Ray Tracing Method for System Planning and Analysis of UHF-RFID Applications With Passive Transponders

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Contents

Motivation

RFID in the UHF band using passive transponders — present status:

- Identification of consumer goods
- Handling logistics of consumer goods between manufacturer and end-consumer
- Suppy-chain management
- Theft prevention

Photo: METRO Group

Motivation

Ray tracing method for system planning:

- Integration of RFID system hardware into given / new infrastructures
- RFID system planning / analysis
- Optimizing existing RFID systems

Advantages:

⇨Much faster results as compared to field tests / measurements.
Measuring wave propagation on-site is time consuming, especially when a large area is to be examined.

⇨Same high accuracy as compared to measurements.

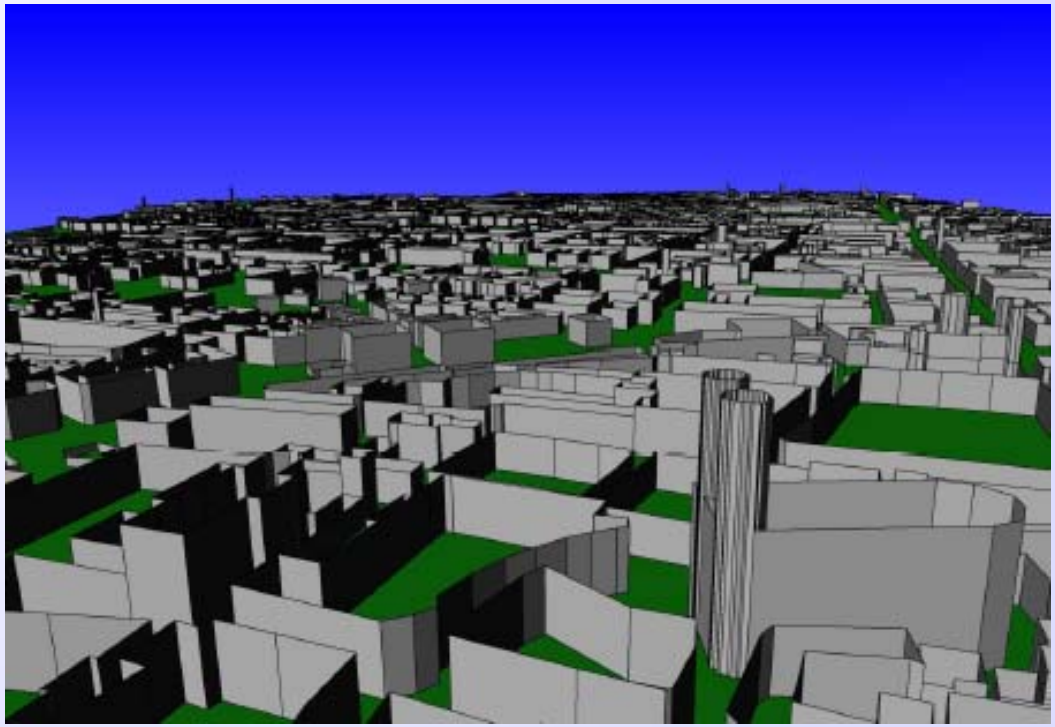
⇨Easily configurable: Different system constellations, such as operating frequency, transmit power, antenna configurations, orientations, mounting positions, etc., can be specified.

⇨Prediction of RFID system functionality / optimization is possible even for infrastructures which don‘t exist yet (design / construction of new buildings etc.).

Ray Tracing Overview

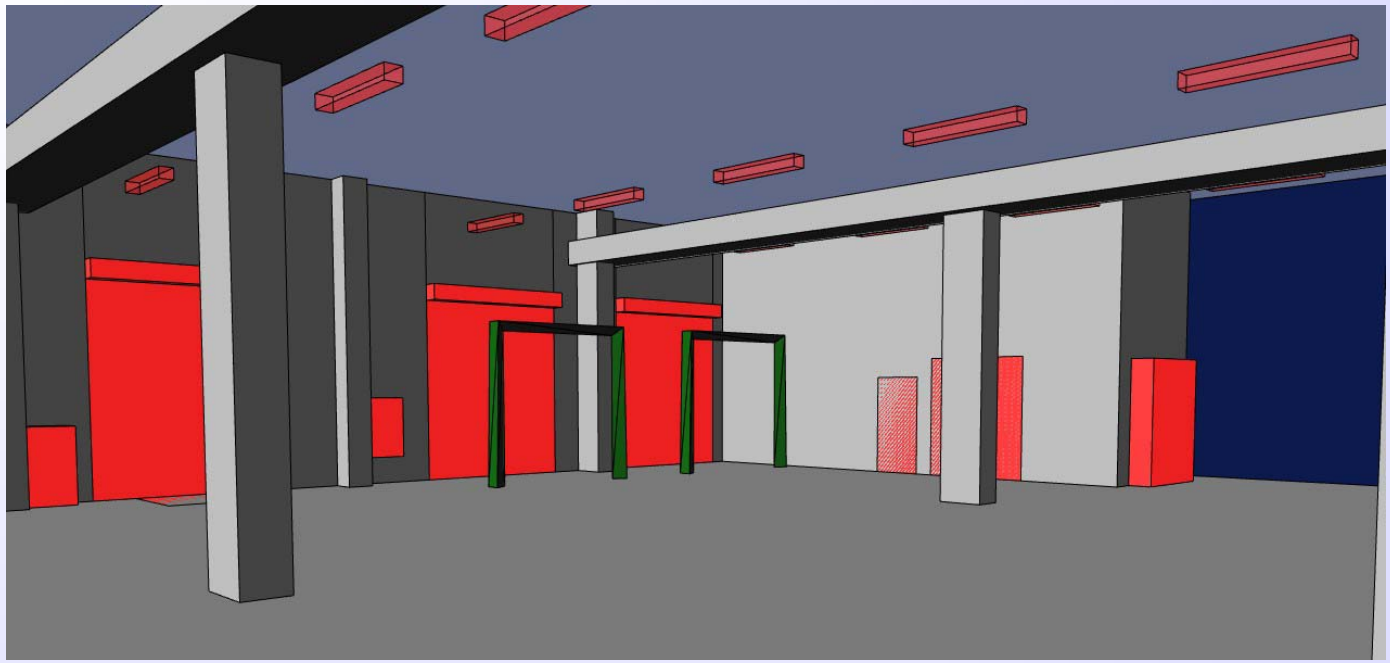
General properties:

- Fast, efficient simulation tool for calculation of wave propagation
- Flat polygon based modelling
- Single or few transmitters
- Few or up to thousands of receiver positions
- Ray optical approach (ap-proximation for large objects)
- Search for multipath propagation between each transmitter and receiver
- Result: complex channel coefficients and deduced parameters
- Completely developed at the IHF, RWTH Aachen



outdoor example: city of Munich, 3D model w/o rooftops (source: COST 231)

3D Modelling



example 2

VRML model: **distribution center for consumer goods, loading area**

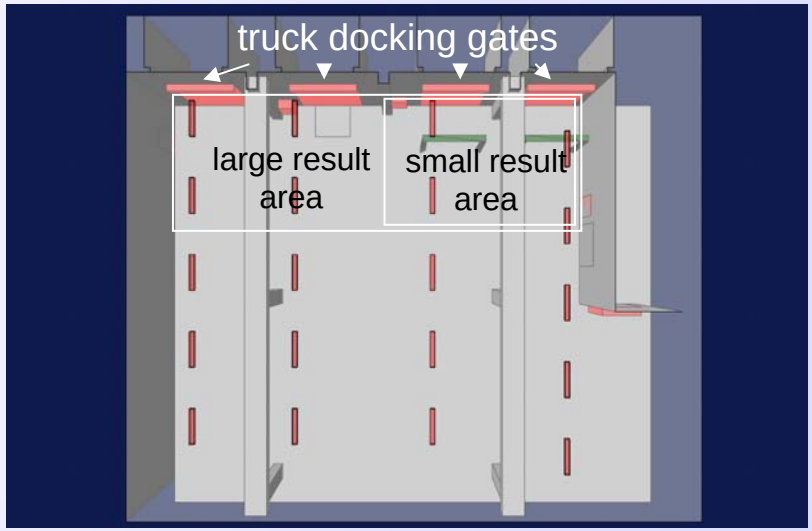
Ray tracer setup for RFID simulations:

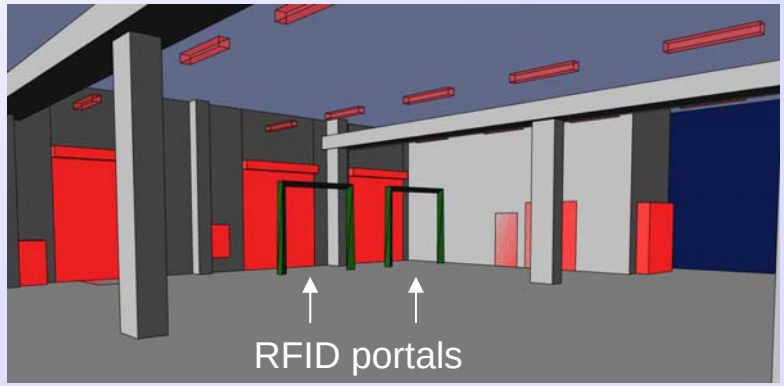
- Multipath propagation, up to 10^6 rays considered
- Up to 15 reflections and 2 wall transmissions allowed
- Found paths will be summed up with respect to correct phase information

RFID for logistics handling

Loading area of a distribution center for consumer goods:

- Modelled part of building: 24 m x 20 m
- 4 docking gates for trucks, each one having a RFID portal
- Fully 3D geometry model
- Properties of obstacles (walls etc.), such as thickness and dielectric parameters, were realistically modelled to match on-site conditions.





Small / large result area:

- An evenly spaced grid of transponder positions (resolution 5 cm x 5 cm, height z = 75 cm) will yield 2D results of received tag power (in total 24.000 and 50.000 receivers resp.).

Simulation Parameters

Setup according to typical RFID specifications:

- Operation frequency: 868 MHz.
- Transmit power: 1 W.
- Read/write unit antennas are mounted at RFID portal constructions at height z = 75 cm.
- Transponder antennas: half-wavelength dipoles assuming different orientations.
- Transponder sensitivity: -7 dBm (min. tag power needed to operate and transmit data).
- Read/write unit sensitivity: -70 dBm.
- Antenna pattern of read/write units: cross-dipole characteristics having right-hand circular polarization.

RFID portal, mounted with reader antennas, scanning incoming and outgoing shipment transfer.

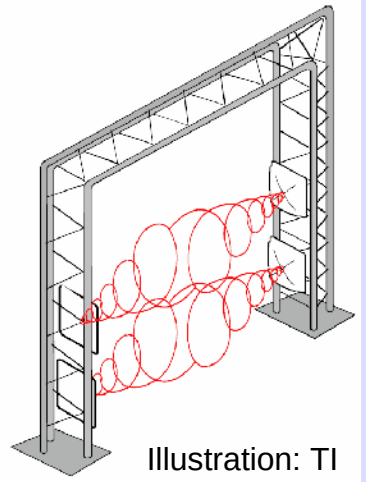
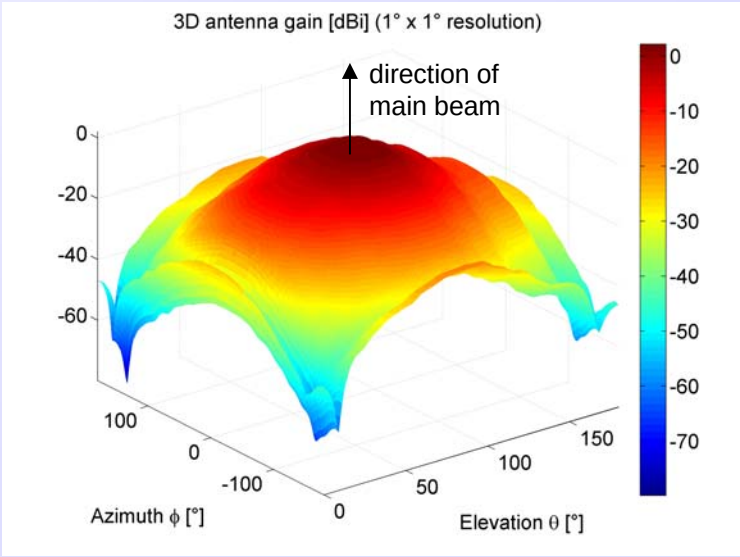


Illustration: TI



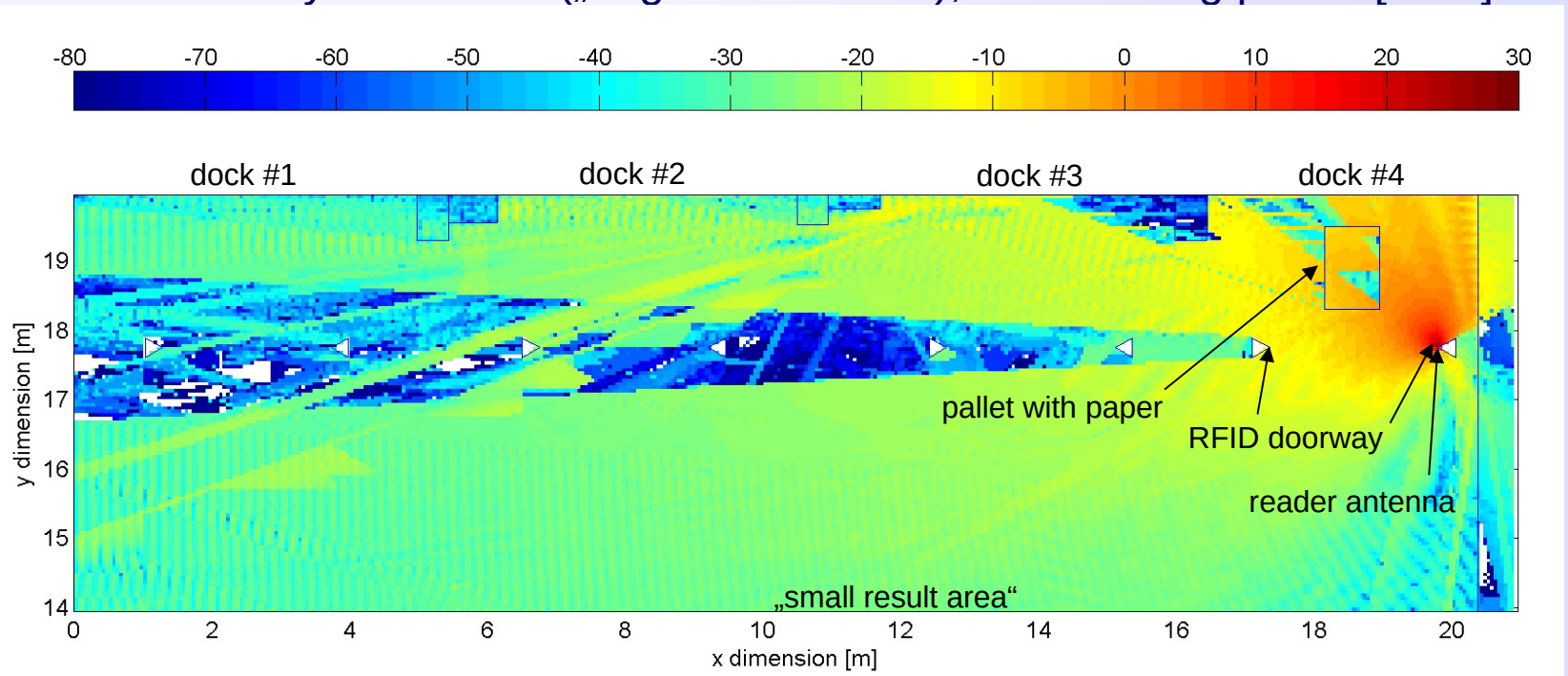
Antenna characteristics for read/write units, G_{max} = 1.64

One-way Simulation Results

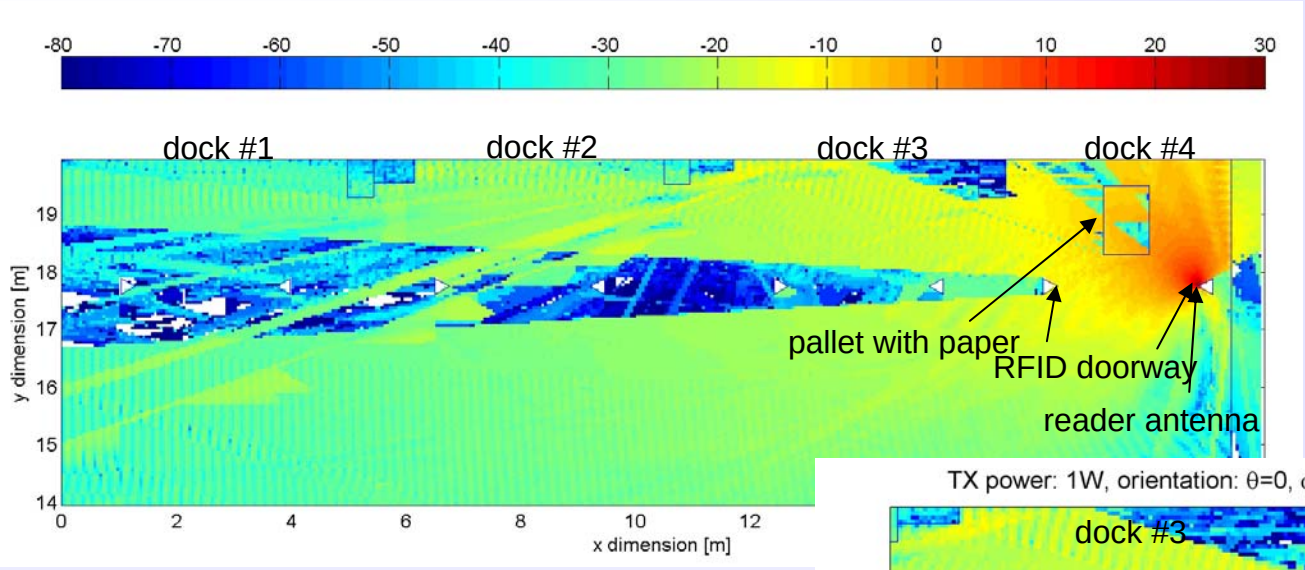
„Transmitter → Tag“ operation:

- Sample shipment unit consisting of paper materials at door #4
- Transponder antennas vertically polarized (parallel to *z* axis)

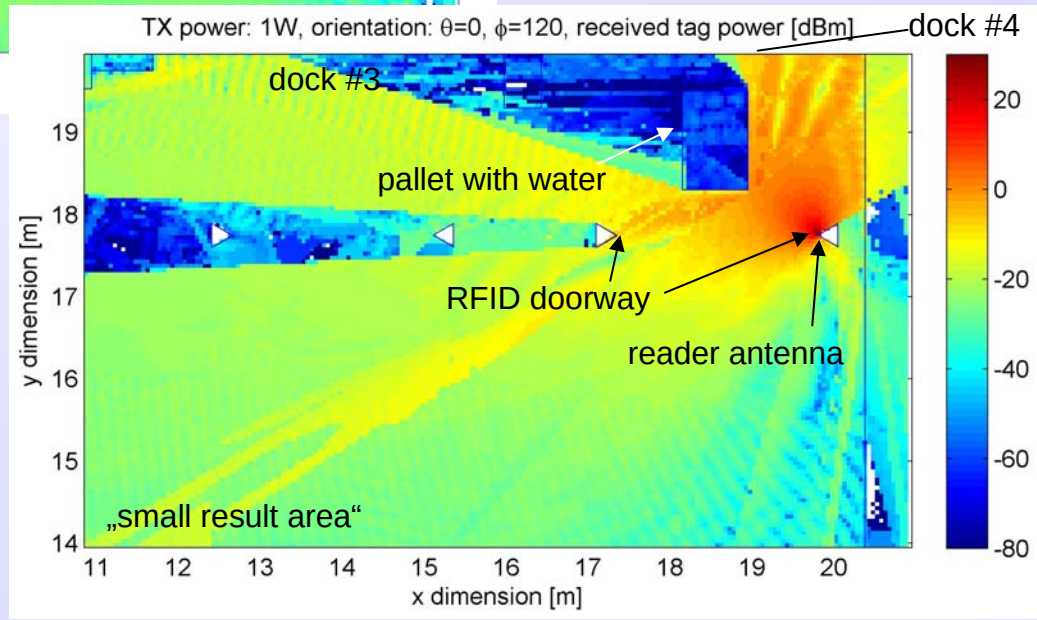
One-way simulation („large result area“), received tag power [dBm]



One-way Simulation Results



Paper vs. Water

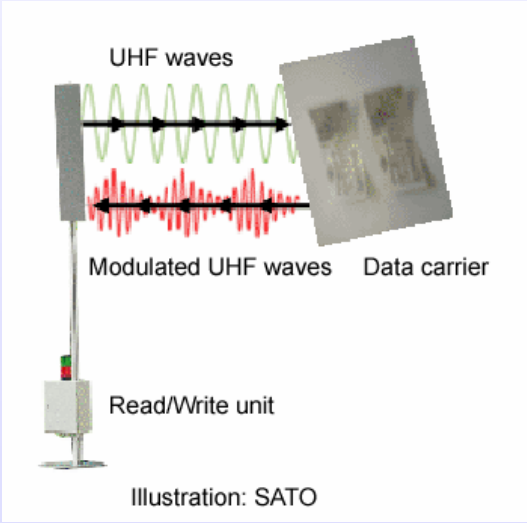


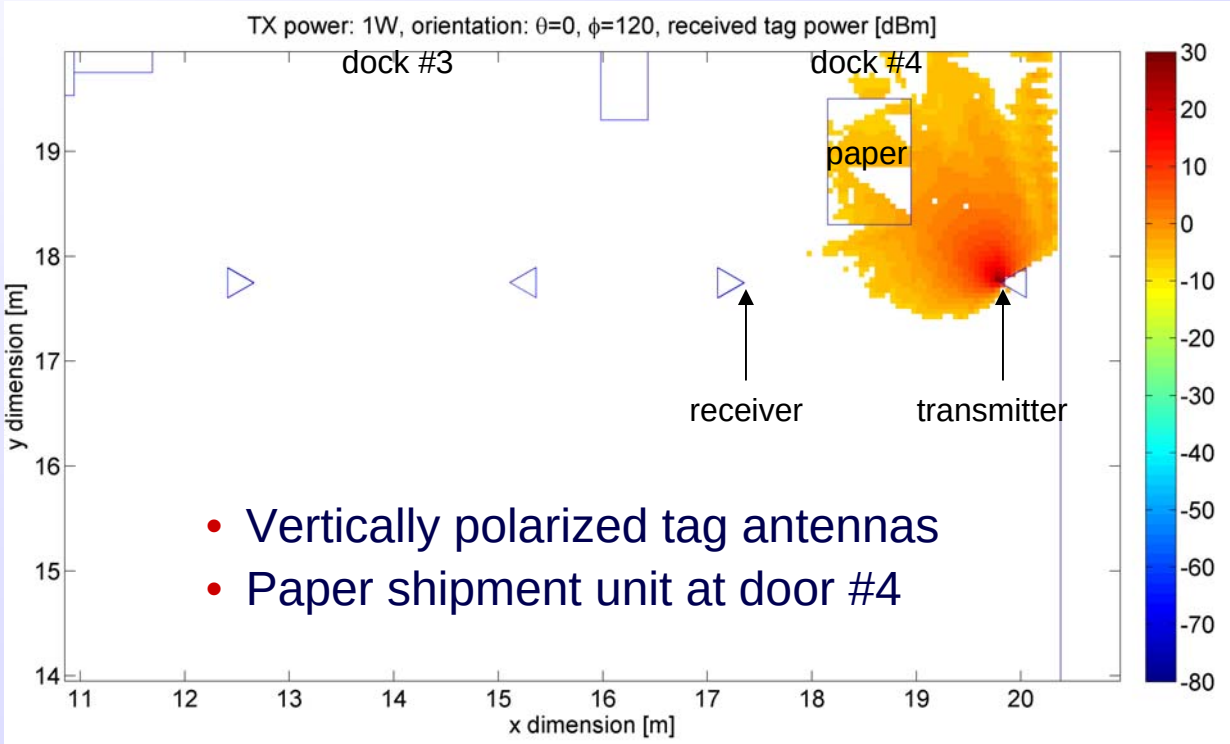
Backscatter Simulations

Requirements for operation:

1. Is received tag power high enough for the transponder chip to operate?
2. Does the reflected signal reach the reader?

Result:





Backscatter Simulations (contd.)

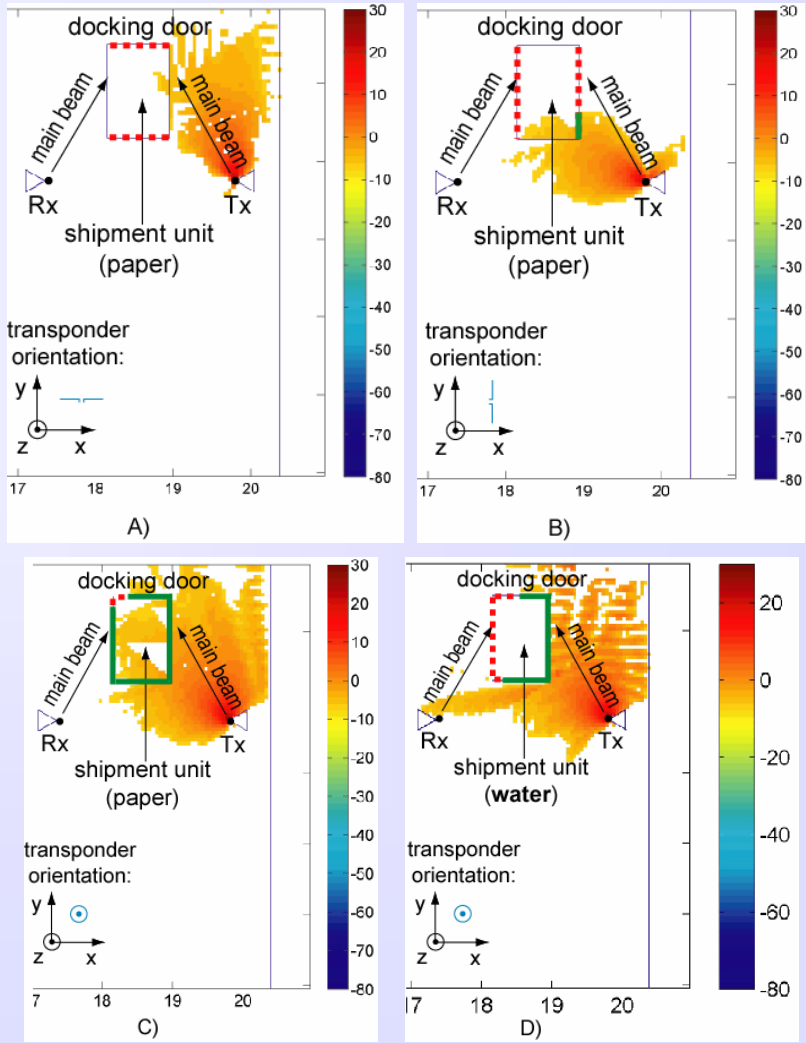
Other tag polarizations?

Paper shipment unit

- A) transponder antenna horizontally polarized (parallel to *x* axis)
- B) transponder antenna horizontally polarized (parallel to *y* axis)
- C) transponder antenna vertically polarized (parallel to *z* axis)

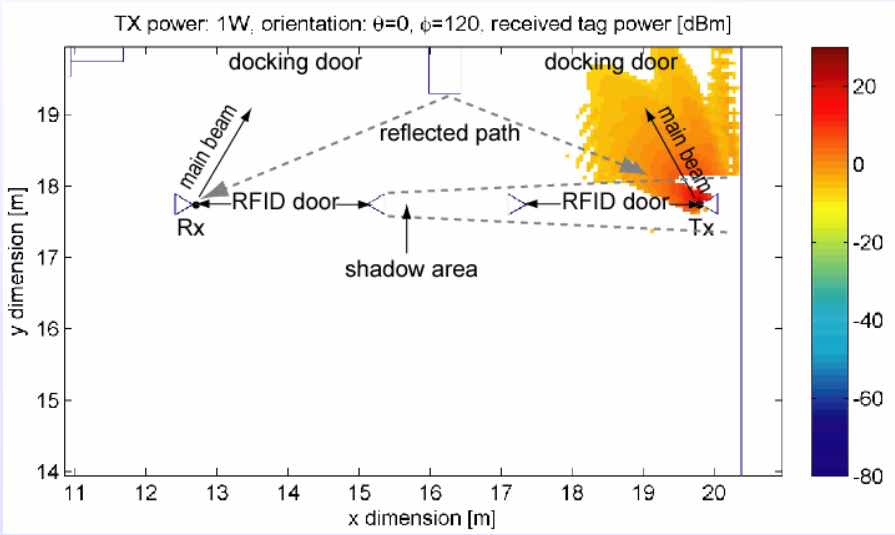
Water shipment unit

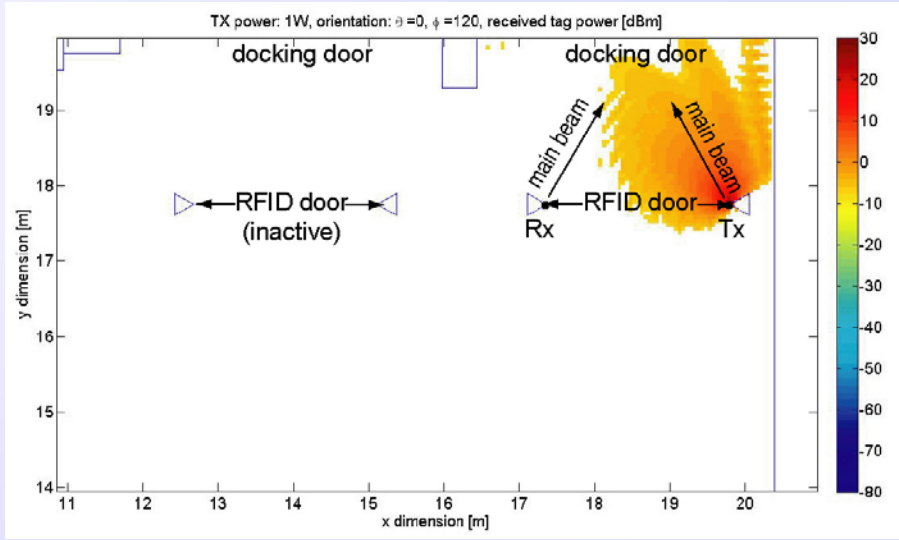
- D) transponder antenna vertically polarized (parallel to *z* axis)



Backscatter Simulations (contd.)

Two neighboring RFID portals compared to single gate operation:



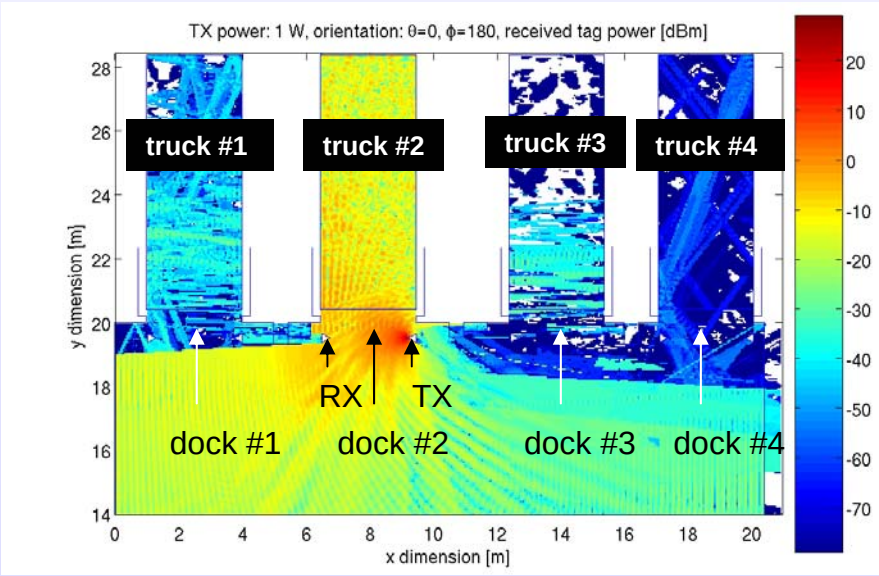


- No shipment units in these cases.
- Transponder antennas vertically polarized (parallel to *z* axis).

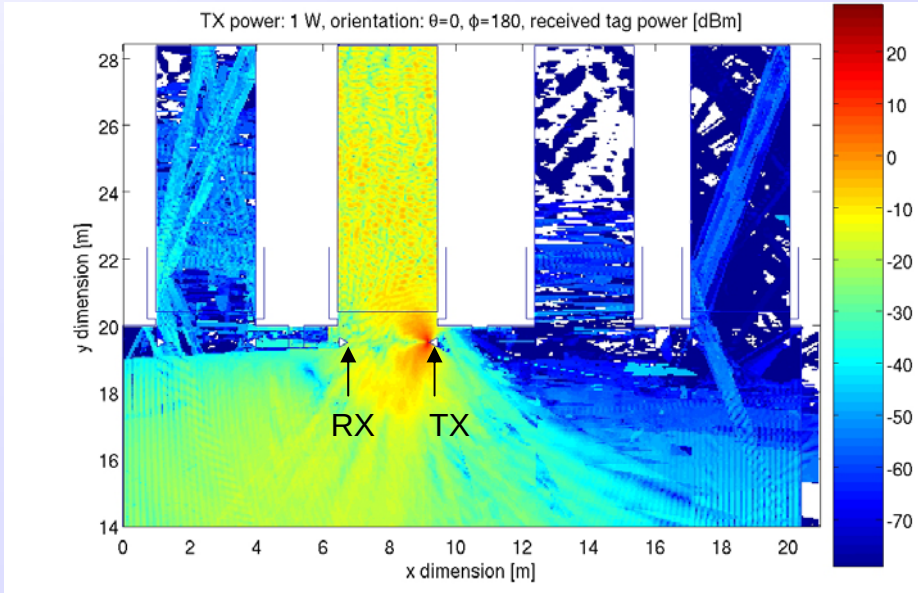
Simulation with docked trucks

Trucks docked at each loading gate, all gates open, no shipment units:

Vertical polarization



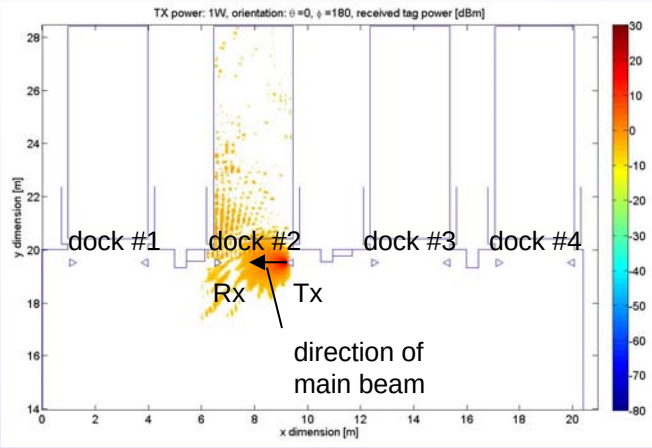
Horizontal polarization (x axis)

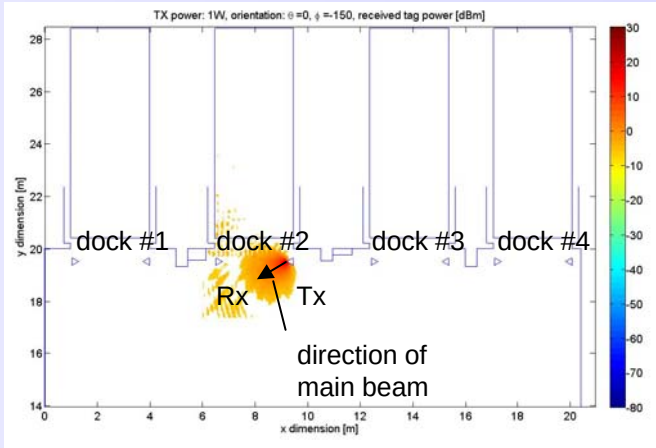


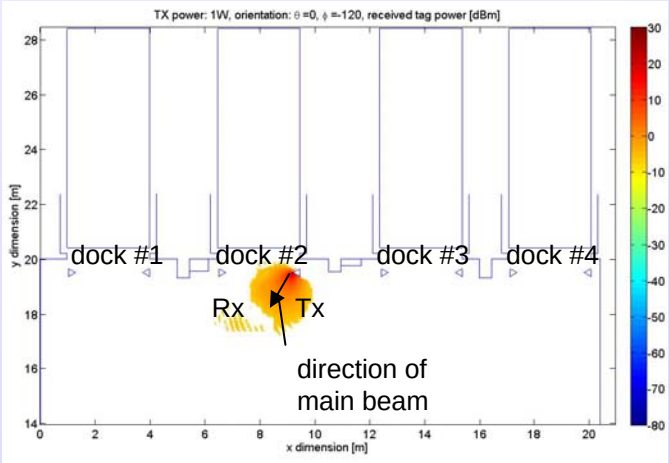
Backscatter with docked trucks

Trucks docked at each loading gate, all gates open:

- No shipment units, vertical tag polarization







Summary

Evaluation of shown simulations:

- RFID reader sensitivity is so high that neighboring RFID installations can easily scan transponders unintentionally. → System separation in the frequency or time domain or higher spatial separation (use absorbers etc.).
- Vertically oriented transponder antennas show much better scanning results than horizontally oriented ones. ← Higher suppression of ground reflections and omnidirectional antenna characteristics (azimuth direction in the x-y plane) contribute to this.
- The first propagation part of backscatter operations (transmitter to tag), is more sensitive in terms of sufficient tag power supply than the reflection part. → If a tag receives enough power to operatre, it is very likely that the backscattered modulation will also reach the reader. → If a tag fails to be read, it is very likely that the received power at the tag location is insufficient, rather than the reflected path back to the reader is obscured.
- When docked trucks present, a significant part of RF energy enters the truck interior and tags could be scanned unintentionally. → Avoid this by proper shielding of the antenna beam, re-orientation of the antenna direction or antennas with smaller HPBW.

Summary

RFID system planning using ray tracing:

- Planning / optimizing RFID systems can be done fast and efficiently using deterministic ray tracing.
- Reduces time and costs.
- Intensive testing phases and field tests can be minimized.

Outlook:

- RFID system planning also on modulation / coding level.
- Extend simulation capabilities for common RFID modulation schemes and protocols.
- Compare system constellations not only on physical layer (wave propagation), but also with respect to complete system description.

The End

Thank you for your attention!

Questions?