Ultra-Wideband Interference Modelling for Indoor Wireless Channels using the FDTD Method

Andrew Austin and Costas Sarris

Department of Electrical and Computer Engineering
University of Toronto, Canada

July 13, 2012

Outline

Motivations

- Considerable attention has been focused on the potential interference from UWB to existing systems. This research focuses on the UWB-UWB interference problem.

Motivations

- Considerable attention has been focused on the potential interference from UWB to existing systems. This research focuses on the UWB-UWB interference problem.
- Previous research has shown that the channel can significantly impact UWB system performance.

Motivations

- Considerable attention has been focused on the potential interference from UWB to existing systems. This research focuses on the UWB-UWB interference problem.
- Previous research has shown that the channel can significantly impact UWB system performance.
  - i.e. UWB systems are sensitive to the channel characteristics (in particular temporal characteristics).

Motivations

- Considerable attention has been focused on the potential interference from UWB to existing systems. This research focuses on the UWB-UWB interference problem.
- Previous research has shown that the channel can significantly impact UWB system performance.
  - i.e. UWB systems are sensitive to the channel characteristics (in particular temporal characteristics).
- Analytical models for the system performance (e.g. BER) assume an generalised or statistical channel.

Motivations

- Considerable attention has been focused on the potential interference from UWB to existing systems. This research focuses on the UWB-UWB interference problem.
- Previous research has shown that the channel can significantly impact UWB system performance.
  - i.e. UWB systems are sensitive to the channel characteristics (in particular temporal characteristics).
- Analytical models for the system performance (e.g. BER) assume an generalised or statistical channel.
- Analysis of the UWB channel with time-domain methods can yield useful information, e.g. [Zhao '07, Alighanbari '08].

Motivations

- Considerable attention has been focused on the potential interference from UWB to existing systems. This research focuses on the UWB-UWB interference problem.
- Previous research has shown that the channel can significantly impact UWB system performance.
  - i.e. UWB systems are sensitive to the channel characteristics (in particular temporal characteristics).
- Analytical models for the system performance (e.g. BER) assume an generalised or statistical channel.
- Analysis of the UWB channel with time-domain methods can yield useful information, e.g. [Zhao '07, Alighanbari '08].
- Goal here: use the FDTD to model the channel and use the results to predict UWB *system performance*.

Power Delay Profile Modelling

- Generally based on time-domain experimental characterisation of the UWB channel.

Power Delay Profile Modelling

- Generally based on time-domain experimental characterisation of the UWB channel.
- Important for predicting performance of UWB systems.

Power Delay Profile Modelling

- Generally based on time-domain experimental characterisation of the UWB channel.
- Important for predicting performance of UWB systems.
- A number of reported studies, but generally two "functional descriptions":

Power Delay Profile Modelling

- Generally based on time-domain experimental characterisation of the UWB channel.
- Important for predicting performance of UWB systems.
- A number of reported studies, but generally two "functional descriptions":
  - Clustered Exponential Decay [Saleh-Valenzuela]:

$$P(\tau) = c \sum_{L} |\xi_L|^2 \sum_{k} \overline{|\beta_{k,L}|^2}\, \delta(\tau - T_L - \tau_{k,L})$$

where terms in L are related to the clusters and terms in k are related to the components within a cluster.

Power Delay Profile Modelling

- Generally based on time-domain experimental characterisation of the UWB channel.
- Important for predicting performance of UWB systems.
- A number of reported studies, but generally two "functional descriptions":
  - Clustered Exponential Decay [Saleh-Valenzuela]:

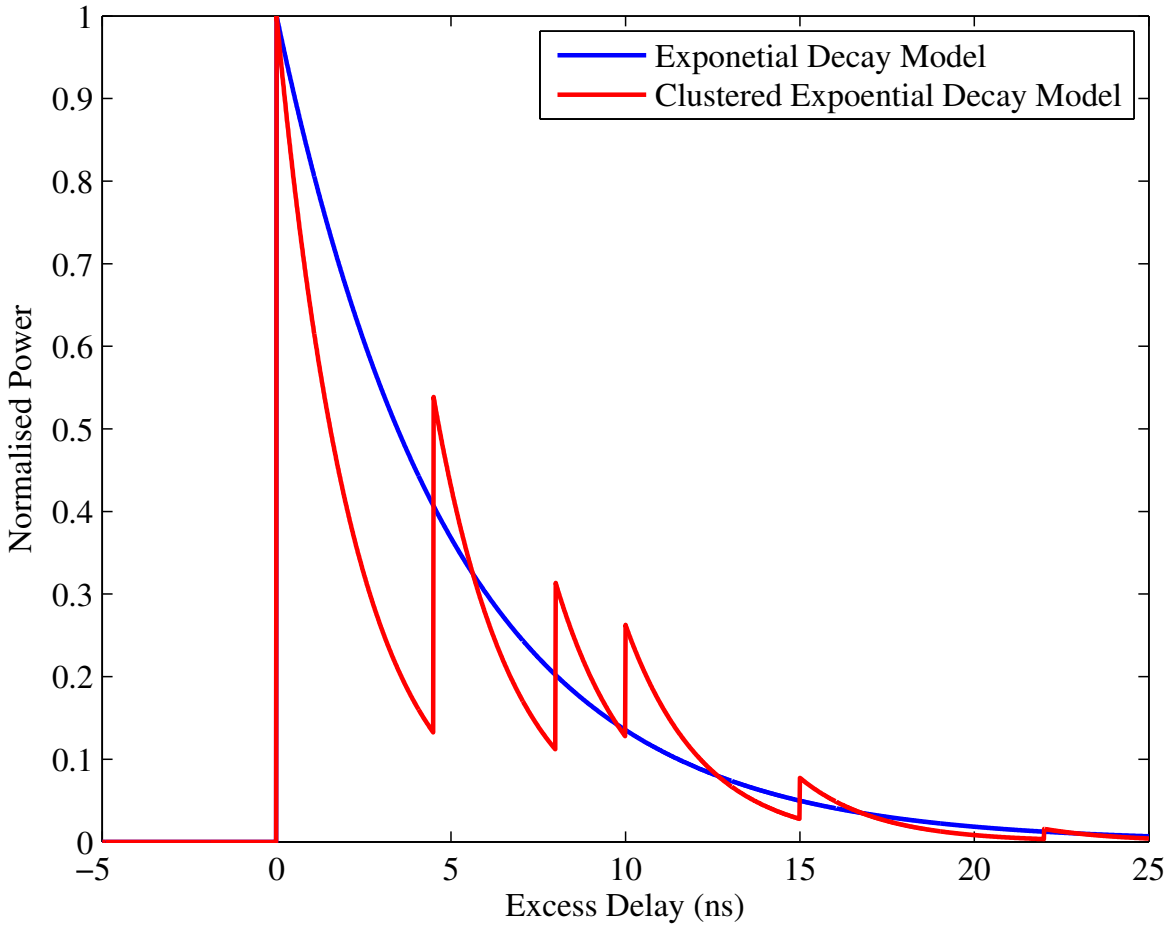
$$P(\tau) = c \sum_{L} |\xi_L|^2 \sum_{k} \overline{|\beta_{k,L}|^2}\, \delta(\tau - T_L - \tau_{k,L})$$

    where terms in L are related to the clusters and terms in k are related to the components within a cluster.
  - Exponential Decay [e.g. Ghassemzadeh et. al. 2005]:

$$P(\tau) = \begin{cases} c & \tau = 0 \\ cr \exp\left(\frac{-\tau}{\epsilon}\right) & 0 < \tau \leq 5\epsilon \end{cases}$$

    where r is the power ratio and ϵ the decay rate.

Power Delay Profile Modelling



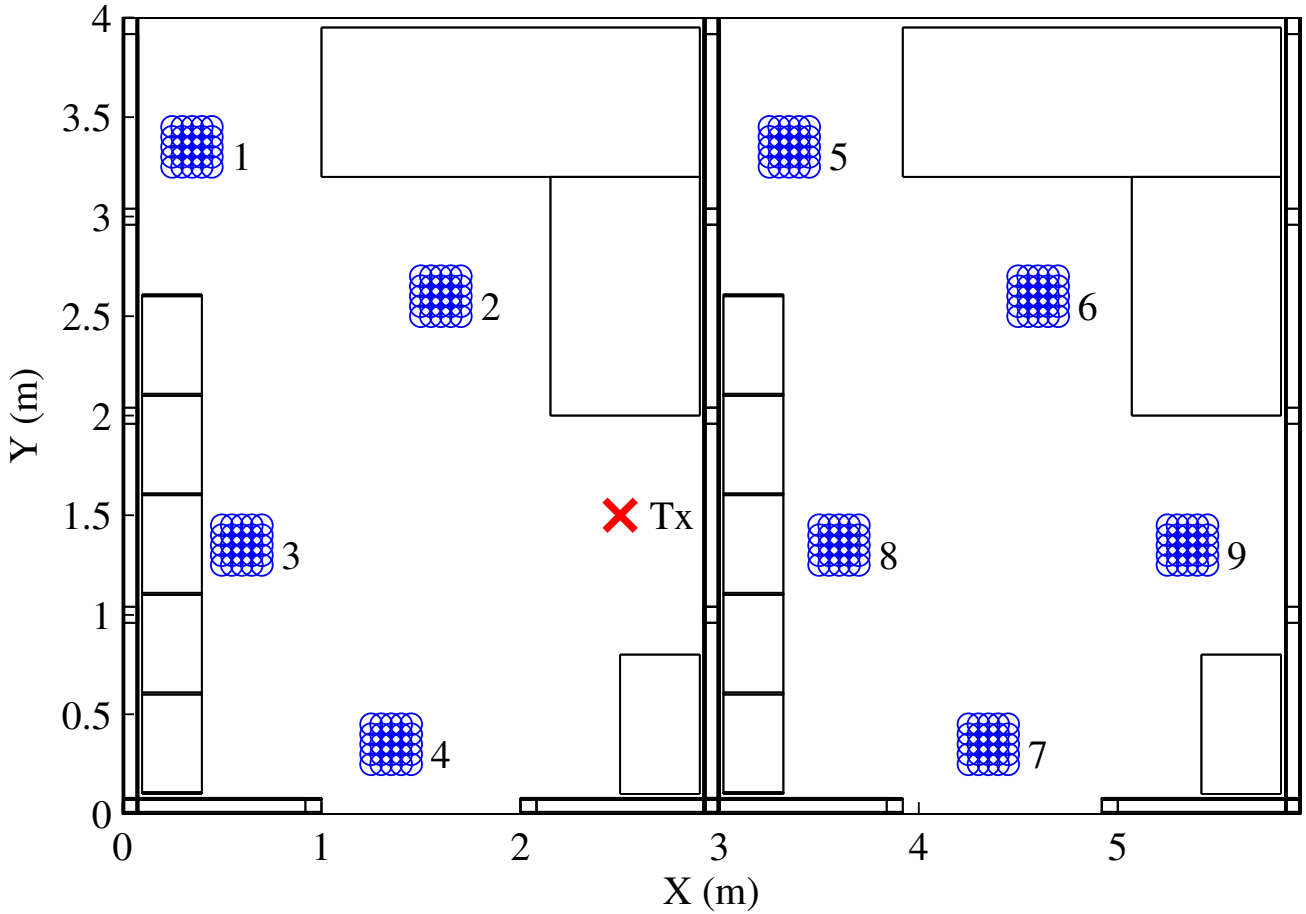
- To what extent does the local environment affect the PDP?

Two-dimensional Office Environment

- 4^{th} order Gaussian Monocycle pulse, width $= 0.5$ ns (compliant with FCC-UWB mask).

Two-dimensional Office Environment

- 4^{th} order Gaussian Monocycle pulse, width = 0.5 ns (compliant with FCC-UWB mask).
- Indoor geometry contains dielectric and metallic structures.

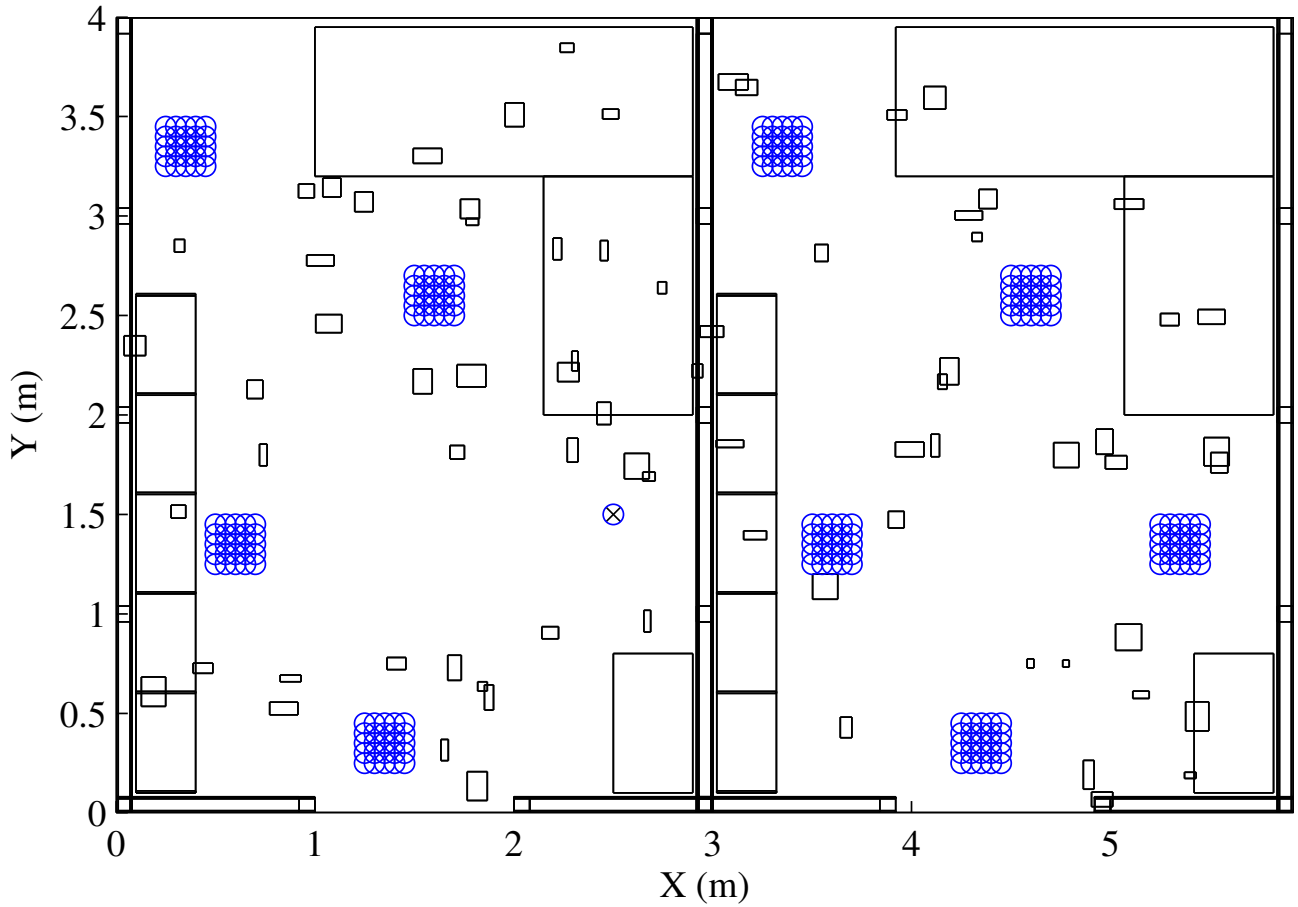


"Cluttered" Indoor Environment

- Typical indoor environments usually contain varying degrees of randomly positioned and sized dielectric and metallic "clutter".

"Cluttered" Indoor Environment

- Typical indoor environments usually contain varying degrees of randomly positioned and sized dielectric and metallic "clutter".
- In a 2D FDTD simulation we include 75 small PEC blocks.



Two-dimensional Office Environment

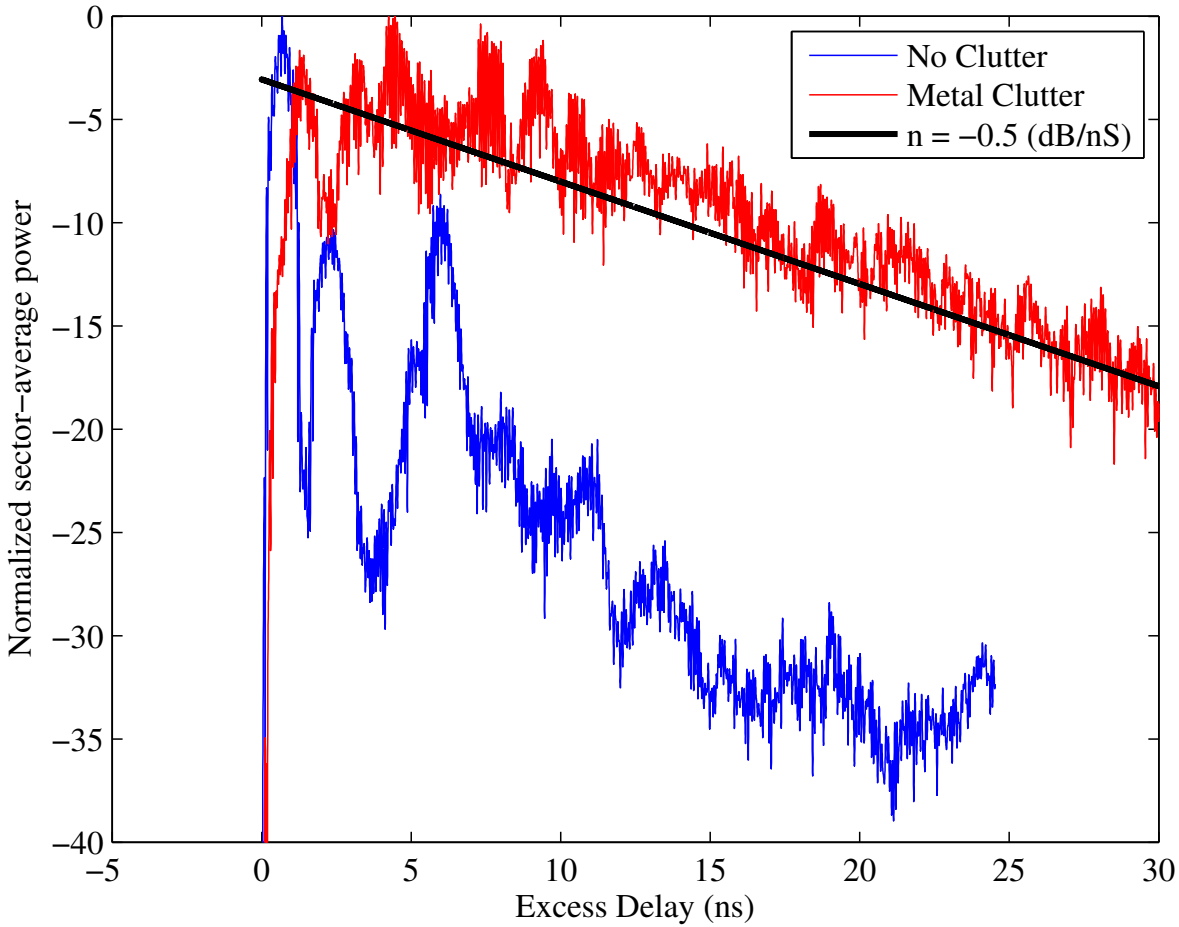
2D TM_z polarized lattice, $\Delta = 1$ mm

- Extract the PDP at each 0.20 m$\times$0.20 m sector by temporally aligning and spatially averaging over 100 points.

Two-dimensional Office Environment

2D TM_z polarized lattice, $\Delta = 1$ mm

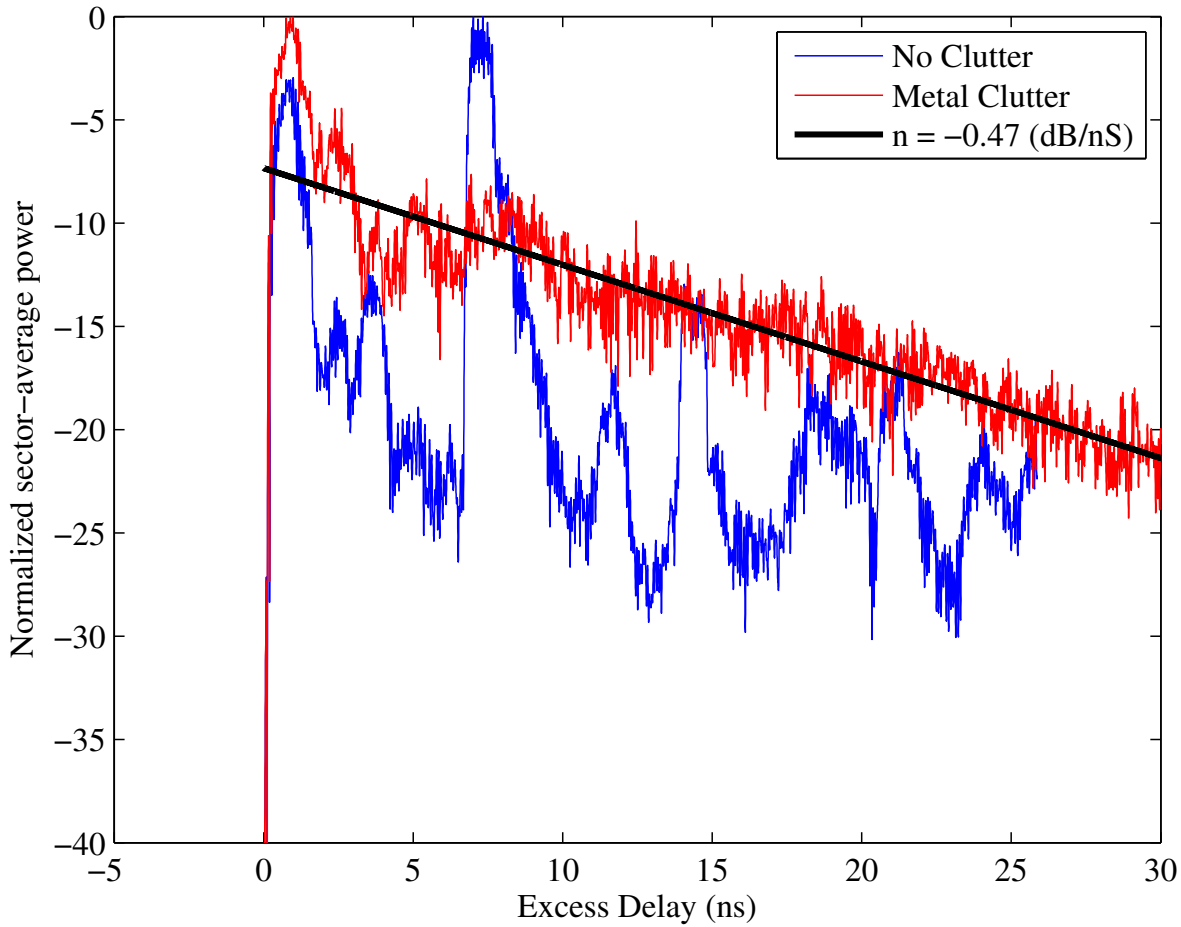
- Extract the PDP at each 0.20 m$\times$0.20 m sector by temporally aligning and spatially averaging over 100 points.
- PDP at sector 1:



Two-dimensional Office Environment

2D TM_z polarized lattice, $\Delta = 1$ mm

- PDP at sector 7:



Modelling UWB-UWB interference

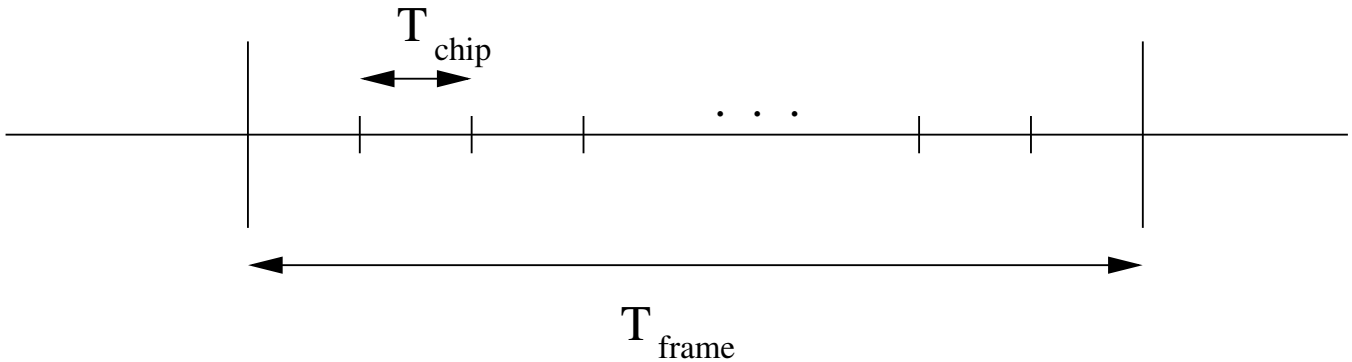
Multi-user Time-Hopping System [Win & Scholtz 2000]

- Pulse position modulation is used to transmit a user's data.

Modelling UWB-UWB interference

Multi-user Time-Hopping System [Win & Scholtz 2000]

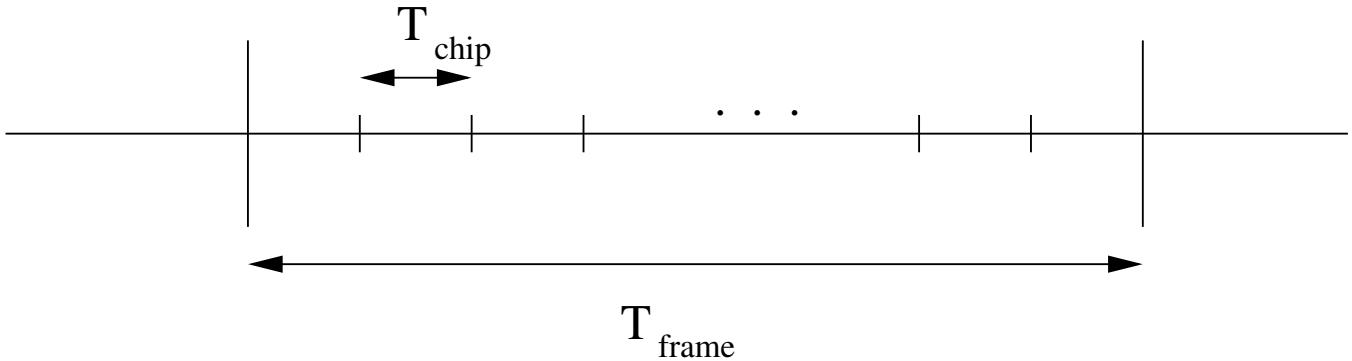
- Pulse position modulation is used to transmit a user's data.
- Each frame is divided in N_h chips and users are separated with time-hopping codes.



Modelling UWB-UWB interference

Multi-user Time-Hopping System [Win & Scholtz 2000]

- Pulse position modulation is used to transmit a user's data.
- Each frame is divided in N_h chips and users are separated with time-hopping codes.

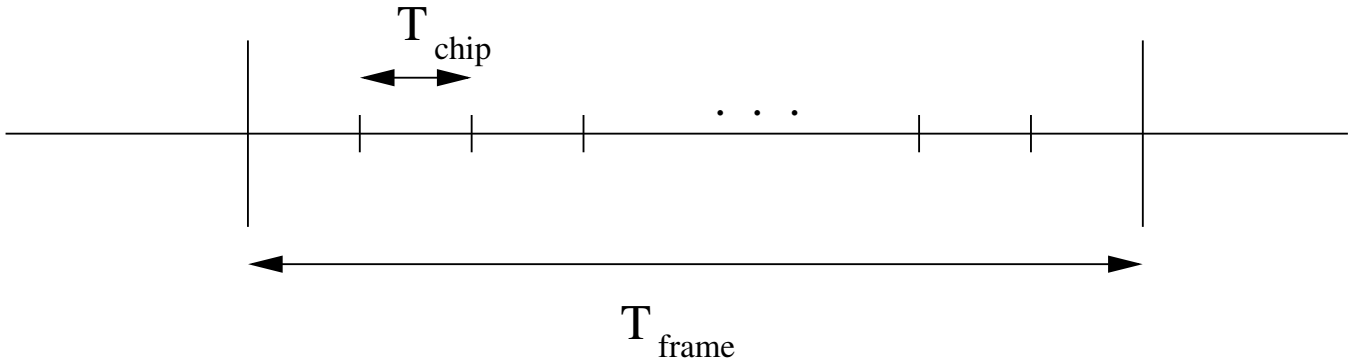


- At the receiver, frame-level synchronization is assumed:

Modelling UWB-UWB interference

Multi-user Time-Hopping System [Win & Scholtz 2000]

- Pulse position modulation is used to transmit a user's data.
- Each frame is divided in N_h chips and users are separated with time-hopping codes.

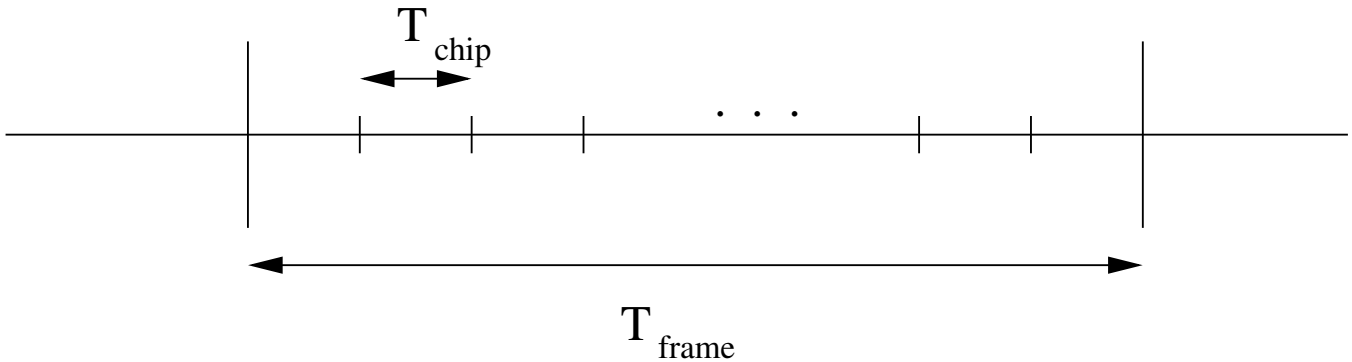


- At the receiver, frame-level synchronization is assumed:
  - Data is recovered by correlating the received signal against the pulse over the appropriate chip.
  - Neighbouring UWB systems can introduce interference.

Modelling UWB-UWB interference

Multi-user Time-Hopping System [Win & Scholtz 2000]

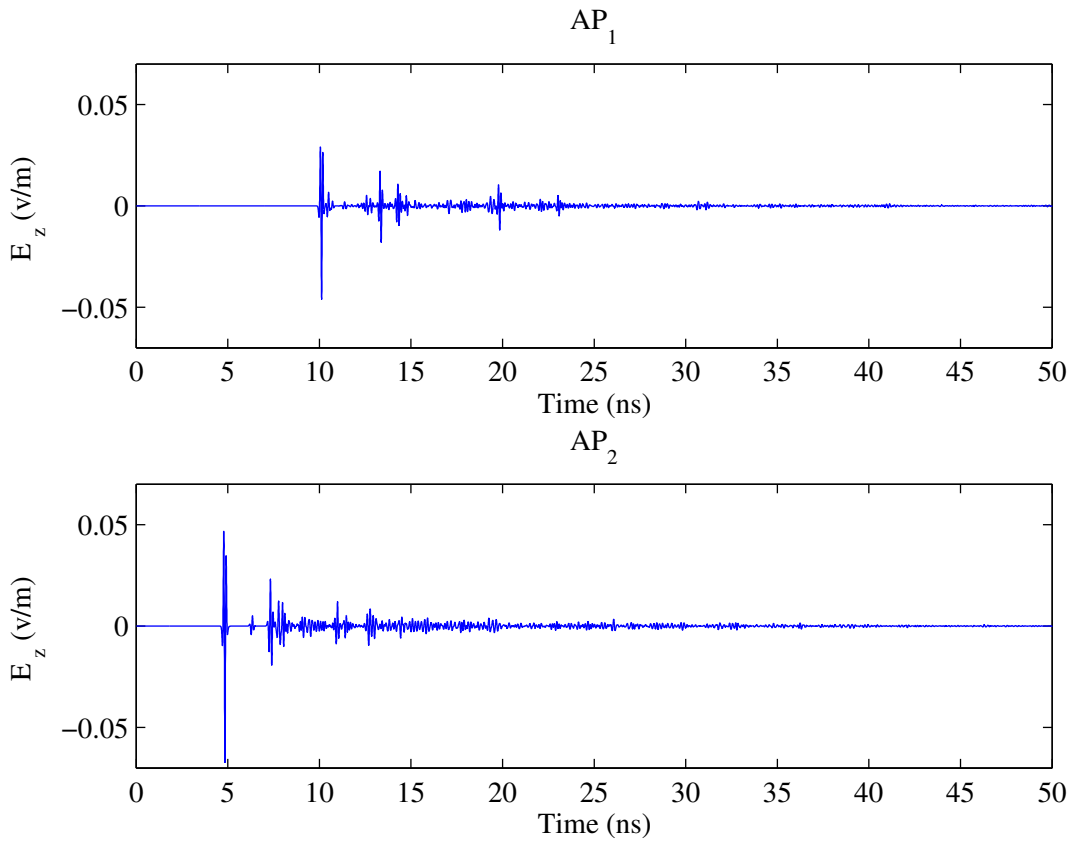
- Pulse position modulation is used to transmit a user's data.
- Each frame is divided in N_h chips and users are separated with time-hopping codes.



- At the receiver, frame-level synchronization is assumed:
  - Data is recovered by correlating the received signal against the pulse over the appropriate chip.
  - Neighbouring UWB systems can introduce interference.
  - Impact depends on the impulse response.

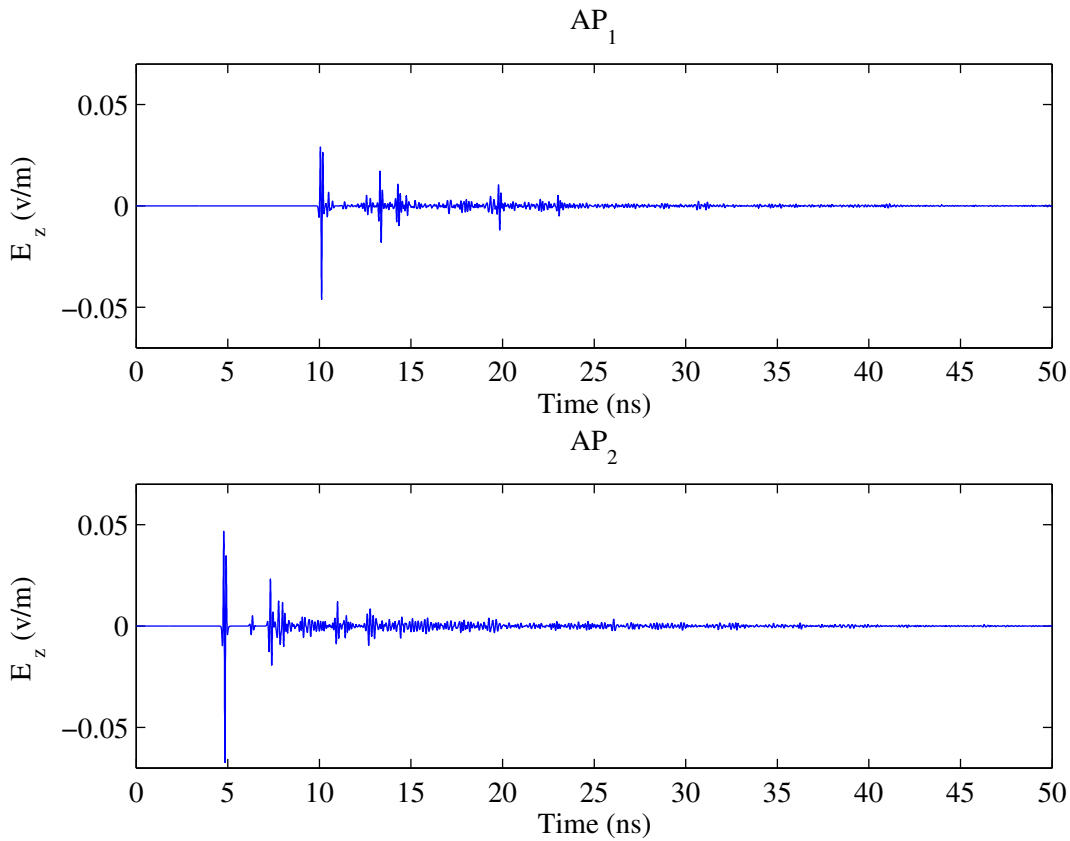
Modelling UWB-UWB interference

- For a typical indoor environment the pulse has usually decayed within $T_{frame} = 50$ ns.



Modelling UWB-UWB interference

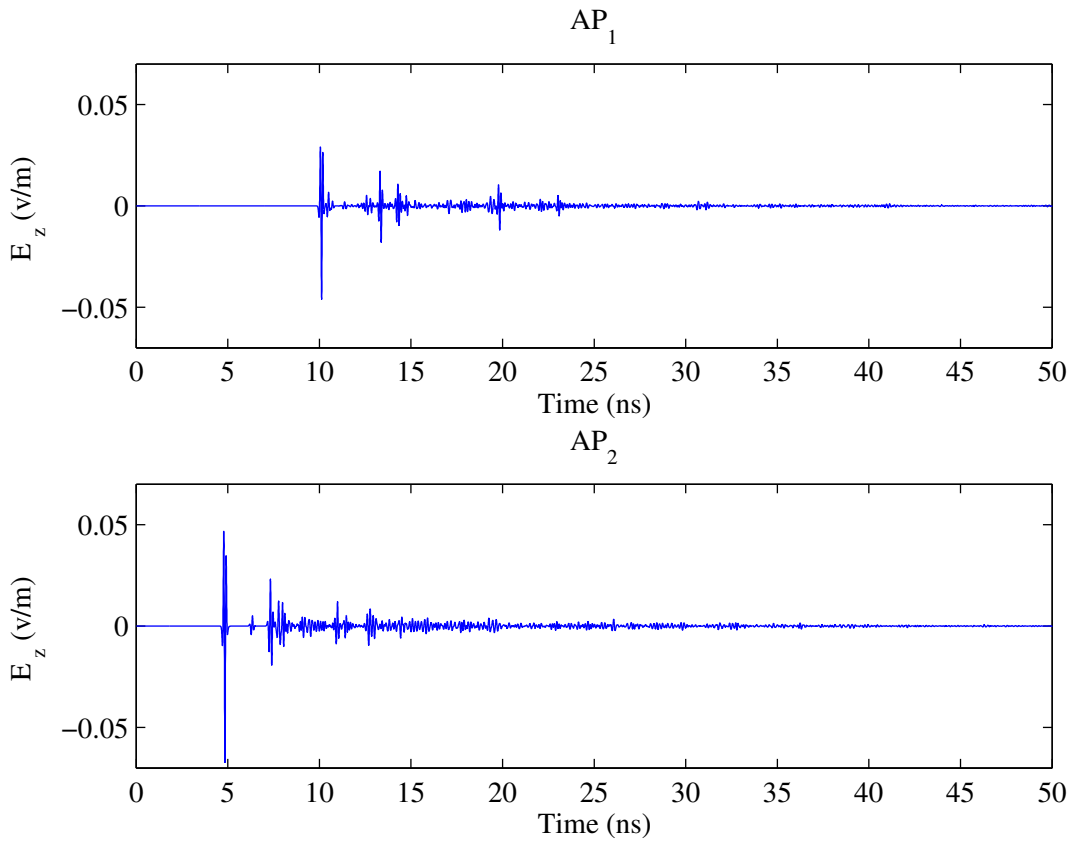
- For a typical indoor environment the pulse has usually decayed within $T_{frame} = 50$ ns.



- However, neighbouring systems are not synchronized.

Modelling UWB-UWB interference

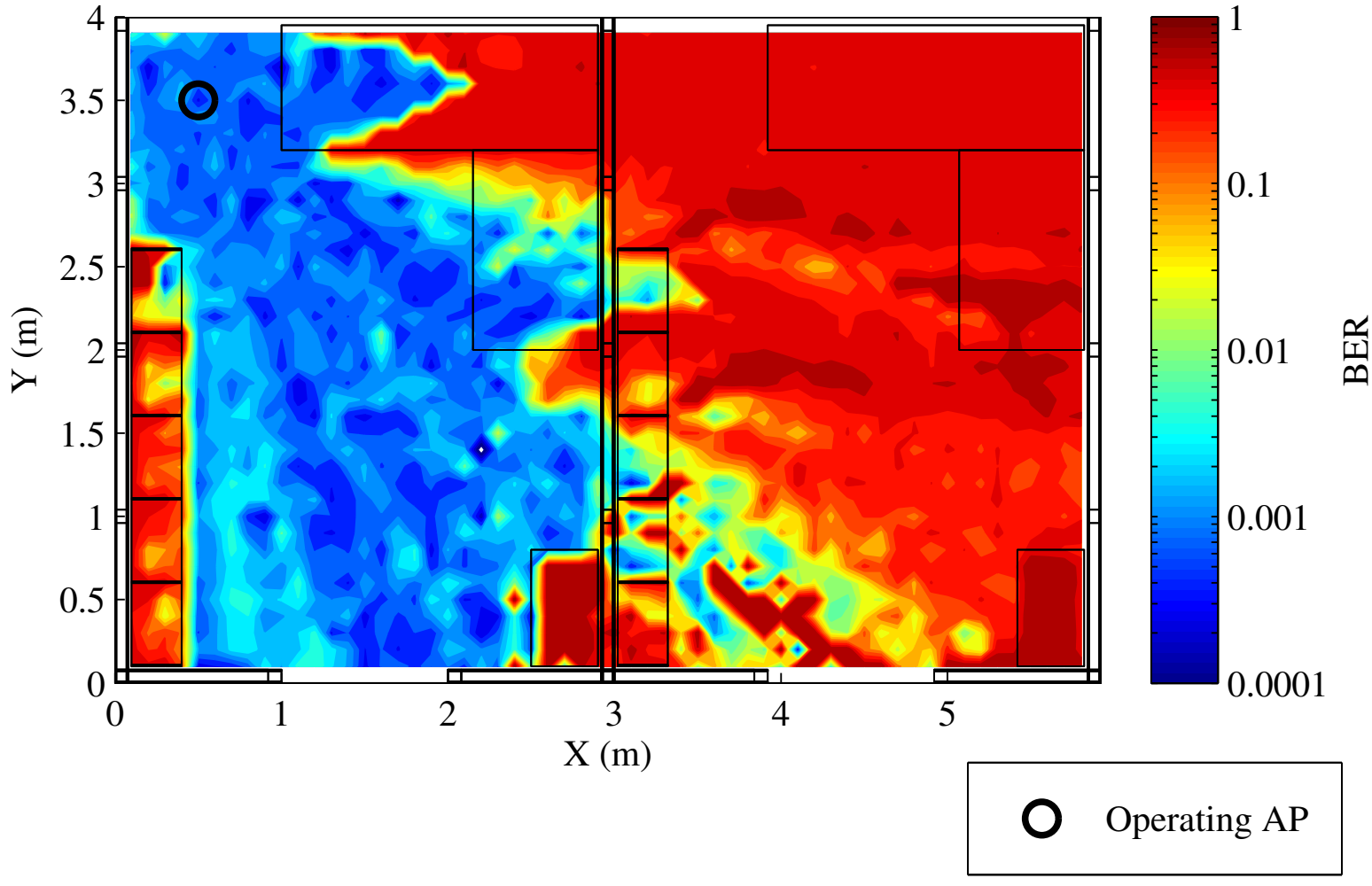
- For a typical indoor environment the pulse has usually decayed within $T_{frame} = 50$ ns.



- However, neighbouring systems are not synchronized.
- The relative time difference is assumed to be random and uniformly distributed.

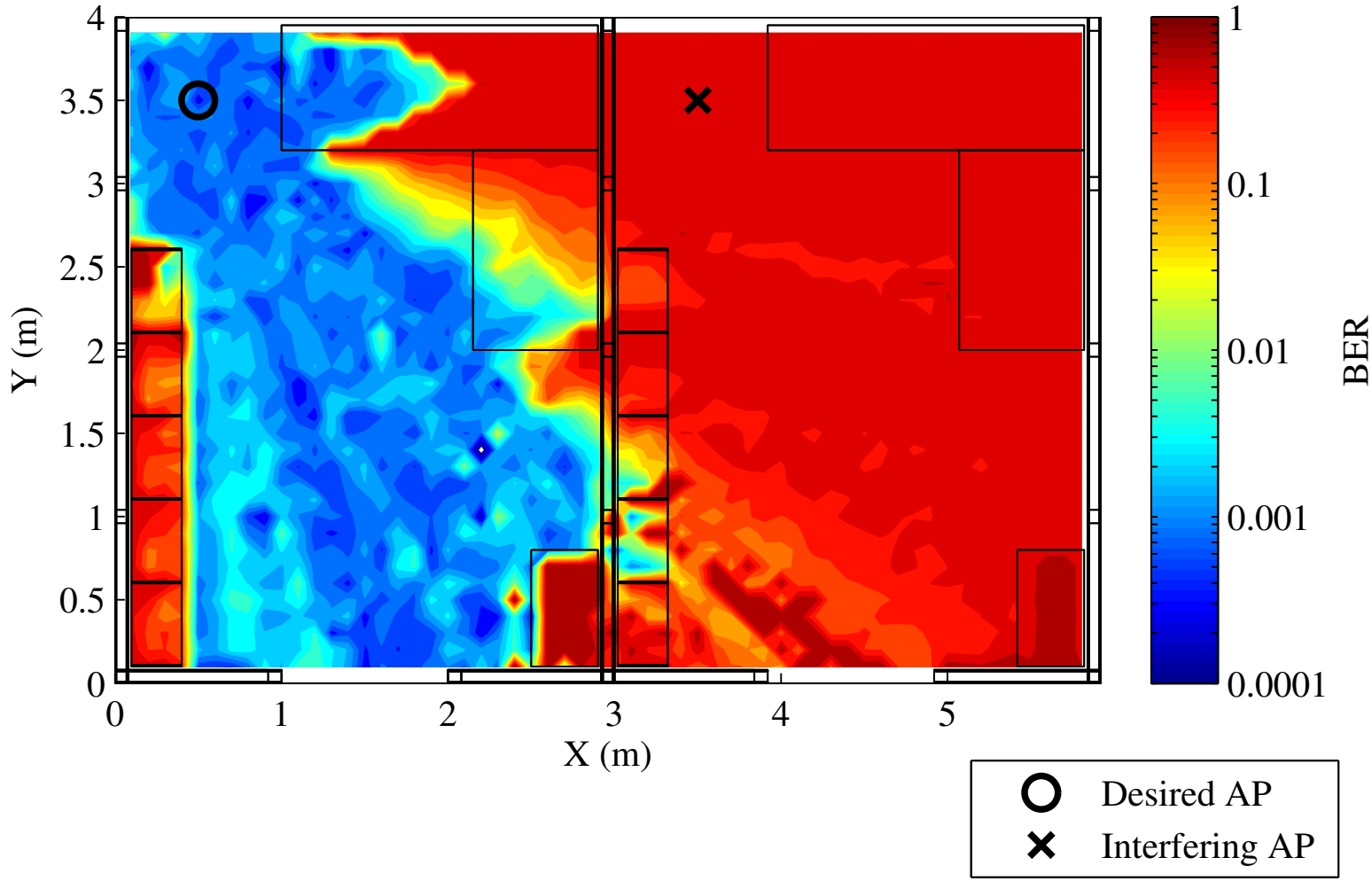
Bit-Error-Rate Coverage Maps: Noise Only

2D TM_z polarization; SNR= 12 dB; 8 users/AP.



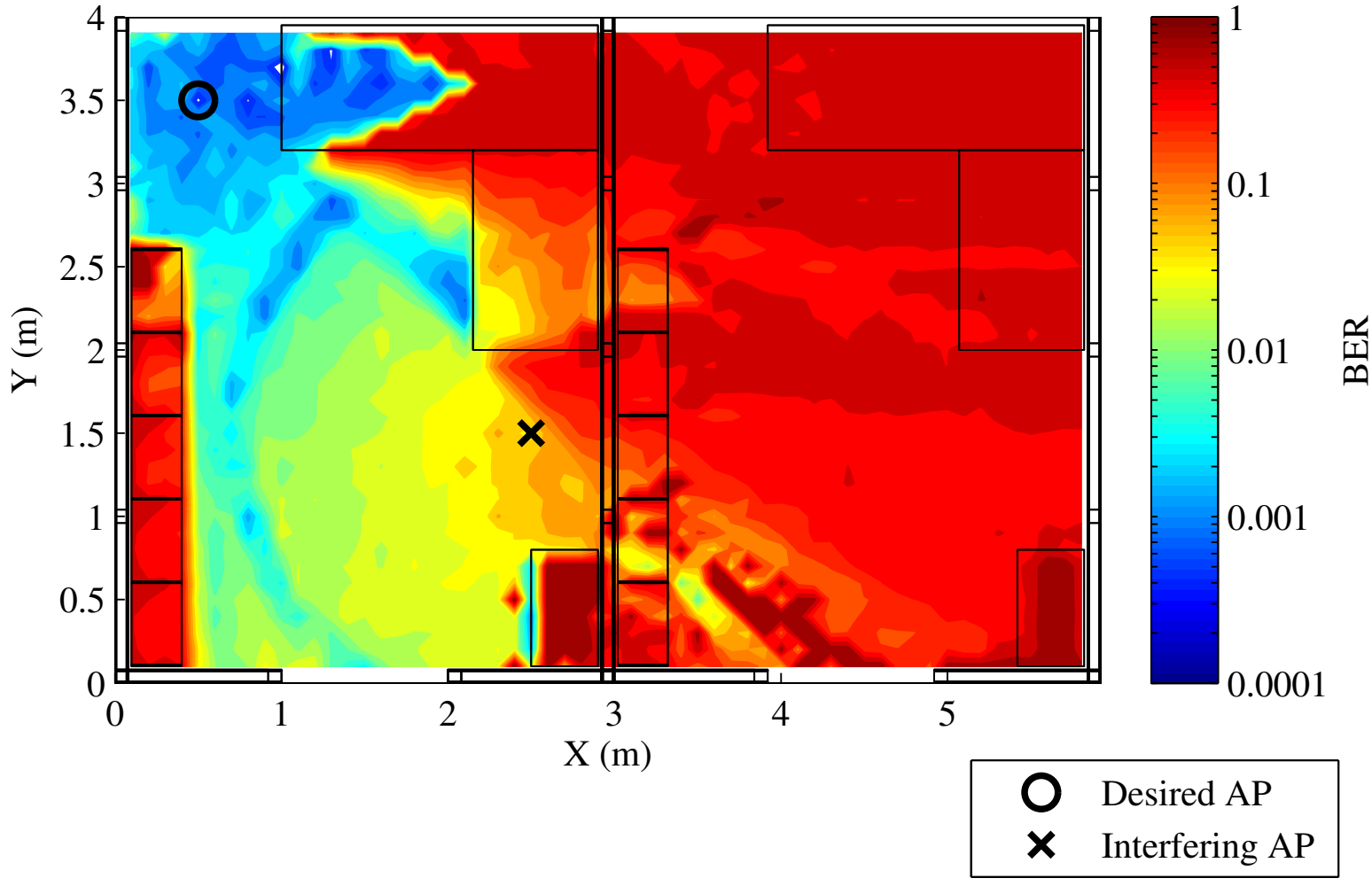
Bit-Error-Rate Coverage Maps: Interference

2D TM_z polarization; SNR= 12 dB; 8 users/AP.



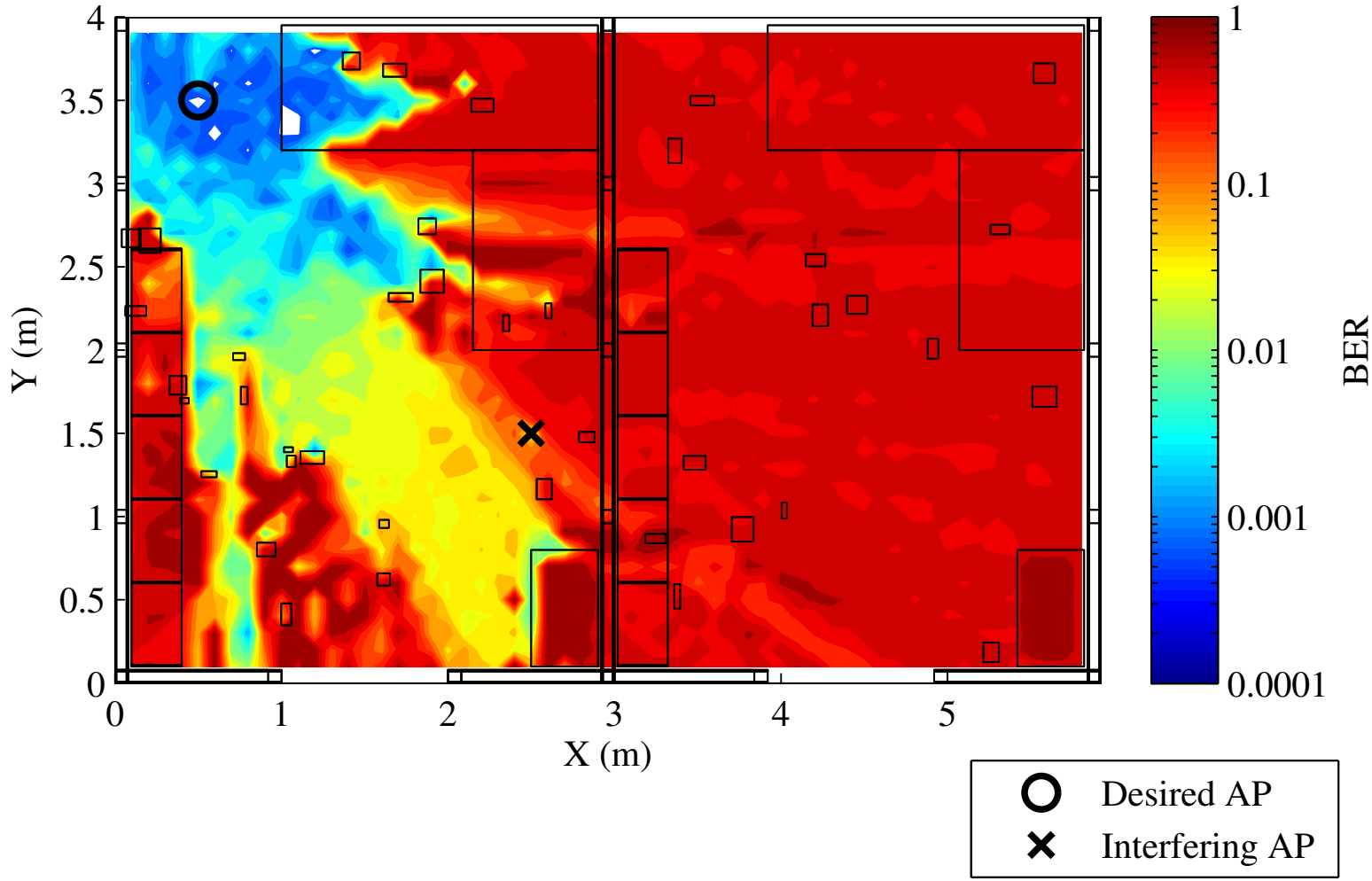
Bit-Error-Rate Coverage Maps: Interference

2D TM_z polarization; SNR= 12 dB; 8 users/AP.



Impact of Clutter

2D TM_z polarization; SNR= 12 dB; 8 users/AP.



Summary

- Local clutter in the environment may influence the channel impulse response (single- vs. clustered-exponential).

Summary

- Local clutter in the environment may influence the channel impulse response (single- vs. clustered-exponential).
- A measure of the UWB-UWB interference (in terms of the BER) can be predicted using FDTD simulations of the indoor channel.

Summary

- Local clutter in the environment may influence the channel impulse response (single- vs. clustered-exponential).
- A measure of the UWB-UWB interference (in terms of the BER) can be predicted using FDTD simulations of the indoor channel.
  - Dependent on the (specific) temporal characteristics.

Summary

- Local clutter in the environment may influence the channel impulse response (single- vs. clustered-exponential).
- A measure of the UWB-UWB interference (in terms of the BER) can be predicted using FDTD simulations of the indoor channel.
  - Dependent on the (specific) temporal characteristics.
  - Clutter in the environment can significantly increase the local BER.

Thank you.
Questions?