RFID at mm-Waves

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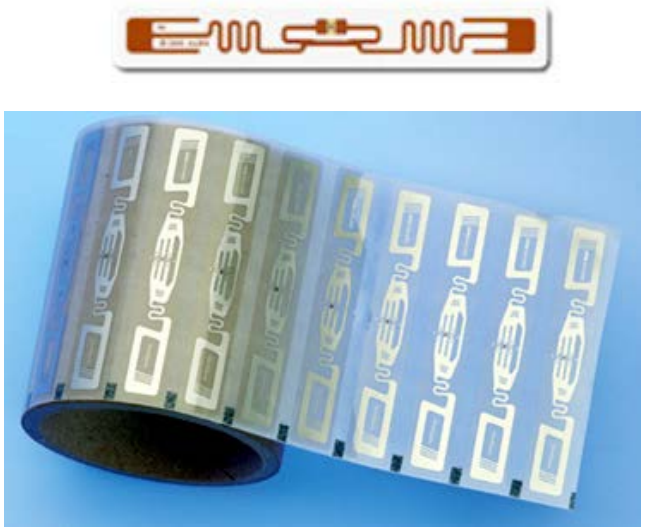
Agenda

- Introduction Into mm-Wave RFID Systems
- mm-Wave RFID Systems – a Review
- System Overview
- Base Station Concept
- Transponder Concept
- Conclusion

Introduction Into mm-Wave RFID Systems

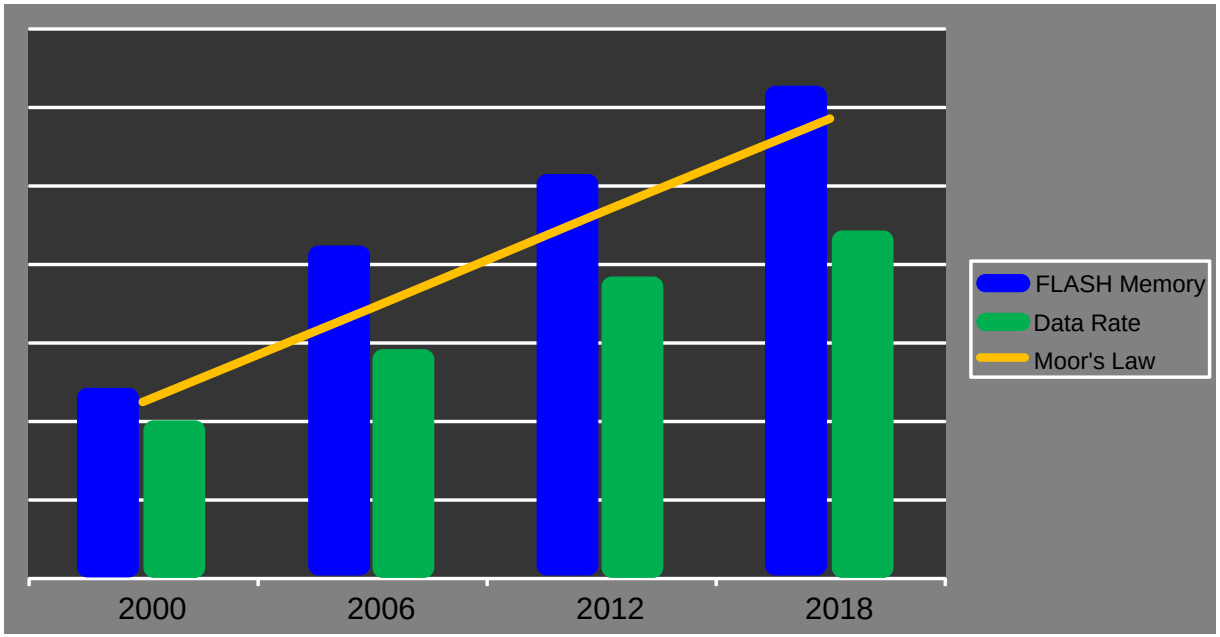
RFID… **R**adio **F**requency **ID**entification

LF-, HF- and UHF-RFID systems are wide spread

UHF-Tag	**UHF-Reader**
	

Source: hcaeditor.blogspot.com, hk-cxj.en.alibaba.com

Introduction Into mm-Wave RFID Systems



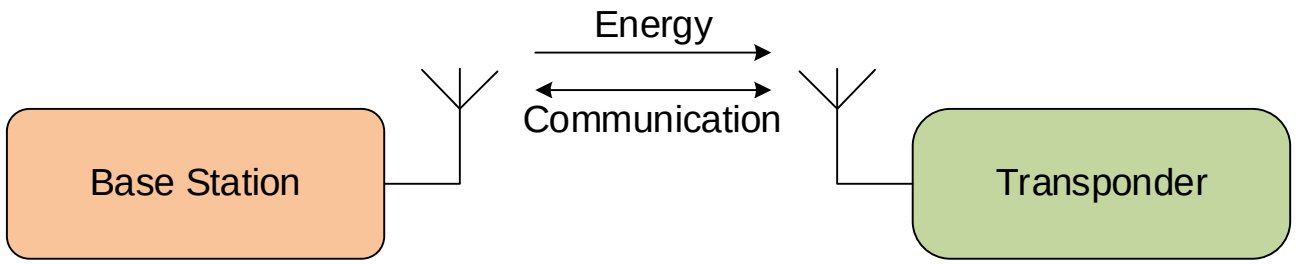
Source: NXP Semiconductors

- Growth of **FLASH memory** and **data rate** follows approx. **Moor's law**
  - Clear tendency to move to higher transmission speeds

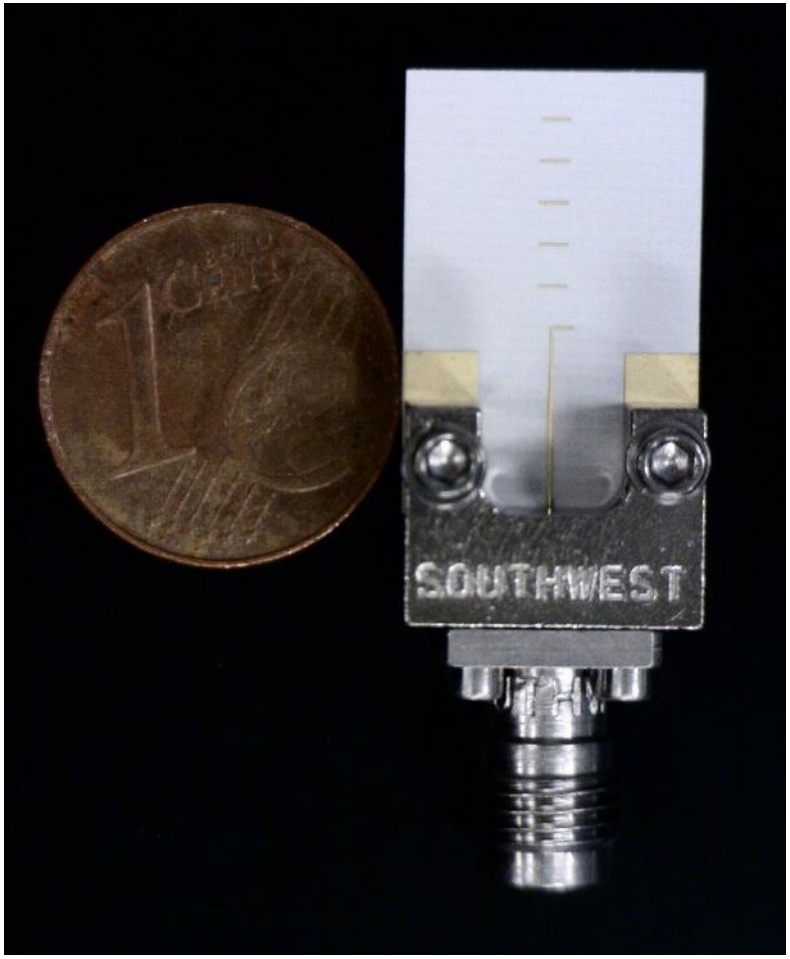
Introduction Into mm-Wave RFID Systems

mm-wave RFID (MMID):

- Similar structure as UHF RFID systems
- Base station – transponder communication
  - Energy transport at mm-waves
  - Pulse-interval encoding (PIE) downlink transmission
- Transponder – base station communication
  - Backscatter(like) modulation



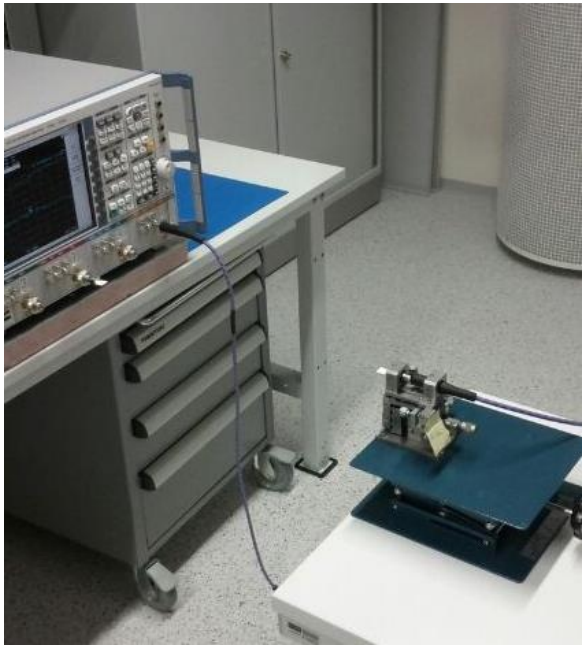
Advantages of MMID



- Small wavelengths
  $\lambda_{FS}(60\ \mathrm{GHz}) = 5\ \mathrm{mm}$
  → Small antenna
  → Antenna arrays

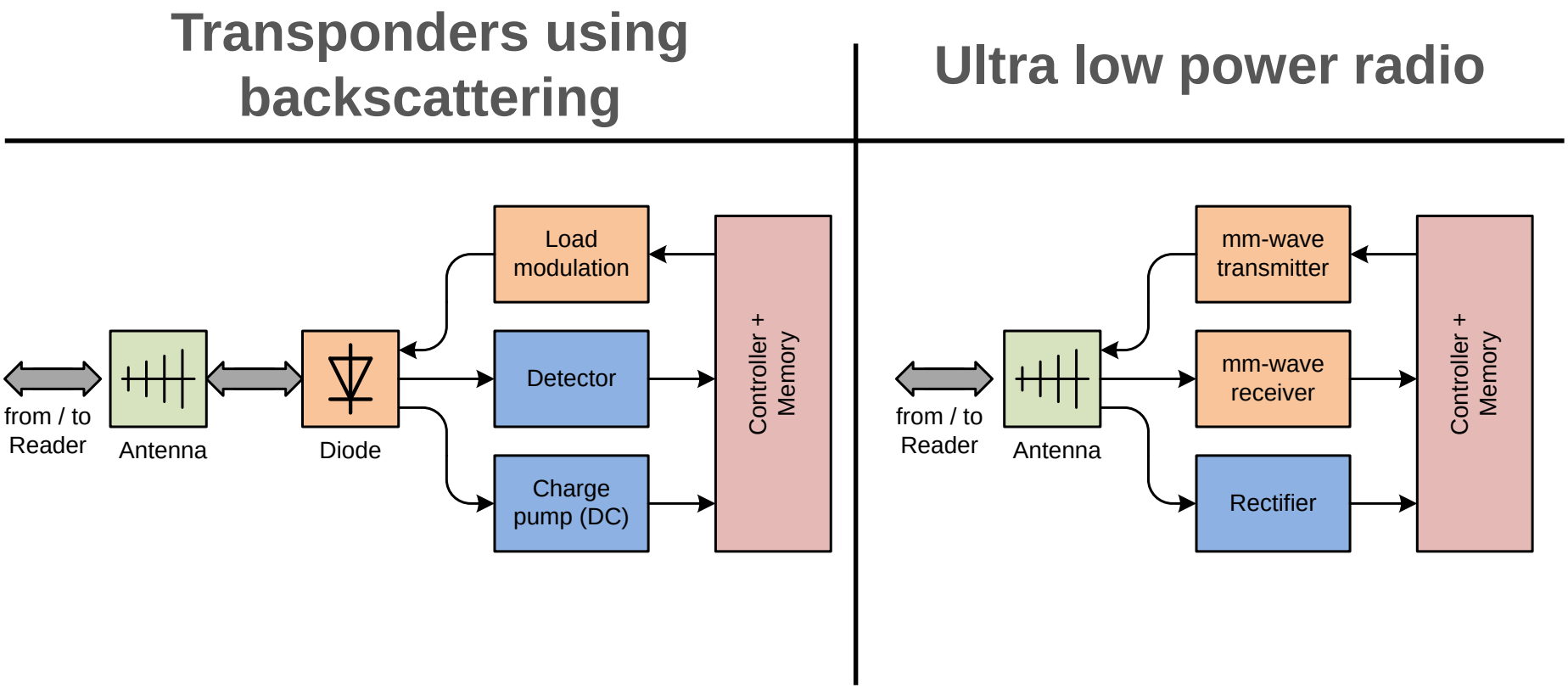
- Availability of higher bandwidths
  → Higher data rates
  → Localization

Disadvantages of MMID



- High development and prototype production costs
- High channel attenuations (free space loss, atmospheric attenuation)

MMID – a Review
Structure of a MMID



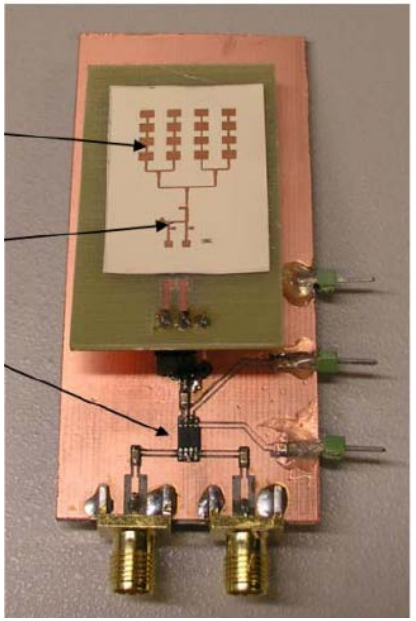
MMID – a Review
Rectifiers using discrete diodes

f_0 (GHz)	P_{in} (dBm)	Efficiency (%)	Reference	Year
10	21	60	[1]	1992
24	15	40	[2]	2013
24	23	48	[3]	2014
24	12	42	[4]	2014
35	18	39	[1]	1992
35	23	34	[5]	2015
35	8	67	[6]	2015

MMID – a Review
RFIC based rectifiers

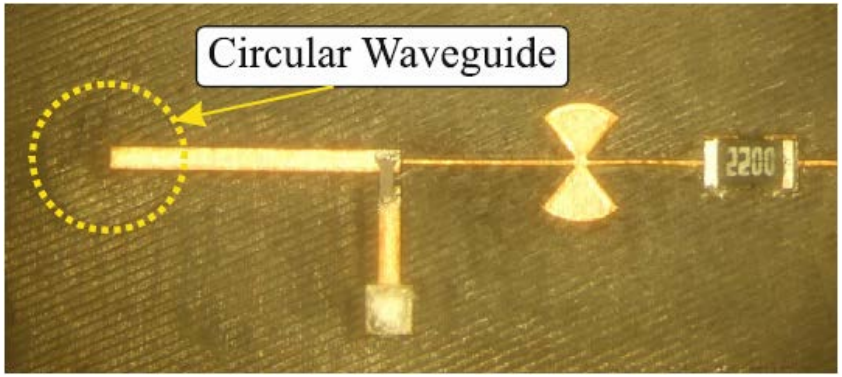
f_0 (GHz)	P_{in} (dBm)	Efficiency (%)	Technology	Reference	Year
24	6	20	65 nm CMOS	[7]	2014
35	6	18	65 nm CMOS	[7]	2014
35	n.a.	53	13 µm CMOS	[8]	2010
45	2	1.2	90 nm CMOS	[9]	2010
60	3	11	65 nm CMOS	[7]	2014
62	-14	7	65 nm CMOS	[10]	2013
71	5	8	65 nm CMOS	[11]	2013
94	n.a.	37	13 µm CMOS	[8]	2010

MMID – a Review
MMIDs using discrete components



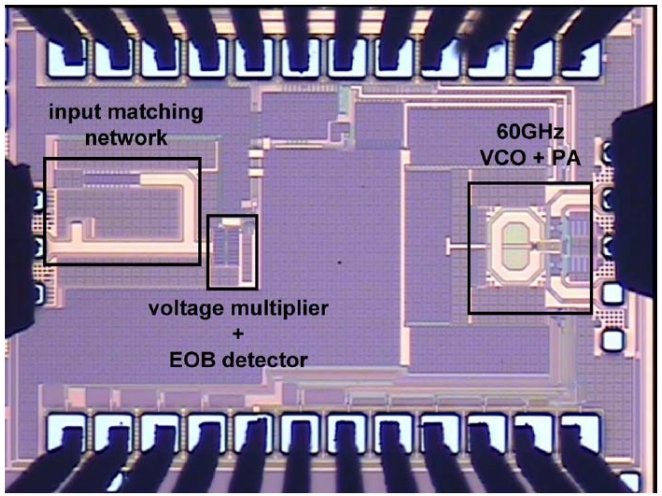
- Semipassive 60 GHz MMID transponder [12]
  - W-band zero bias diode operating as rectifier and load modulator
  - 100 kΩ DC resistor
  - 4x4 series fed array of patch antennas
  - 10 MHz rectangular-wave modulation signal

- Semipasive 61 GHz modulated backscatter transponder [13]
  - Schottky diode operating as load modulator
  - 220 Ω feeding resistor
  - waveguide antenna
  - Operation range of 20 m uncertainty 25 mm

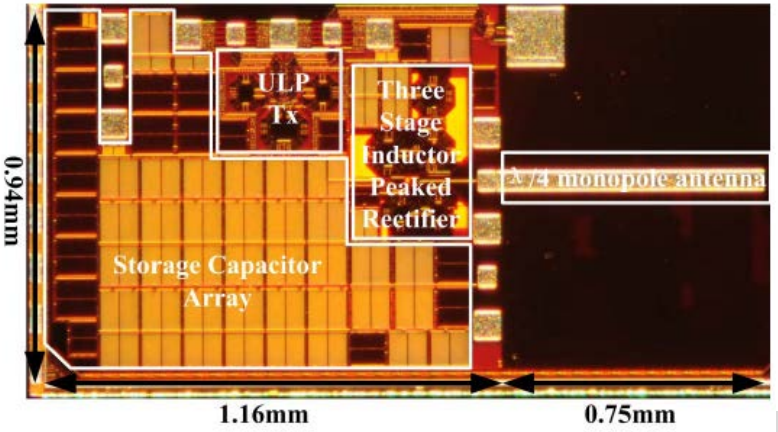


MMID – a Review
RFIC based MMID implementations

- Passive 45 GHz MMID transponder in 90 nm CMOS [9]
  - RFIC size: 1.3 x 0.95 mm incl. pads (without antenna)
  - Active transmission of the uplink signal
  - Data rate of 5 kb/s @ P_{in} = 2 dBm (distance: 3 cm)

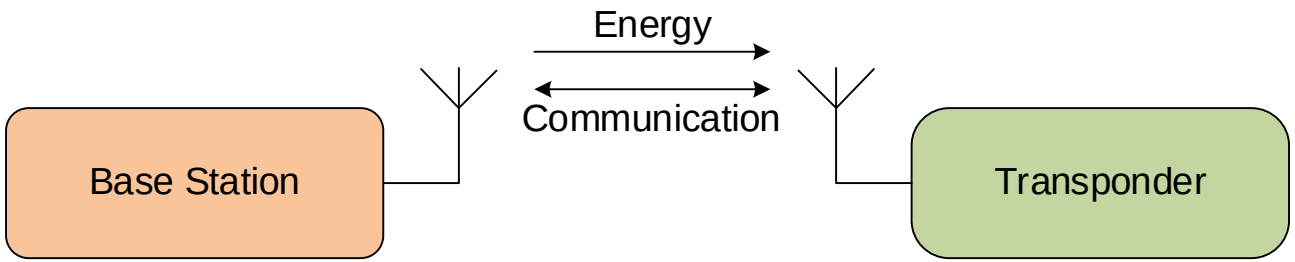


- Passive 71 GHz Tag for wireless temp. sensors in 65 nm CMOS [11]
  - RFIC size: 1.16 x 0.94 mm incl. pads
  - Active transmission of the uplink sig.
  - P_{in} = 5 dBm, V_{DC} = 0.94 V
  - f_{TX}: 79.12 - 78.88 GHz with a slope k = -22 MHz/℃

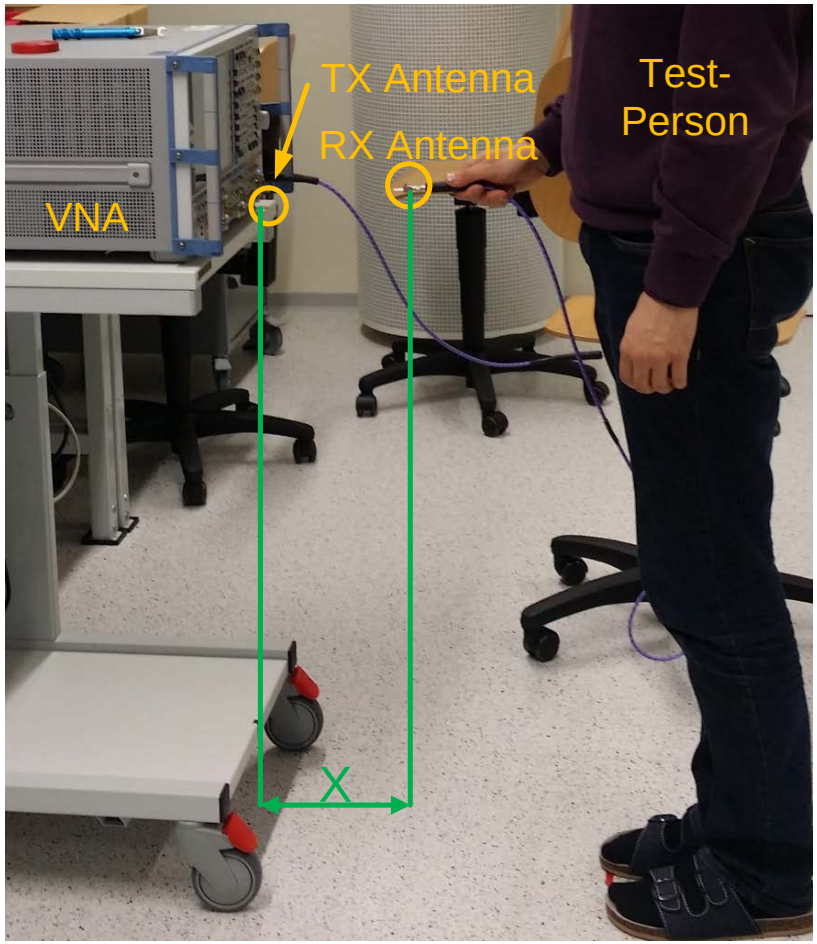


System Overview

- Base station
  - Generate EPC Gen2 commands
  - Supply carrier for backscatter communication
  - Decode backscatter communication
- Transponder
  - Decode base station commands
  - Generate response
  - Send response using backscatter modulation



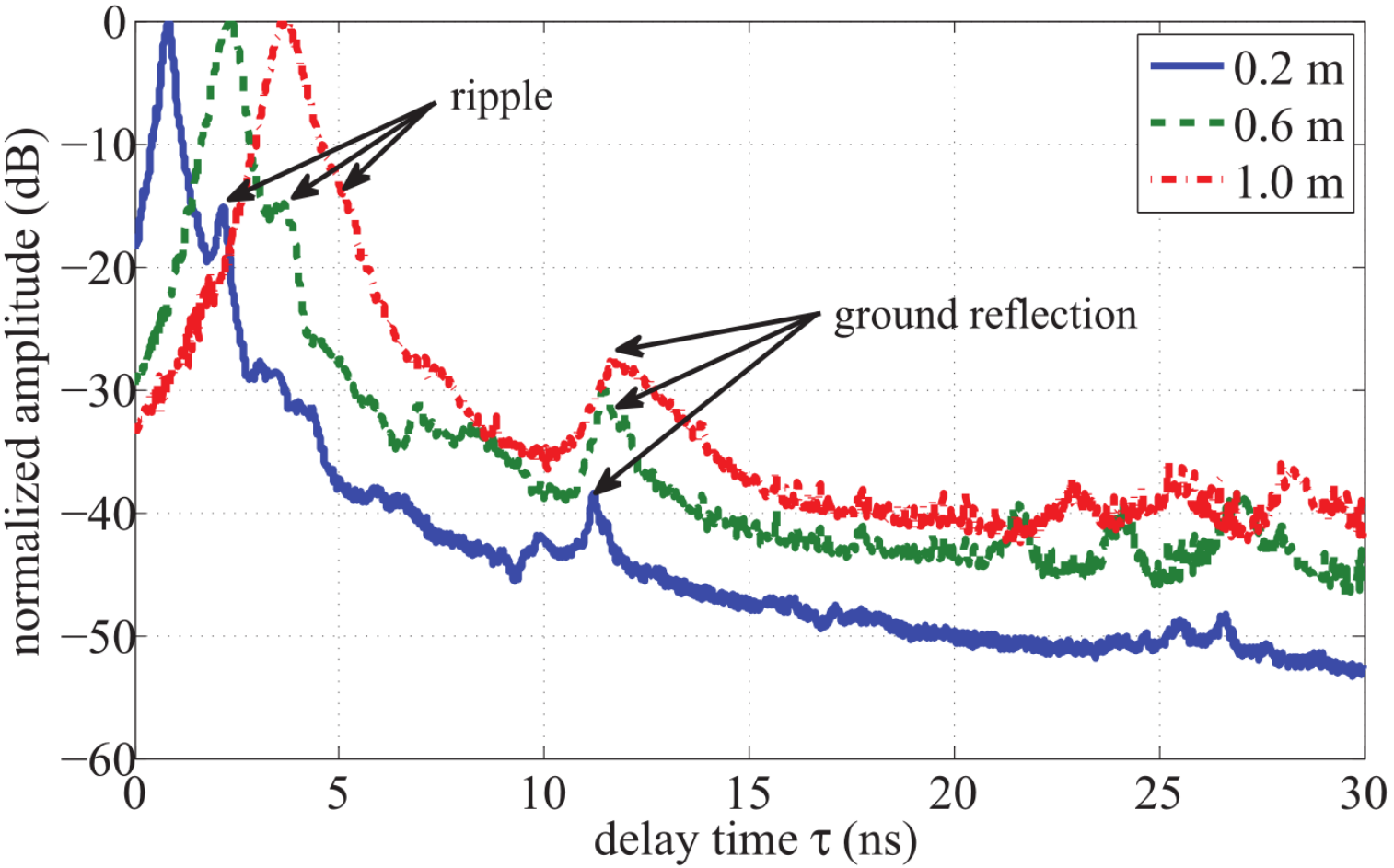
System Overview mm-Wave Channel



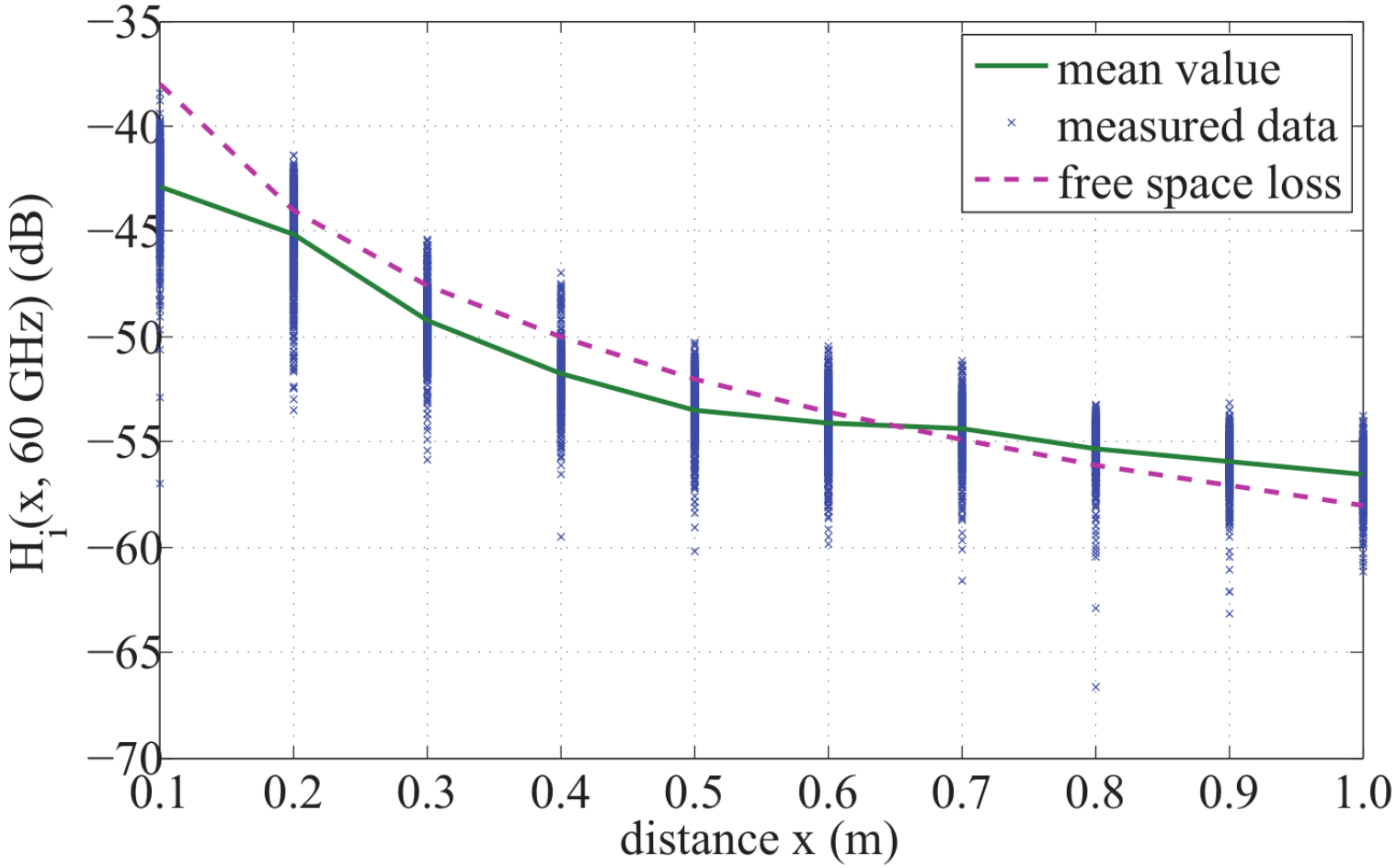
Realistic MMID application scenarios:

- Objects with MMID tags in a shelf, hand-held reader operated by a user
- Stationary MMID reader, user with tag starts a communication

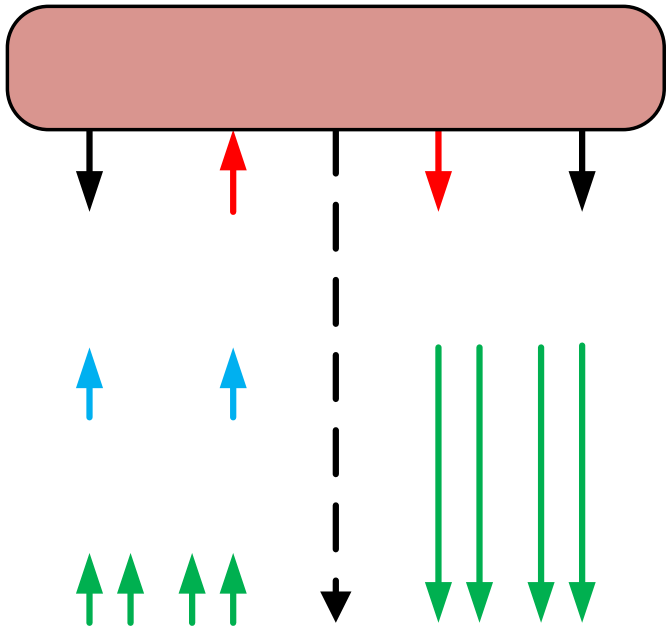
System Overview
Average Power Delay Profile



MMID System Overview
Channel Transfer Function



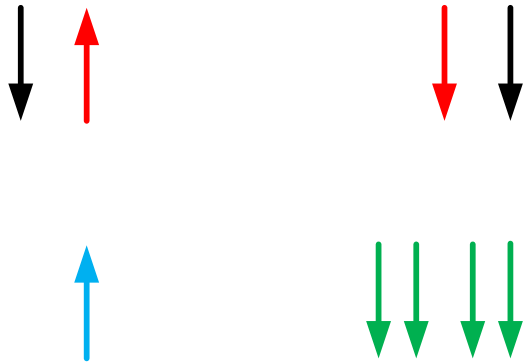
Base Station



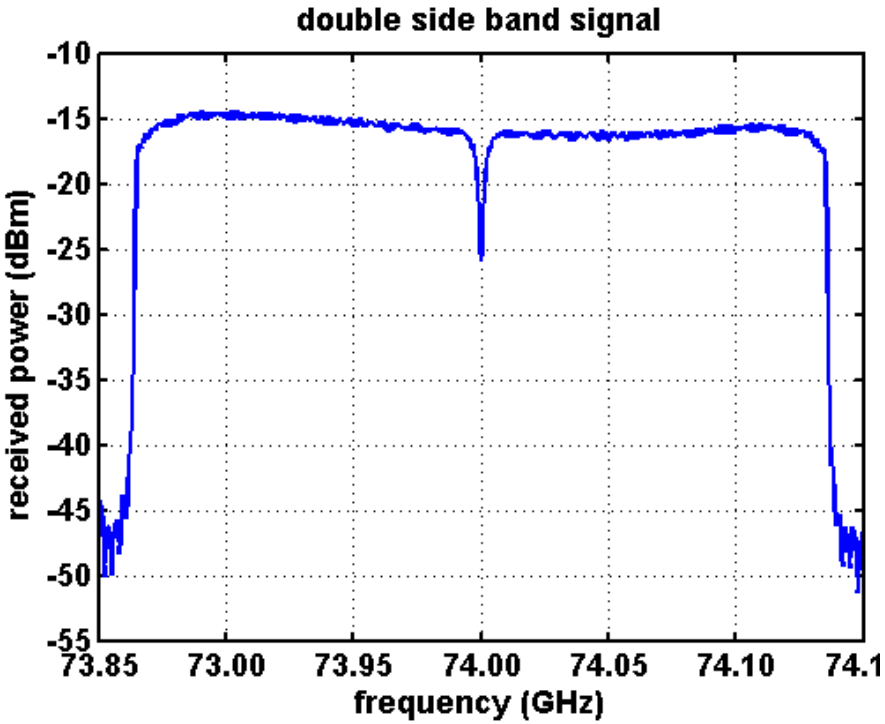
- Infineon BGT70 mm-wave direct conversion transceiver
  - 71.0-76.0 GHz
  - P_{1dB}: 12 dBm
  - NF_{DSB}: 8.0 dB
  - IF_{BW}: 500 MHz
- Baseband generation and analyzation using measurement equipment and MATLAB®

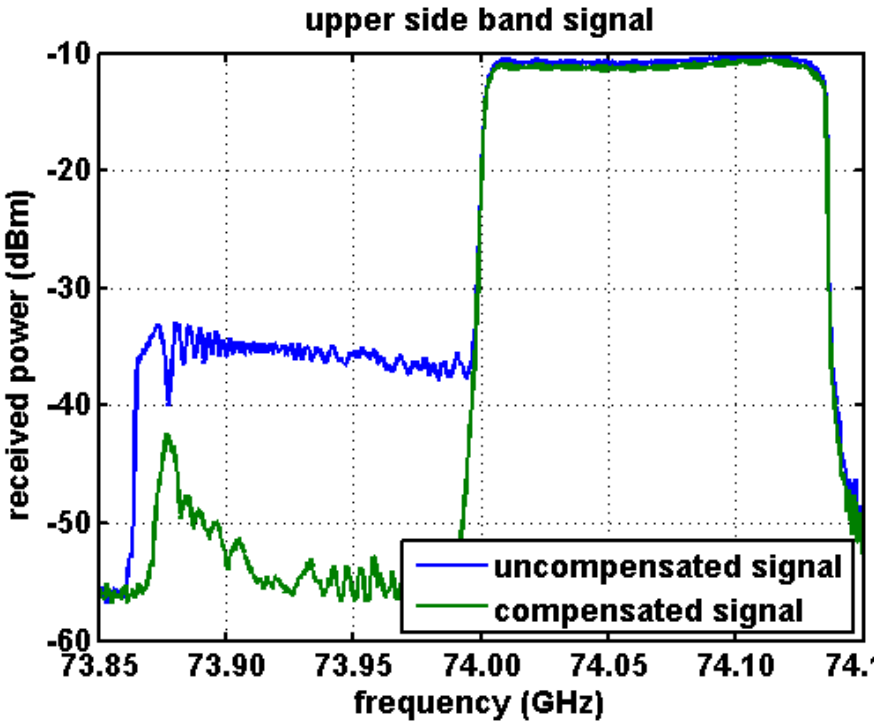
mm-Wave Frontend Measurements

- Imbalance Measurements
- Linear Characterization
- Nonlinear Characterization

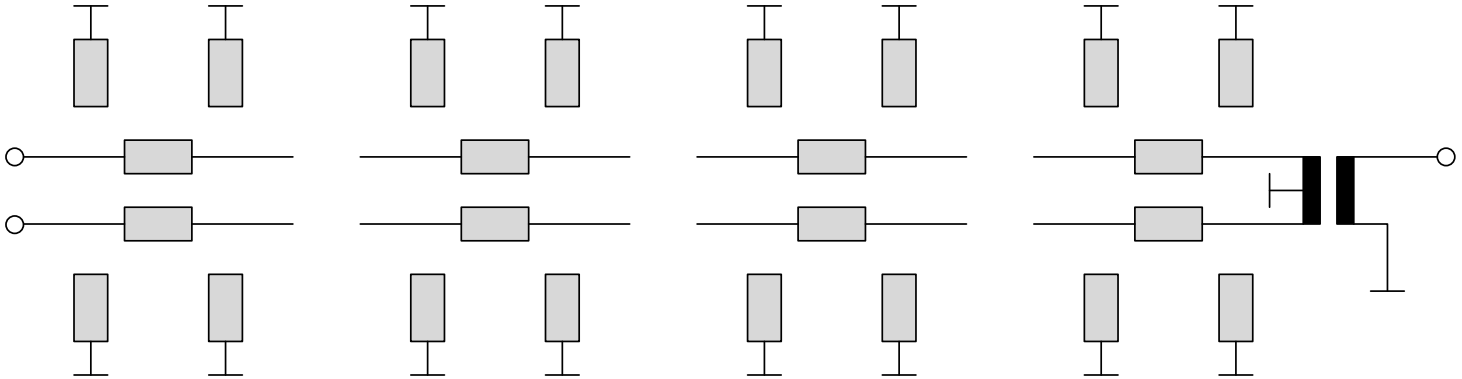


mm-Wave Frontend Imbalance Measurements



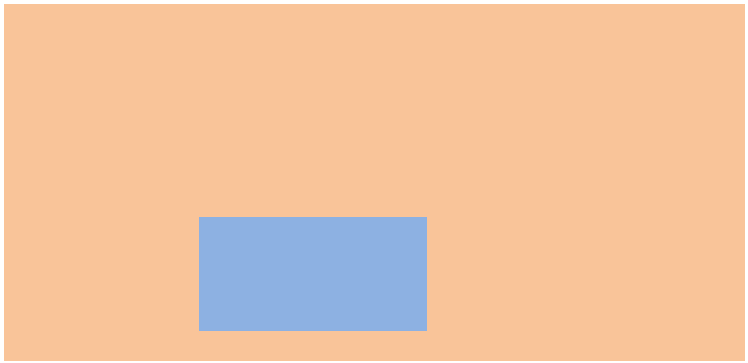


Differential to Single-Ended Baseband Amplifier



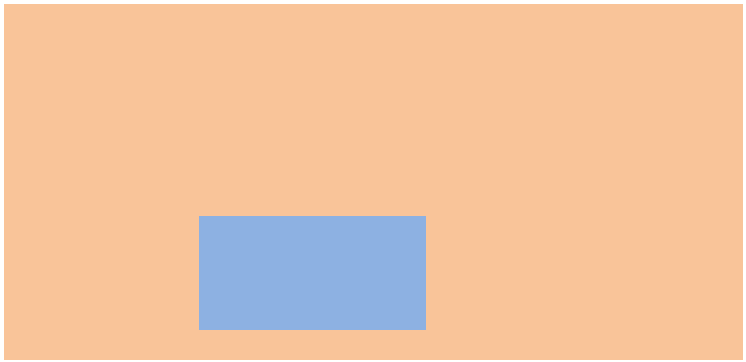
- Variable gain
- Output Voltage 1 V_{pp}
- Flat gain characteristic over the operating bandwidth (3-200 MHz)
- Low distortion

Transponder



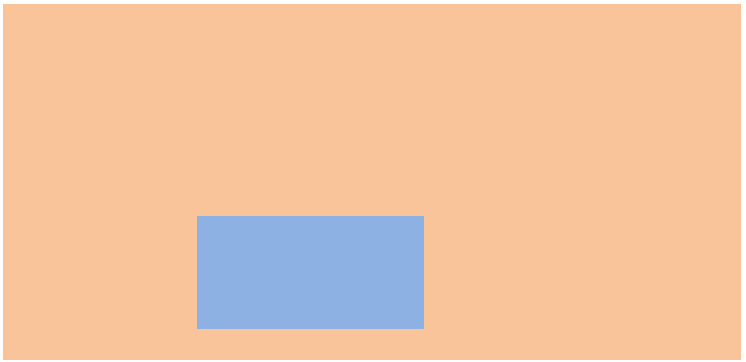
- Custom made mm-wave antenna
- Infineon mm-wave mixer diode (BAT14-077D)
- Adaptor network
- NXP Digital EPC Gen 2 Chip

Transponder Receive Path



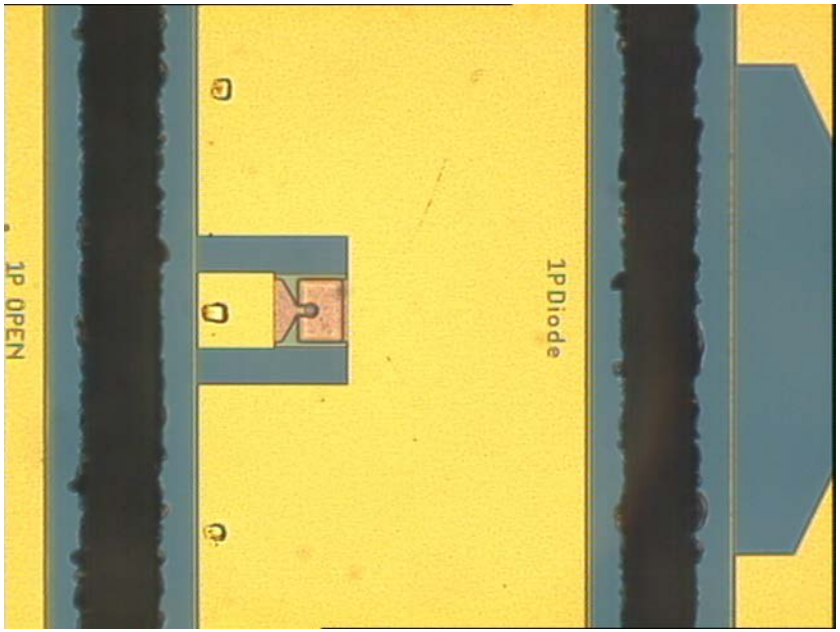
- mm-wave diode works as envelope detector

Transponder Transmit Path

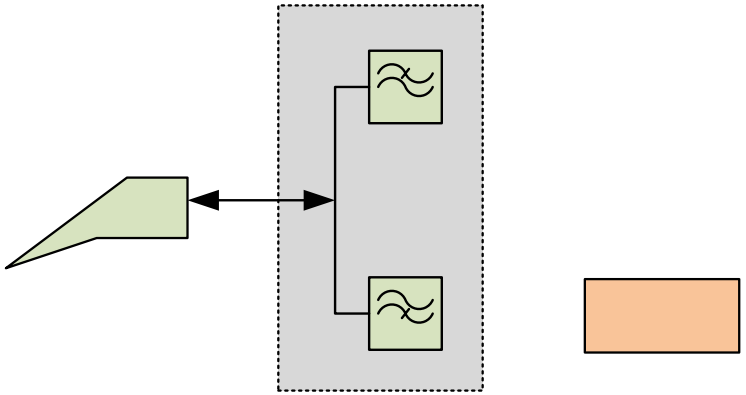


- mm-wave diode works as backscatter modulator

Diode Measurements

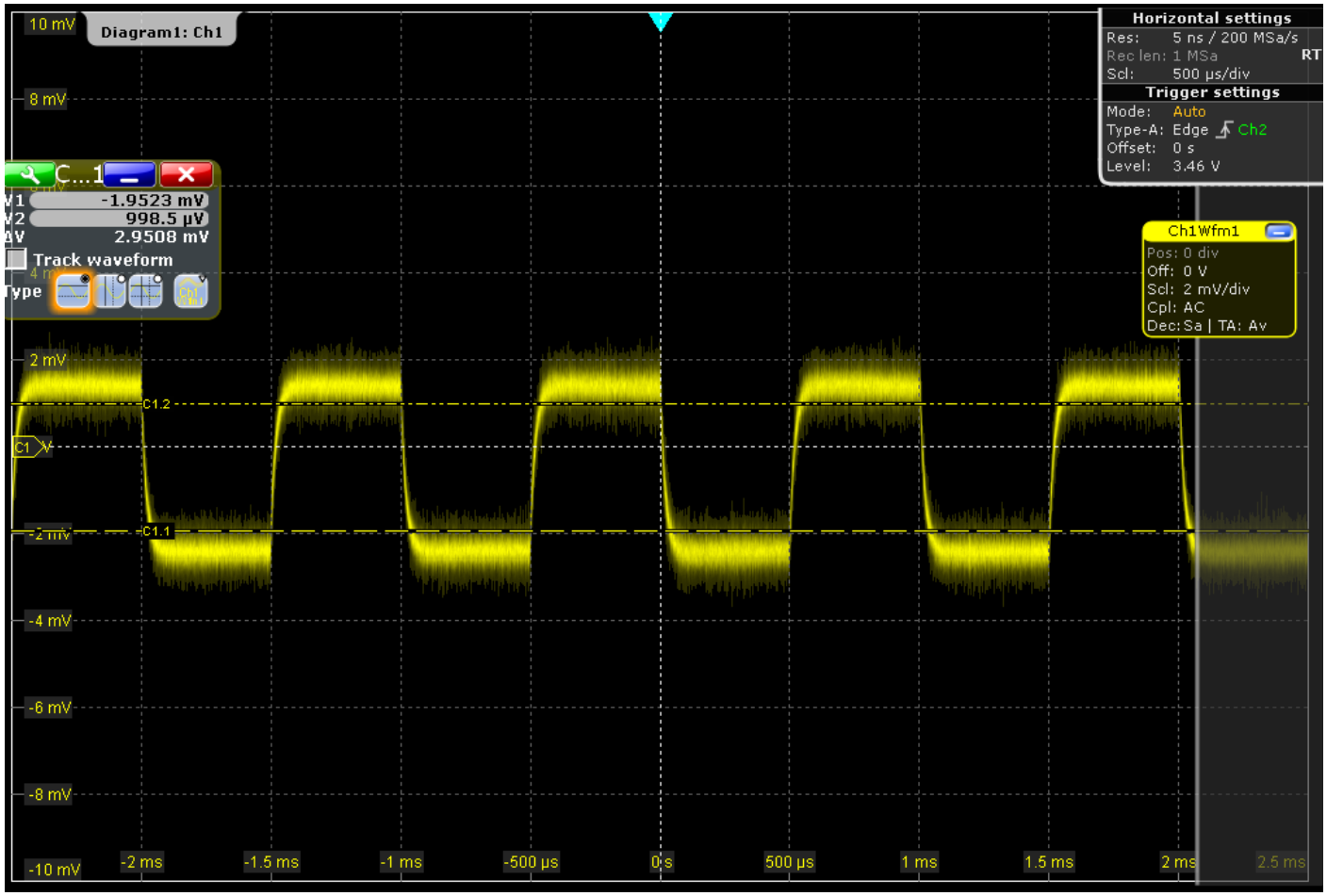


AM Demodulation Measurements

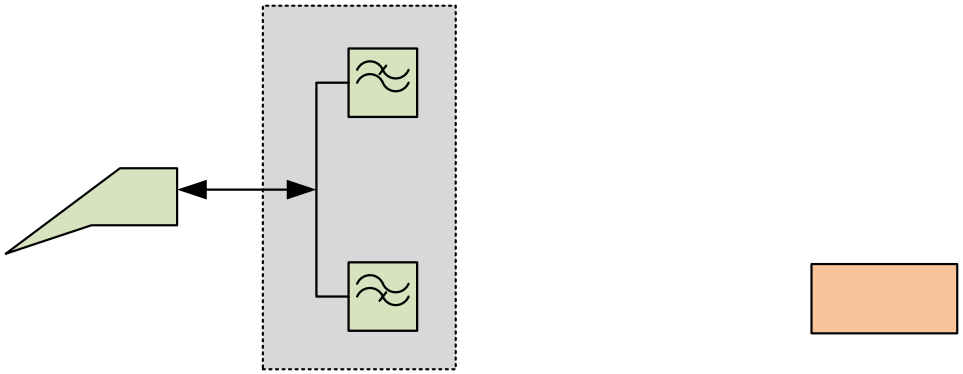


- 100% Amplitude Modulation at 74 GHz with a 1 kHz square-wave signal
- DC offset sweep for optimum demodulation characteristics

AM Demodulation Measurements

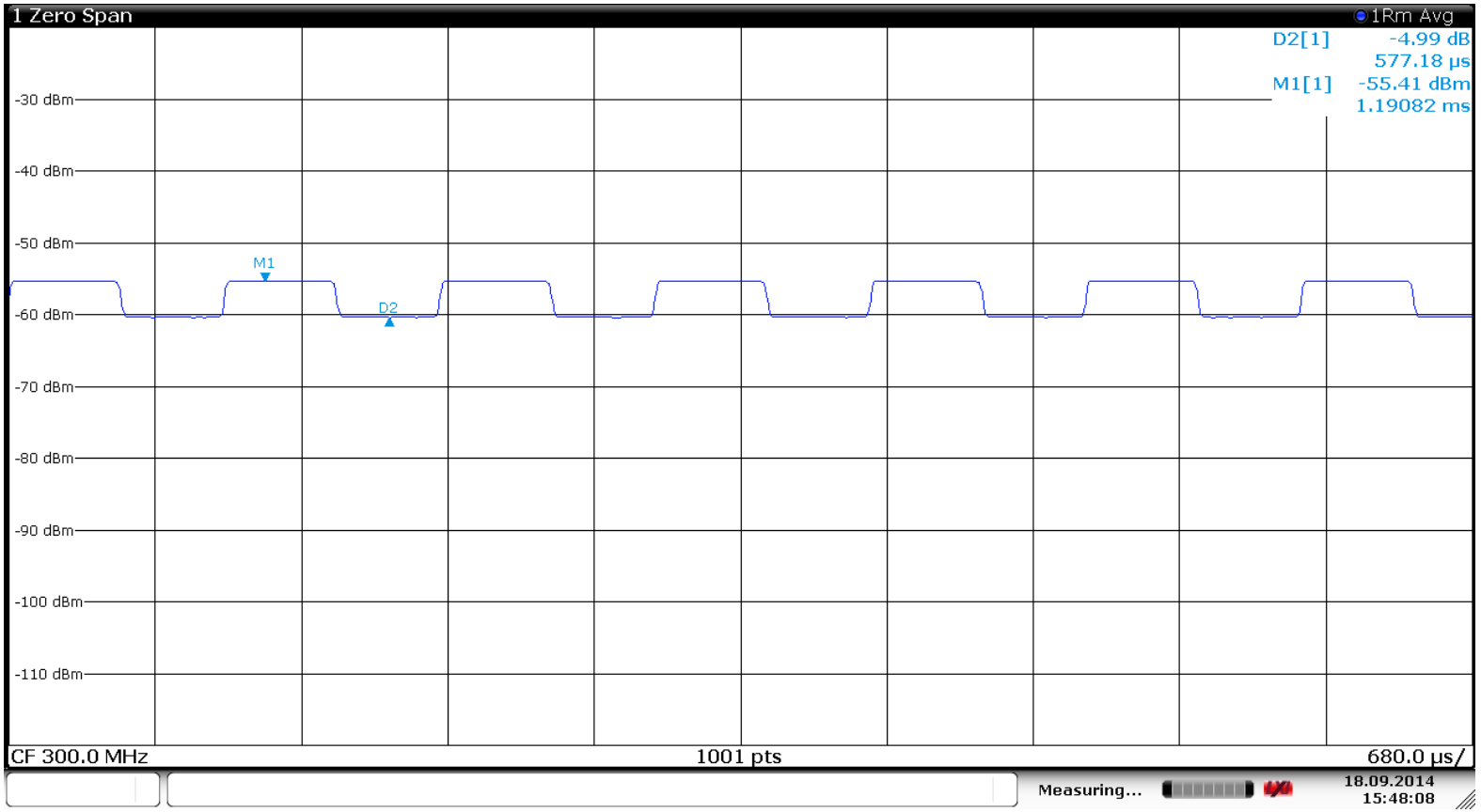


Backscatter Modulation Measurements



- Modulation of the diode voltage with a 1 kHz square-wave signal
- DC offset sweep for optimum modulation characteristics

Backscatter Modulation Measurements



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Conclusion / Outlook

- Overview on mm-wave WPT and published MMID systems
- Performance of single system components has been evaluated
- MMID Base Station test setup is implemented

- Implementation of the mm-wave Transponder
- Performance measurement of the MMID System in a laboratory environment and in realistic scenarios
- Optimize system for maximum reading distance

SeCoS – Secure Contactless Sphere

Smart RFID-Technologies for a Connected World

infineon

AVL

NXP

ENSO detego

JOANNEUM RESEARCH DIGITAL

freaquent
Frosch Electronics Gmbh

IAIK TU Graz

ihf

Key facts

SeCoS is funded by:

Overall funding: 4.5 Mio €

Main research topics:

- Web of Things Application Platform
- Integrated Secure Technologies
- Future Contactless Transmission Technologies
- Development of five “Future Application Demonstrators“

References

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(12)T. Kiuru, P. Pursula, J. Rajamaki, and T. Vaha-Heikkila, "A 60-GHz semipassive MMID transponder for backscattering communications," IEEE MTT-S International Microwave Symposium Digest (IMS), pp.1 - 3, Jun. 2013.

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RFID at mm-Waves

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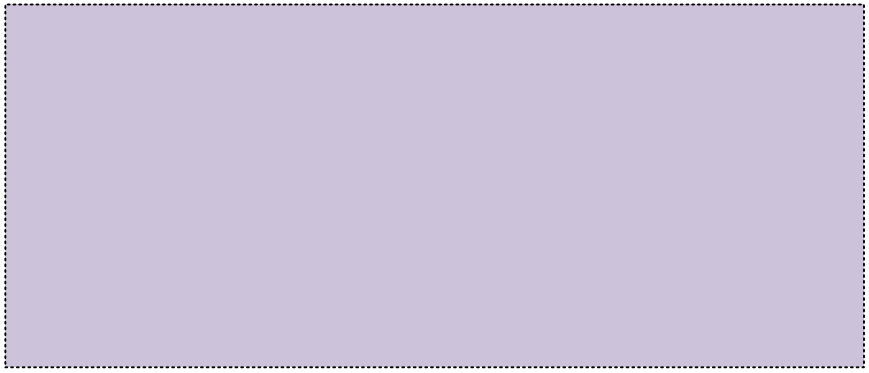
Transmit / Receive Switch



- Switches between receive and transmit mode of the 1-bit EPC Gen2 chip
- Configured for the duration of a request command/response

Transmit / Receive Switch