We1G-2

A Compact 77 GHz IQ-Modulated Transponder for High Gain and High Dynamic Range Radar Target Simulation

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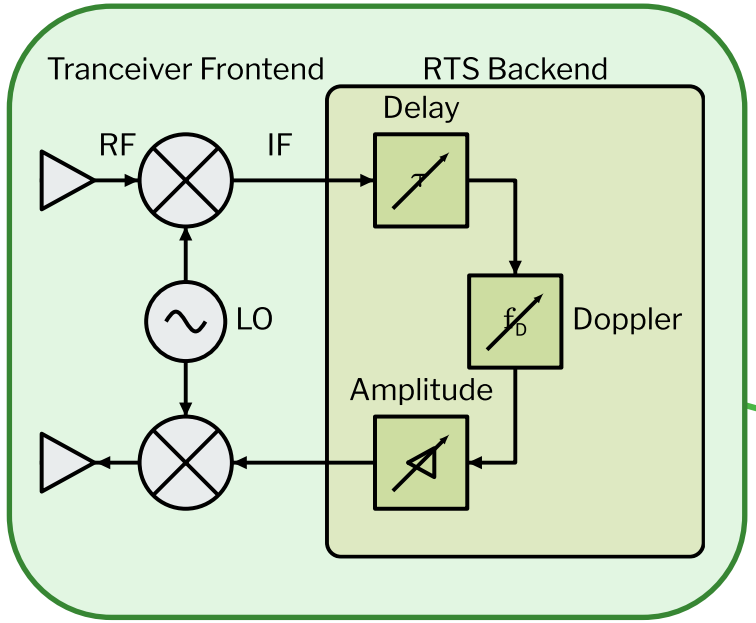
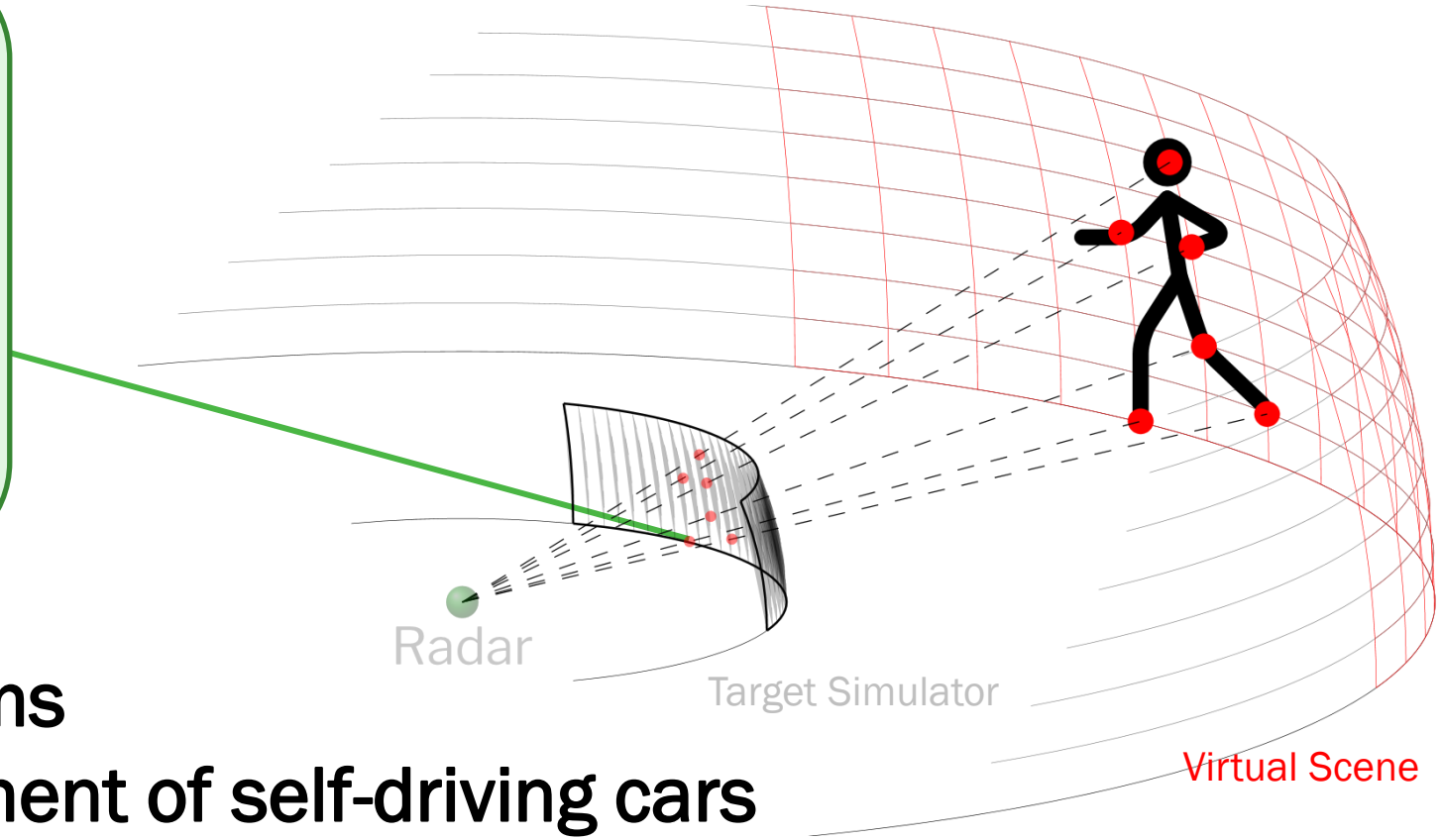
Outline

- Motivation: Radar Target Simulation
- Radar Target Modulator Architectures
- Design Considerations
- Implemented Realization of a Modulator
- Experimental Results
- Conclusion

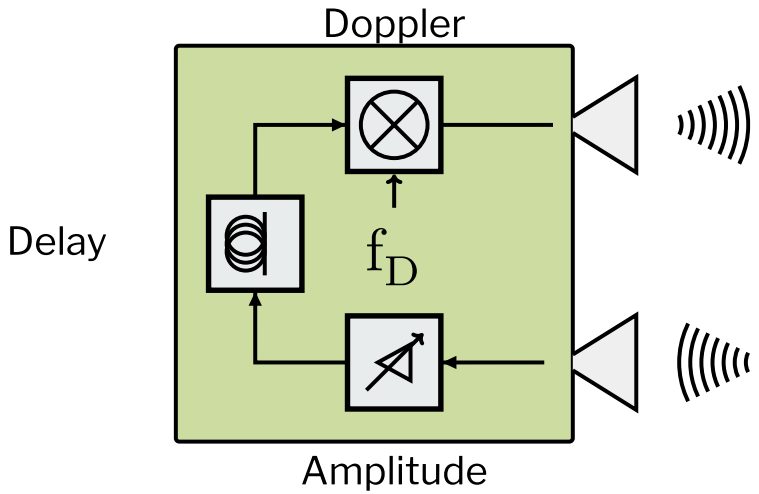
Radar Target Simulation

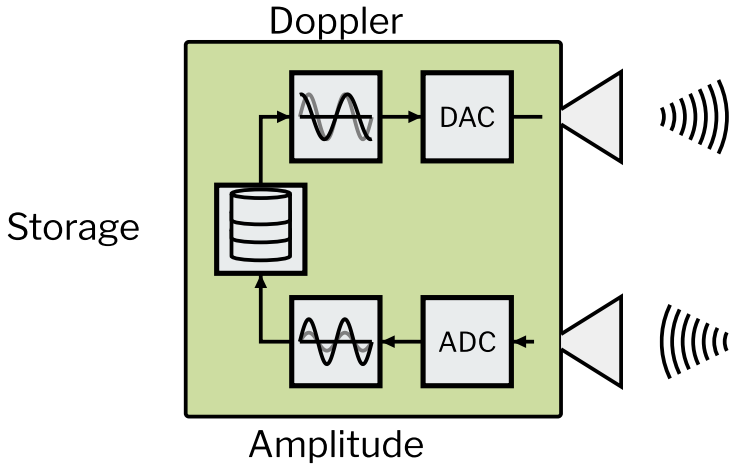




- Verification of safety systems
- Building block for development of self-driving cars
- Simulation of targets instead of mechanical construction
- Target parameters emulated by RTS: RCS, distance, velocity

Classical Approach





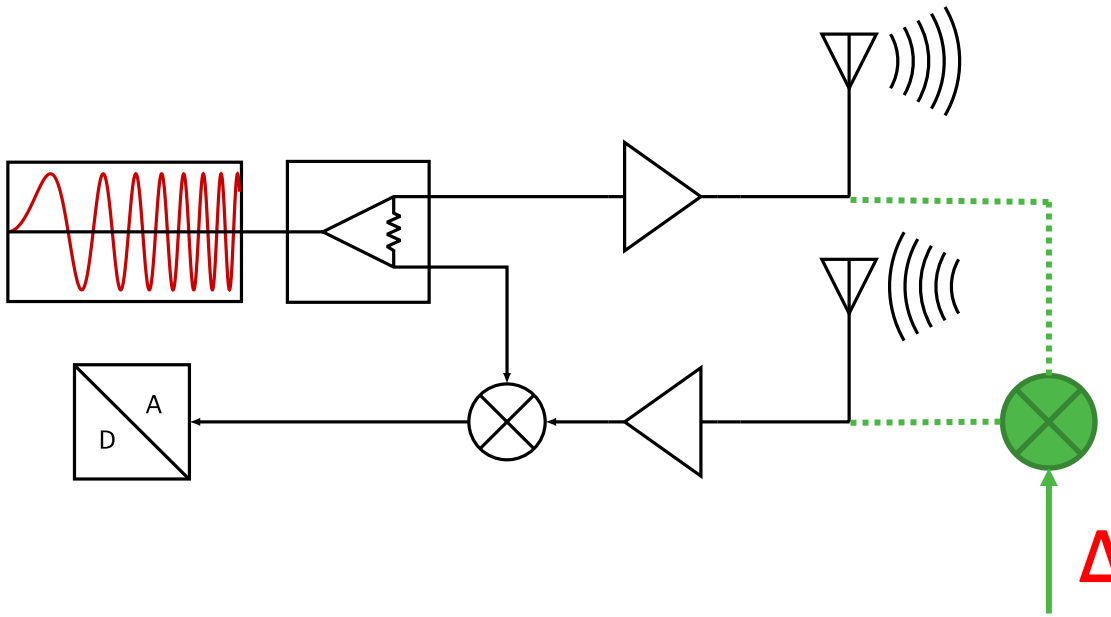
Analog RTS

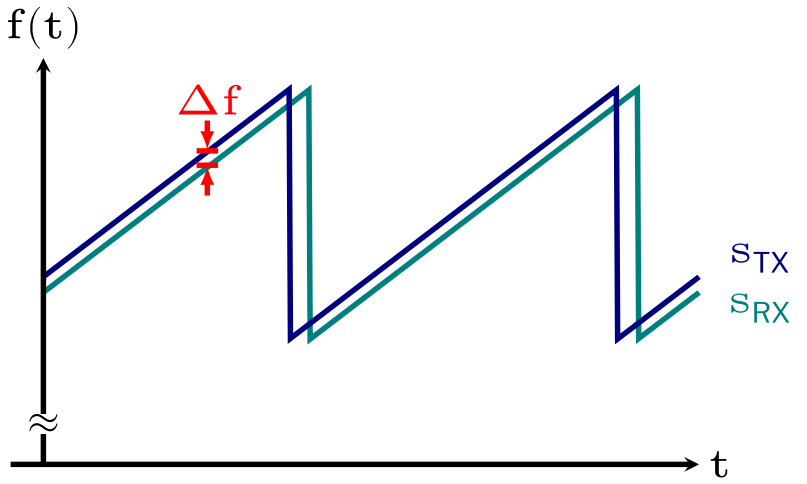
- Propagation time simulated with delayline
- Moving targets replicated by Doppler modulation
- RCS by adjustable amplification
- Only limited target parameters
  - Step width for distances
  - Single target

Digital RTS

- Propagation time simulated with storage
- Doppler modulation in digital domain
- RCS by adjustable gain
- ADC, DAC, processing expensive

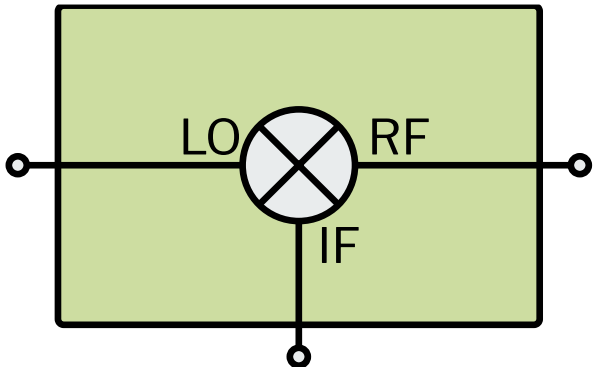
Alternative RTS Concept for FMCW





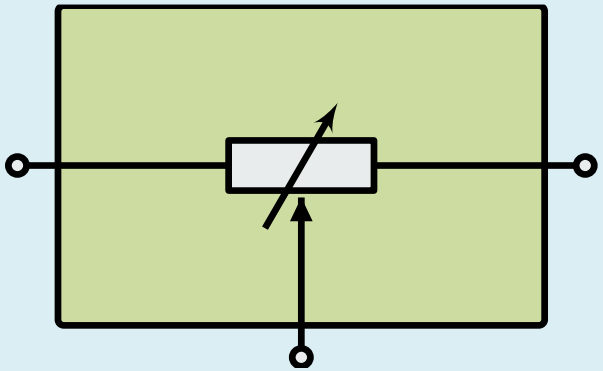
- Round trip time results in frequency difference
- Modulation as means to create a frequency shift without time delay

Possible Modulation Techniques



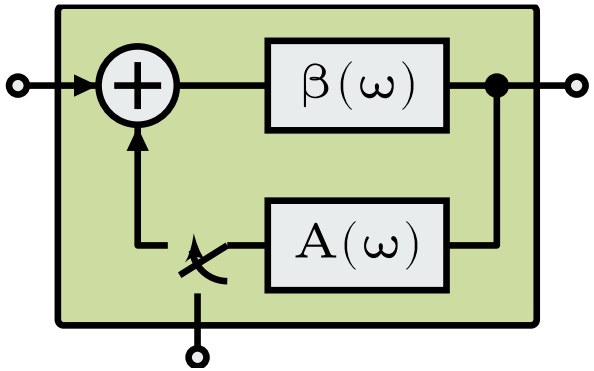
Mixer

- Straight-forward design
- LO power variation



Attenuator (PIN Diode)

- Low modulation index
- Independent from input level



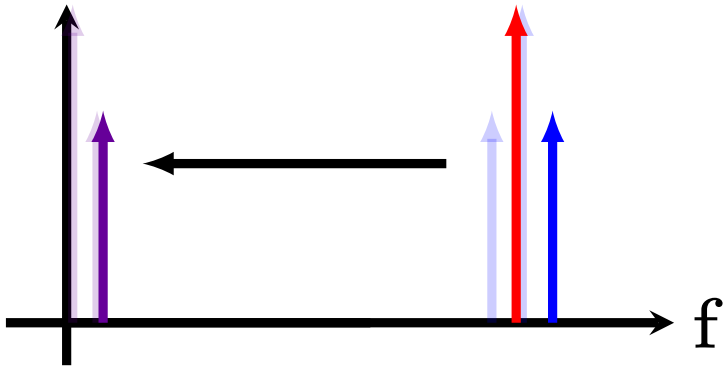
SILO

- Pulse duration limited
- Low bandwidth
- Non-linear relation between modulation and envelope

SSB Modulator Architecture

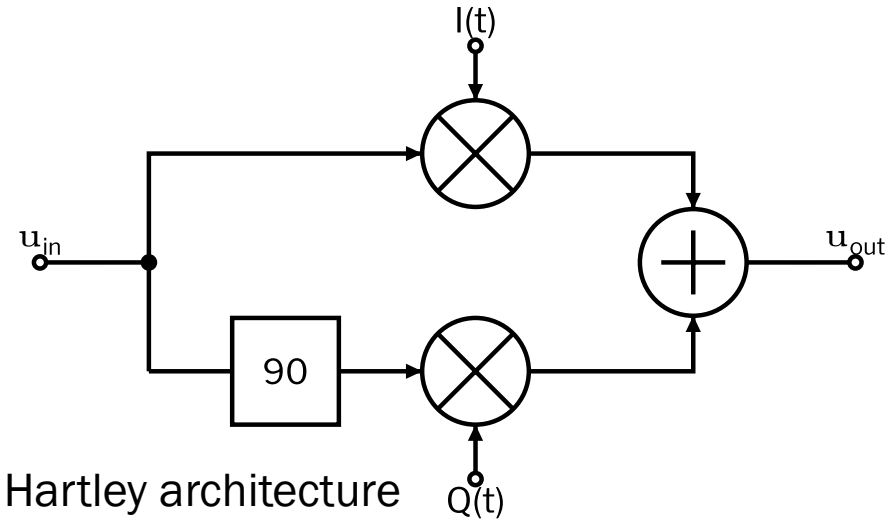
Resulting spectral Components

- Carrier (near DC)
- Right sideband
- Left sideband (mirrored)



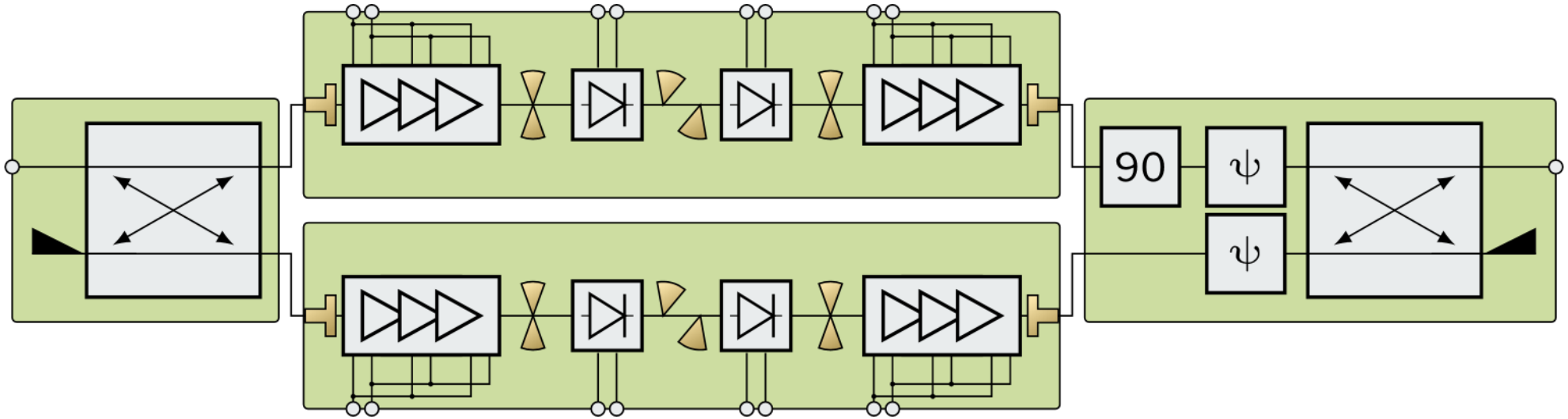
Modulator Architecture

- SSB to reduce unwanted sideband
- Optional: Carrier cancelation



Hartley architecture

Concept for the Frontend



Input Network

- Passive SIW structure
- Provides phase shift for IQ-modulation

Active Modulation Channel

- LNA for gain setting
- PIN diode for modulation
- Configuration for high dynamic range and reverse isolation

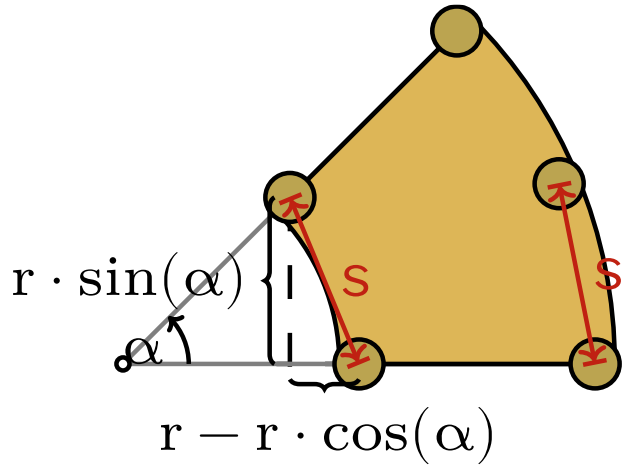
Output Network

- Passive SIW-structure
- In-phase combination

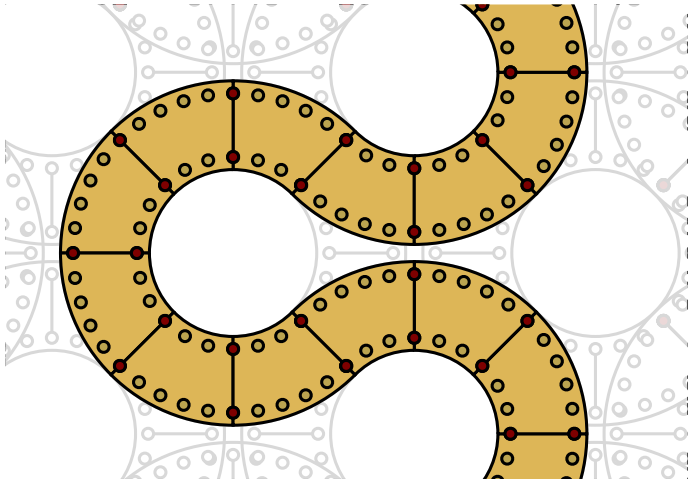
SIW Dimensions

- Minimal realizable via spacing desirable for low losses
- Fixed set of radii

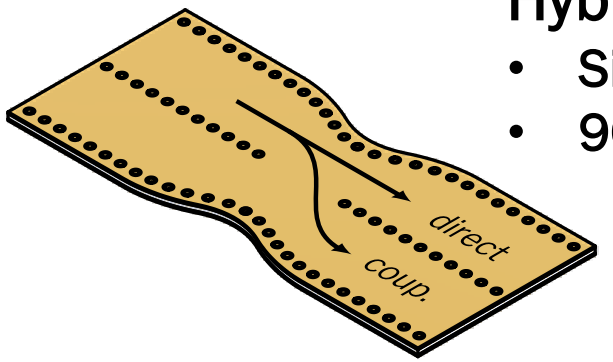
$$r = \frac{s}{2\sin(22.5^\circ/n)}$$



- Perfect fit on virtual grid
- Complex designs can be created by predefined elements or library

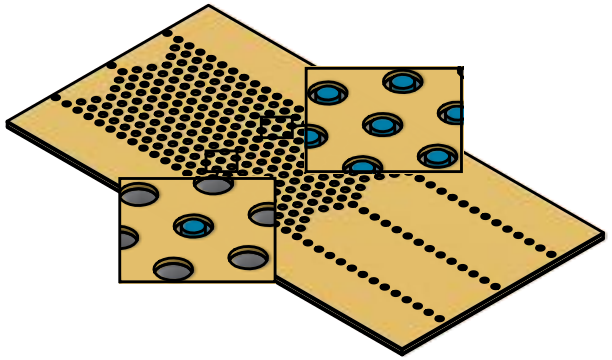


Design of Passive Structures



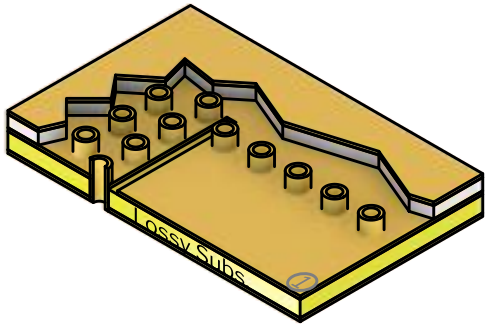
Hybrid Coupler

- Signal split
- 90°phase difference



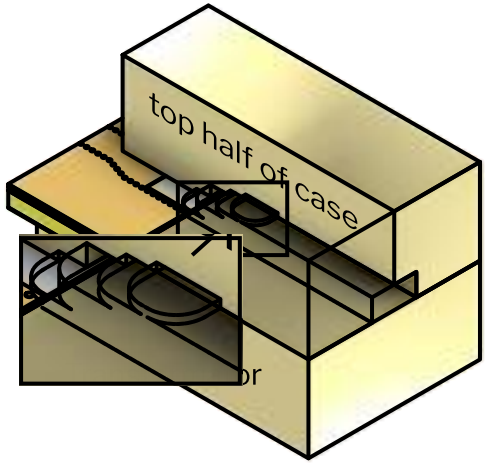
Phase tuning

- Air holes change effective dielectric properties
- Additional filling allows tuning after fabrication



Integrated Load

- Termination of unwanted signal energy
- FR4 substrate is used as load



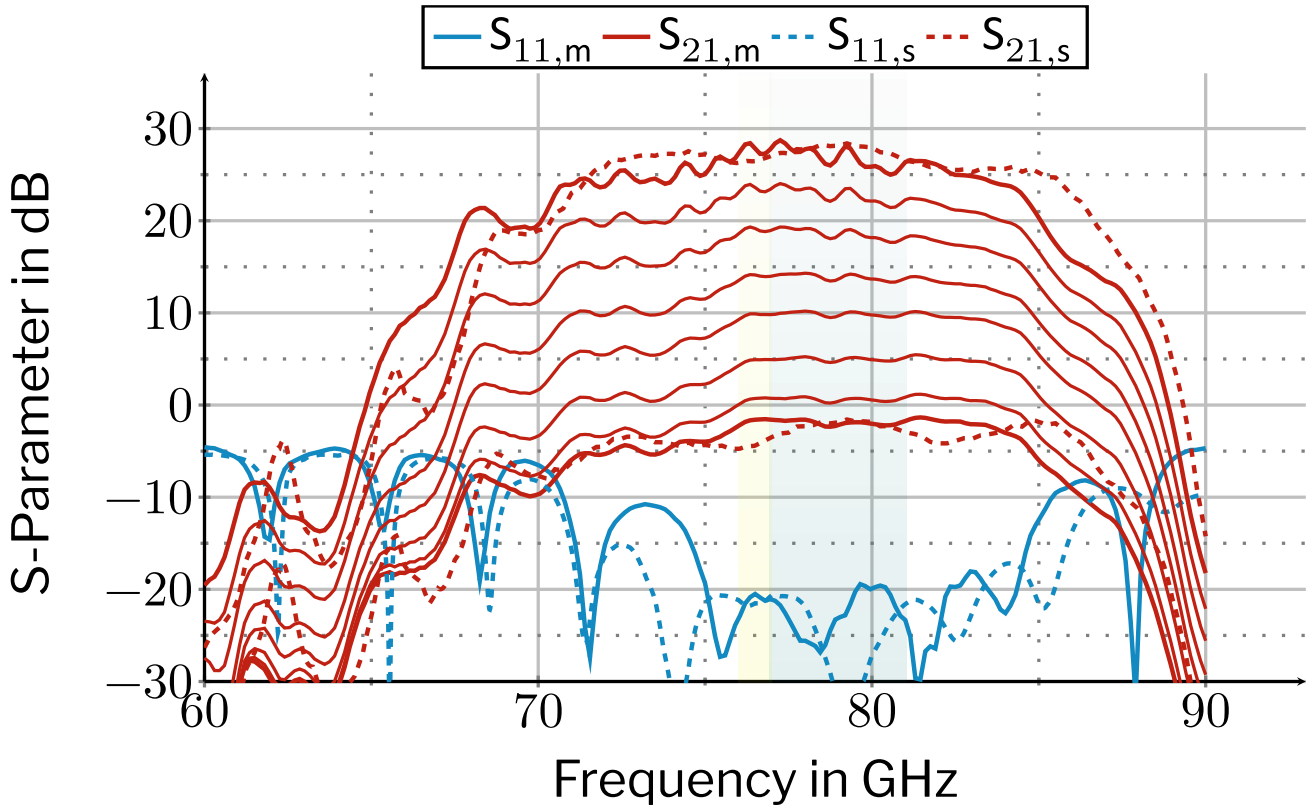
WR12 connector

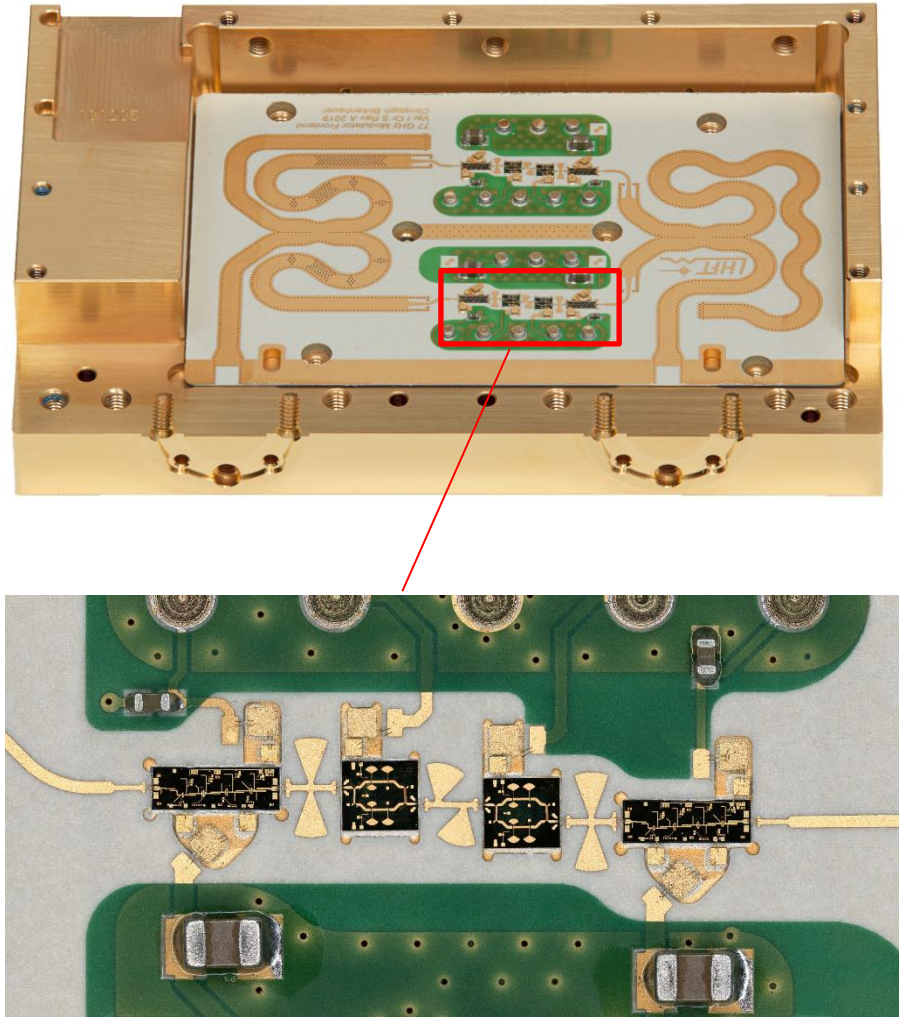
- Matching with stepped transformer
- Additional external circuitry possible
- Application specific antennas

Frontend Integration

Input Network

- passive SIW structure
- provides phase shift for IQ-modulation

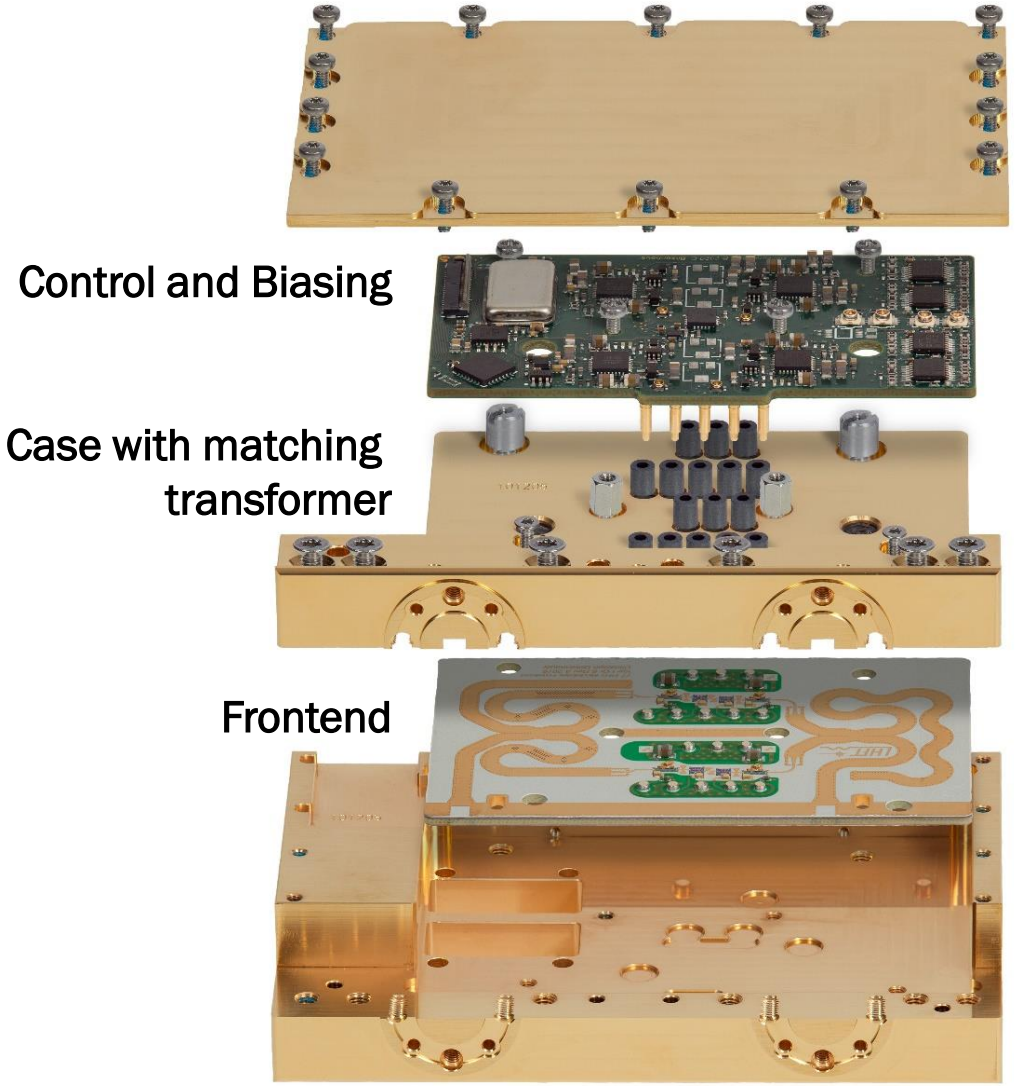




Completed Modulator Assembly

Modulation Unit

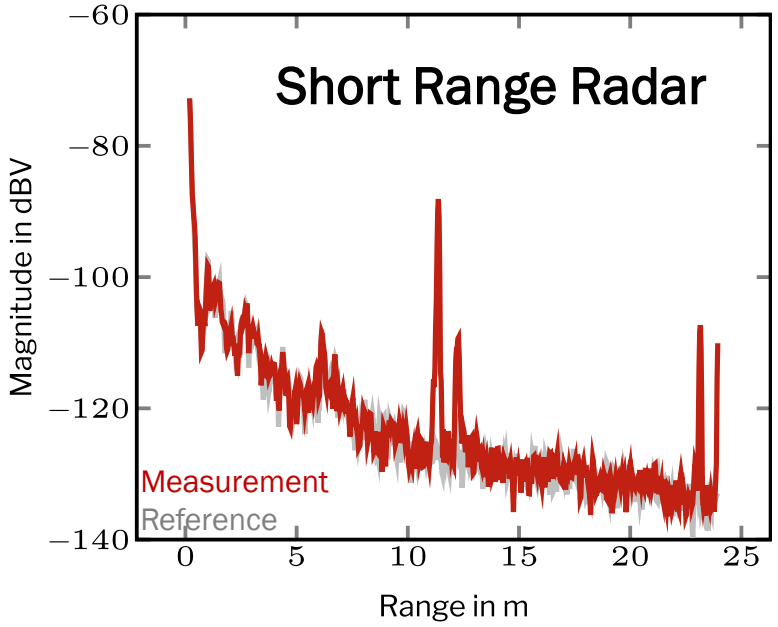
- 28 dB extinction ratio via PIN diodes
- 24 dB gain variation via amplifiers
- I,Q and I2C connections
- WR12 for external components
- Modular design allows use of different frontends

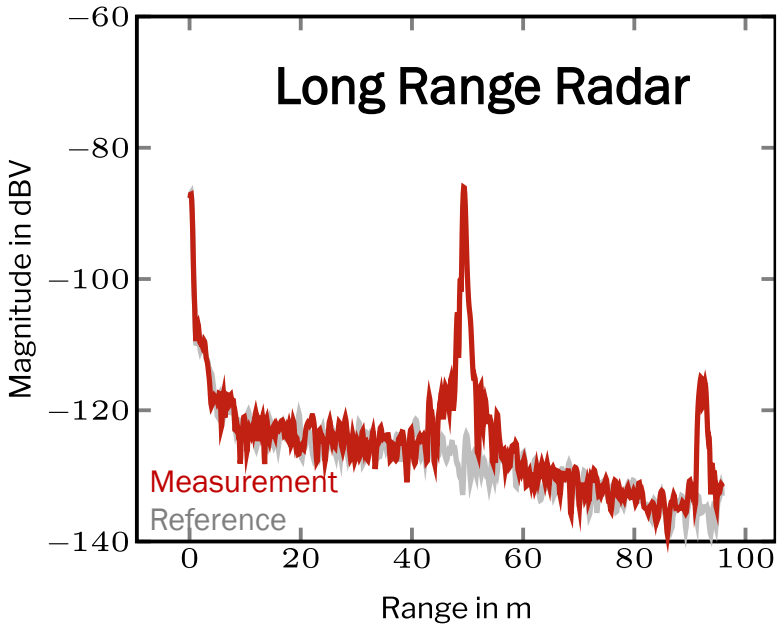


Experimental Results

Preliminary performance estimation

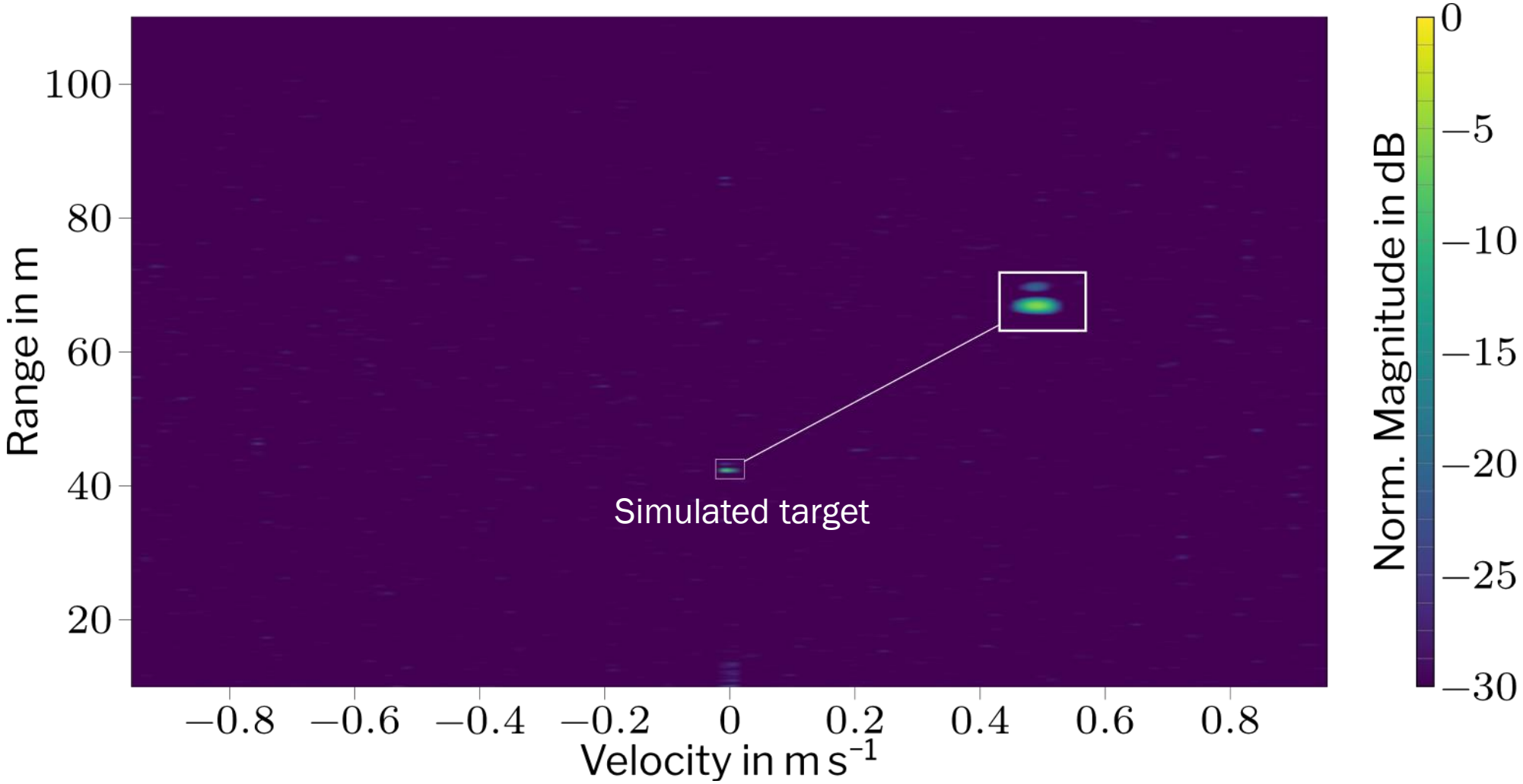
- Non-perfect sideband suppression visible for SRR
- Nonlinearities of PIN diode lead to additional targets
  - ➢ Predistortion useful





Test Setup

Experimental Results

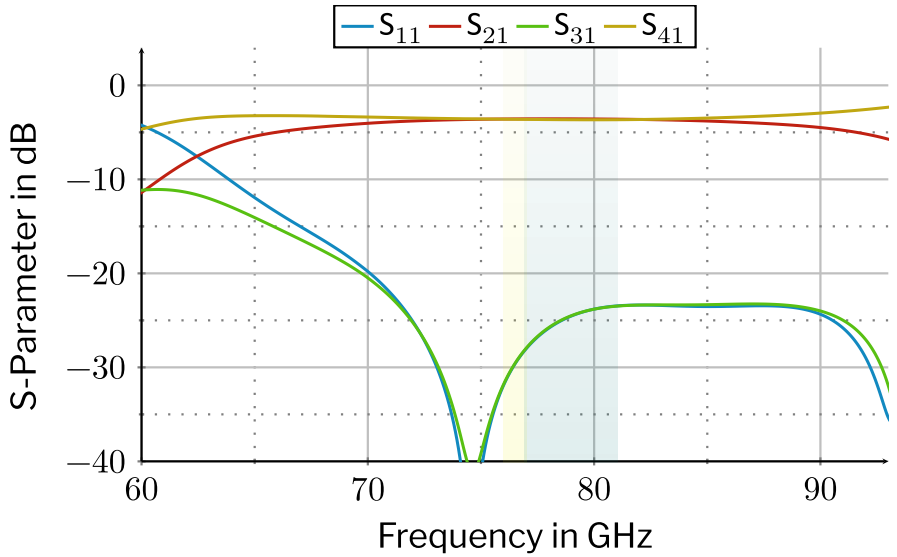


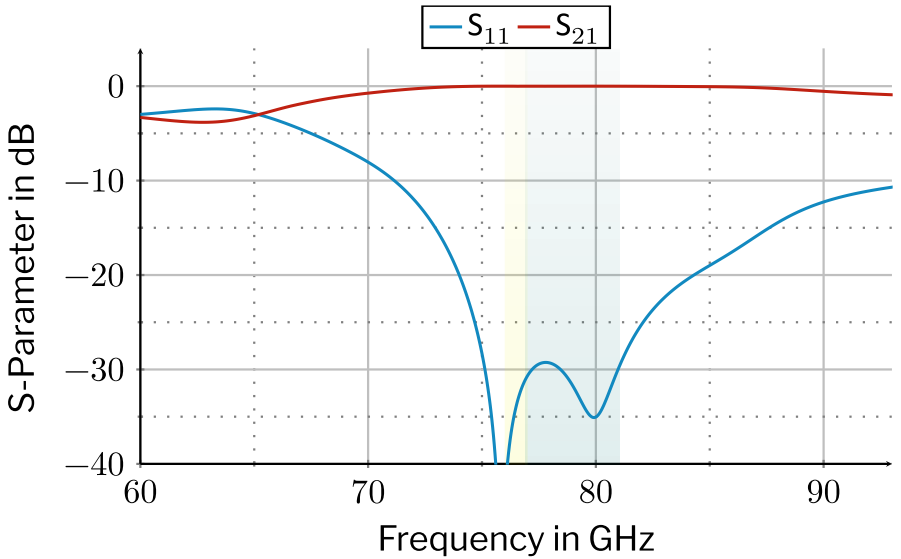
Conclusion

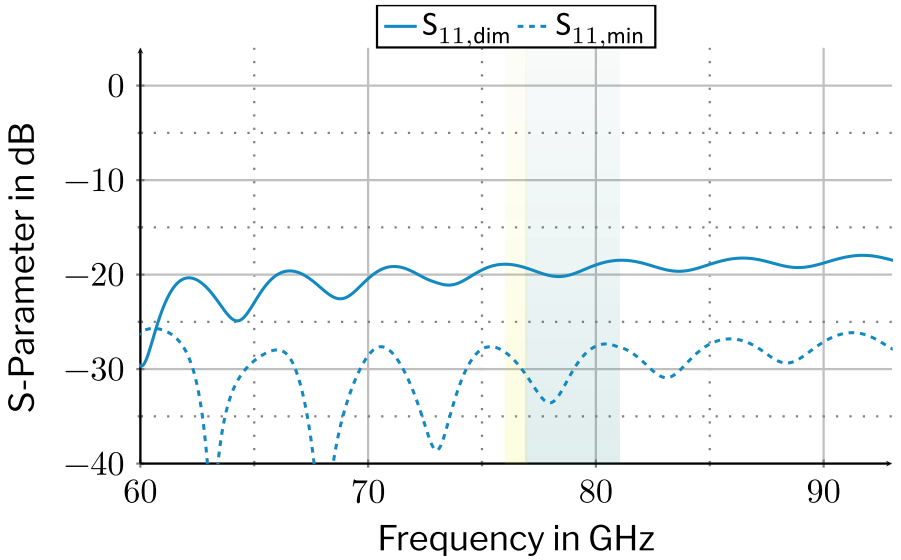
- Novel modulator concept based on PIN diodes was presented
- Basis for cost effective Radar Target Simulation
- Dynamic range only limited by noise floor and amplifier parameters
- Sideband suppression not required for all use cases
- Carrier can be hidden depending on radar and distance
- Predistortion useful to reduce additional targets

Backup Slides

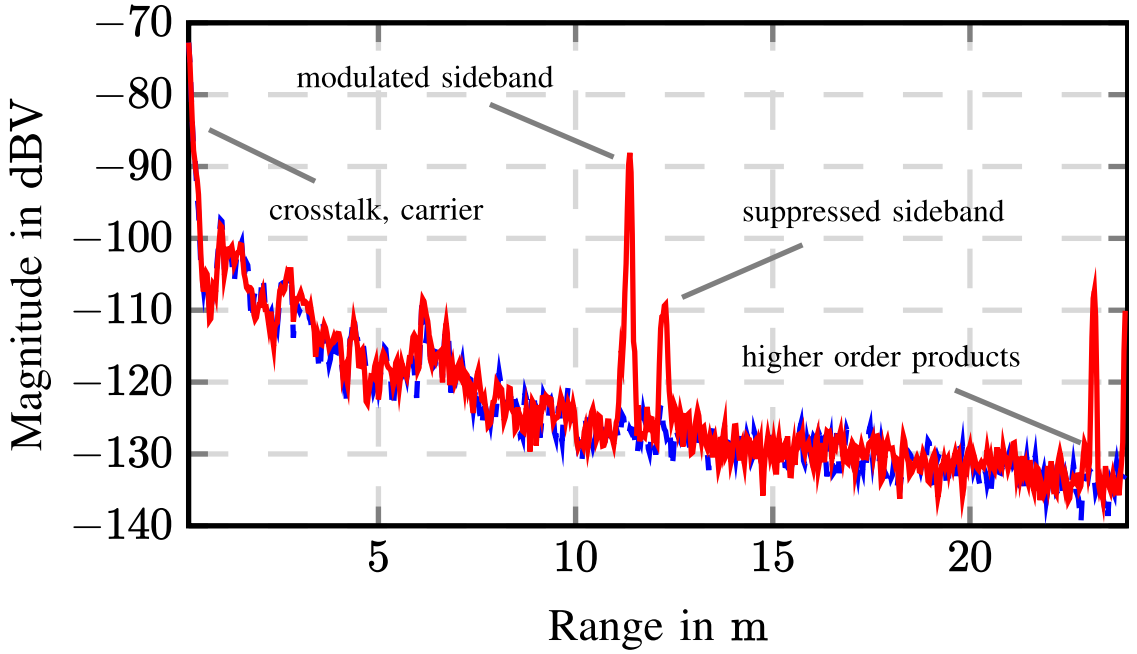
S-Parameters

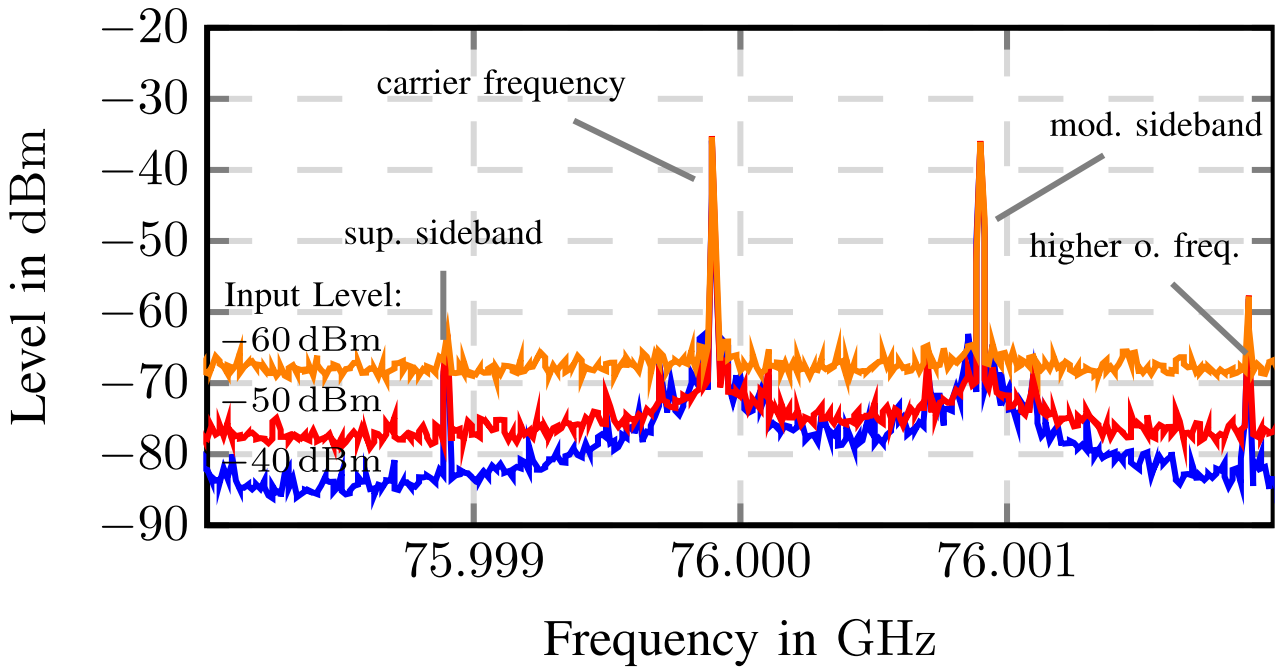




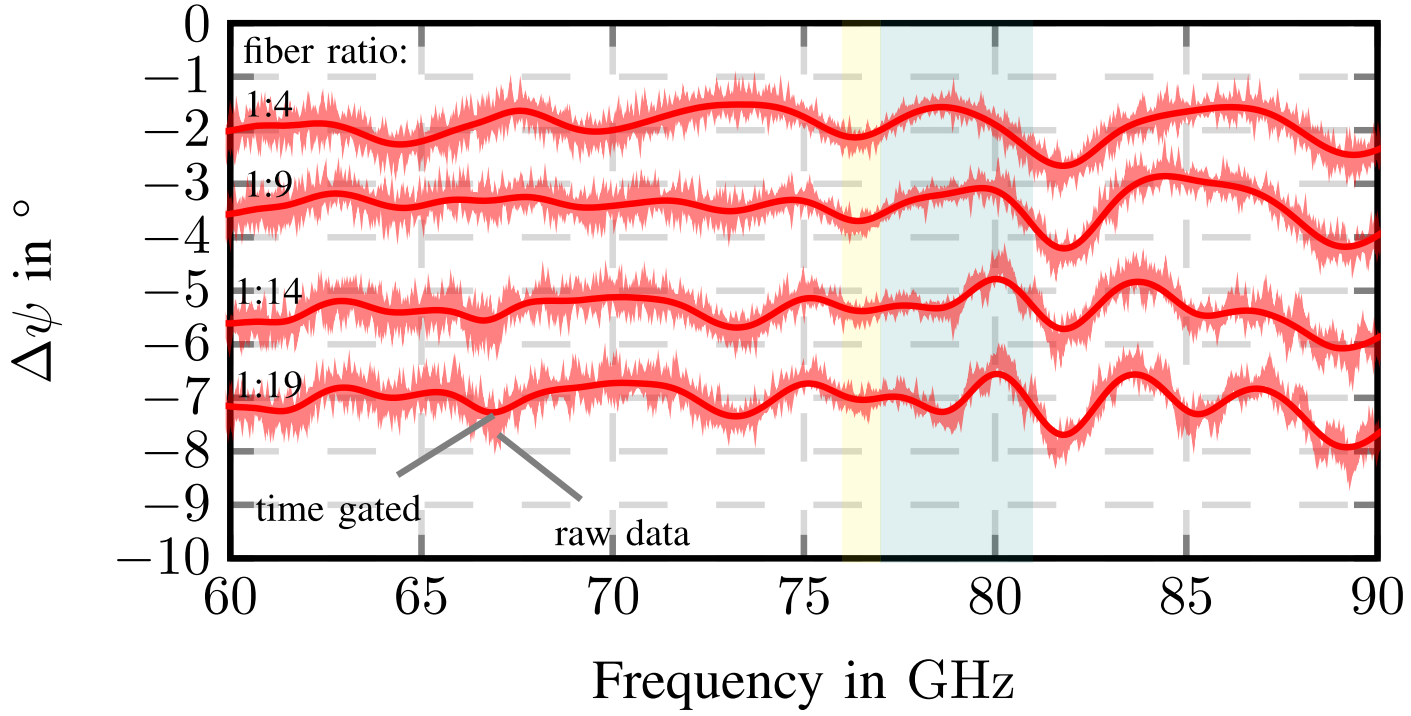


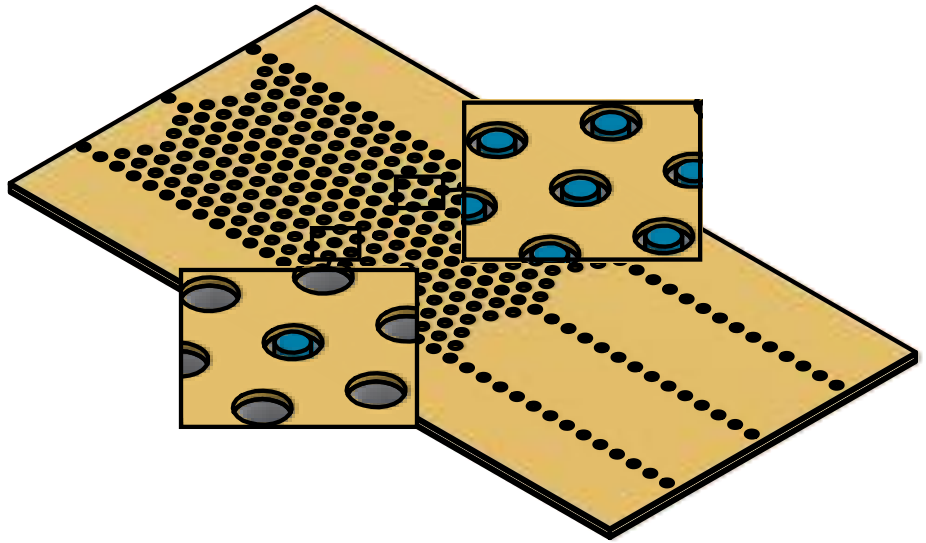
Plots


−70
−80
−90
−100
−110
−120
−130
−140
Magnitude in dBV
modulated sideband
crosstalk, carrier
suppressed sideband
higher order products
5
10
15
20
Range in m

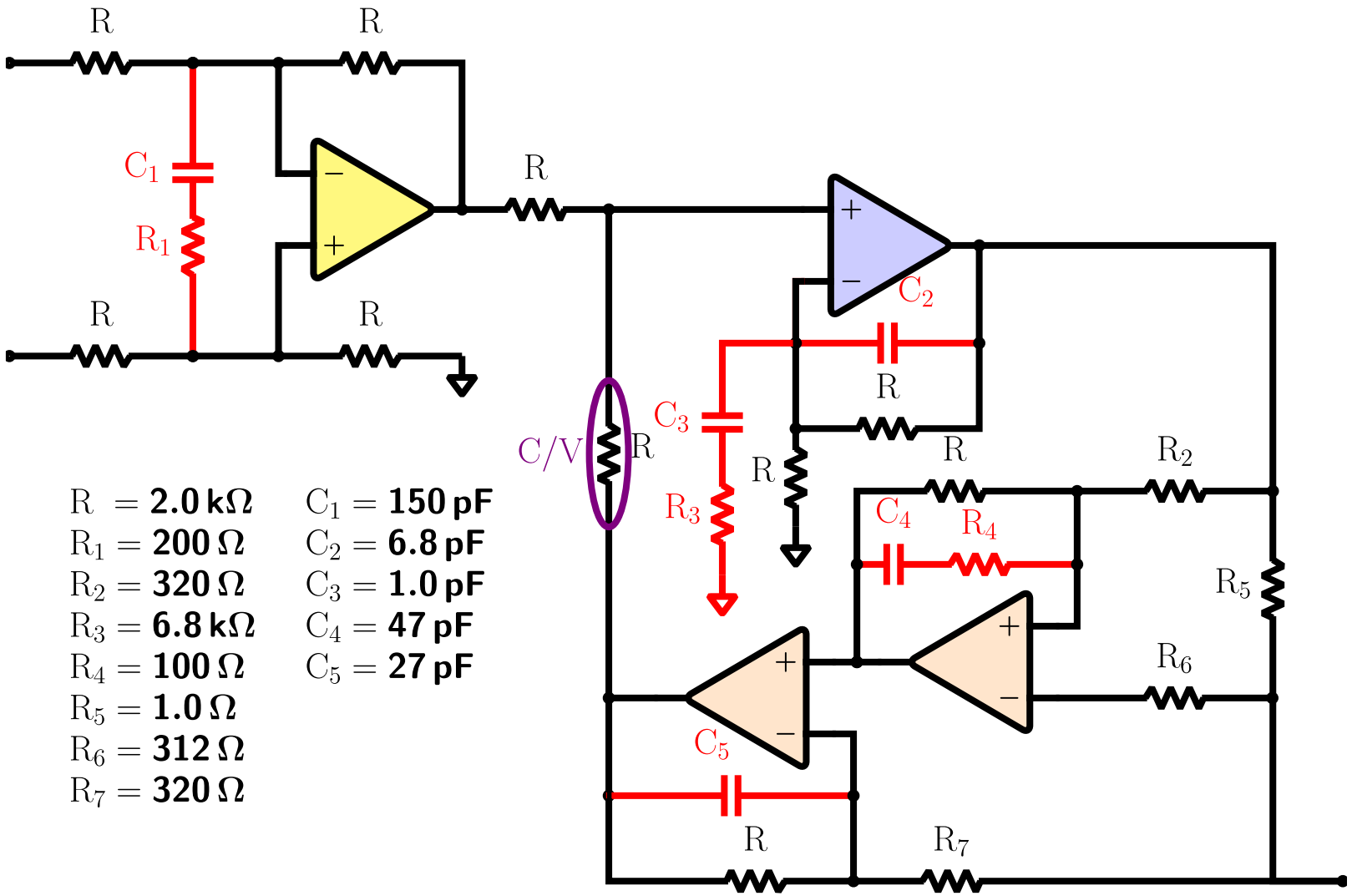

−20
−30
−40
−50
−60
−70
−80
−90
Level in dBm
carrier frequency
mod. sideband
sup. sideband
higher o. freq.
Input Level:
−60 dBm
−50 dBm
−40 dBm
75.999
76.000
76.001
Frequency in GHz

Plots


fiber ratio:
1:4
1:9
1:14
1:19
time gated
raw data
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
60
65
70
75
80
85
90
Δψ in °
Frequency in GHz



Schematic



$R = 2.0\,k\Omega$	$C_1 = 150\,pF$
$R_1 = 200\,\Omega$	$C_2 = 6.8\,pF$
$R_2 = 320\,\Omega$	$C_3 = 1.0\,pF$
$R_3 = 6.8\,k\Omega$	$C_4 = 47\,pF$
$R_4 = 100\,\Omega$	$C_5 = 27\,pF$
$R_5 = 1.0\,\Omega$	
$R_6 = 312\,\Omega$	
$R_7 = 320\,\Omega$	