Special Session 2C

Tag Measurement Principles

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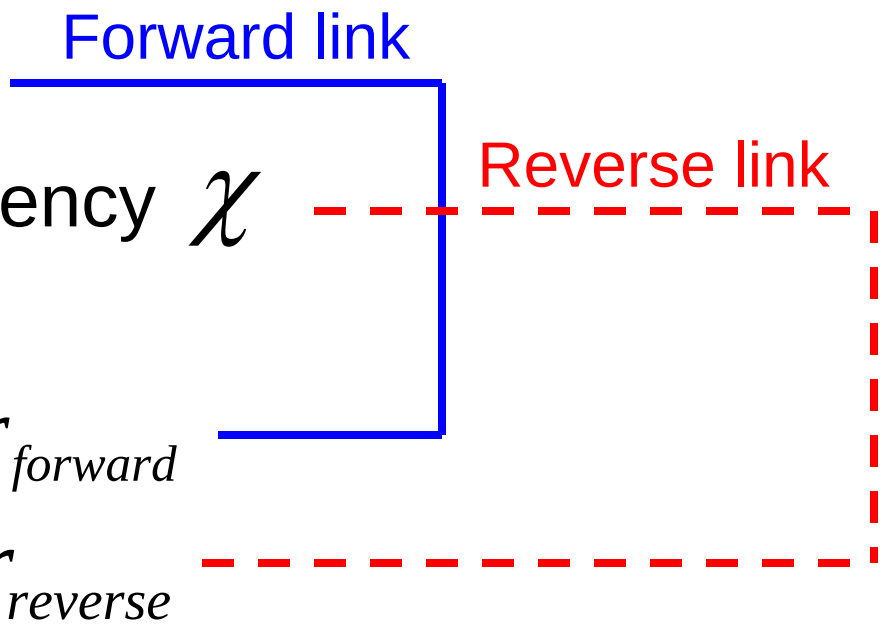
Outline

- Tag and system characteristics
- Measurement methods
- Conducted measurements
- Test system example
- Conclusions

Tag and System Characteristics

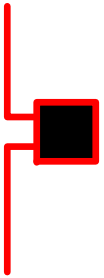
- Tag
  - Sensitivity P_{tag}
  - Backscatter efficiency χ
- System
  - Forward range $r_{forward}$
  - Reverse range $r_{reverse}$



Sensitivity: $P_{tag}[W], E_{tag}[V/m]$

- Minimum incident power (or field) needed to turn on the tag

$$P_{tag} = \frac{P_{chip}}{G\,\tau} = \frac{E_{tag}^2}{120\pi} \cdot \frac{\lambda^2}{4\pi}$$



$$\tau = \frac{4R_{c_1}R_a}{\left|Z_{c_1} + Z_a\right|^2}$$

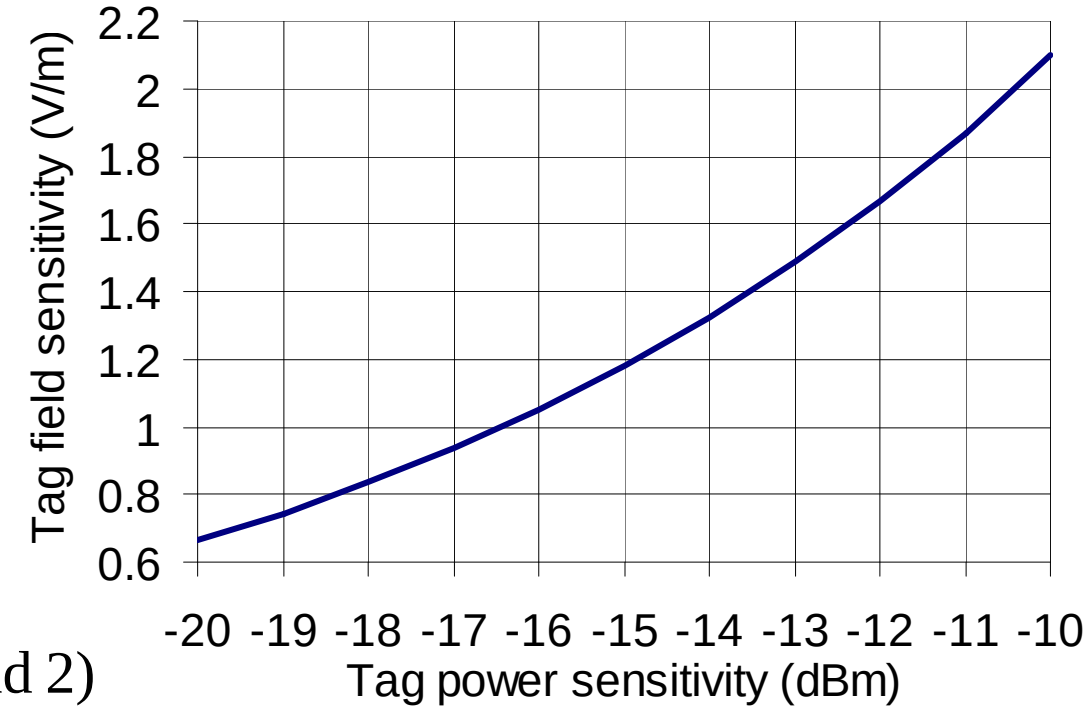
P_{chip} – chip sensitivity

G – gain of the tag antenna

τ – tag impedance matching coefficient

Z_a – antenna impedance

$Z_{c1,2}$ – chip impedances (1 and 2)



Backscatter Efficiency: $\chi[dB]$

- How much of incident RF power is "converted" to modulated backscatter
- Depends on incident power, waveform details

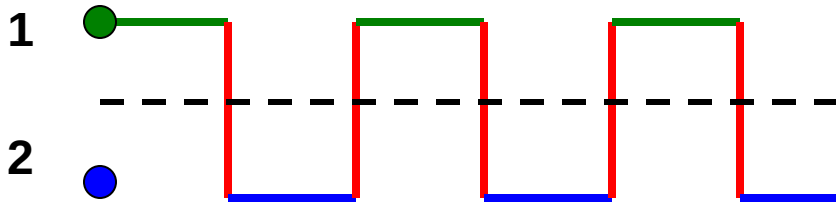
$$\chi = p^2 G^2 K = \frac{4\pi \Delta\sigma}{\lambda^2}$$

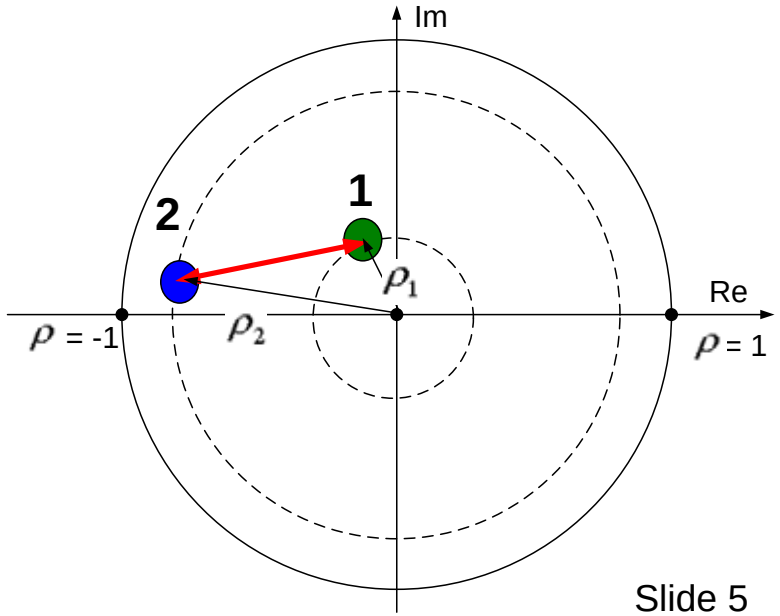
$$K = \alpha \left| \rho_1 - \rho_2 \right|^2$$

K – tag modulation loss

$\Delta\sigma$ – tag differential RCS

$\rho_{1,2}$ – complex reflection coefficients



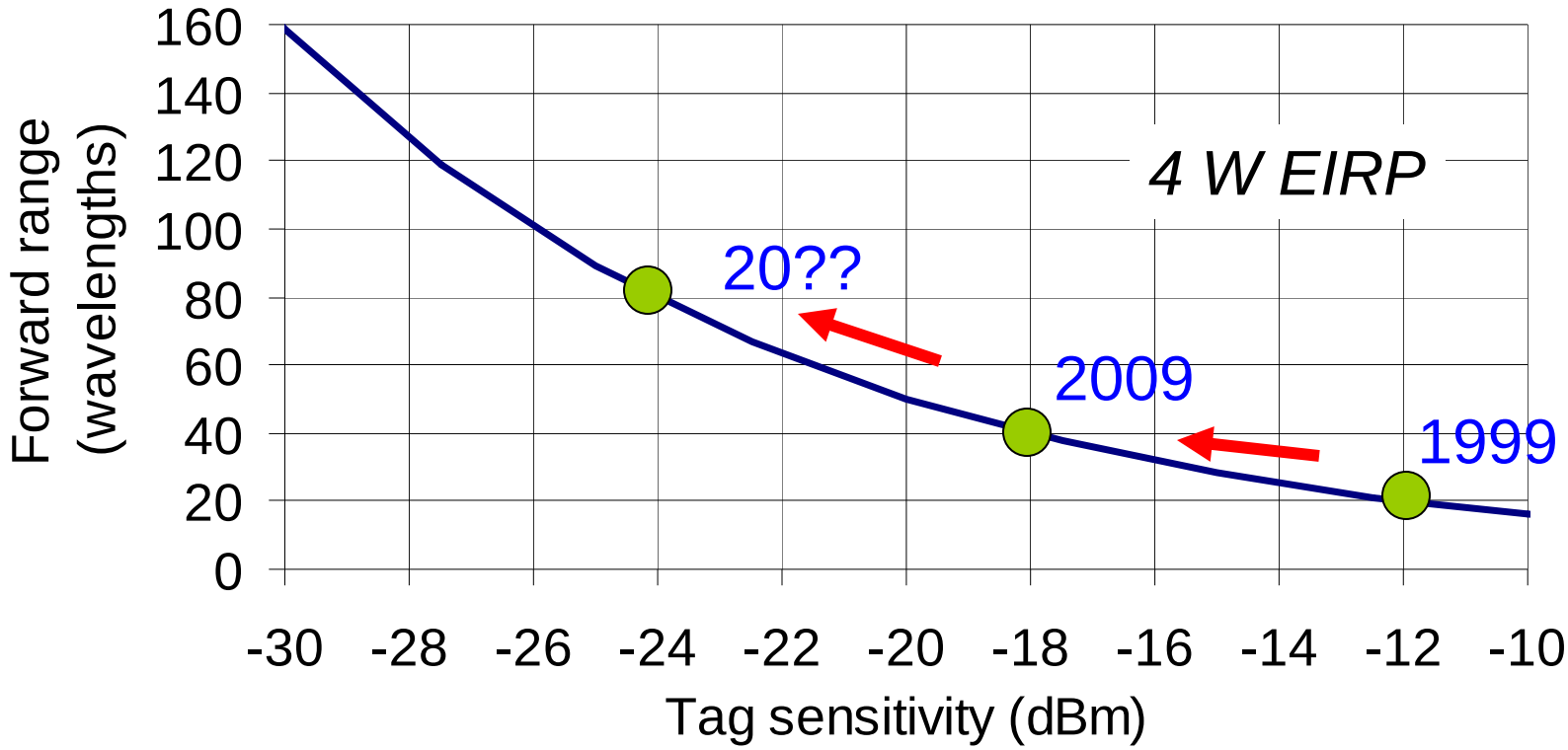


State 1	Matched	Matched	Short
State 2	Short	Open	Open
rho1	0	0	-1
rho2	-1	1	1
alpha	¼	¼	¼
K	-6 dB	-6 dB	0 dB

Forward Range

- Maximum distance at which tag can be read (or written to)
- Depends on the tag, the environment, and reader power
- In free space:

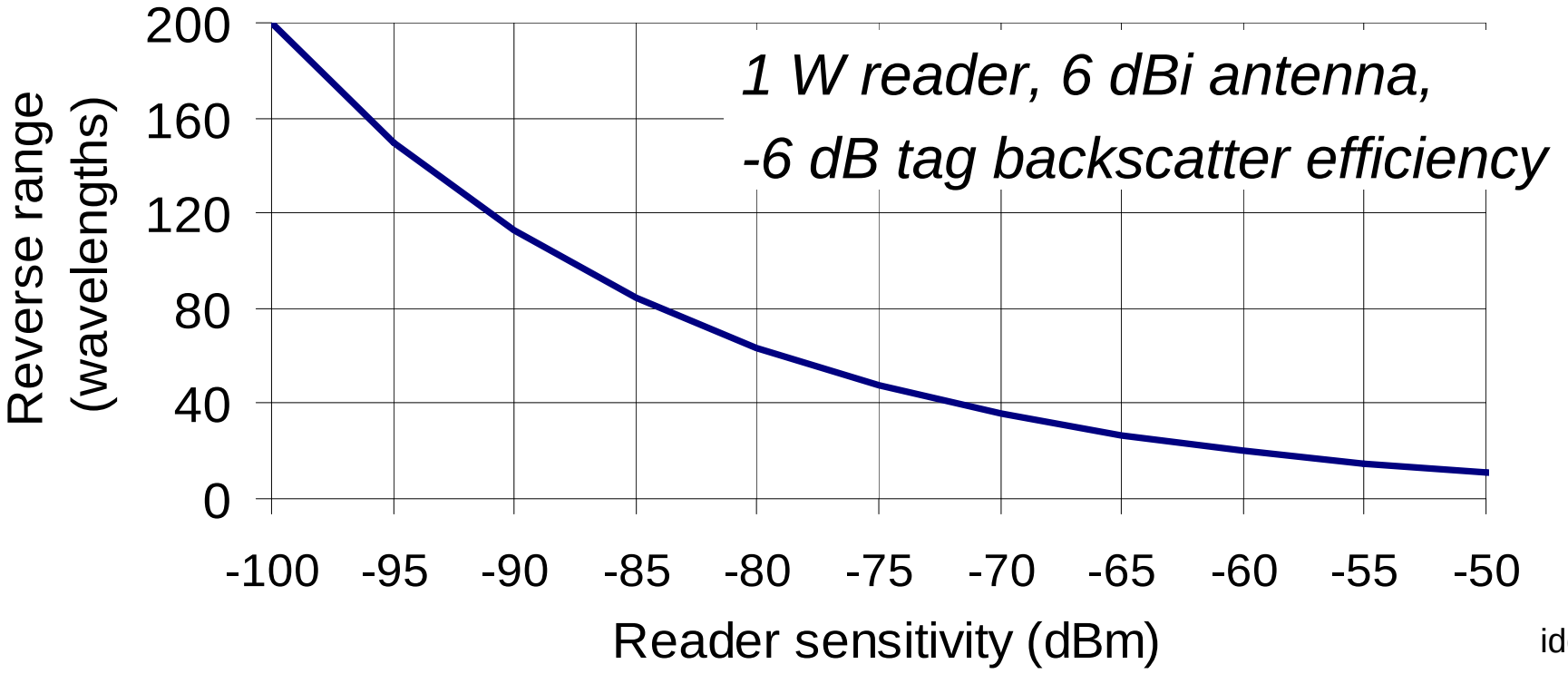
$$r_{forward} = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t}{P_{tag}}}$$



Reverse Range

- Maximum distance at which tag signal can be received
- Depends on the tag, the environment, and reader power and sensitivity
- In free space:

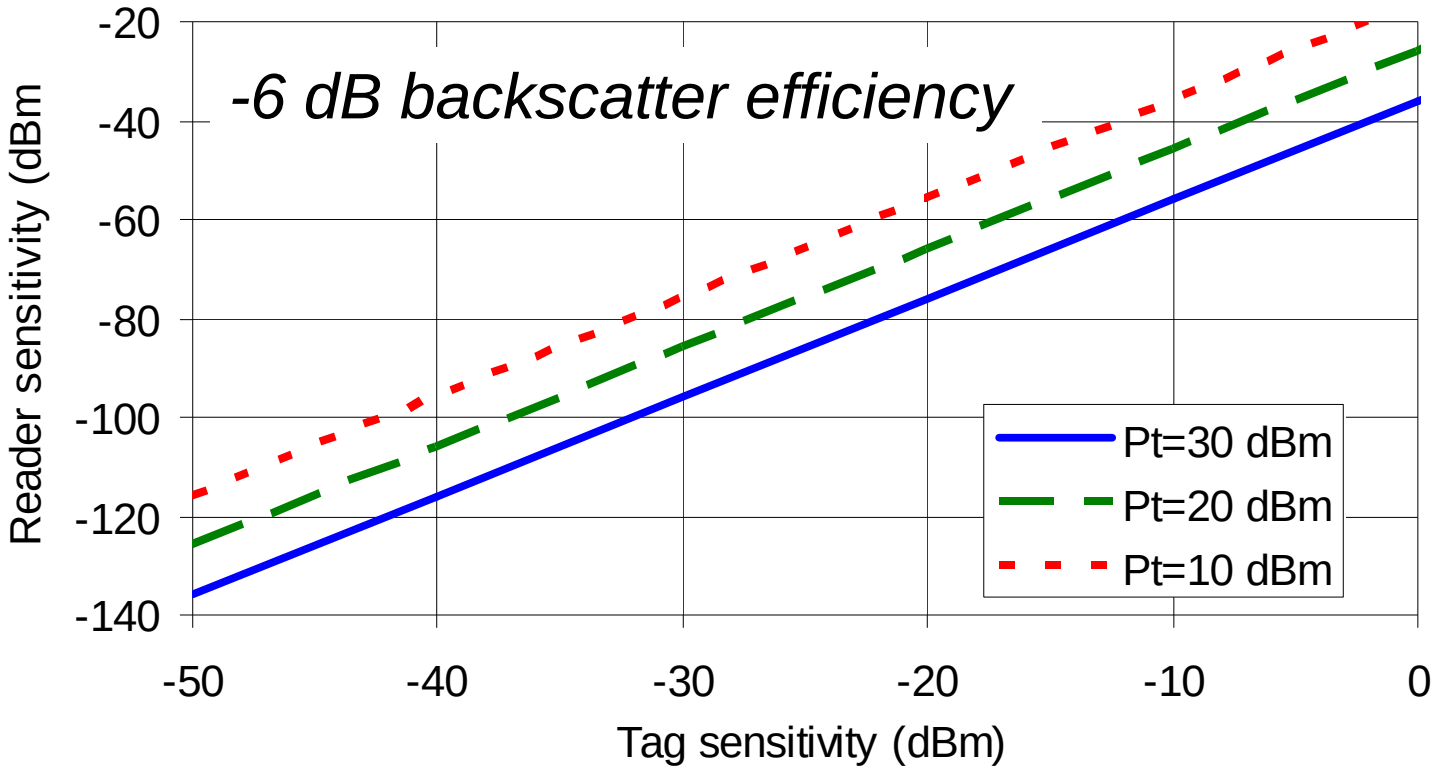
$$r_{reverse} = \frac{\lambda}{4\pi}\left(\frac{P_t G_t^2 \chi}{P_{reader}}\right)^{1/4}$$



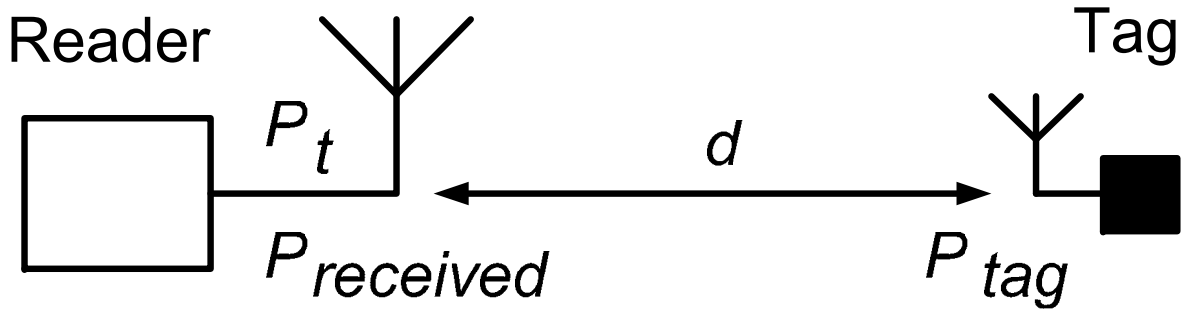
Reader Sensitivity vs. Tag Sensitivity

- Minimum reader sensitivity needed to read a tag of certain sensitivity at its maximum range:
- Valid for any environment (path loss is embedded into formula)

$$P_{reader} = \frac{P_{tag}^2}{P_t}\chi$$



Tag Measurement Methods

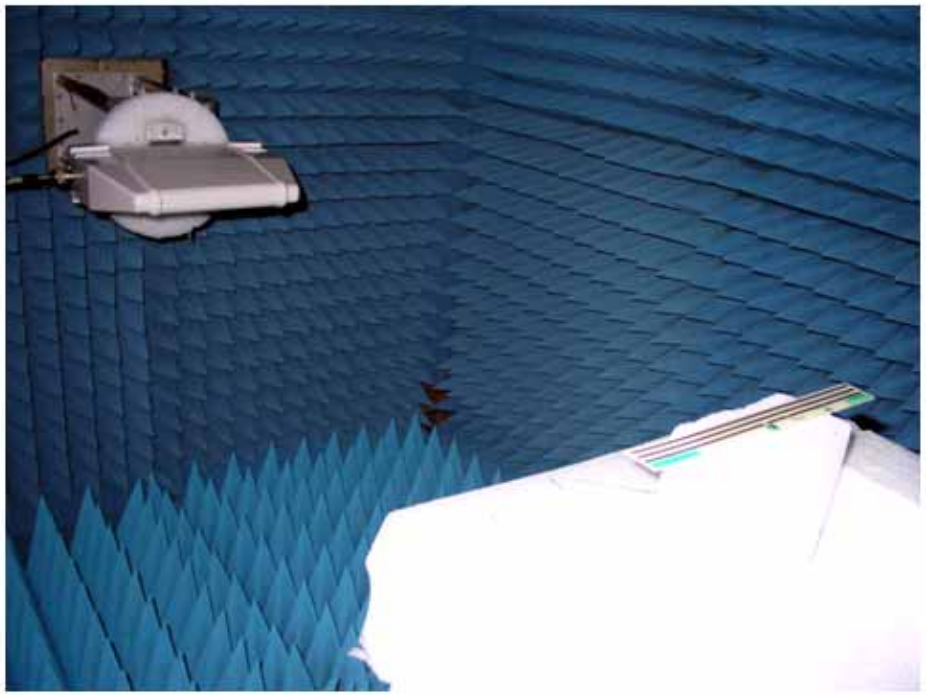


- Varied distance (*P* = const)
- Varied power (*d* = const)
- Measure transmitted and received power
- In free space:

$$P_{tag} = P_t G_t \left(\frac{\lambda}{4\pi d} \right)^2 \qquad P_{received} = P_t G_t^2 \left(\frac{\lambda}{4\pi d} \right)^4 \chi$$

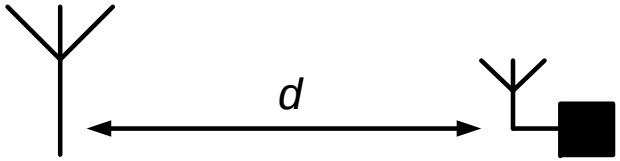
Controlled Test Environment

1. Anechoic chamber



2. TEM cell

3. Free space

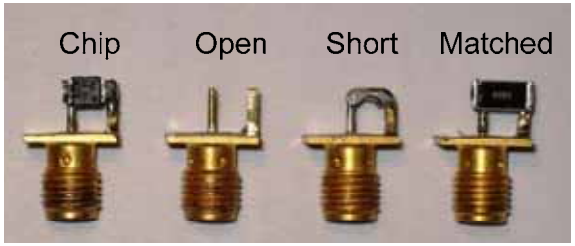


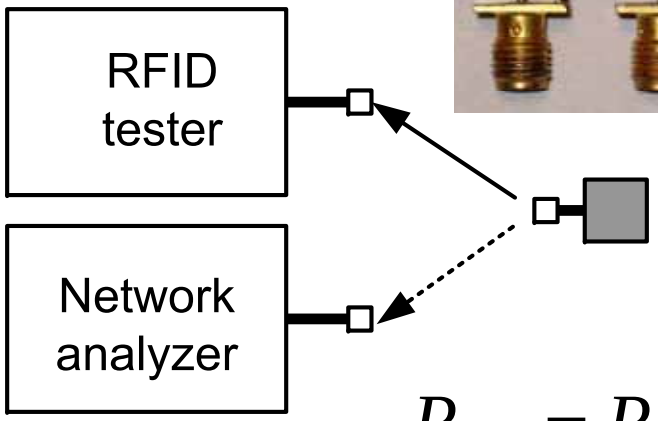
$$E_{\min} = \frac{V_{\min}}{h} = \frac{\sqrt{P_{\min} Z}}{h}$$

h – cell height at tag location

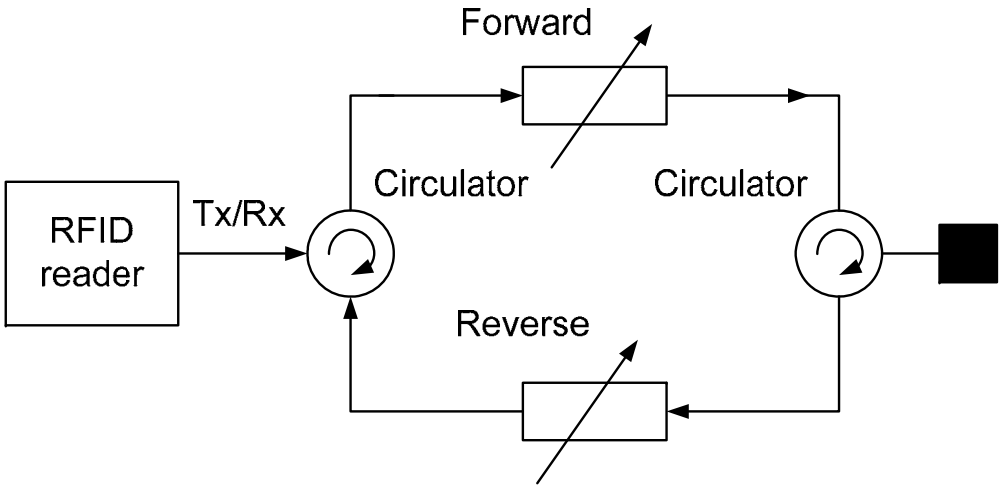
Conducted Measurements

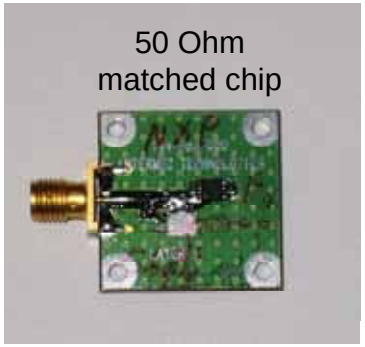
- Unmatched chips
  - Threshold sensitivity
  - Input impedance
- Matched chips
  - Reader testing
  - Antenna measurements

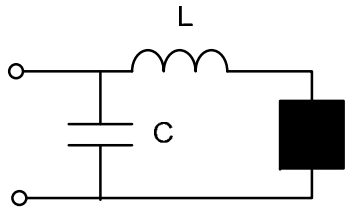




$$P_{chip} = P_{\min}\left(1 - \left|S_{11}\right|^2\right)$$

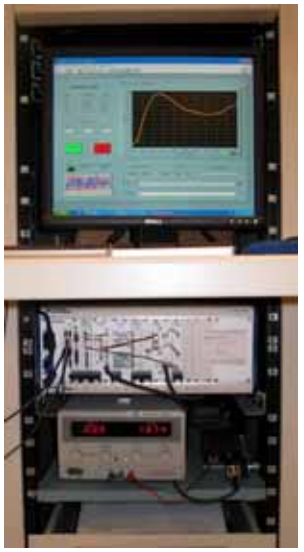


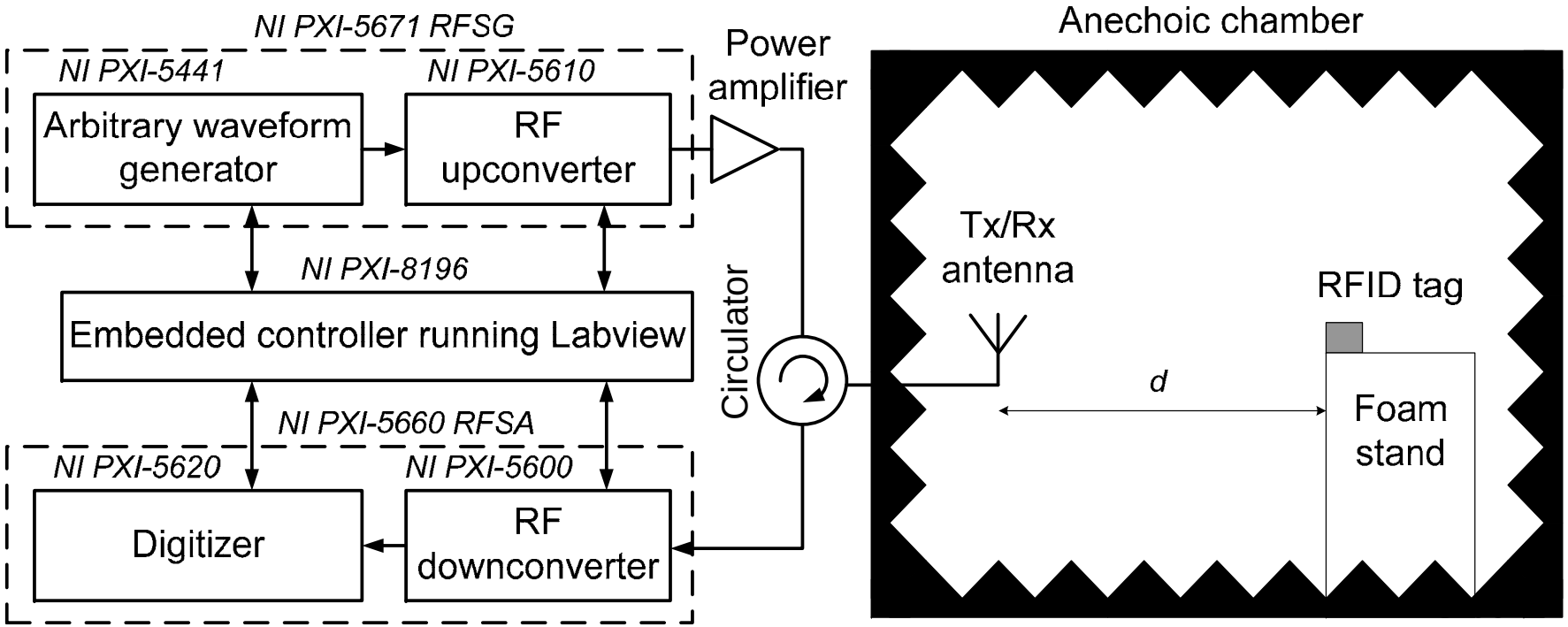




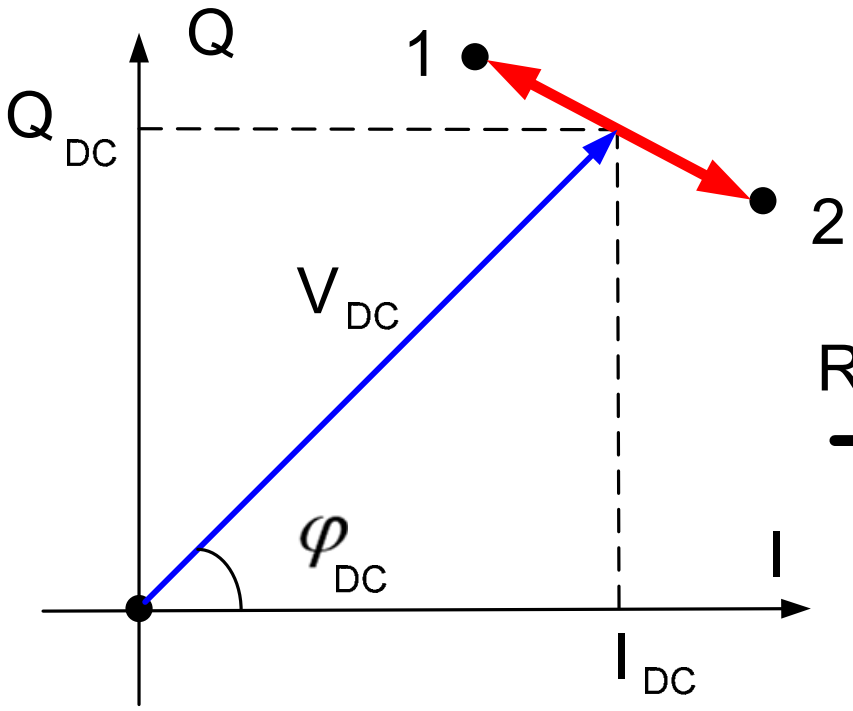
Test System Example

- National Instruments LabVIEW PXI RF platform
- Controlled:
  - Power (max. 30 dBm, 0.1 dB step)
  - Frequency (800-100 MHz)
  - Gen2 protocol parameters (link timing, modulation)



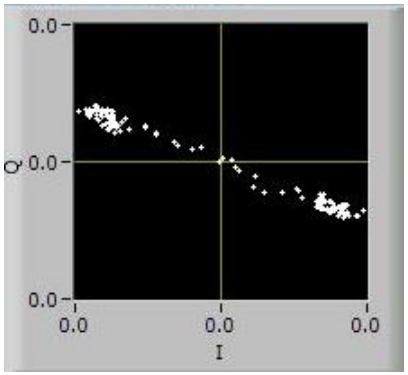


Processing I and Q

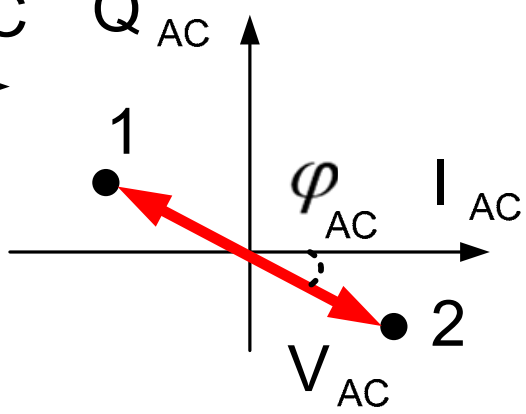


$$I = I_{DC} + I_{AC}$$

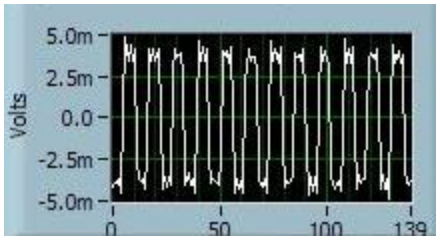
$$Q = Q_{DC} + Q_{AC}$$

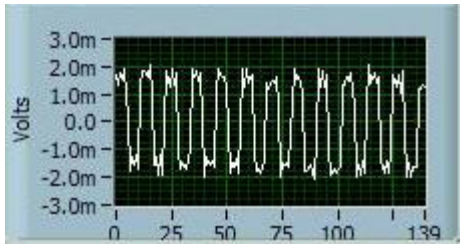


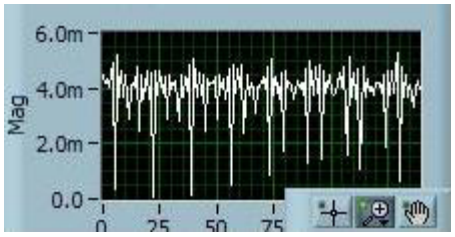
Remove DC

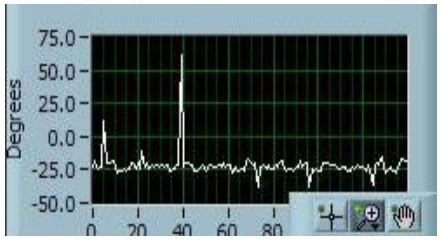


I_{AC} Q_{AC} V_{AC} φ_{AC}

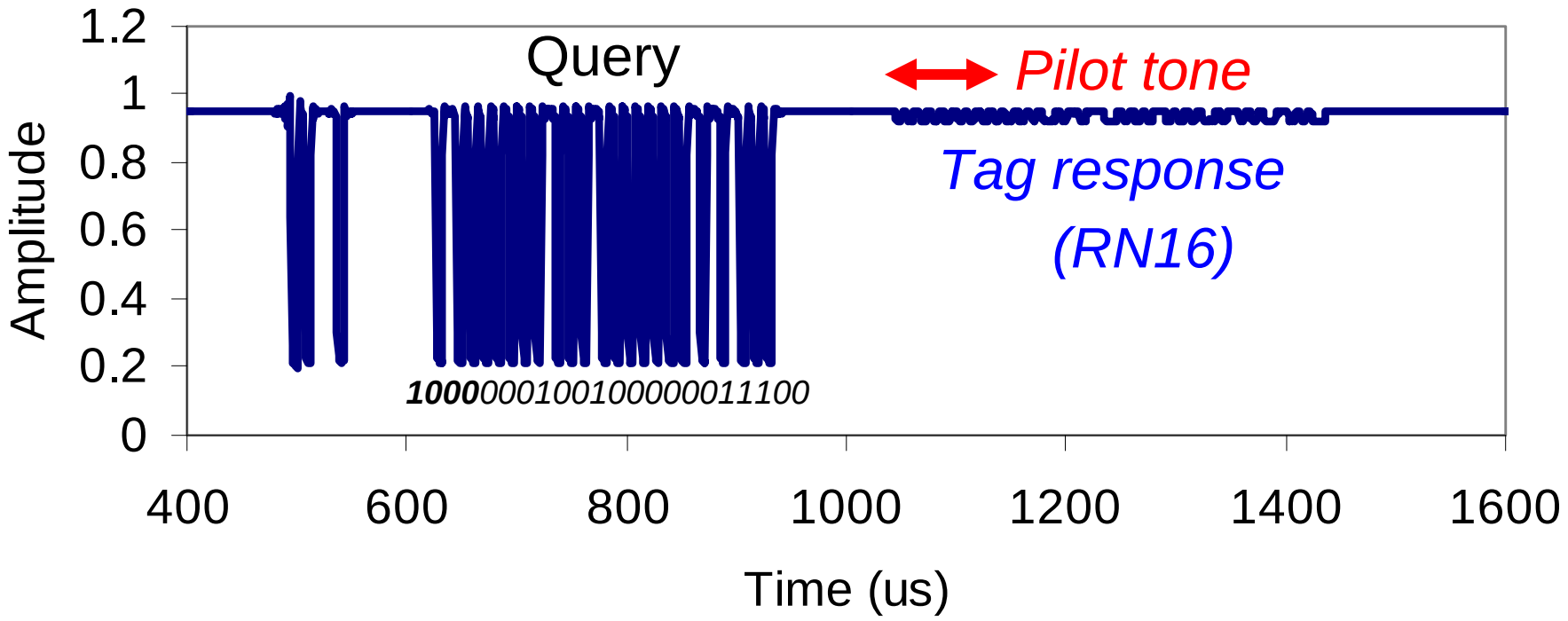








Tag Detection and Power Calculation



- Tag response detection (frequency domain)
  - Look for spectral component around expected BLF
- Received power calculation (time domain)
  - Average power in pilot tone

$$P_{received} = \frac{\left\langle V_{AC}^2 \right\rangle}{Z_o}$$

Conclusions

- Forward and reverse link measurements are important (especially for BAP tags)
- Accurate characterization requires:
  - RFID reader with power and frequency control
  - Controlled test environment
  - Careful RF calibration
- Challenges: characterizing tag performance in presence of other tags and readers

Thank you!

Questions or comments?

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