# Ambient Intelligence with RIS and backscatter-type devices 

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## Light control



## Gesture recognition from 4D Point-clouds


(c) Two-hand circle


Aalto University
School of Electrical
Engineering

## Outline

Ambient Intelligence

Sensing with a FMCW mmWave radar

## Sensing with a RIS

## FMCW radar sensing




## FMCW radar sensing



## FMCW radar sensing



Reflected signal
from multiple
objects


## FMCW radar sensing



1mm displacement is $\overline{4}$ for a radar working at 77 GHz :

$$
\begin{aligned}
& \Delta \phi=\frac{4 \pi \Delta d}{\lambda}=180^{\circ} \\
& \Delta f=\frac{S 2 \Delta d}{c}=333 H z \Longrightarrow \Delta f T_{c}=0.013
\end{aligned}
$$

## FMCW radar sensing



## FMCW radar sensing



FMCW radar sensing


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Ambient Intelligence

Sensing with a FMCW mmWave radar

## Sensing with a RIS

## RIS sensing

\& mbient

## RIS sensing



Assessing Wireless Sensing Potential With Large Intelligent Surfaces, Vaca-Rubio, IEEE Open Journal of the Communication Society, 2021

## RIS sensing




Assessing Wireless Sensing Potential With Large Intelligent Surfaces, Vaca-Rubio, IEEE Open Journal of the Communication Society, 2021

## RIS sensing

## RIS sensing

Ambient

## RIS sensing



## RIS sensing



$$
\begin{aligned}
\mathbf{h}_{d, n} & =\left[\begin{array}{ll}
h_{n, 0}^{d} & h_{n, 1}^{d}
\end{array}\right] \quad n=1,2 \\
\mathbf{h}_{s, n} & =\left[\begin{array}{ll}
h_{n, 0}^{s} & h_{n, 1}^{s}
\end{array}\right]^{\top} \quad n=1,2
\end{aligned}
$$

## RIS sensing



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\end{aligned}
$$

Phase profile at each tag group at time $t$

$$
\boldsymbol{\alpha}_{n, t}=\left[\begin{array}{ll}
\alpha_{n t 0} & \alpha_{n t 1}
\end{array}\right]^{\top} \quad n=1,2 \quad t=0,1
$$

## RIS sensing



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$$

Received signal at time $t$

$$
y_{t}=\sum_{n=1}^{2} H_{n}\left(\boldsymbol{\alpha}_{n, t}\right) \sqrt{E} x_{0}+z_{t}
$$

## RIS sensing

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Received signal at time $t$

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y_{t}=\sum_{n=1}^{2} H_{n}\left(\alpha_{n, t}\right) \sqrt{E} x_{0}+z_{t},
$$

signal components $v_{t}$ at time 0 and 1

$$
\begin{aligned}
v_{0} & =\left(H_{1}\left(\boldsymbol{\alpha}_{1,0}\right)+H_{2}\left(\boldsymbol{\alpha}_{2,0}\right)\right) \sqrt{E}+z^{\prime}{ }_{0} \\
& =\left(h_{1,0}^{d} h_{1,0}^{s}+h_{1,1}^{d} h_{1,1}^{s}-\left(h_{2,0}^{d} h_{2,0}^{s}+h_{2, h}^{d} h_{2,1}^{s}\right)\right) \sqrt{E}+z^{\prime}{ }_{0},
\end{aligned}
$$

$$
v_{1}=\left(H_{1}\left(\boldsymbol{\alpha}_{1,1}\right)+H_{2}\left(\boldsymbol{\alpha}_{2,1}\right)\right) \sqrt{E}+z^{\prime}{ }_{1}
$$

$$
=\left(h_{1,0}^{d} h_{1,0}^{s}+h_{1,1}^{d} h_{1,1}^{s}+\left(h_{2,0}^{d} h_{2,0}^{s}+h_{2,1}^{d} h_{2,1}^{s}\right)\right) \sqrt{E}+z^{\prime}{ }_{1} .
$$

Remove pilot: multiply with $x_{0}^{*}\left(x_{0} x_{0}^{*}=1\right)$

$$
\begin{aligned}
v_{t} & =y_{t} x_{0}^{*}=\sum_{n=1}^{2} H_{n}\left(\alpha_{n, t}\right) \sqrt{E}+z_{t}^{\prime} \\
& =\left(H_{1}\left(\alpha_{1, t}\right)+H_{2}\left(\alpha_{2, t}\right)\right) \sqrt{E}+z^{\prime}{ }_{t} .
\end{aligned}
$$

## RIS sensing

signal components $v_{t}$ at time 0 and 1

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\begin{aligned}
v_{0} & =\left(H_{1}\left(\boldsymbol{\alpha}_{1,0}\right)+H_{2}\left(\boldsymbol{\alpha}_{2,0}\right)\right) \sqrt{E}+z^{\prime}{ }_{0} \\
& =\left(h_{1,0}^{d} h_{1,0}^{s}+h_{1,1}^{d} h_{1,1}^{s}-\left(h_{2,0}^{d} h_{2,0}^{s}+h_{2,1}^{d} h_{2,1}^{s}\right)\right) \sqrt{E}+z^{\prime}{ }_{0}, \\
v_{1} & =\left(H_{1}\left(\boldsymbol{\alpha}_{1,1}\right)+H_{2}\left(\boldsymbol{\alpha}_{2,1}\right)\right) \sqrt{E}+z^{\prime}{ }_{1} \\
& =\left(h_{1,0}^{d} h_{1,0}^{s}+h_{1,1}^{d} h_{1,1}^{s}+\left(h_{2,0}^{d} h_{2,0}^{s}+h_{2,1}^{d} h_{2,1}^{s}\right)\right) \sqrt{E}+z^{\prime}{ }_{1} .
\end{aligned}
$$



## Thank you!



