IDEC Chip Design Contest

D-band Quadrature-Hybrid-Based Vector-Modulated Phase Shifter in 28-nm CMOS technology

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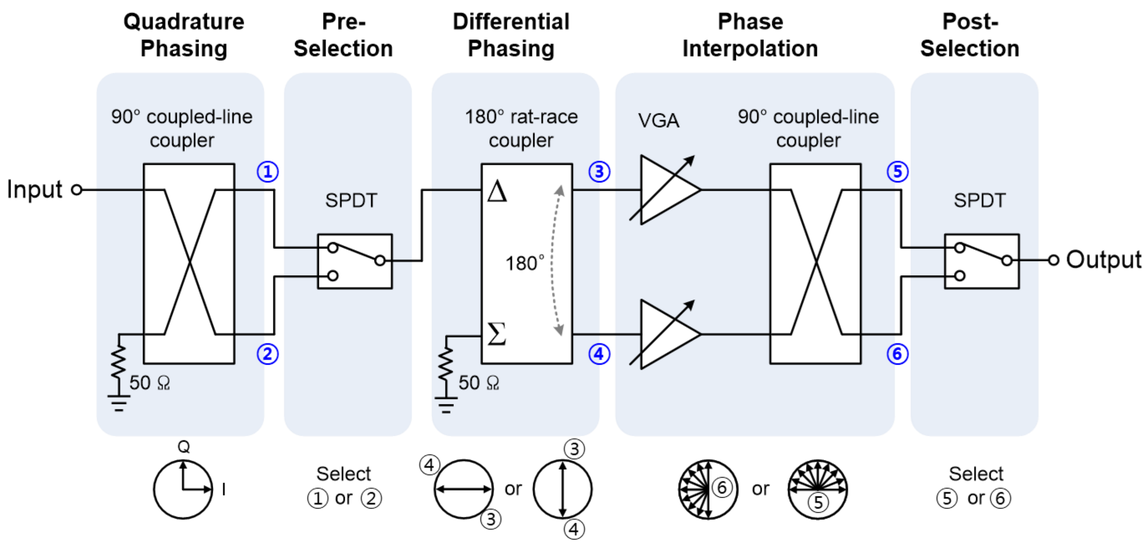
Introduction

- In the D-band (110-170 GHz), a phased array is widely adopted as one of the solutions to overcome the high channel loss and tight link budget.
- A phase shifter is a core circuit block that controls the phase of each channel of the phased-array system.
- D-band quadrature-hybrid-based vector-modulated phase shifter fabricated in 28-nm CMOS is presented.

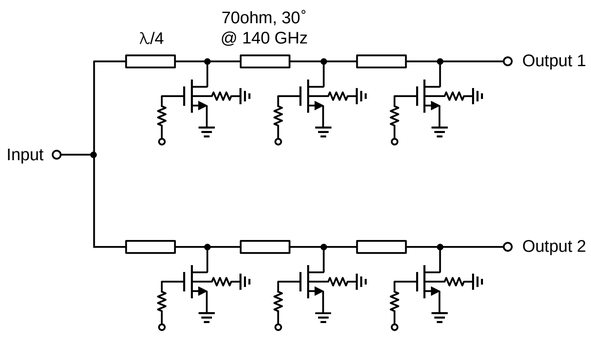
Phase Shifter Design

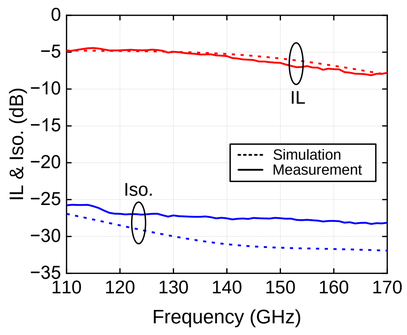
Block diagram of the proposed phase shifter



- Power mode vector modulator (phase synthesis in the power domain)
- SPDT, 90° hybrid coupler, 180° hybrid coupler, VGA

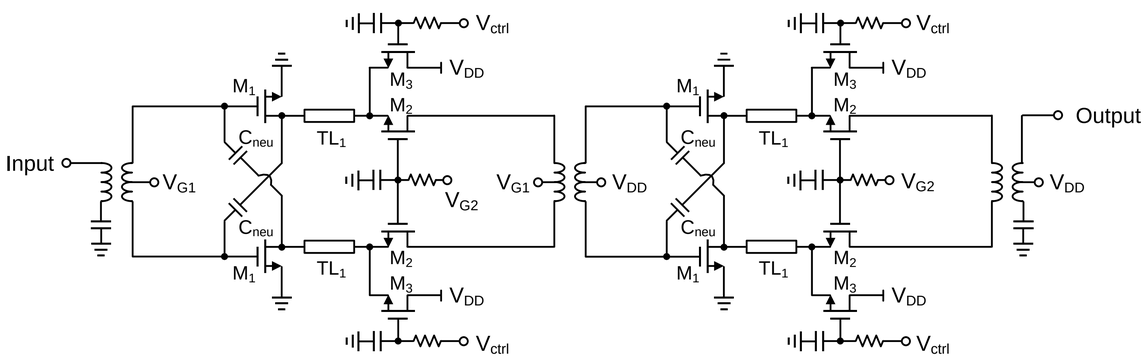
SPDT switch





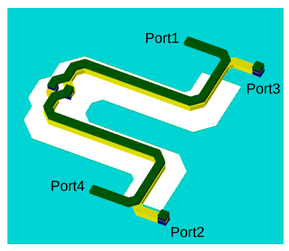
- Triple shunt topology for improve isolation
- Body floating technique for lower insertion loss
- Measurement results
  - Insertion loss : 5.5 dB @ 140 GHz
  - Isolation < -25.7 dB

VGA

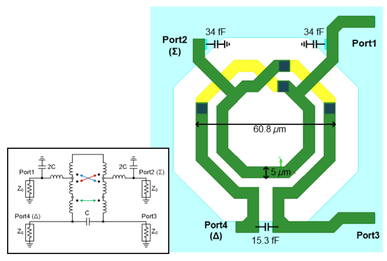


- 2-stage differential cascode topology with current steering
- C_{neu} and TL_1 are added for gain and stability improvement
- Measurement results
  - Peak gain : 9.7 dB @ 128 GHz
  - Gain control range : 14 dB
  - P_{DC} = 34.5 mW

90° & 180° hybrid coupler



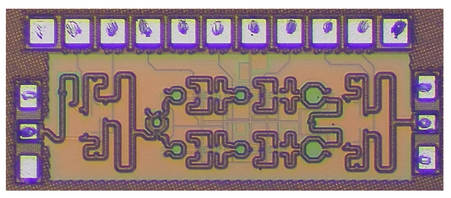
- Coupled-line 90° hybrid coupler
  - Simulated S21 & S31 : -4.5~-3.1 dB @ 110–170 GHz
  - Simulated phase difference : 88.3~91.6° @ 110–170 GHz

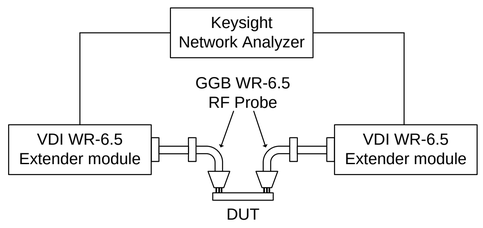


- Folded inductor-based rat-race coupler
  - Simulated S21 & S31: -4.6 dB @ 143 GHz
  - Simulated phase difference: 175° @ 140 GHz

Measurement Results

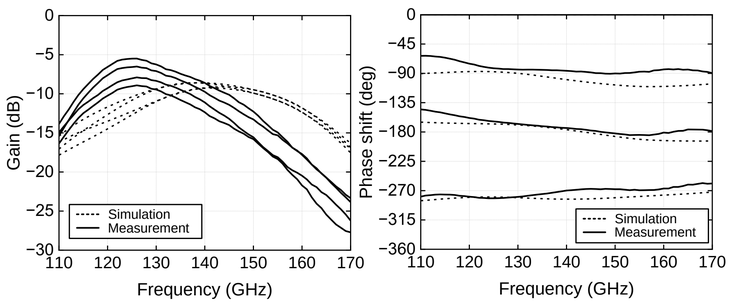
Chip micrograph and S-parameter measurement setup



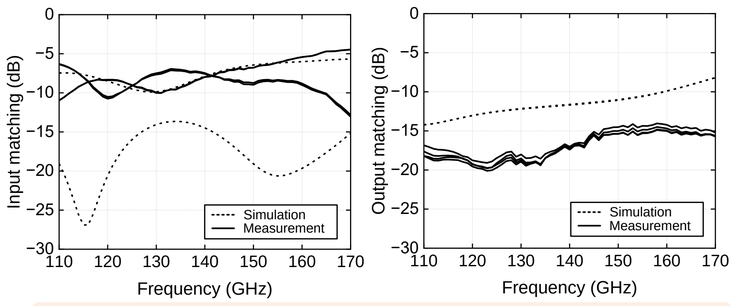


- 28-nm bulk CMOS technology
- Chip size : 1.3 × 0.52 mm^2
- The S-parameters were measured with a Keysight N5227A network analyzer and VDI WR-6.5 extension modules using 100-μm pitch ground-signal-ground (GSG) on-wafer probes.

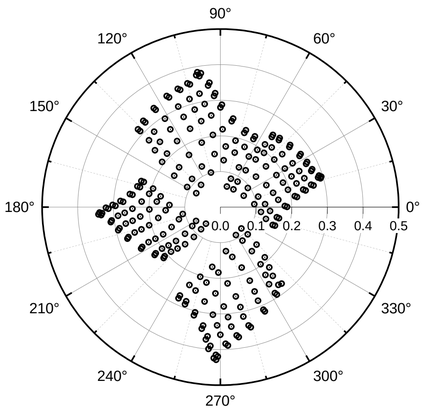
Measurement results



Measured gain and phase shift in 4 reference states



Measured input and output matching



Constellation @ 133 GHz

- Peak average gain = -5.5 dB @ 125 GHz
- 3-dB BW = 23 GHz (116.5 – 139.5 GHz)
- Phase shift range > 360°
- Input return loss < -7 dB @ 110 – 150 GHz
- Output return loss < -10 dB @ 110 – 170 GHz
- P_{DC} = 69 mW

Conclusion

- D-band power mode vector modulator is implemented using a 28-nm bulk CMOS technology.
- Phase interpolation is accomplished in a passive way by a 90° hybrid coupler
- Phase shifter can be used in sub-terahertz phased array systems.

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