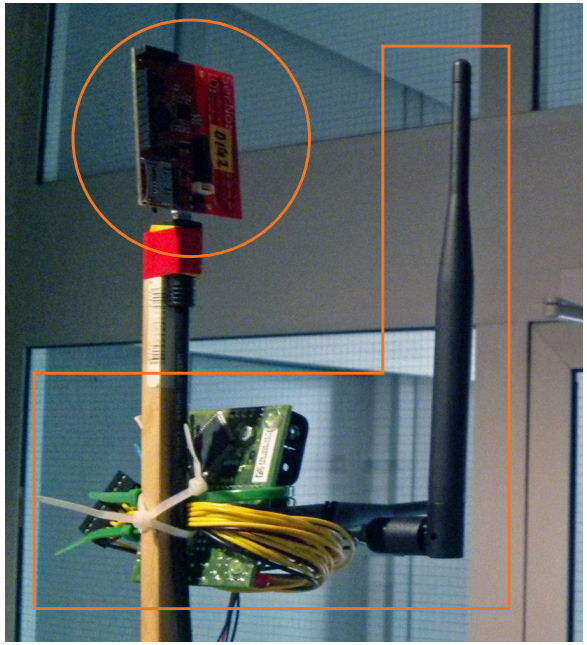
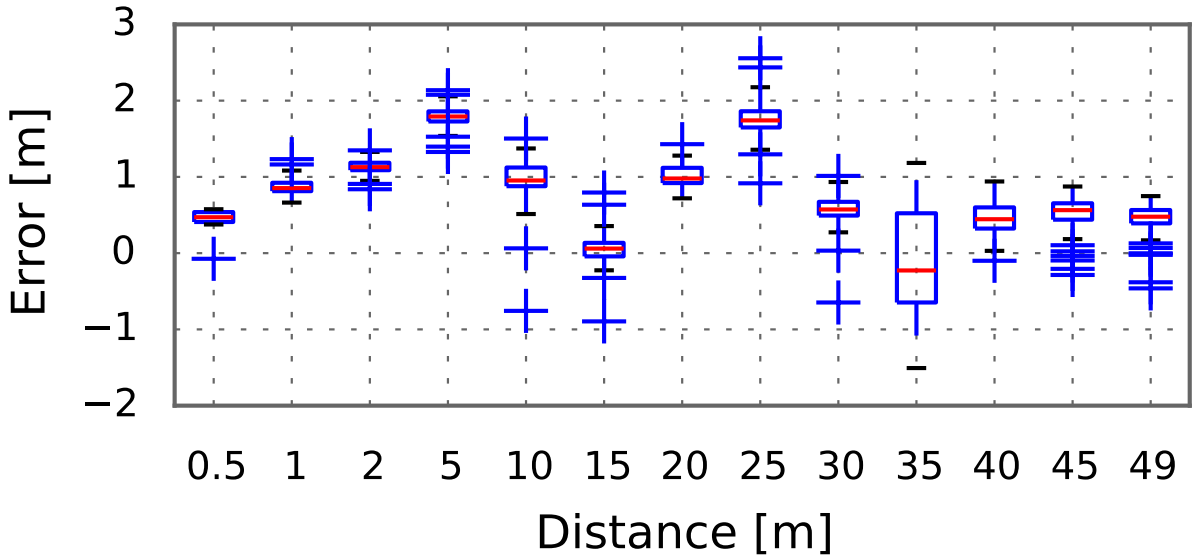
  - **Office Corridor**
- Evaluation against Atmel RTB
- Laser distance measurement as ground truth
- All calculations performed on senor node

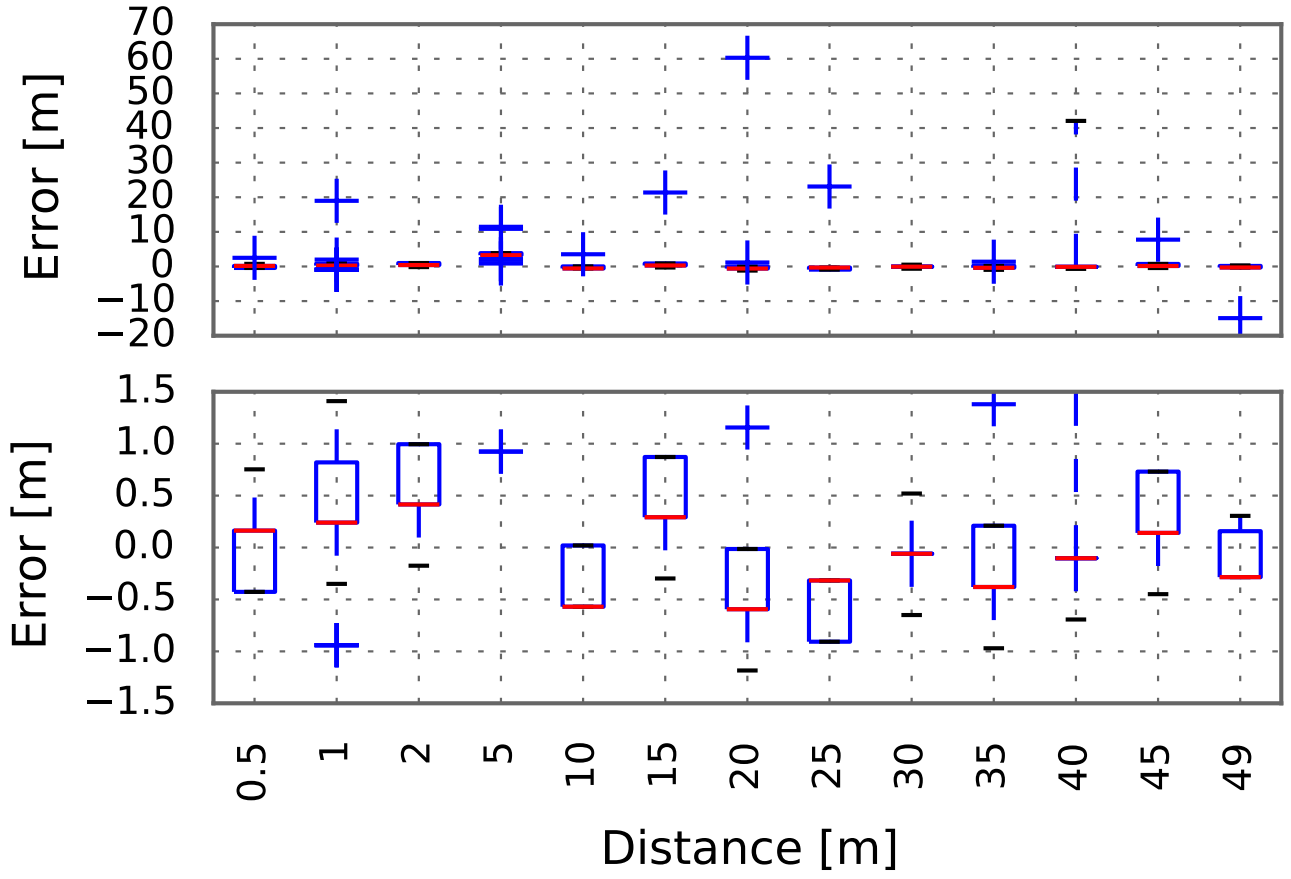


Office Corridor Evaluation



RTB median errors below 1.5m

Office Corridor Evaluation



InPhase median errors below 0.5m

Overall Median Error

	InPhase	RTB
Median Error	0.40 m	0.59 m
# Measurements	2172	1931

DQF filtering

- Both systems calculate a DQF
- DQF give the quality of a measurement
- Drop measurements with a DQF lower than threshold

Overall Median Error with DQF filtering

	InPhase	RTB
Overall Median Error	0.30 m	0.45 m
% accepted measurements	68.55 %	70.64 %
% gain with DQF	25.00 %	23.73 %

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- Novel distance estimation method
- Decreased median error by 33%
- More reliable DQF
- Sufficient accuracy at no additional costs
- Documentation and implementation of distance estimation based on phase measurements

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