RFID SysTech'07

Design and Analysis of a Complete RFID System in the UHF Band Focused on the Backscattering Communication and Reader Architecture

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Contents

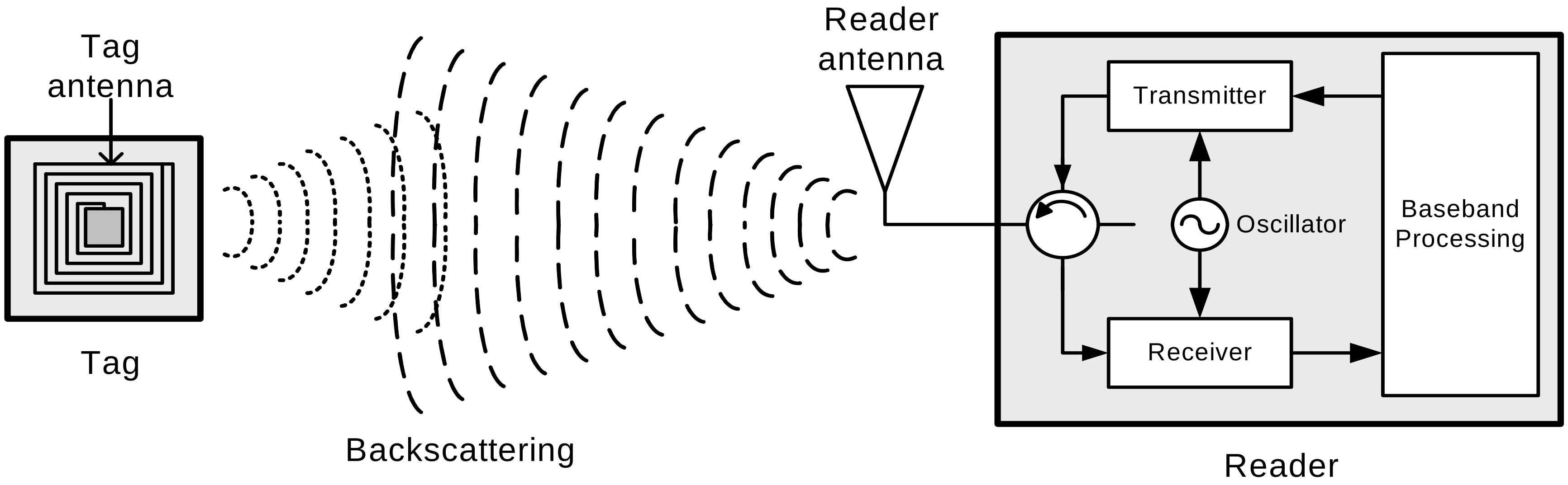
1. Introduction

Introduction (I)

- Passive RFID Systems:
  - Lower size, lower cost, higher lifetime.
- UHF bands:
  - 860-960 MHz and 2.45 GHz ISM Bands
  - Higher data-rates, longer distances.
- Trade-off:
  - Antenna Size vs Reading distance.
  - 868 MHz (Longer distance preferable)
- Normative:
  - EPCGlobal UHF Class 1 Generation 2
  - EN 302 208-1

Introduction (II)

- Reader-to-tag Communication: ASK
- Tag-to-reader Communication: ASK, PSK
  - Backscattering



2. Goals

Goals

- State of the art:
  - Guidelines and results from the tag point of view.
  - Little information about long range RFID reader design.
- Complete long range passive RFID system design and analysis.
- Compliant with the EPCGlobal UHF Class 1 Generation 2 standard and European regulations.
- Focused on reader architecture and backscattering tag-to-reader communication.
- Main objective: maximize operating distance.

3. Tag model

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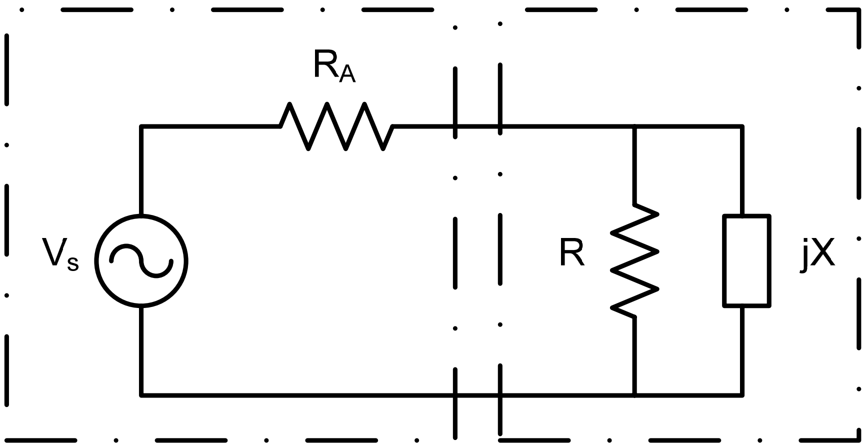
Tag model (I): Backscattering

- Energy reaching the tag:
  - Part is used for supply
  - Part is backscattered
- Changes in reflection coefficient
  - Resistance: ASK modulation
  - Reactance: PSK modulation (longer distances)



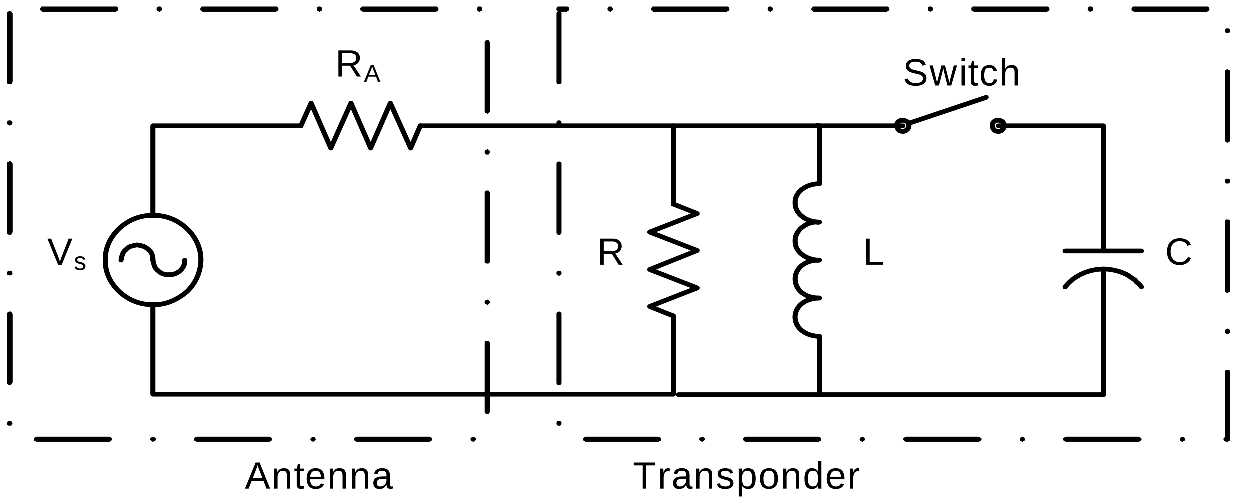
$$\theta = -\arctan\left(\frac{R_A X}{R_A^2 + 2X^2}\right)$$

$$P_{BS} = P_{AV}\frac{4\left(R_A^2 + X^2\right)}{R_A^2 + 4X^2}$$

[1] G. De Vita and G. Iannaccone, “Design Criteria for the RF section of UHF and Microwave passive RFID transponders” IEEE Trans. Microw. Theroy Tech., vol. 53, no.9, pp. 2985-2989, Sep. 2005

Tag Model (II)

- Backscattered power must remain constant
- A series of equations developed to work out L and C in order to cause a predefined dephase in the backscattered signal.



4. Channel Model

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Propagation Channel

- Signal crosses the channel twice
- Free Space Losses:

$$FSL = \left(\frac{\lambda}{4\pi d} \right)^4$$

- Additive White Gaussian Noise (AWGN)
- Random Phase Shift

5. Reader Architecture

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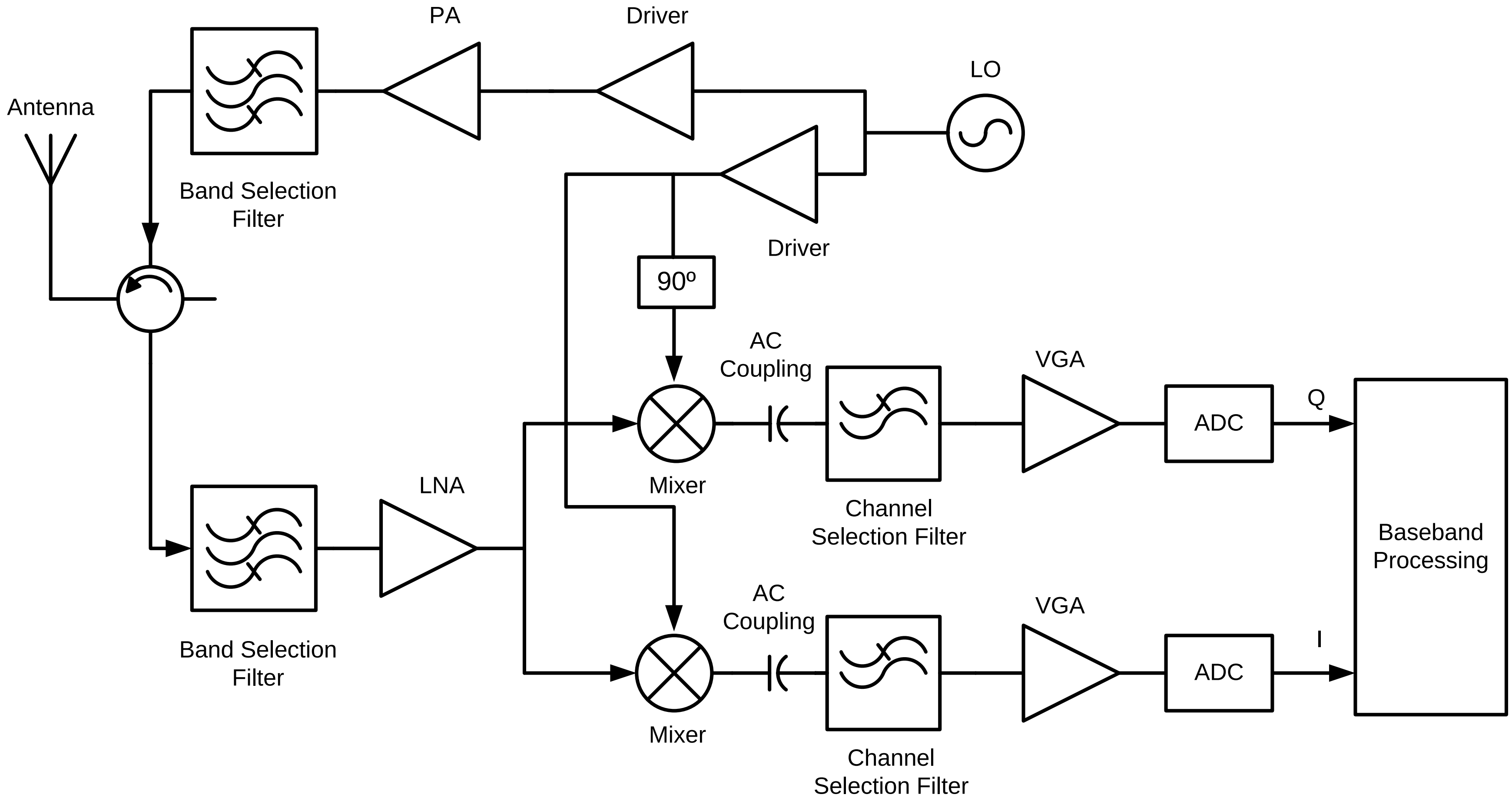
Reader Architecture



Power received at the reader

- Polarization considerations:
  - Tag antenna: linear
  - Tag position: arbitrary
  - Reader antenna transmits circular:
    - 3dB Losses due to polarization mismatch
- Friis Formula:

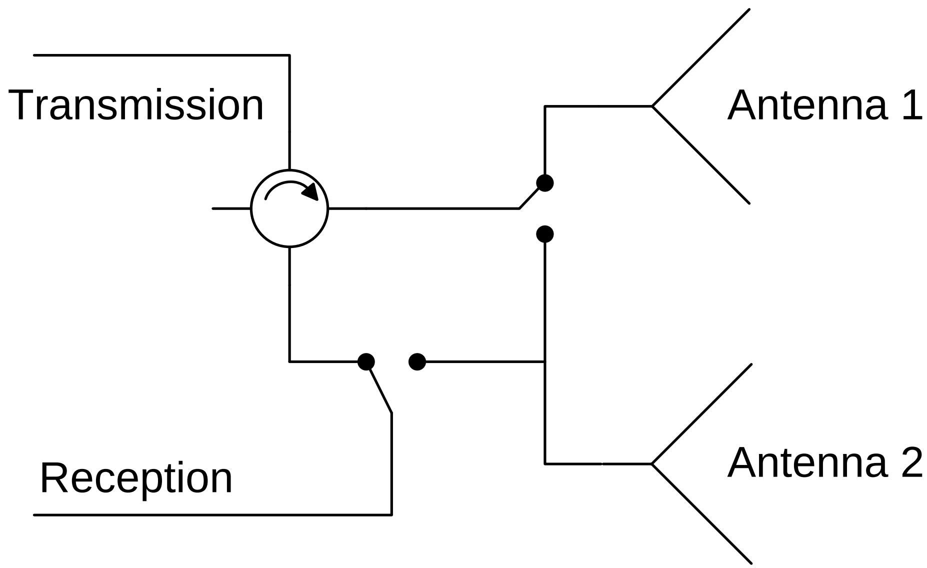
$$P_R = P_T G_{tag}^2 G_{reader}^2 \frac{4(R_A^2 + X^2)}{R_A^2 + 4X^2} p \left(\frac{\lambda}{4\pi d} \right)^4$$

Transmission Leakage

- The reader transmits and receive at the same time and in the same frequency.
- Reader radiated power: 2 W e.r.p. (33 dBm)
  - Circulator isolations around 30 dB
- Backscattered signal masked
- Very high dynamic range required, RF stage can get saturated (mixer)
- DC Offsets at baseband due to self-mixing
  - Coupling stage necessary

Output switching circuitry

- 2 Options for simultaneous Tx/Rx:
  - Circulator (isolation provided by circulator)
  - 2 Antennas (external isolation)
- Both can be combined:



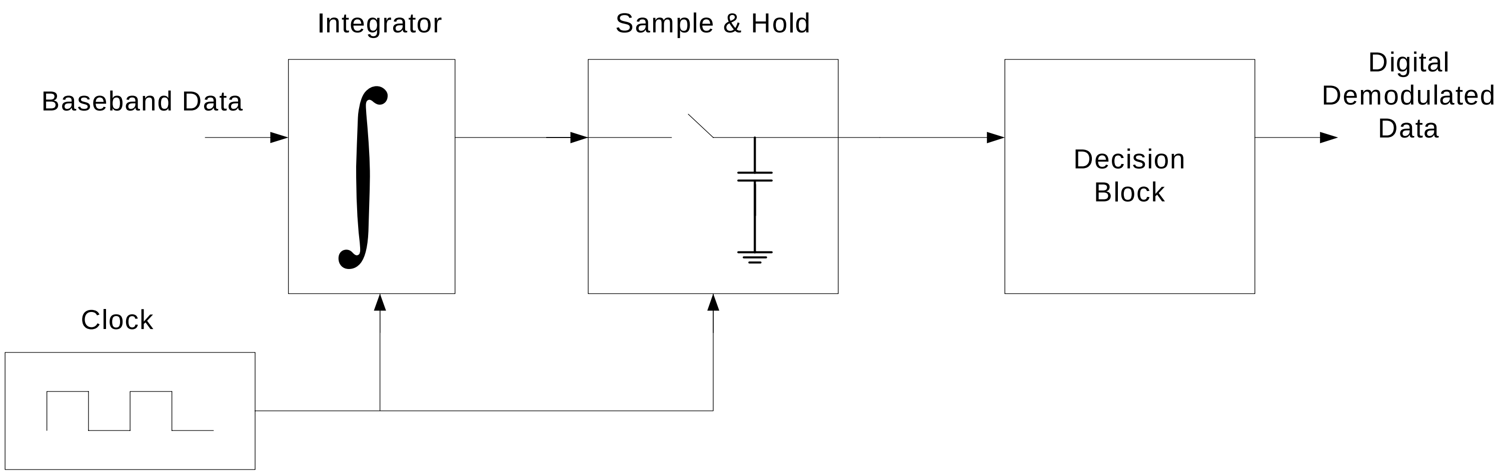
Quadrature downconversion

- Phase shift introduced by the channel.
  - Modulation is not affected but…
- Coherent detection is not realizable.
- I/Q Demodulation necessary:
  - When one channel is at maximum sensitivity, the other is at minimum.
- Two options:
  - Parallel processing
  - I and Q Paths combination

Demodulation

$$i(t) = \sum_{m=0}^{\infty} A\,\mathrm{Rect}\left(\frac{t - T/4 - mT/2}{T/2}\right)\cos\left(\theta_m + \beta + \phi(t)\right) + n(t)$$

$$q(t) = \sum_{m=0}^{\infty} A\,\mathrm{Rect}\left(\frac{t - T/4 - mT/2}{T/2}\right)\sin\left(\theta_m + \beta + \phi(t)\right) + n(t)$$



6. Simulation Results

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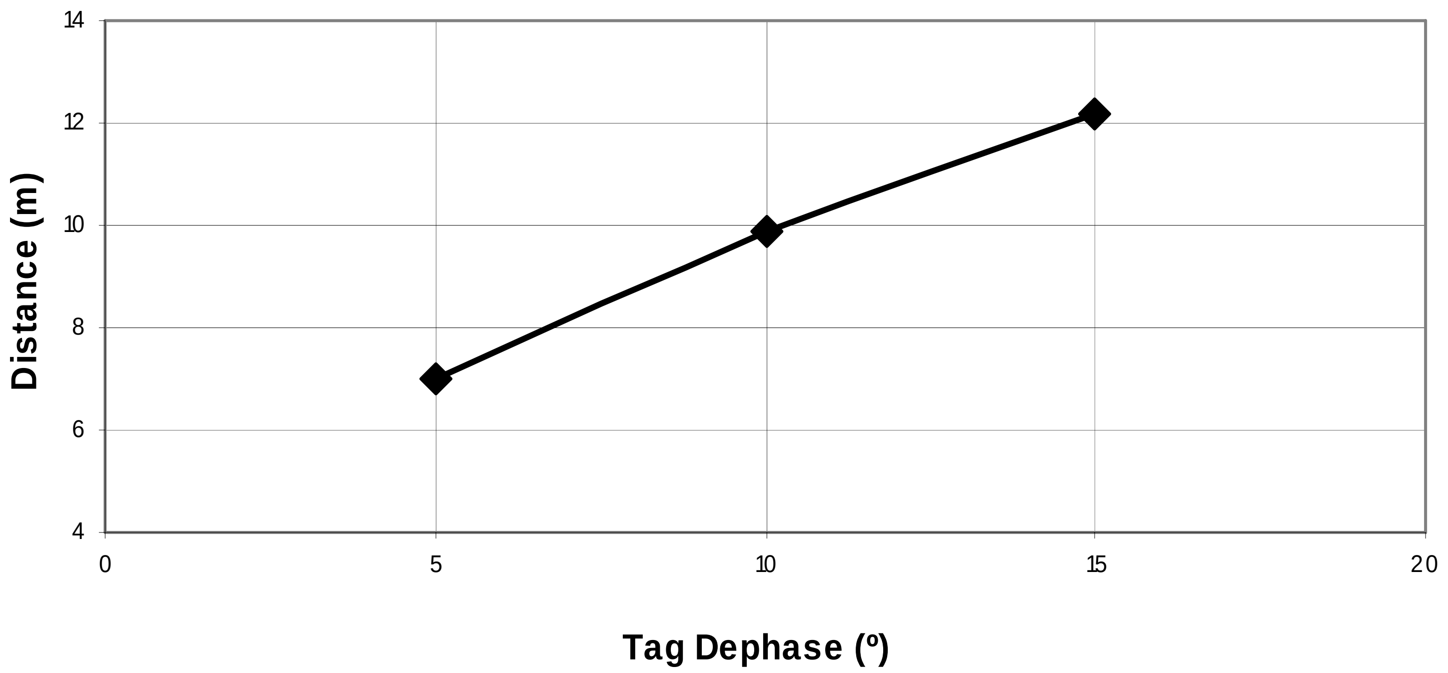
Simulation results

- Study of the parameters that mainly affect reading distance.
- A complete passive RFID system simulation environment has been developed in ADS.
- Reader architecture is simulated with real commercial components.
- Maximum reading distance from the reader point of view.
  - Maximum BER at the reader (10^{-3}).

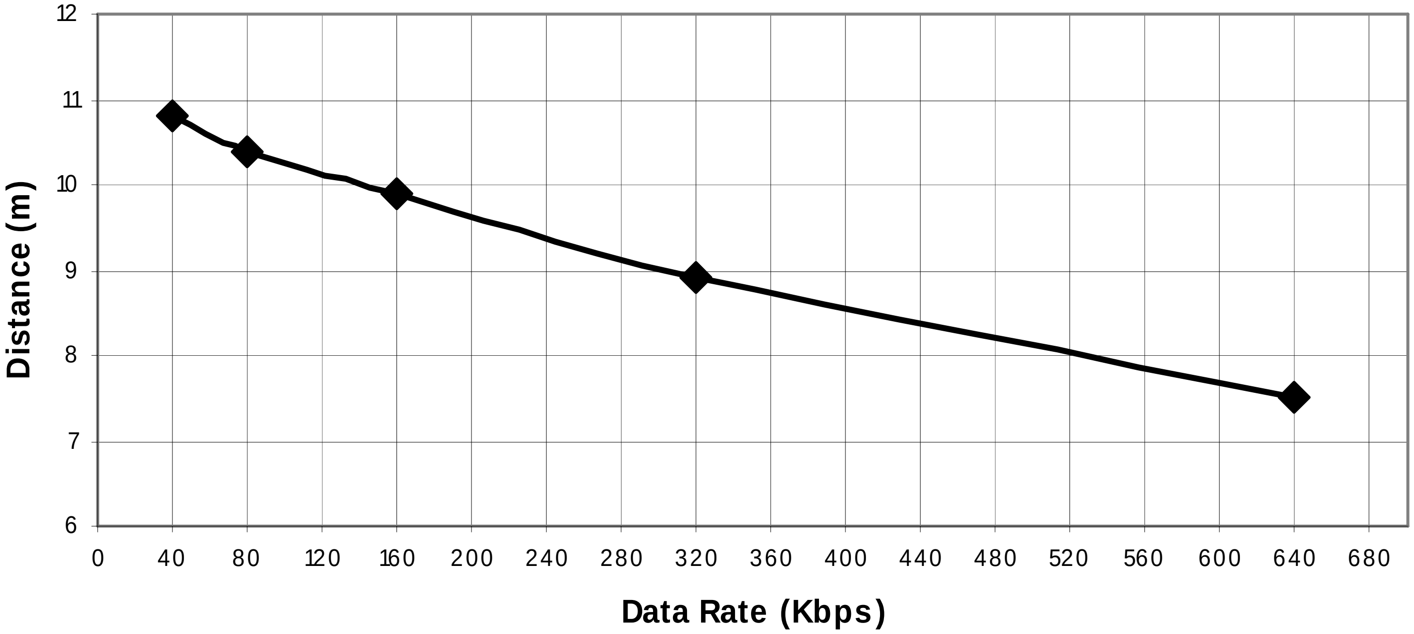
Tag Phase Variation

- Typical phase variations: 5°- 15°



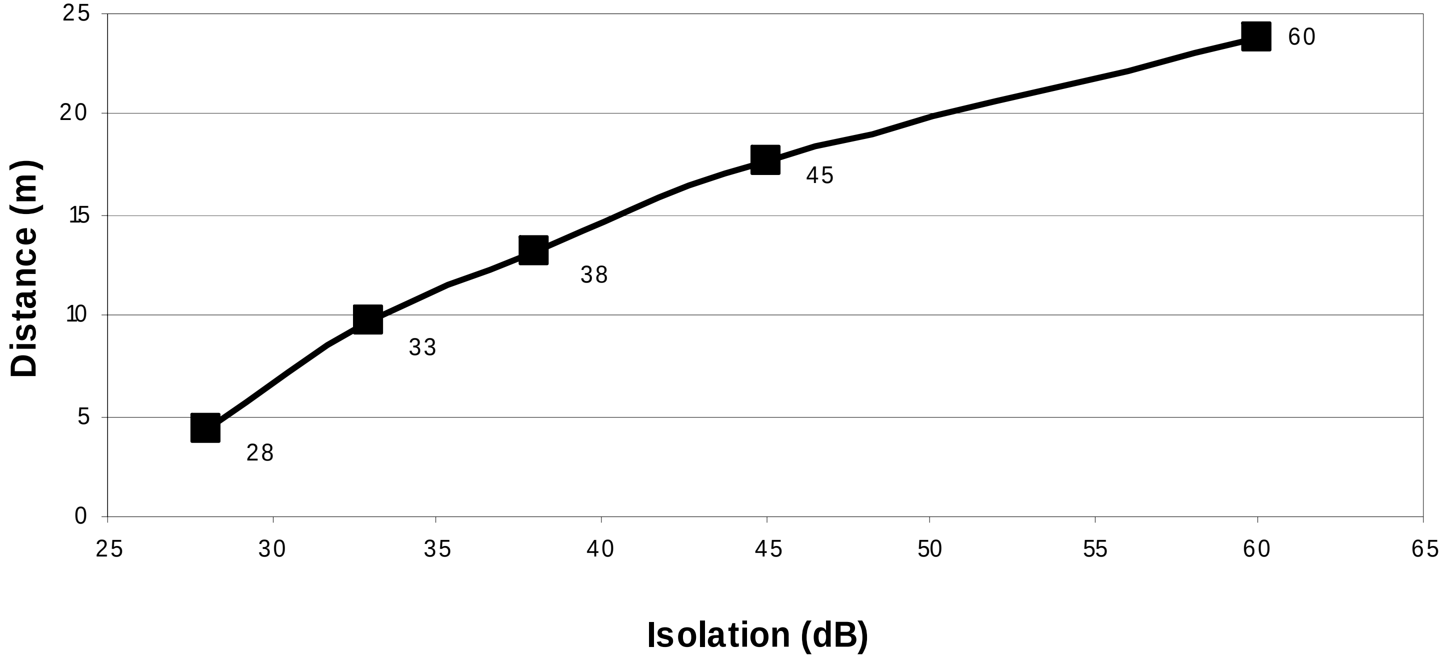
Data Rate (FM0 Encoding)

- Date rates allowed by the standard:
  - From 40 Kbps to 640 Kbps



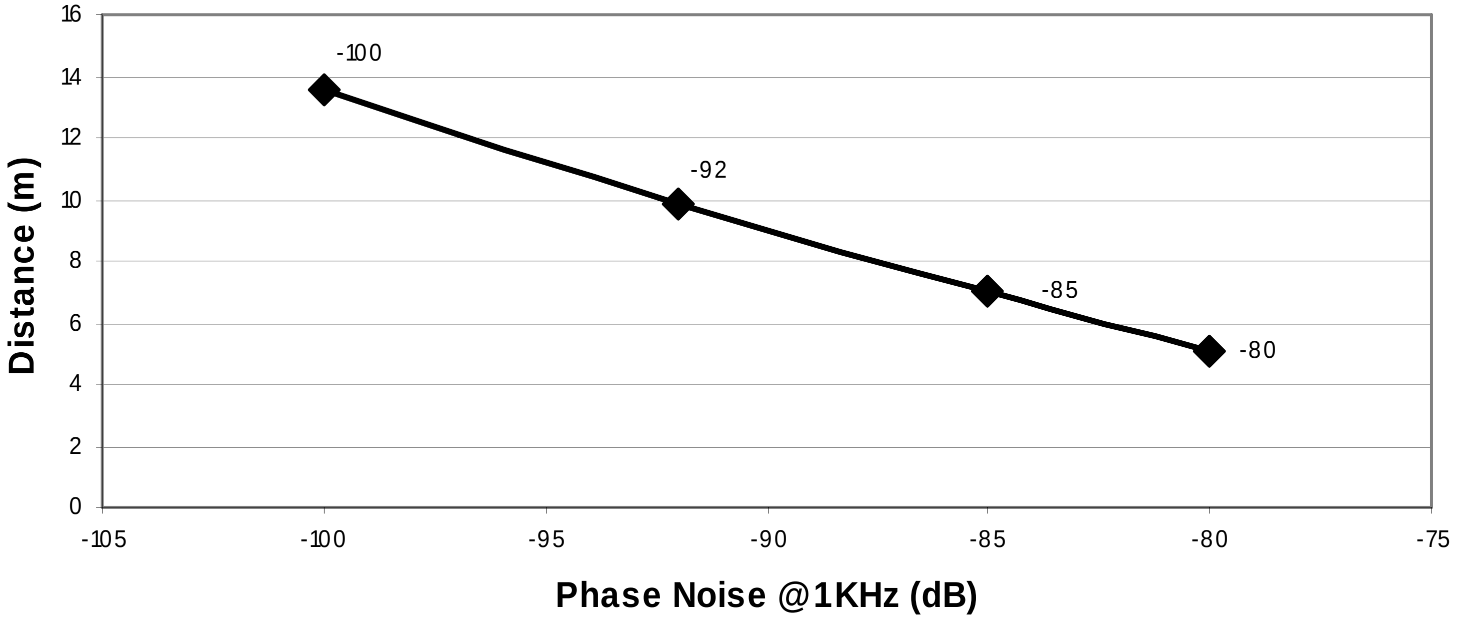
Circulator Isolation

- Commercial circulators: ~30 dB Isolation
  - A 60 dB isolation circulator reported



Phase Noise

- Commercial oscillator phase noise (dBc/Hz):
  - -92@1kHz, -116@100kHz, -138@1MHz, -144@3MHz



7. Conclusions

Conclusions

- A complete long range passive RFID system has been designed and analyzed.
- Guidelines for a proper long range passive RFID reader are derived.
- The tag is not the only limiting factor in a passive RFID system.
- Tx/Rx Isolation and Phase noise are reader key design issues.

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Thank you for your attention.
Questions and comments are welcome.

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