Planning and Analysis of UHF RFID Systems Using Ray Tracing Predictions

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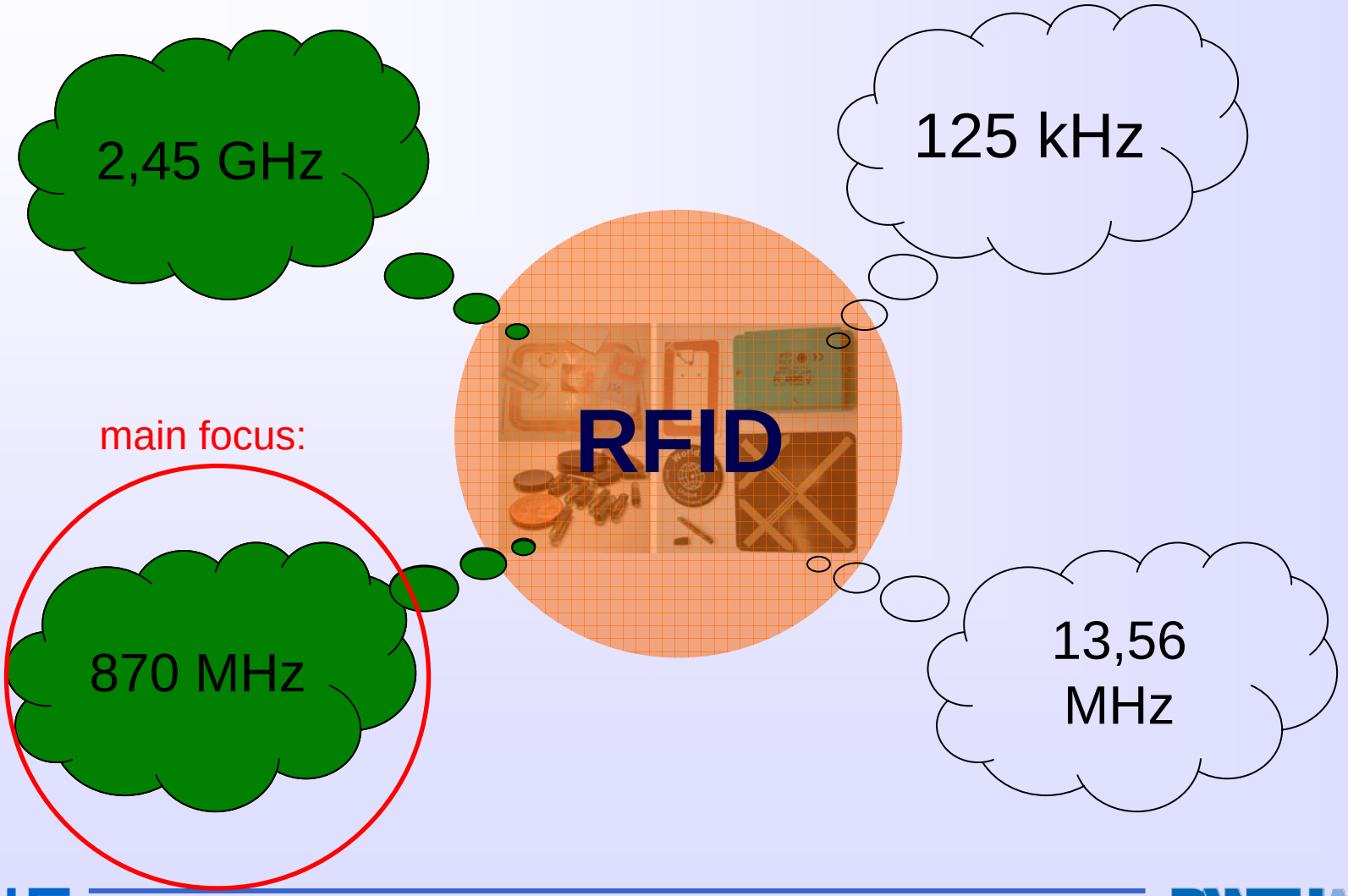
RFID overview



Motivation

UHF: 865 – 960 MHz

main focus

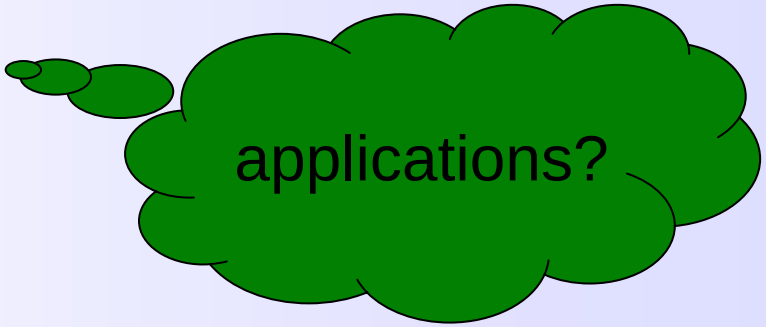
- Supply chain logistics
- Tracking and tracing
- Access control

Examples:

- Identification of storage positions
- Identification of freight containers
- Vehicle toll collect
- Protection of workers in dangerous areas

Transponder types:

- Active or passive
- Disposable or reusable



- International interoperability
- National interoperability
- For internal use only

- Goods
- Individuals

Read range: up to several Meters

Motivation

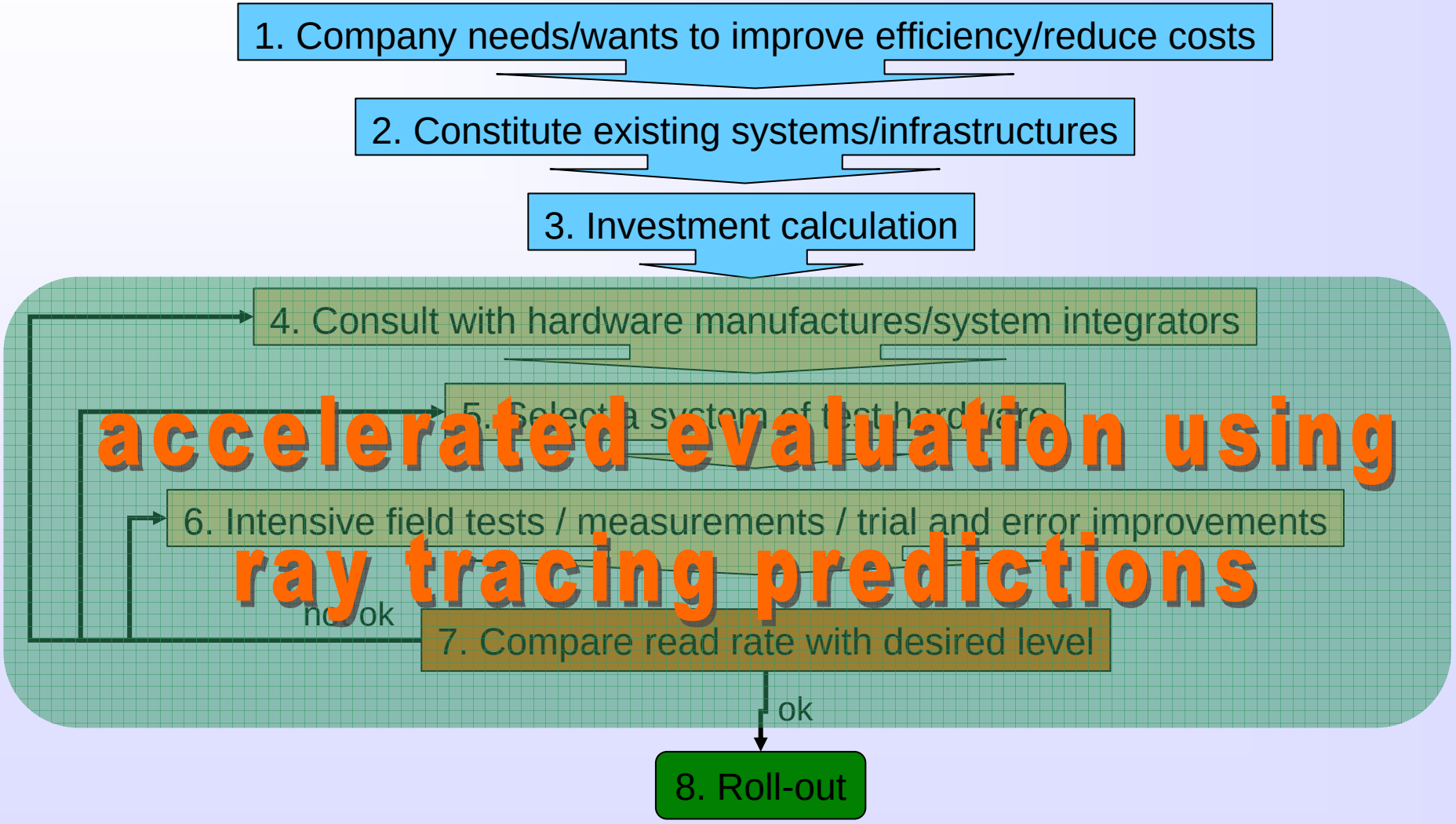
UHF RFID for logistics applications using passive transponders

Photos: REWE Group

Photo: METRO Group

- Identification of shipment units / boxes
- Product tracking within supply chain
- Certificate of authenticity
- Warehouse management
- Theft prevention

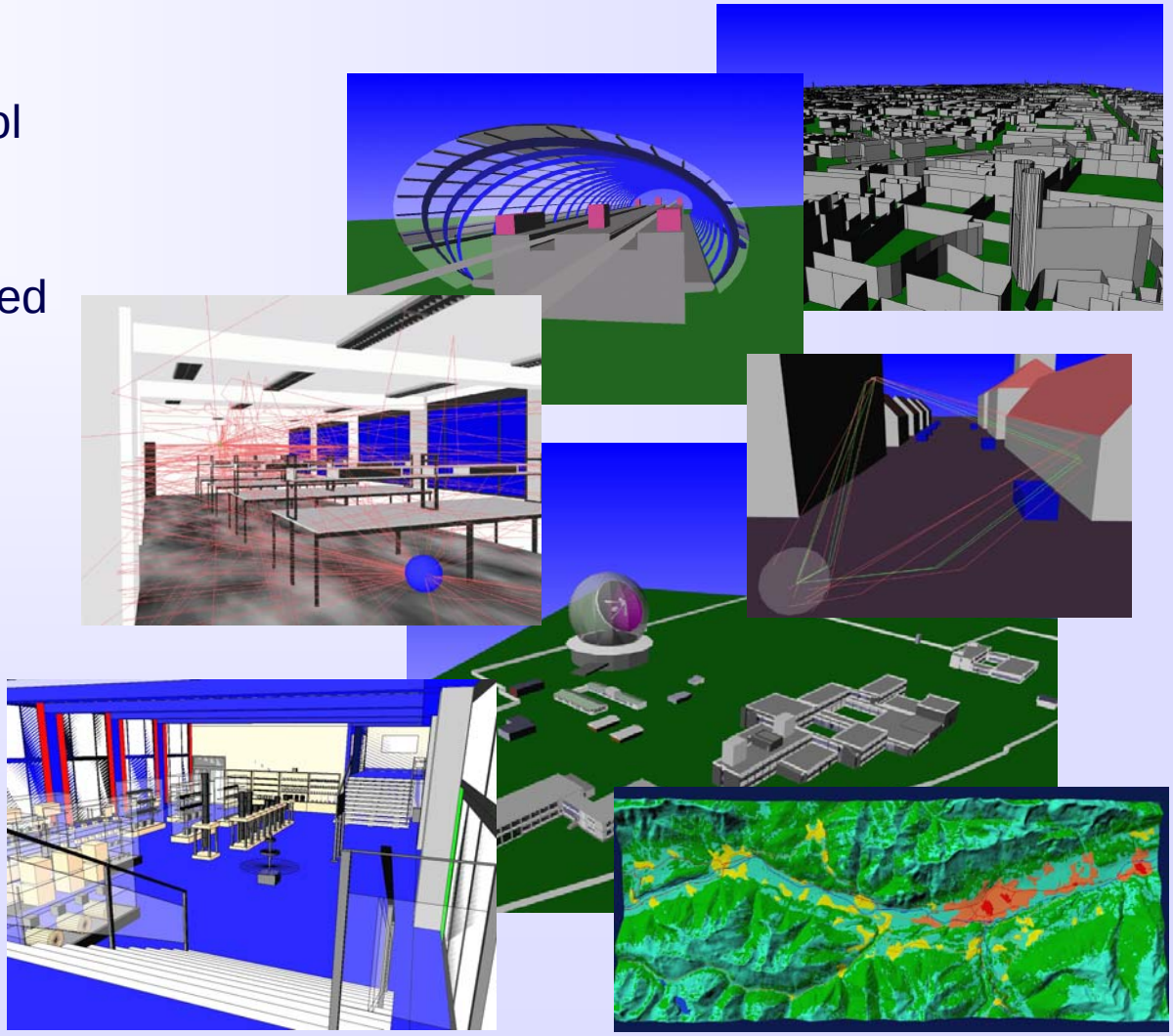
RFID roll-out procedure



Ray Tracing overview

General properties:

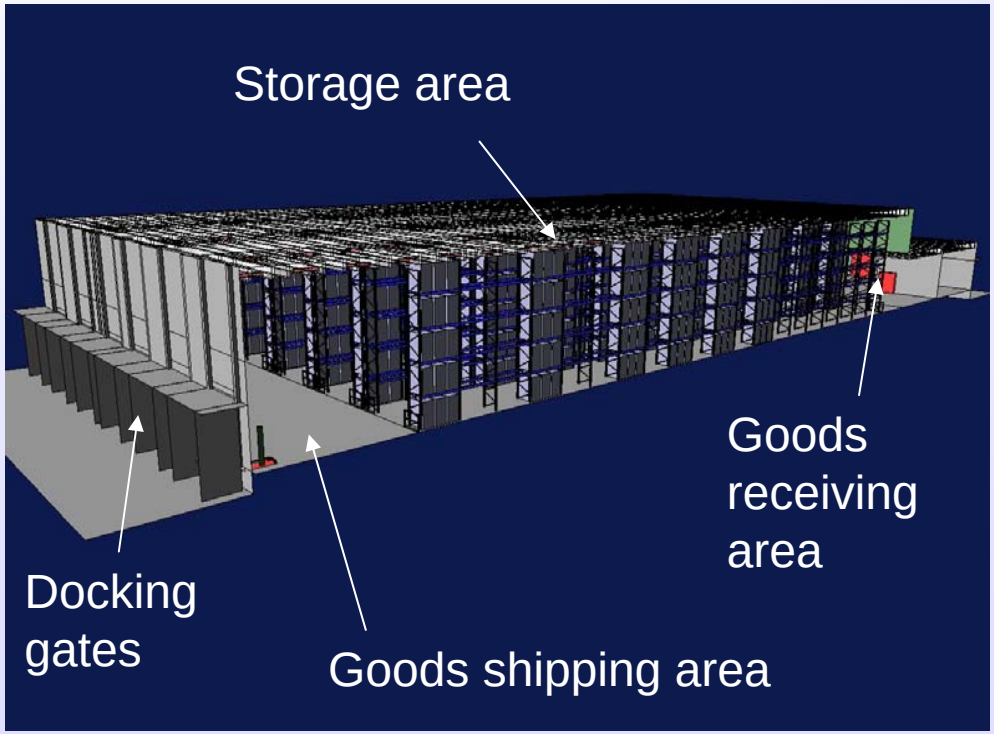
- Fast, efficient simulation tool for calculation of wave propagation
- Environment modelling based on surface descriptions
- Ray optical approach
- Prediction of multipath propagation between transmitters and receivers
- Result: complex channel characteristics
- Completely developed at the IHF, RWTH Aachen

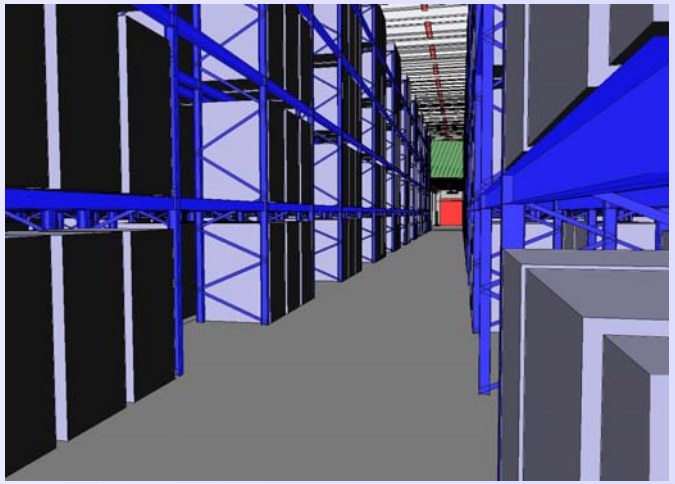


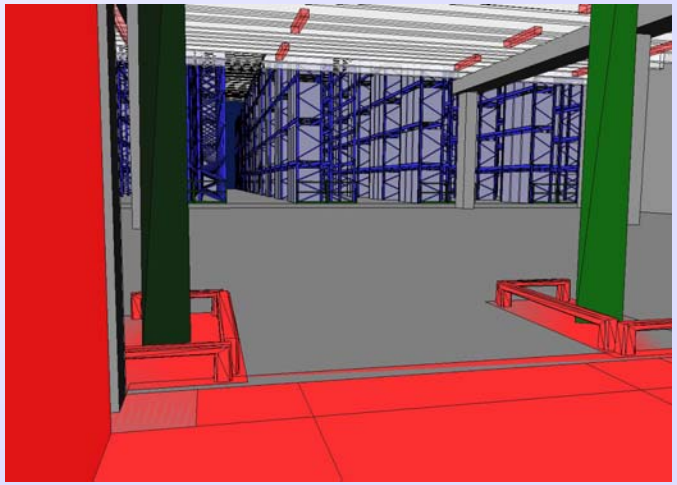
Examples of outdoor and indoor ray tracing applications

3D model

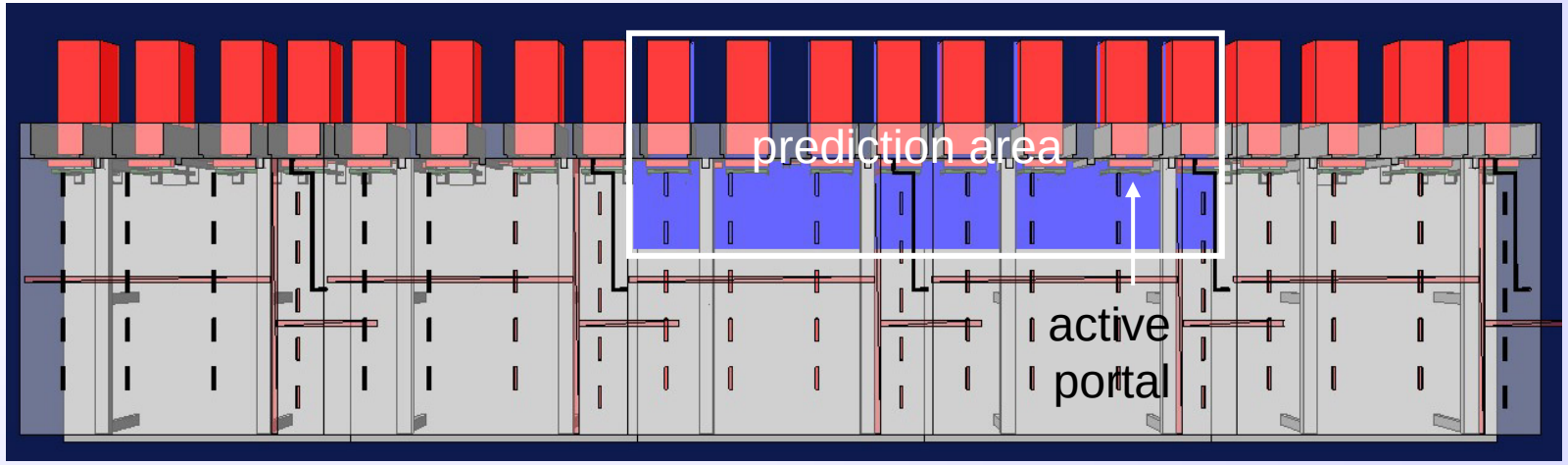
3D VRML view of the simulation model: distribution/reloading center for consumer products (groceries)







Goods receiving area



- 20 docking gates with an RFID portal each
- Trucks docked at each gate
- Dimensions of the building: 103 m x 20 m

enlargement of portal construction and unloading of shipment

Prediction area:

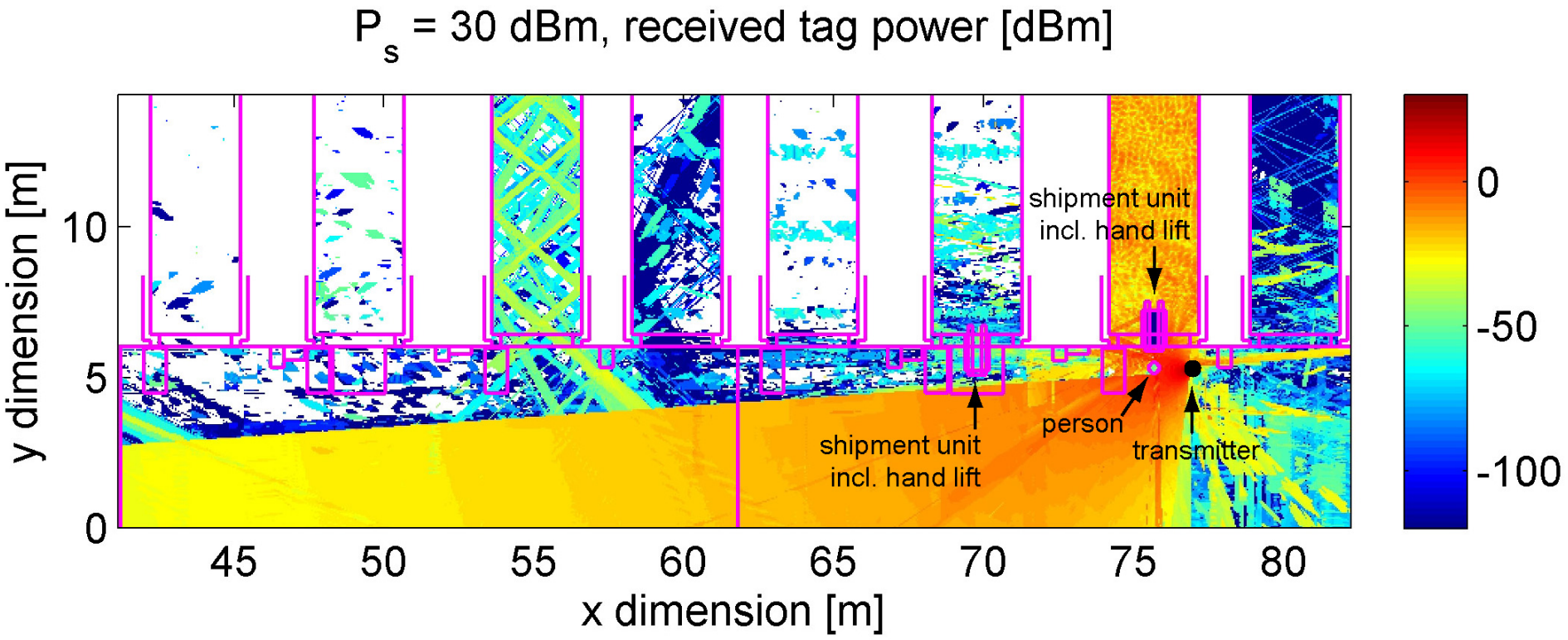
- evenly spaced grid of receive antenna positions
- resolution 5 cm x 5 cm, height z = 75 cm
- yields 2D results of received power

RF and portal setup

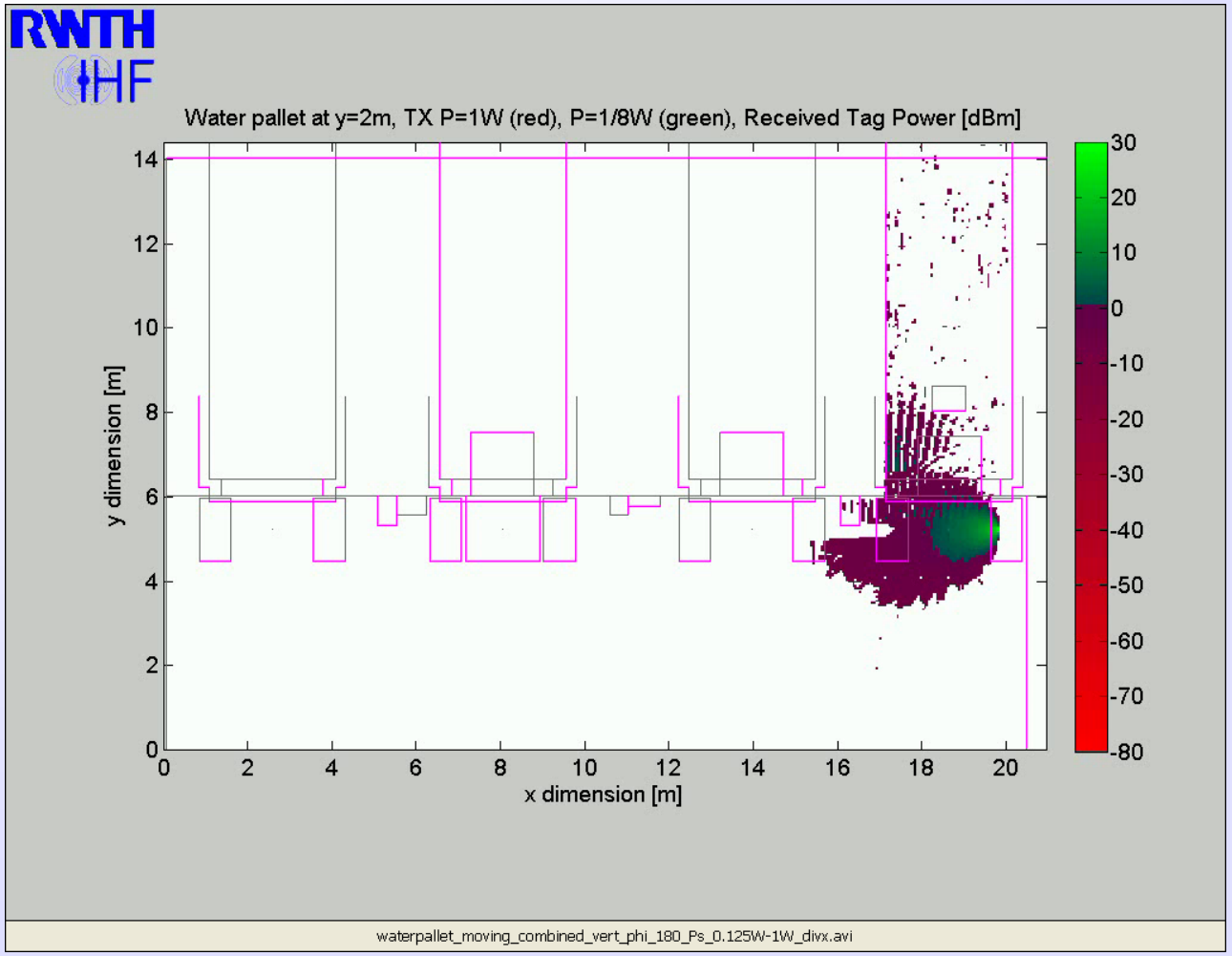
Setup in compliance with typical RFID specifications:

- Operation frequency: 867.5 MHz (Channel 10 in Europe).
- Transmit power: 1 W (30 dBm).
- Portal antenna (read/write unit) mounted at height z = 75 cm.
- Portal antenna: right-hand circular polarization and G_{max} = 6.
- Transponder antennas: half-wavelength dipole characteristics with vertical polarization.

Goods receiving area prediction results



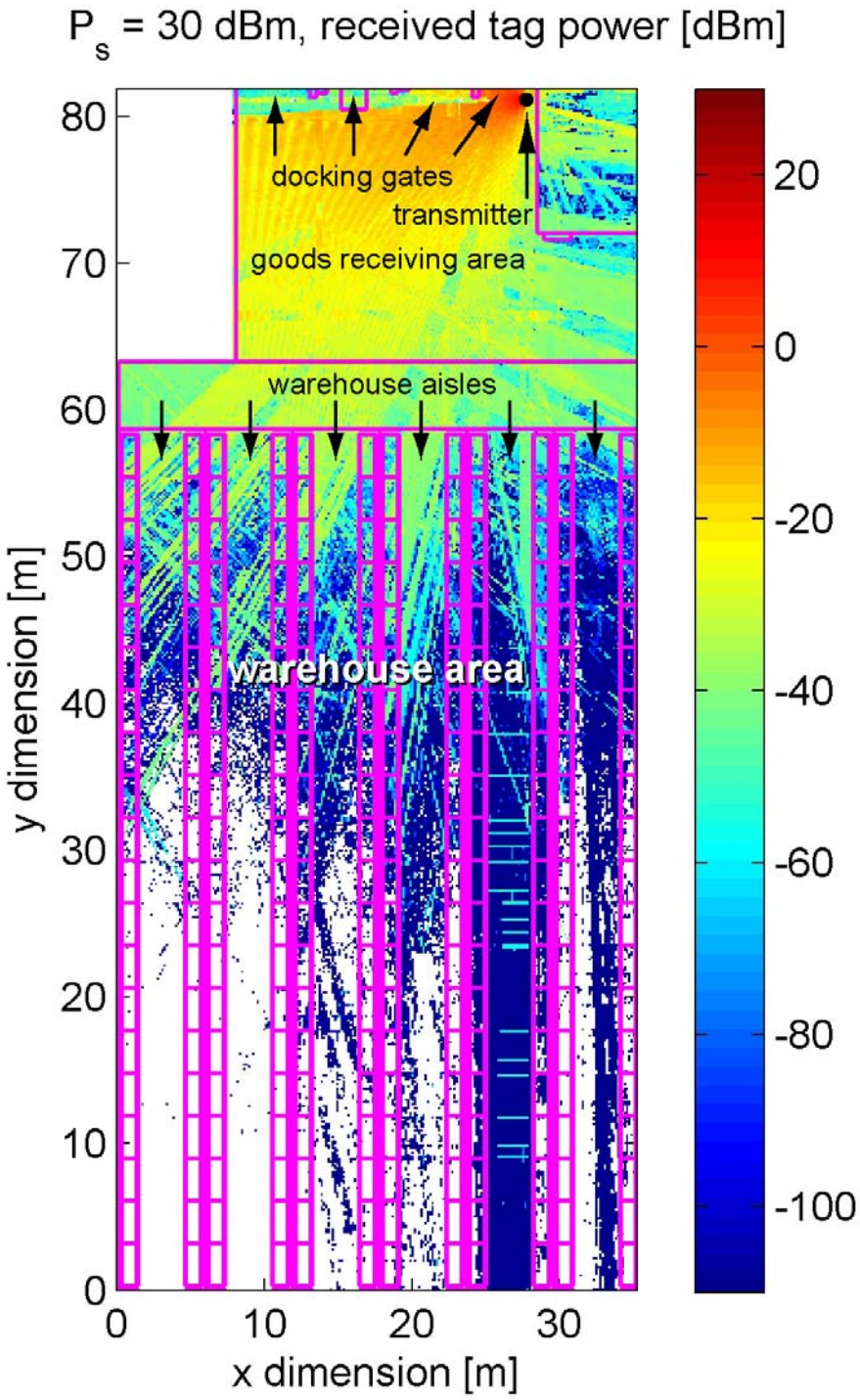
Unloading procedure



Complete warehouse

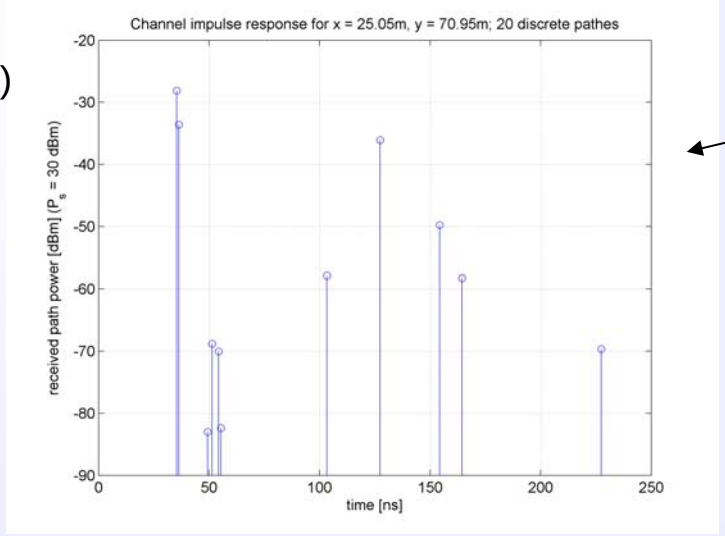
Setup variation:

- Spatial receiver resolution
  15 cm x 15 cm
  (previously 5 cm x 5 cm)
- 4 docking gates at the goods receiving area
  (previously 20)
- Warehouse area half-way filled (alternating pattern) with water shipment units

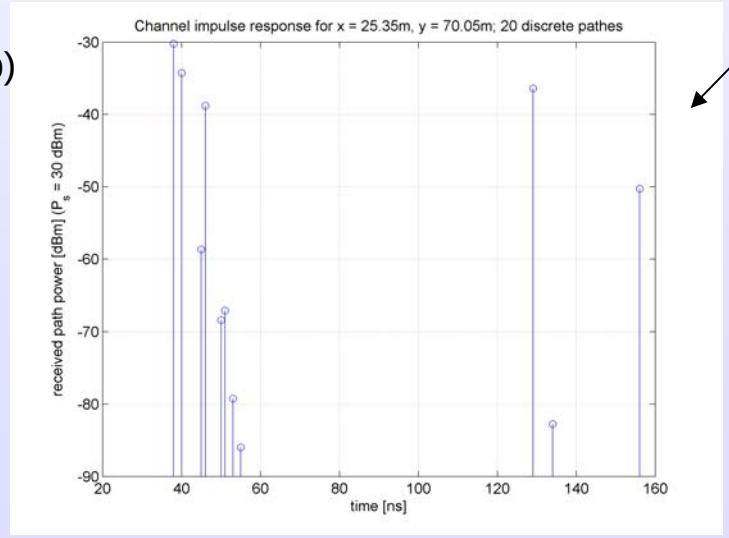


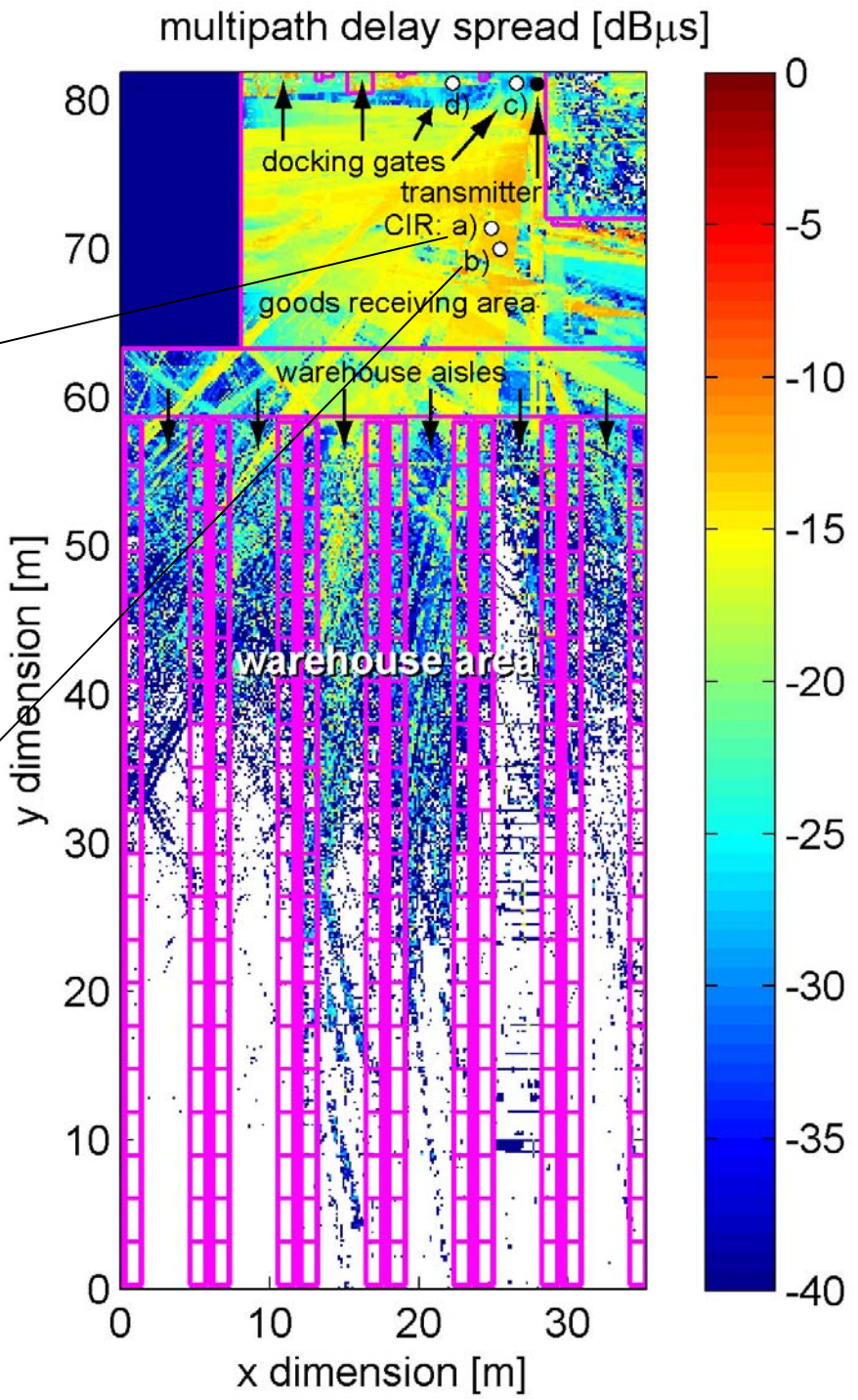
Complete warehouse

CIR a)



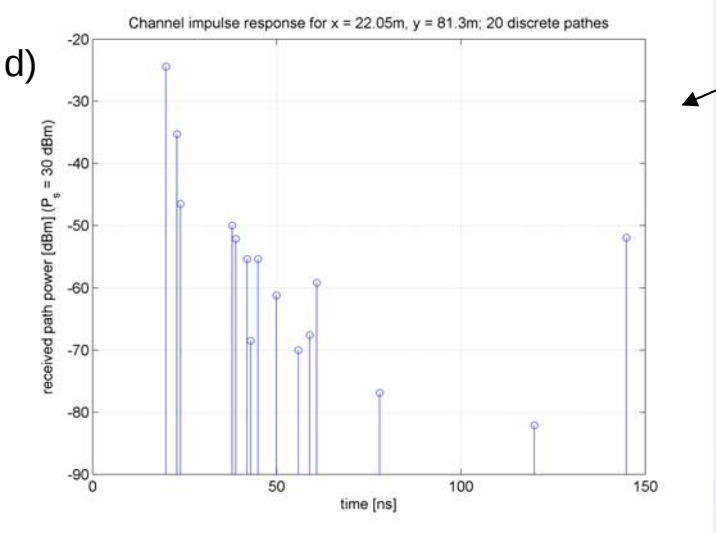
CIR b)



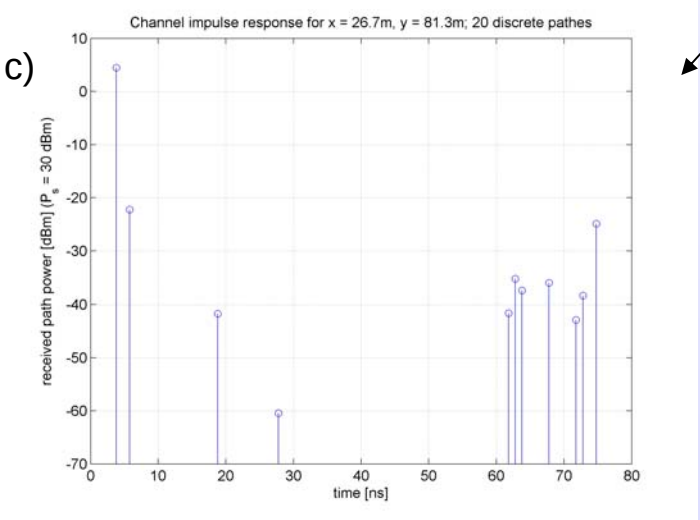


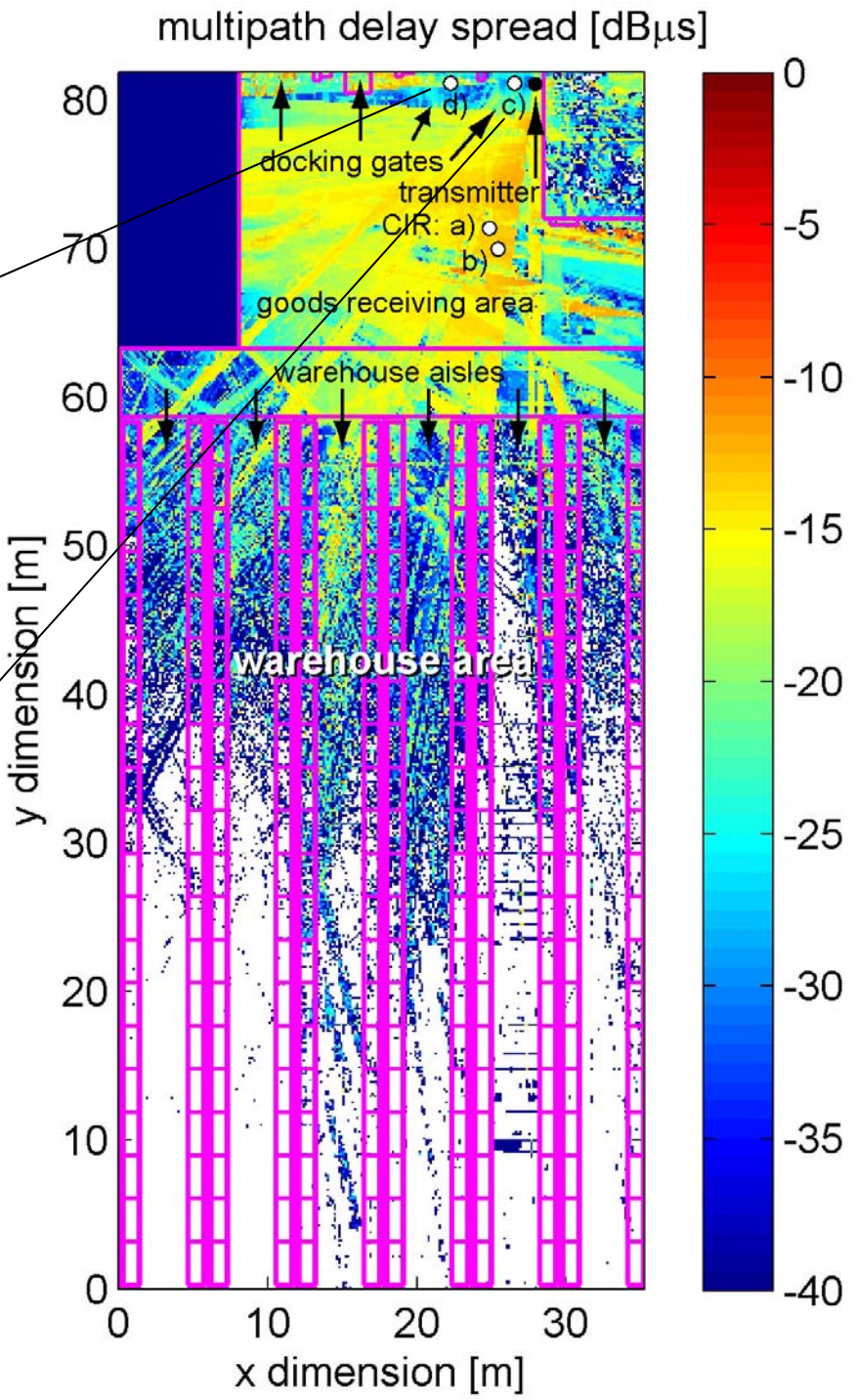
Complete warehouse

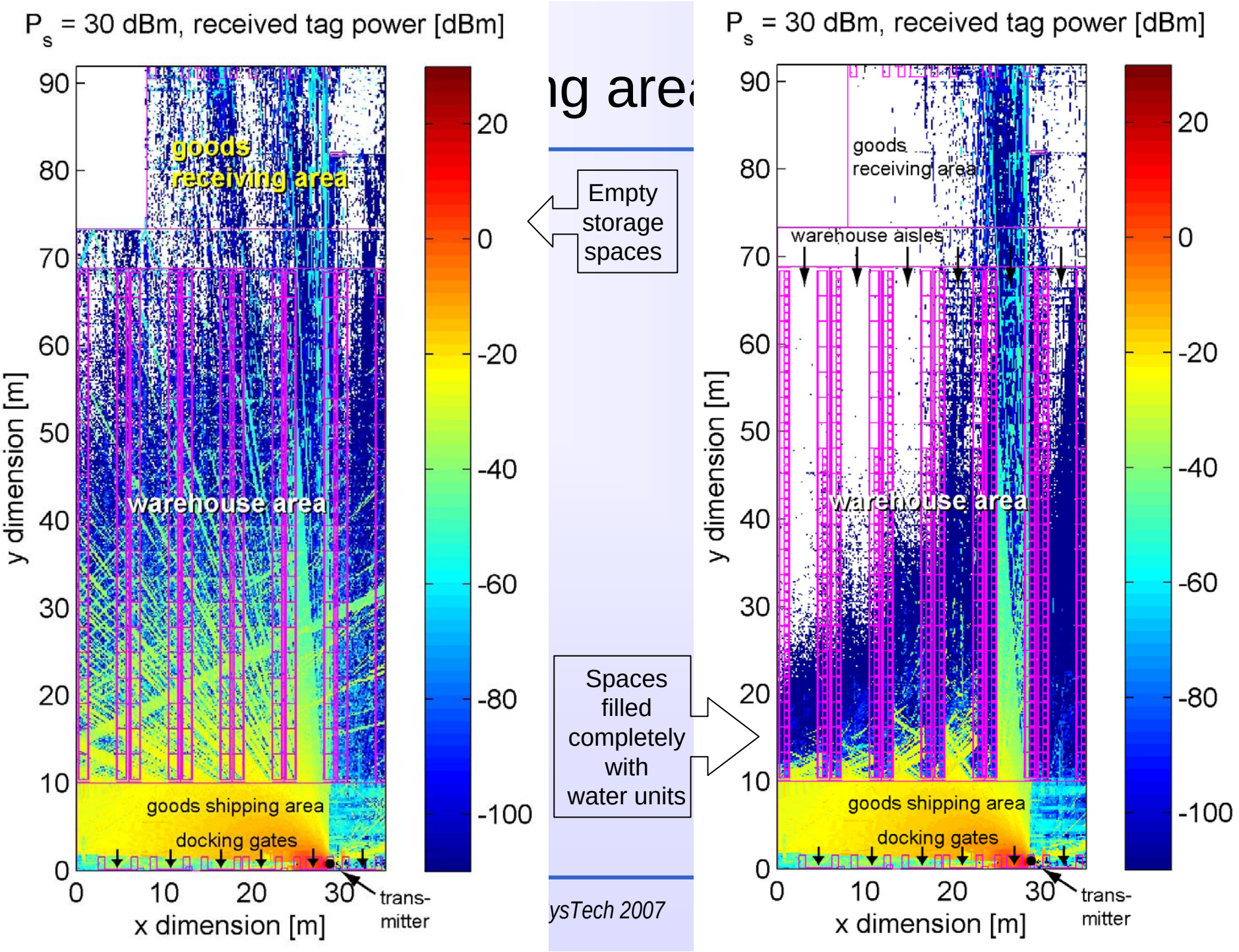
CIR d)



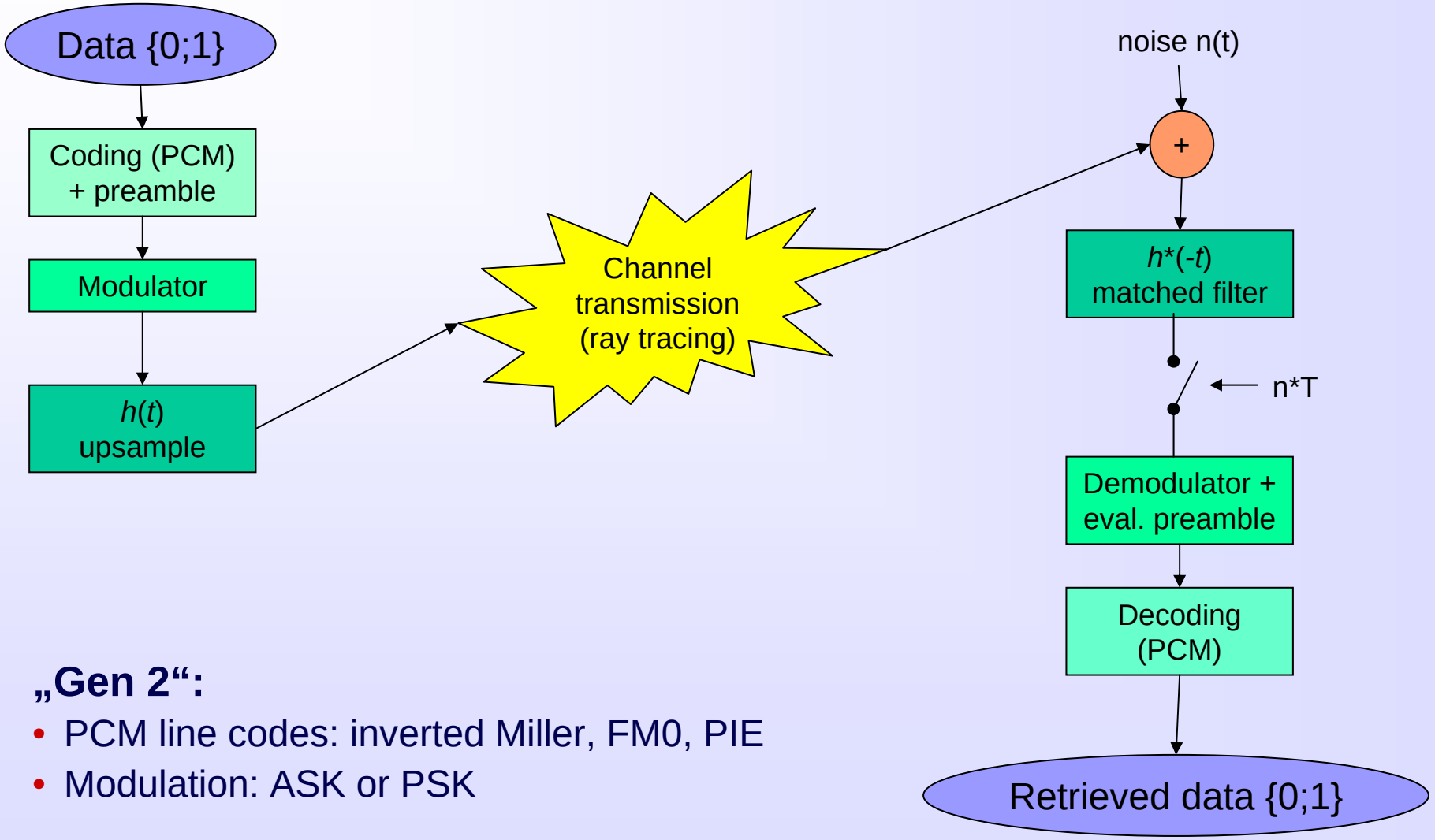
CIR c)






P s = 30 dBm, received tag power [dBm]
goods receiving area
warehouse area
goods shipping area
docking gates
trans-mitter
y dimension [m]
x dimension [m]
Empty storage spaces
Spaces filled completely with water units
P s = 30 dBm, received tag power [dBm]
goods receiving area
warehouse aisles
warehouse area
goods shipping area
docking gates
trans-mitter
y dimension [m]
x dimension [m]

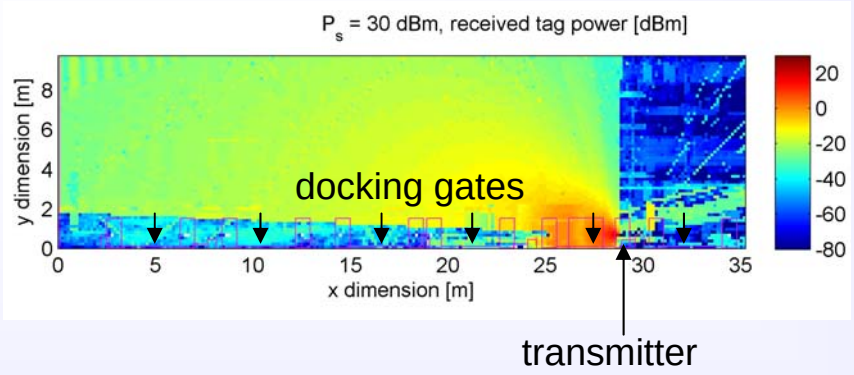
Signal transmission



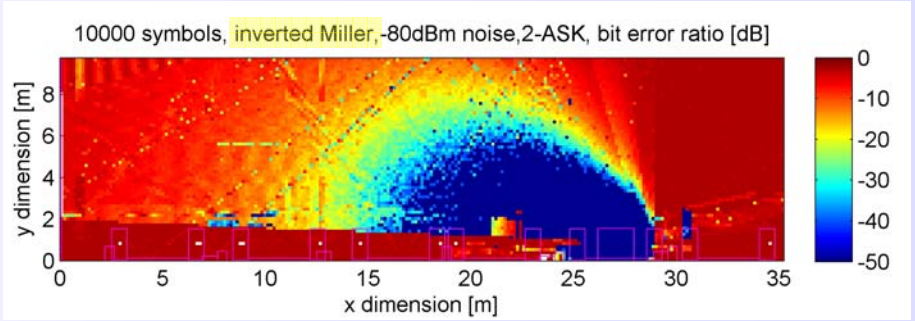
„Gen 2“:

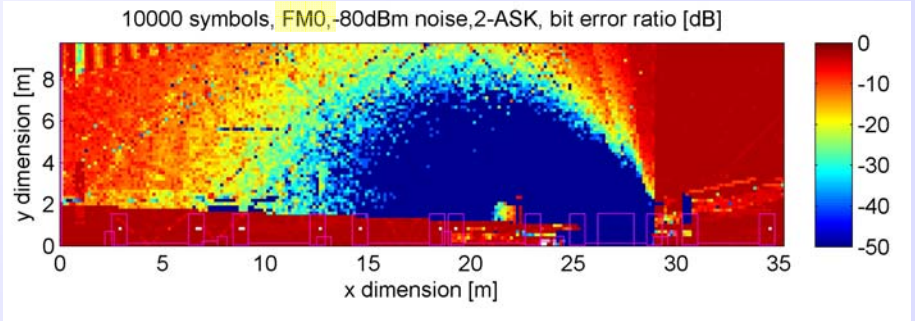
- PCM line codes: inverted Miller, FM0, PIE
- Modulation: ASK or PSK

Bit error ratio prediction results

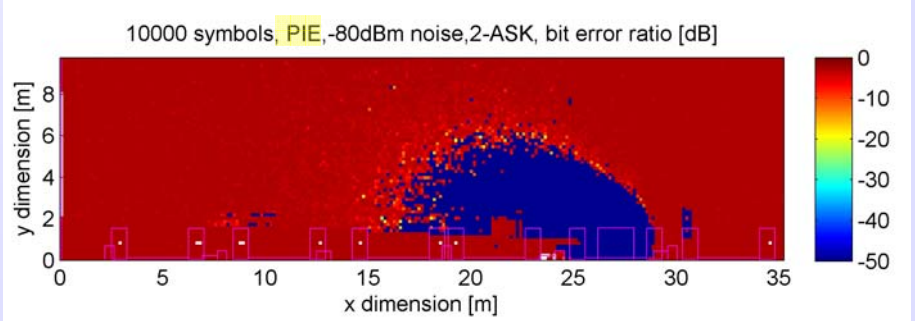


Tag-to-reader communication



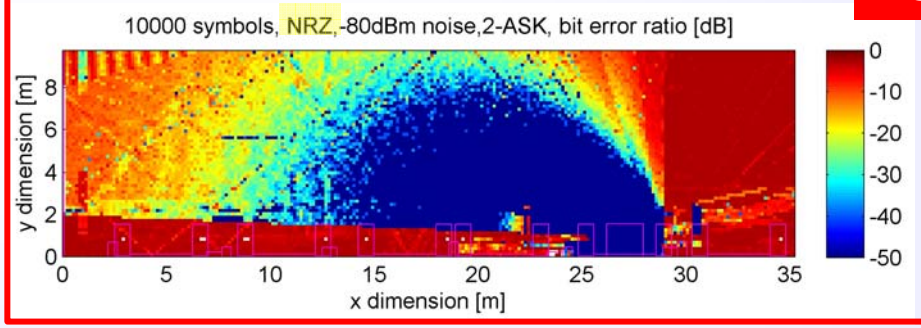


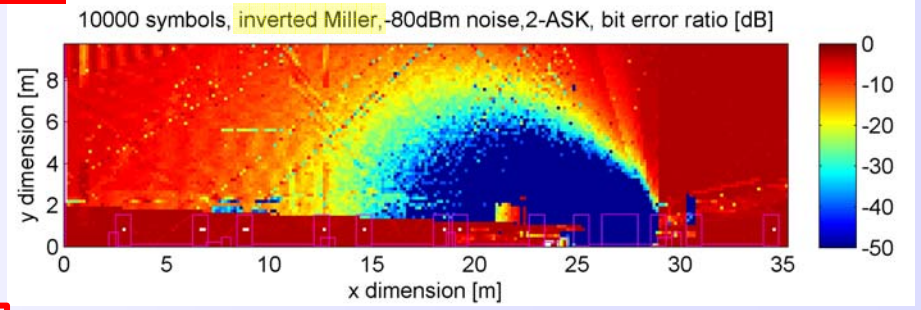
Reader-to-tag communication

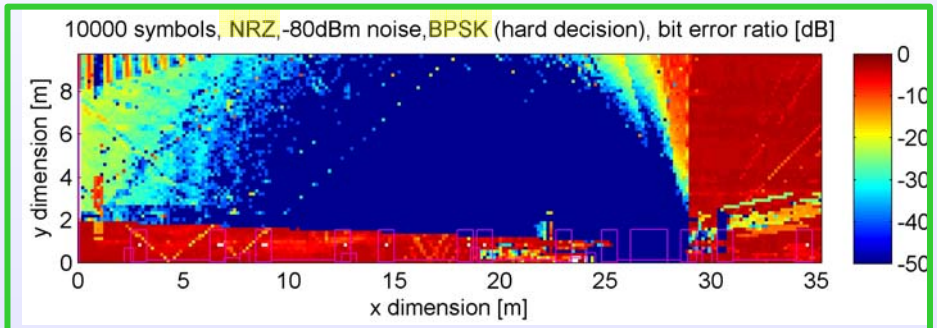


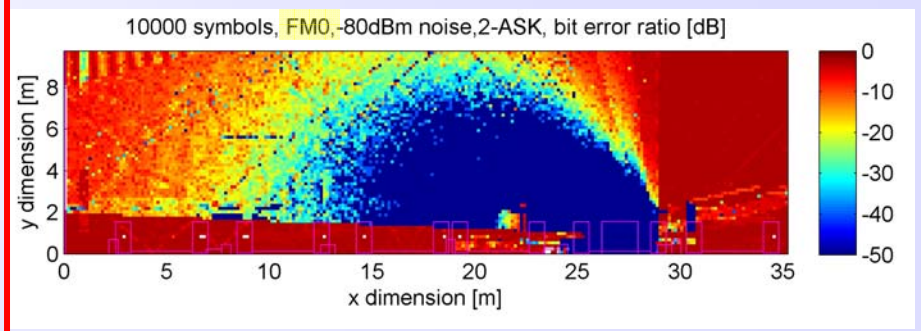
Bit error ratio prediction results

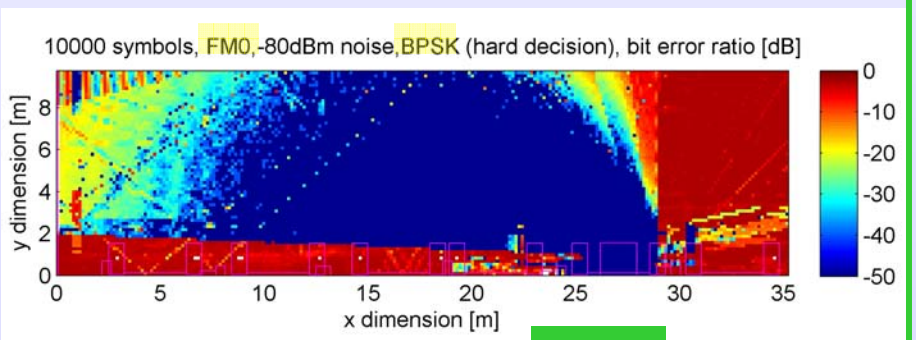
ASK

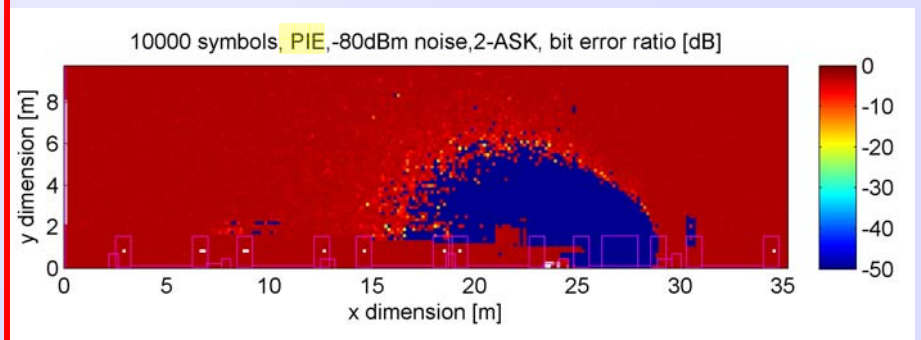




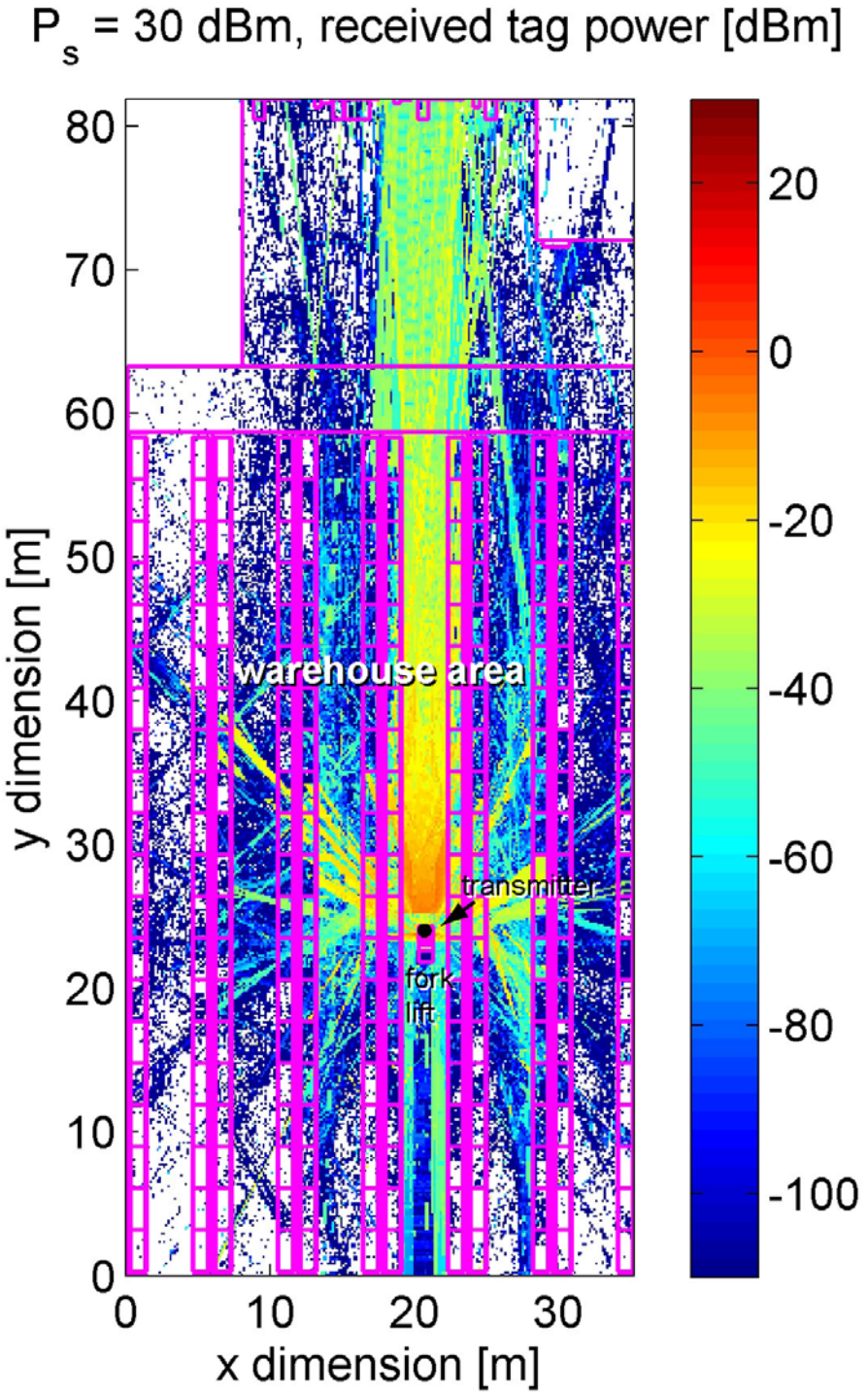




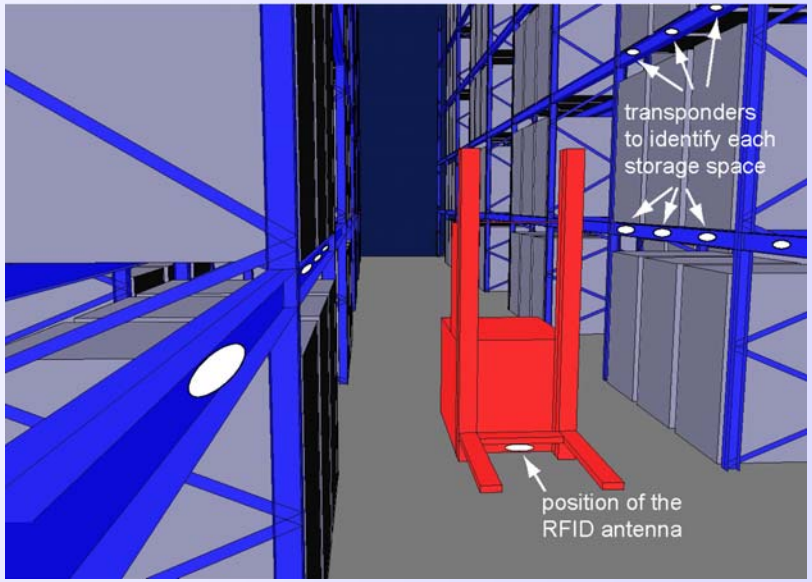




PSK

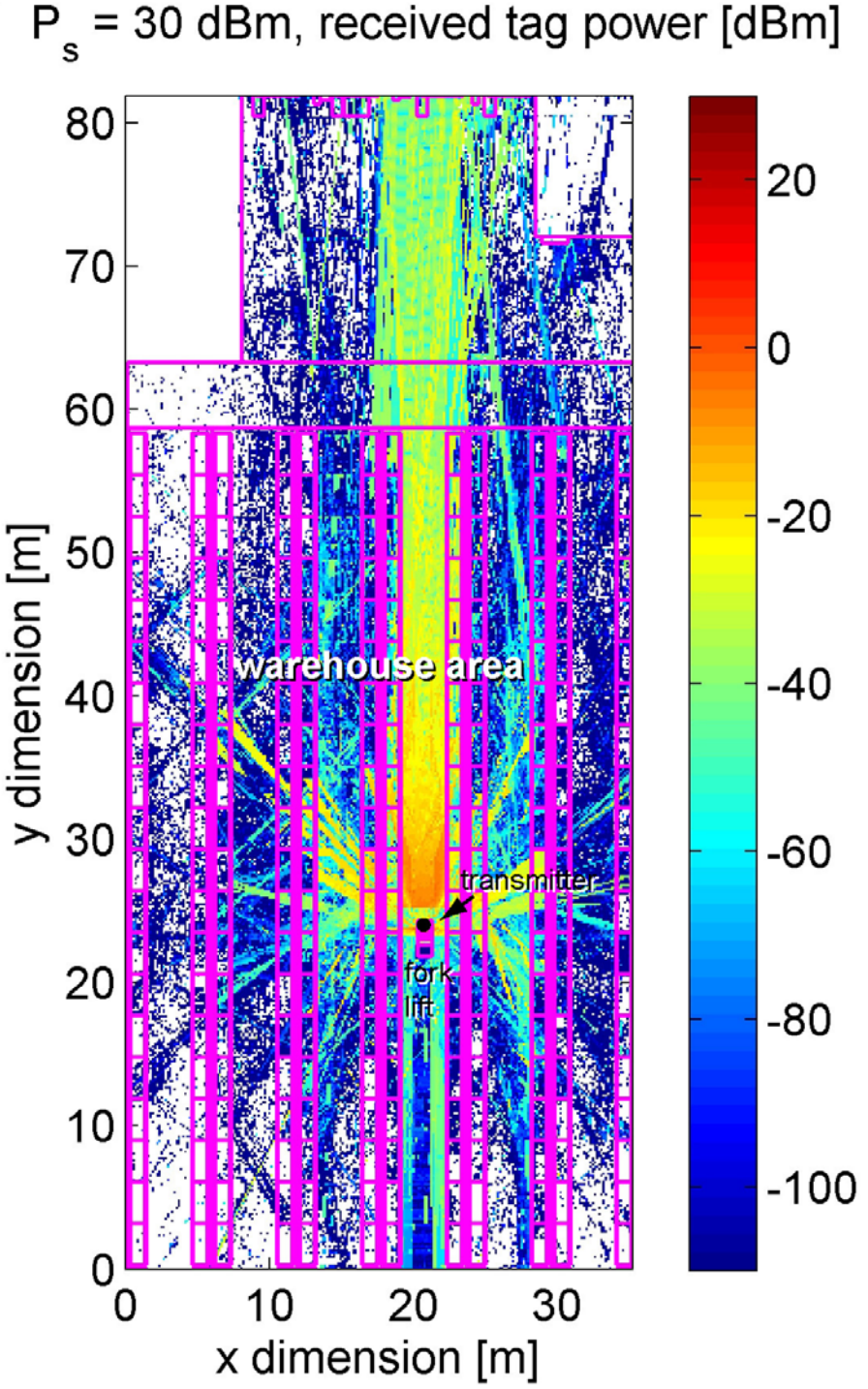


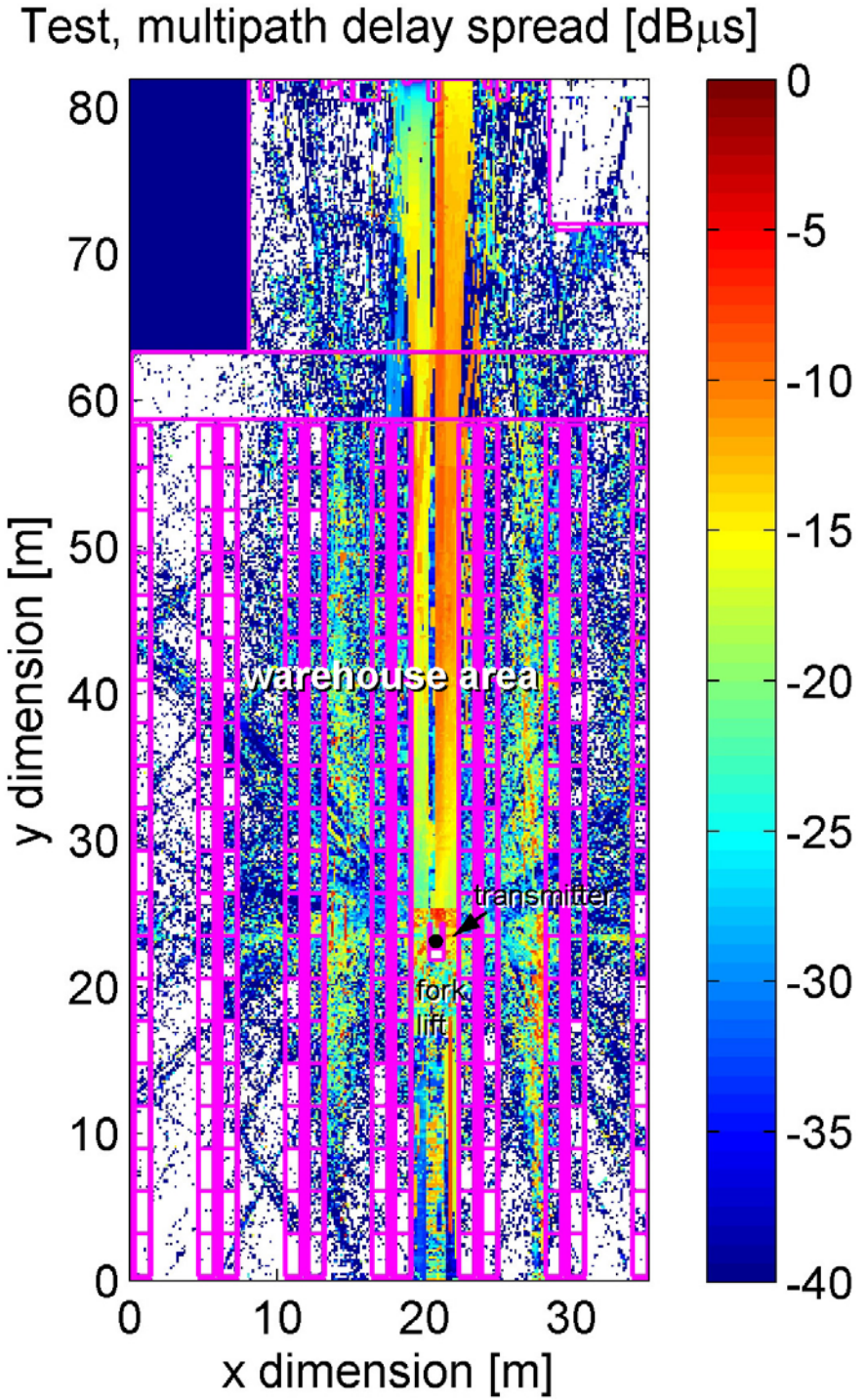
Fork lift prediction



Fork lift antenna:

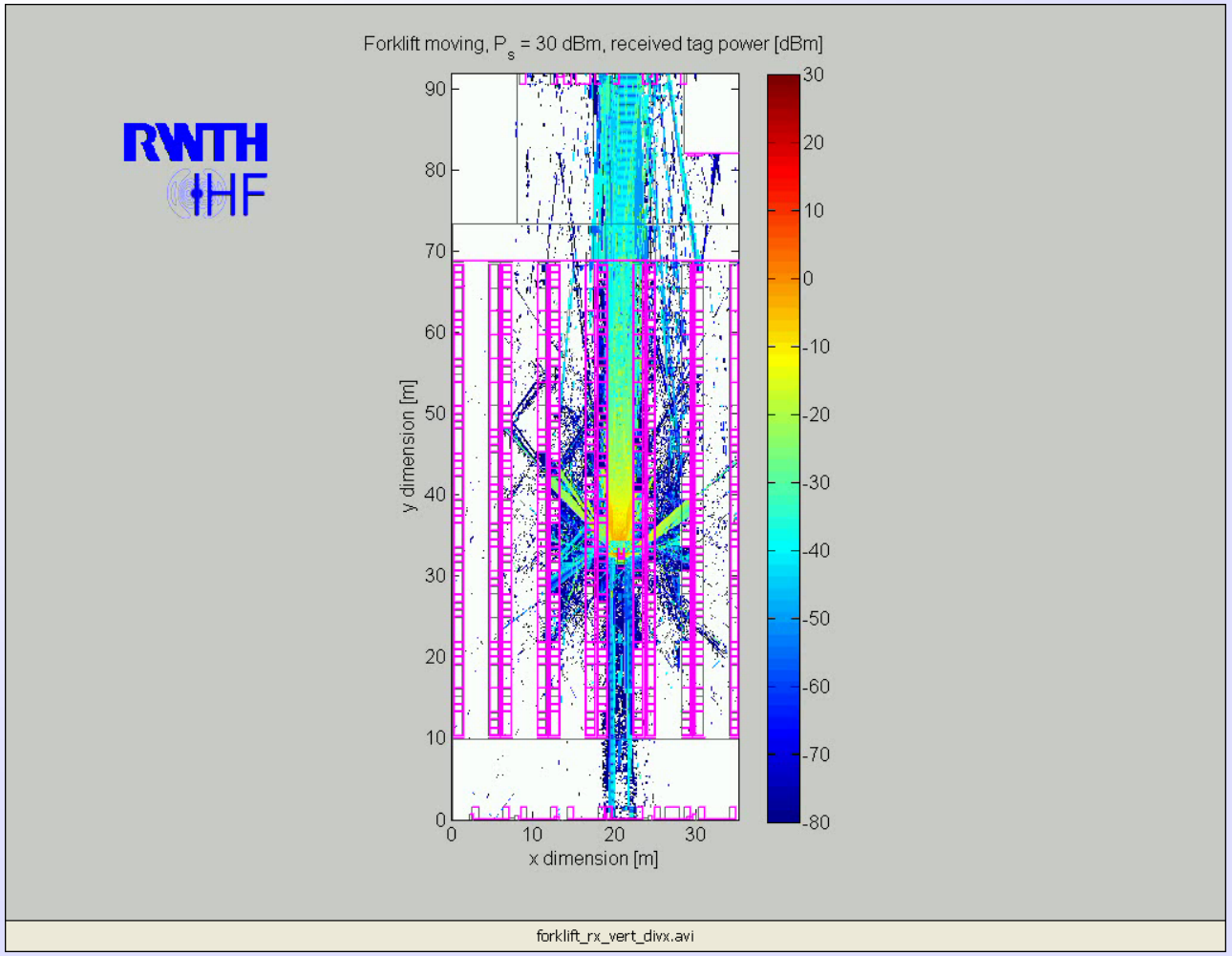
- Tilted down by 30°
- Same properties as stationary reader antenna


P_s = 30 dBm, received tag power [dBm]
y dimension [m]
x dimension [m]
warehouse area
transmitter
fork lift
80
70
60
50
40
30
20
10
0
0
10
20
30
20
0
-20
-40
-60
-80
-100


Test, multipath delay spread [dBμs]
y dimension [m]
x dimension [m]
warehouse area
transmitter
fork lift
80
70
60
50
40
30
20
10
0
0
10
20
30
0
-5
-10
-15
-20
-25
-30
-35
-40

Tech 200

Fork lift movement



Summary (1)

Distortions:

- Tag sensitivity and multipath delay spread of the channel do not cause problems, but high reader sensitivity does!
- Interference among RFID portals is not only critical in close vicinity (neighboring portals), but also across a large building: Receiving and shipping areas on opposite building ends (distance about 100 m) each need frequency channel separation to avoid distortions.

Bit error ratio:

- Modulation consideration: PSK performs better than ASK
- Coding consideration: PIE has worst communications performance (but highest power delivery)

Summary (2)

Fork lift:

- Switching of antenna necessary to avoid unintentional reading
- Antenna recommended with focusing beam

RFID system planning using ray tracing:

- Analyzing / planning RFID systems can be done fast and efficiently using ray tracing predictions.
- Reduces time and costs.
- Testing phases and field tests can be minimized.