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# COMPLEX-VALUED $\Delta$ RCS-MEASUREMENTS

(FOR RFID-RANGING APPLICATIONS)

- RFID Basics & Localization
- $\Delta$ RCS Measurement Setup
- Measurement Results

- **RFID Basics & Localization**
- $\Delta$ RCS Measurement Setup
- Measurement Results

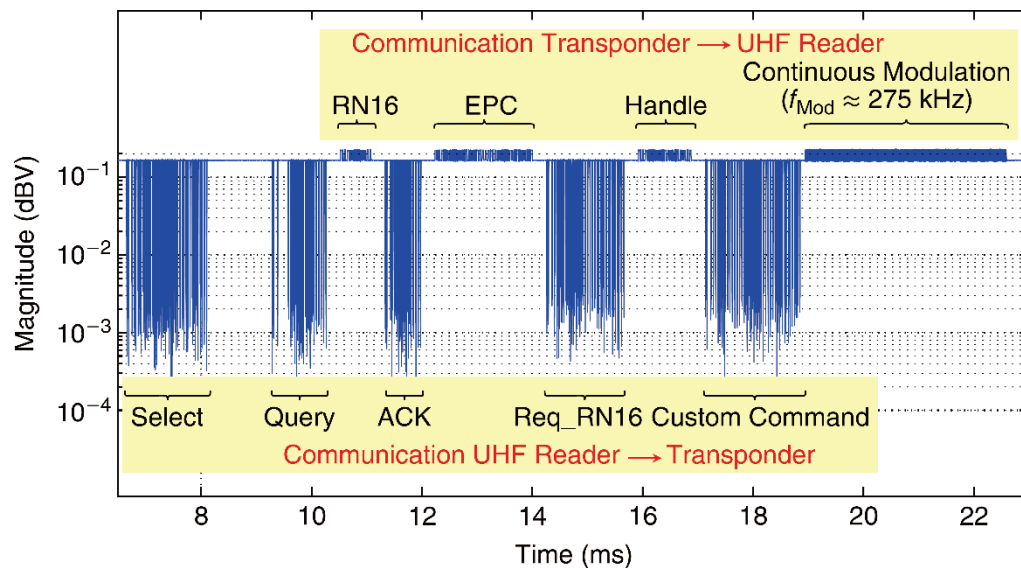
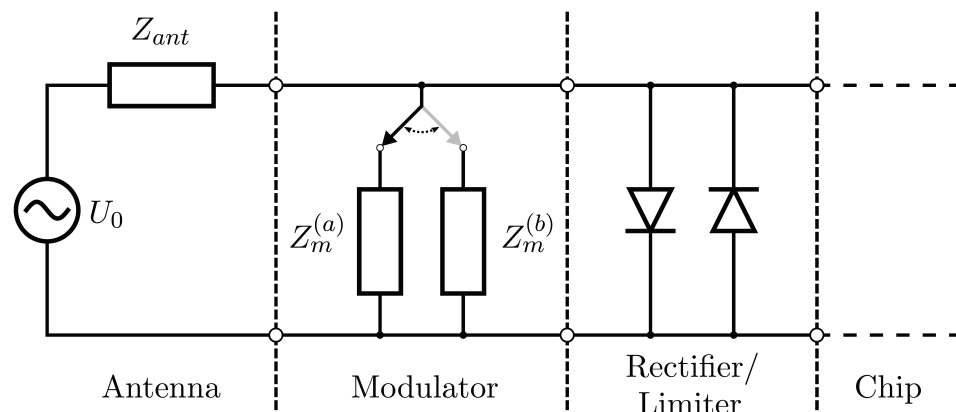
- Interrogator illuminates tag for powering & communication

- Reader → Tag:

- On-off keying
- Pulse interval encoding (PIE)

- Tag → Reader:

- Interrogator transmits CW-signal (for powering)
- Tag modulates input impedance between two different states  
→ Radar cross section changes

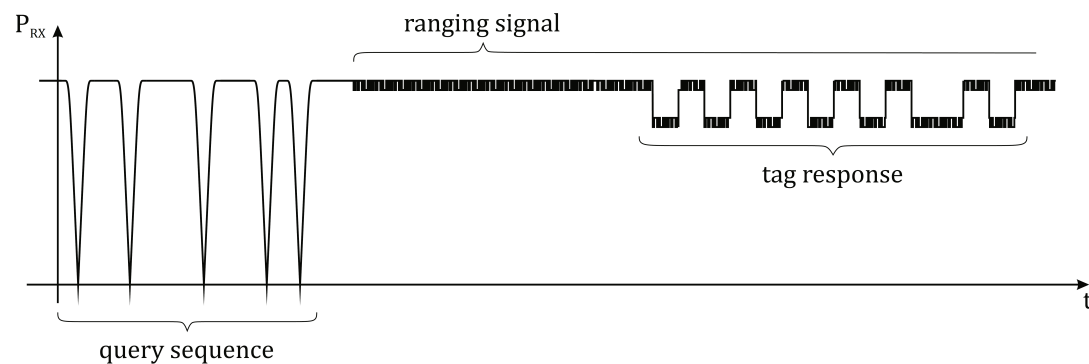


[A. Costanzo, D. Masotti, T. Ussmueller, and R. Weigel. Tag, you're it: Ranging and finding via RFID technology. IEEE Microwave Magazine, 14(5): 36-46, 2013.]

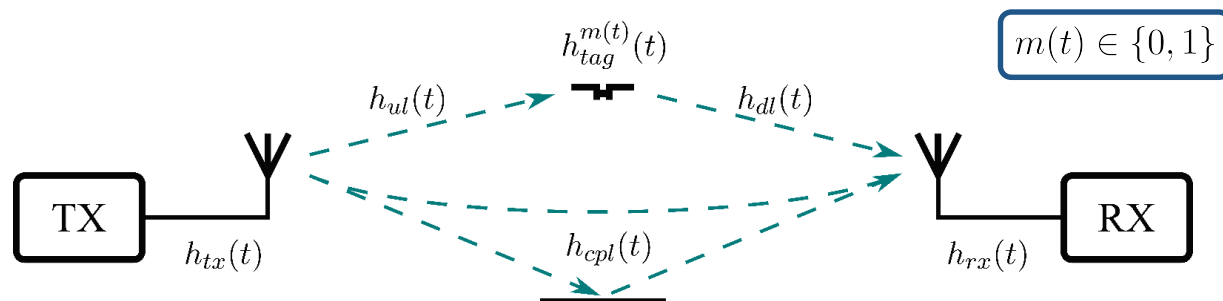
- Localization of RFID tags:
  - **RSSI-based:** depends on tag, chip, spatial orientation...
  - **Angle of Arrival (AoA) based:** rather inaccurate, extremely prone to multipath
  - **Time of Flight (ToF) based:** the method of choice for precise ranging
  - Localization via Triangulation

- Novel ToF method for standard RFID tags:

Superposition of a DSSS ranging signal onto the reader's CW-signal:



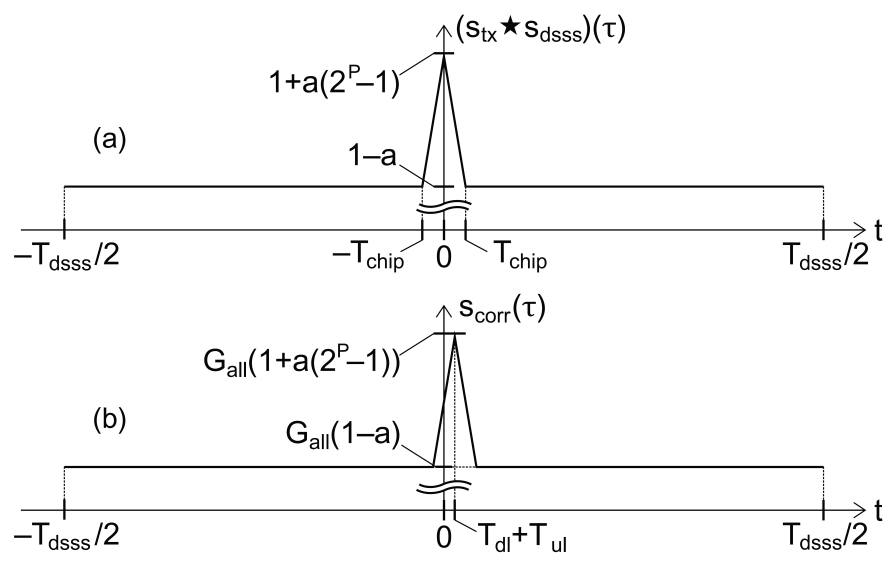
- Received signal is modulated by the tag:



- Correlation of sequentially averaged receive signal:

$$s_{corr}(\tau) = (s'_{avg} \star s_{dsss})(\tau)$$

- Correlation peak allows for ToF estimation:



- Assumed knowledge about the differential tag impulse response:

$$h_{tag}^{\Delta}(t) = \frac{1}{2} [h_{tag}^0 - h_{tag}^1](t)$$

- Relation to complex-valued Delta Radar Cross-Section ( $\Delta$ RCS)

[H. Arthaber, T. Faseth, and F. Galler. Spread-spectrum based ranging of passive UHF EPC RFID tags. IEEE Communications Letters, 19(10): 1734-1737, 2015.]

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# Measurement Setup – Complex RCS

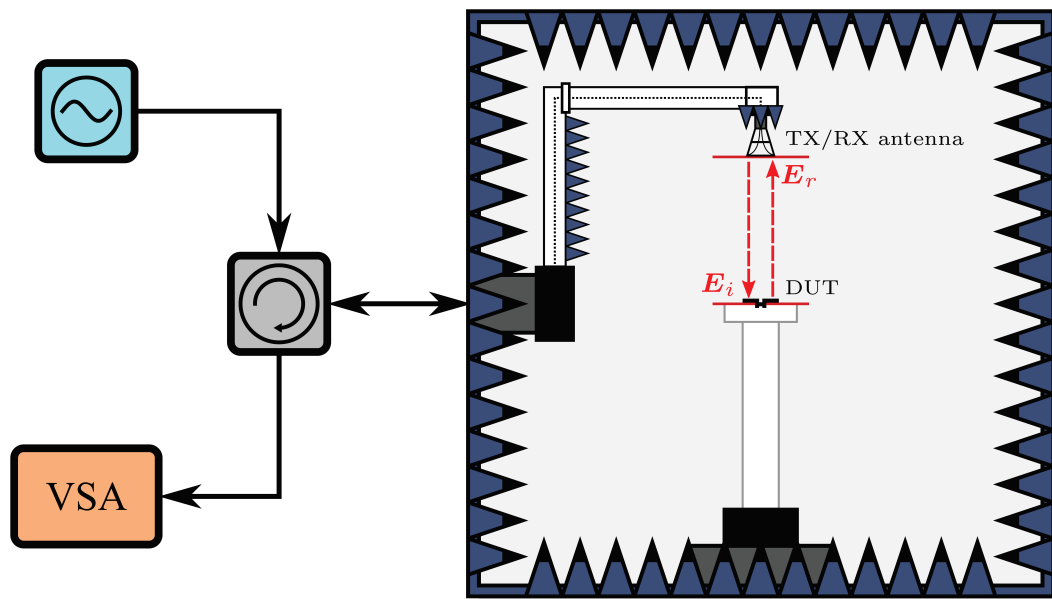
- Scalar RCS:
  - No phase information
  - Scalar correction term  $4\pi R^2$
  - Far field condition

$$\sigma = 4\pi \lim_{R \rightarrow \infty} R^2 \left| \frac{\mathbf{E}_r}{\mathbf{E}_i} \right|^2$$

- Complex RCS:
  - Phase information retained
  - Complex correction term
  - Power quantity

$$\sigma = 4\pi R^2 e^{j2k_0 R} \left( \frac{\mathbf{E}_r}{\mathbf{E}_i} \right)^2 = \left[ \sqrt{4\pi R^2} e^{jk_0 R} \frac{\mathbf{E}_r}{\mathbf{E}_i} \right]^2$$

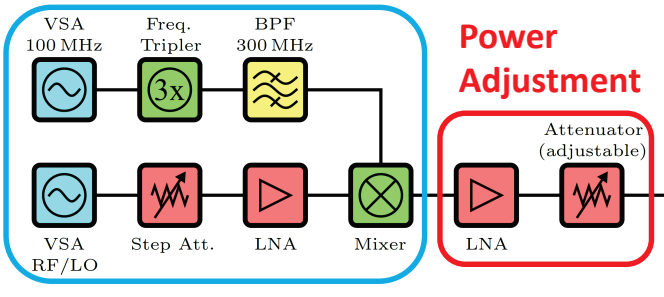
- Square-root RCS:
  - Phase unambiguity
  - Field quantity proportional



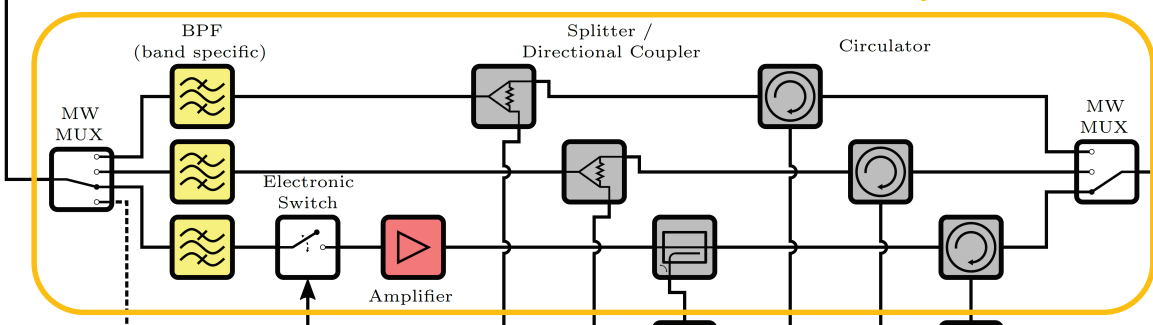


# Measurement Setup – Block Diagram

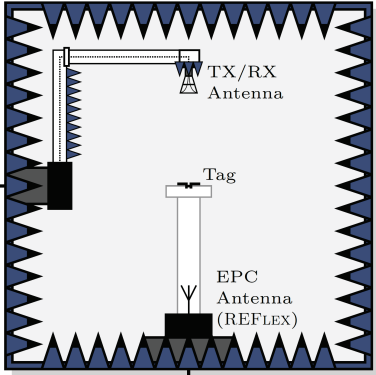
## Coherent Source



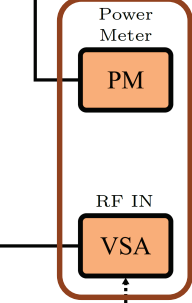
## Frequency Band Separation



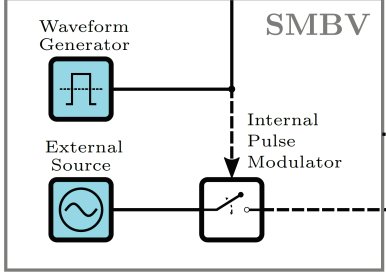
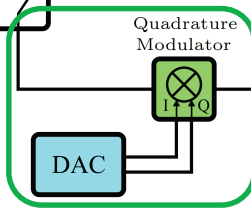
## Anechoic Chamber



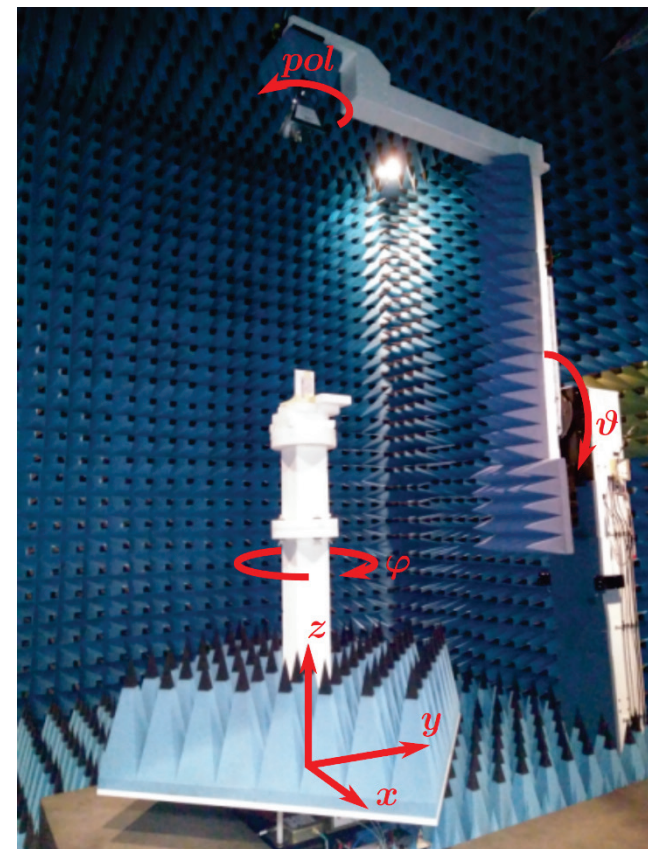
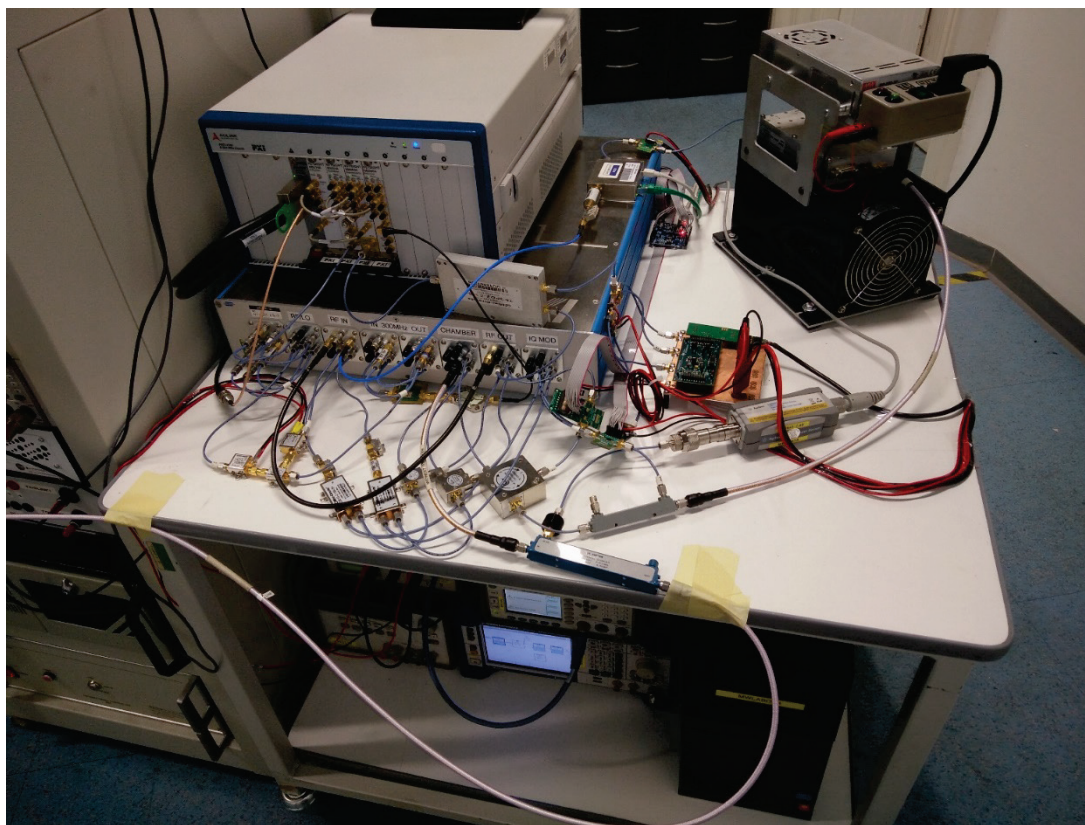
## Measurement Devices



## Carrier Cancellation



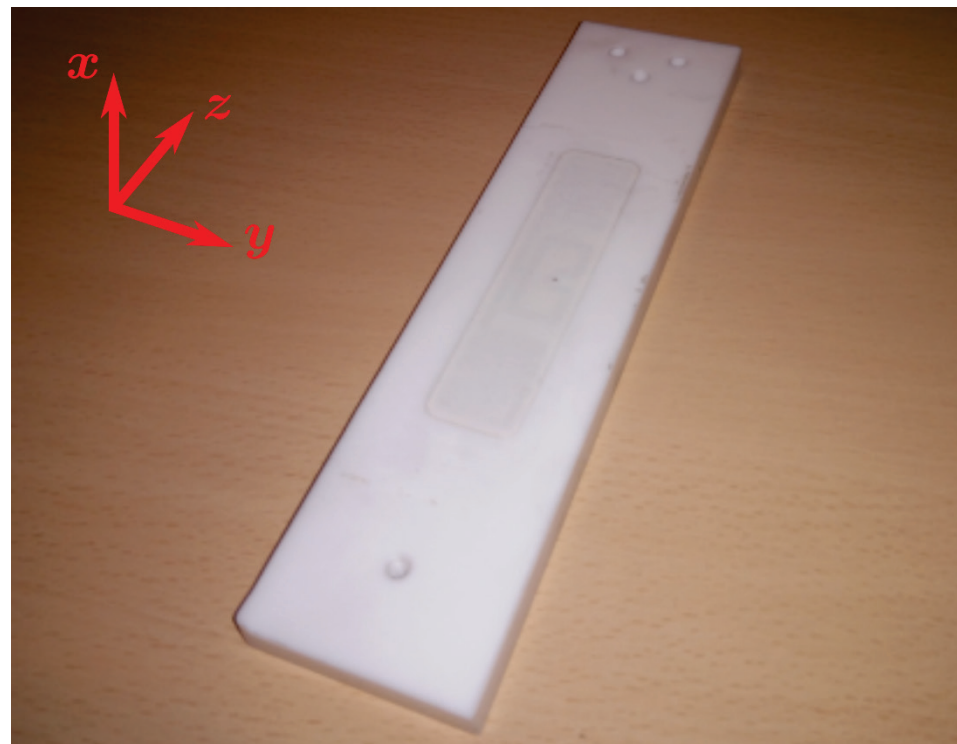
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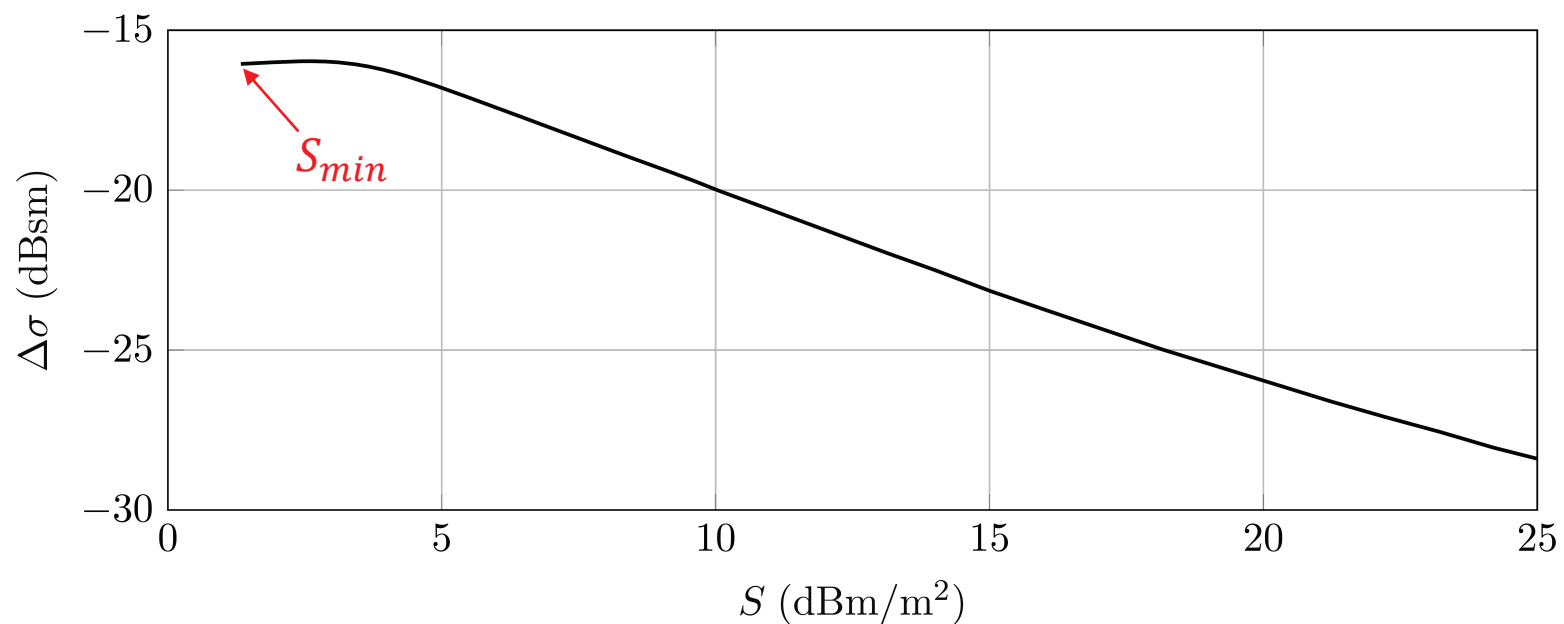


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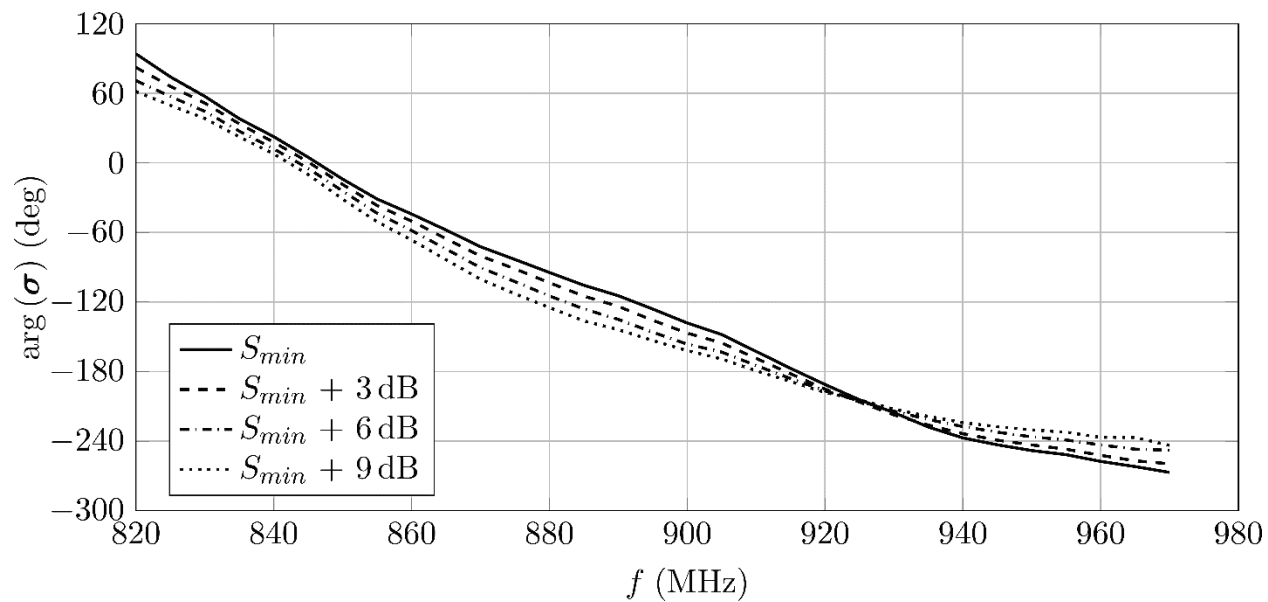
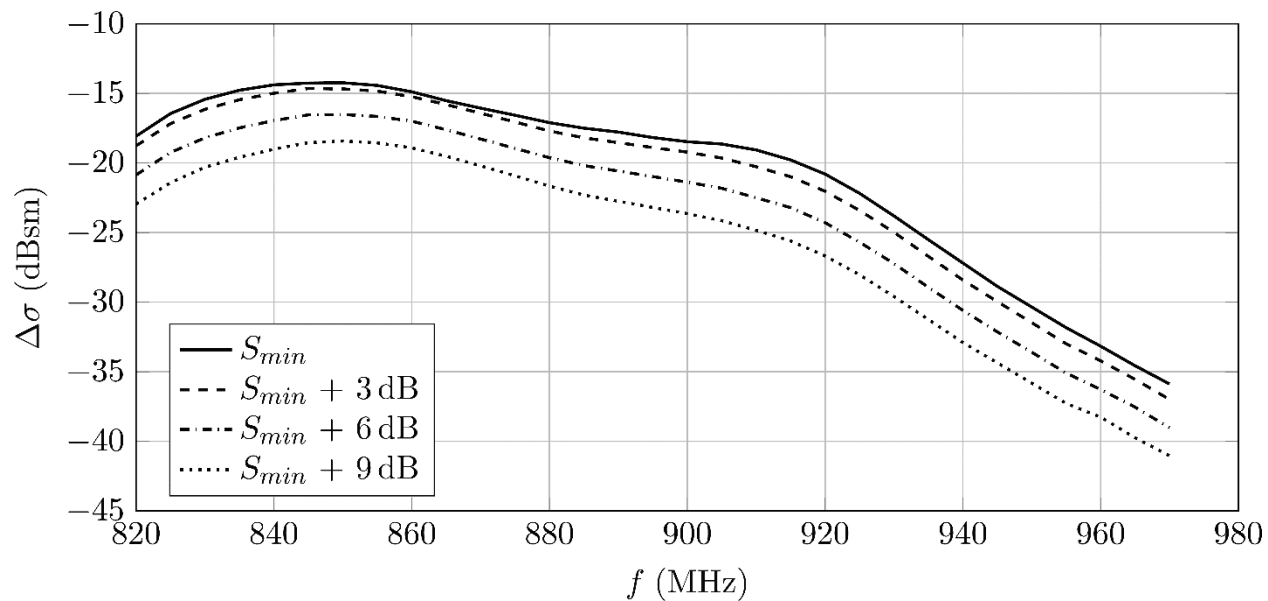
- RFID Basics & Localization
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- **Measurement Results**

- NXP Ucode7
- On a Teflon substrate
- Results in co-polarization
- Results in positive x-direction





- Frequency: 870 MHz
- Abscissa: power density  $S$  in dBm/m<sup>2</sup> at the position of the tag.
- Strong power dependency of the  $\Delta$ RCS.





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**Thank You For Your Attention!**

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