An Open-Source 130-nm Fusion-Enabled Deconvolution Kernel Generator IC For Real-Time mmWave Radar Platform Motion Compensation

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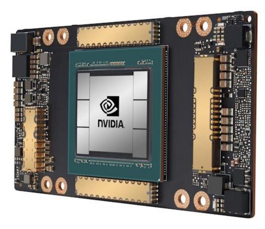
MOTIVATION

Existing Sensor Networks and Systems



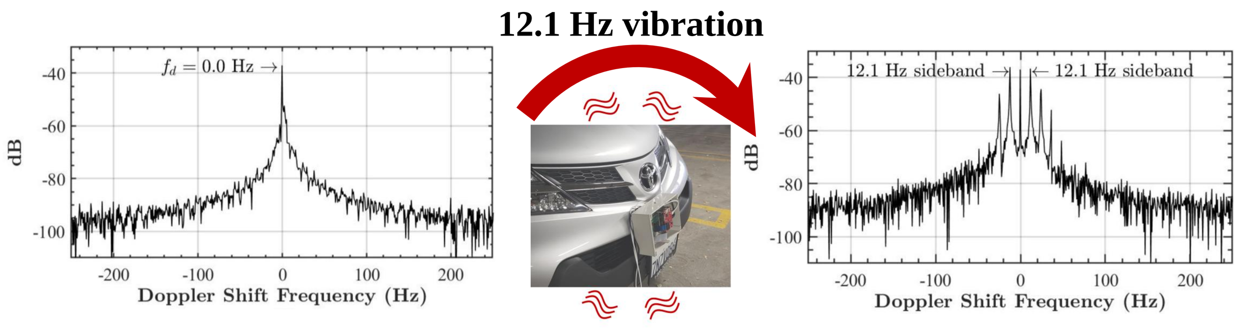
- Perception via **passive** silicon ICs (e.g., mmWave radars) with resource-intensive post-processing information extraction.

Sensing on Edge Devices

- Requires reduced computational cost and resource consumption.
- Reduced latency and increased throughput → real-time perception.

Challenge

- Parasitic platform motion degrades resolution and sensing capacity.
- Existing solutions operate in post-processing → resource-intensive, not real-time.



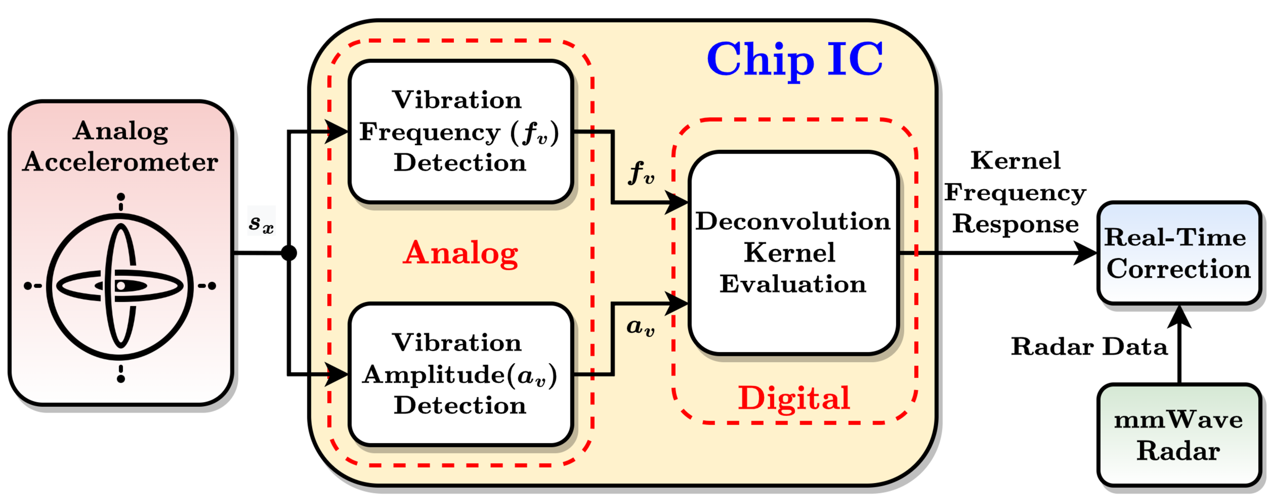
How to compensate for mmWave platform motion in real time on an edge IC?

SOLUTION

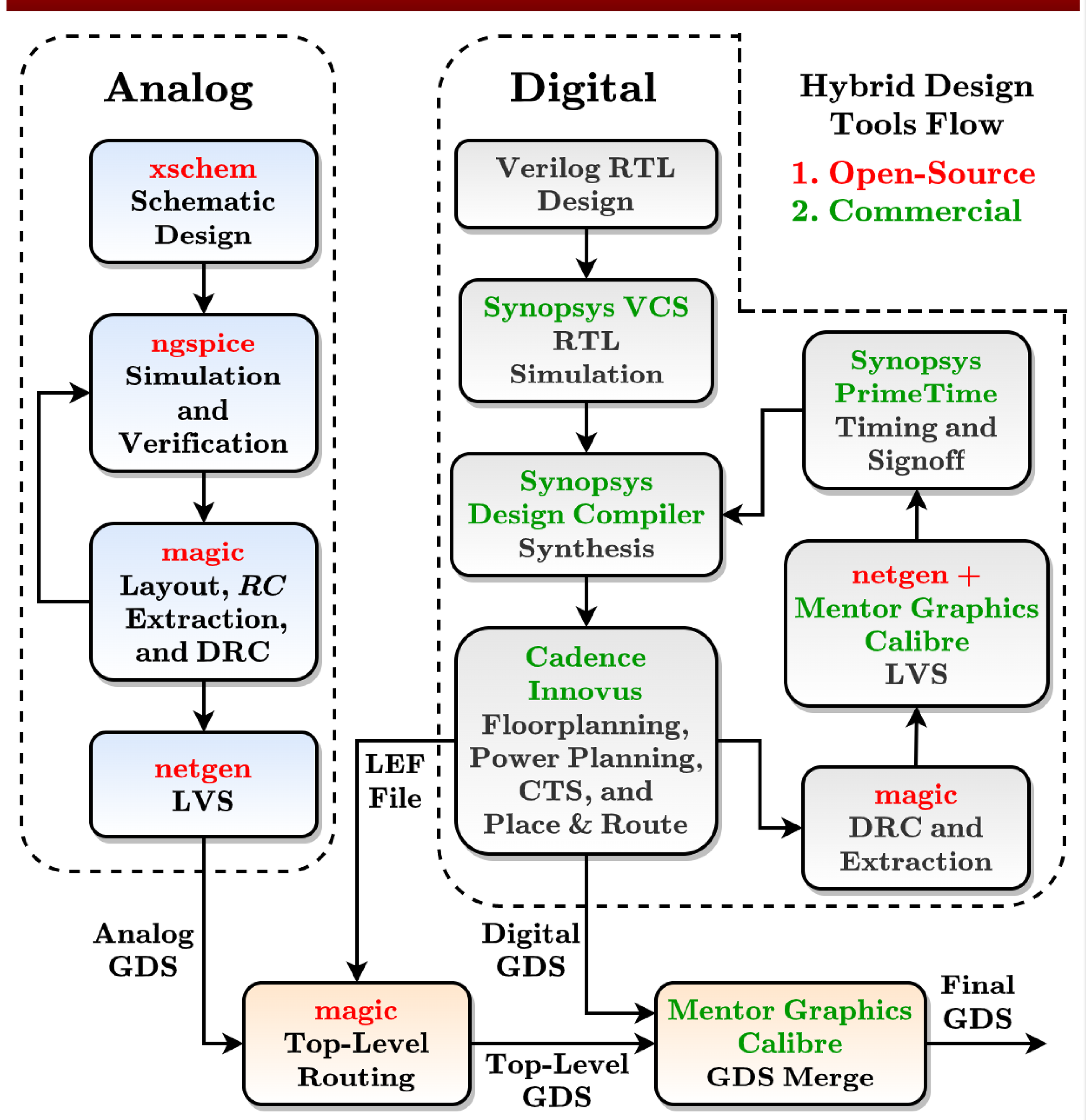
We present the first custom IC dedicated to enabling **real-time**, **resource-efficient** FMCW mmWave radar platform vibration compensation, via early sensor fusion.

Key Features

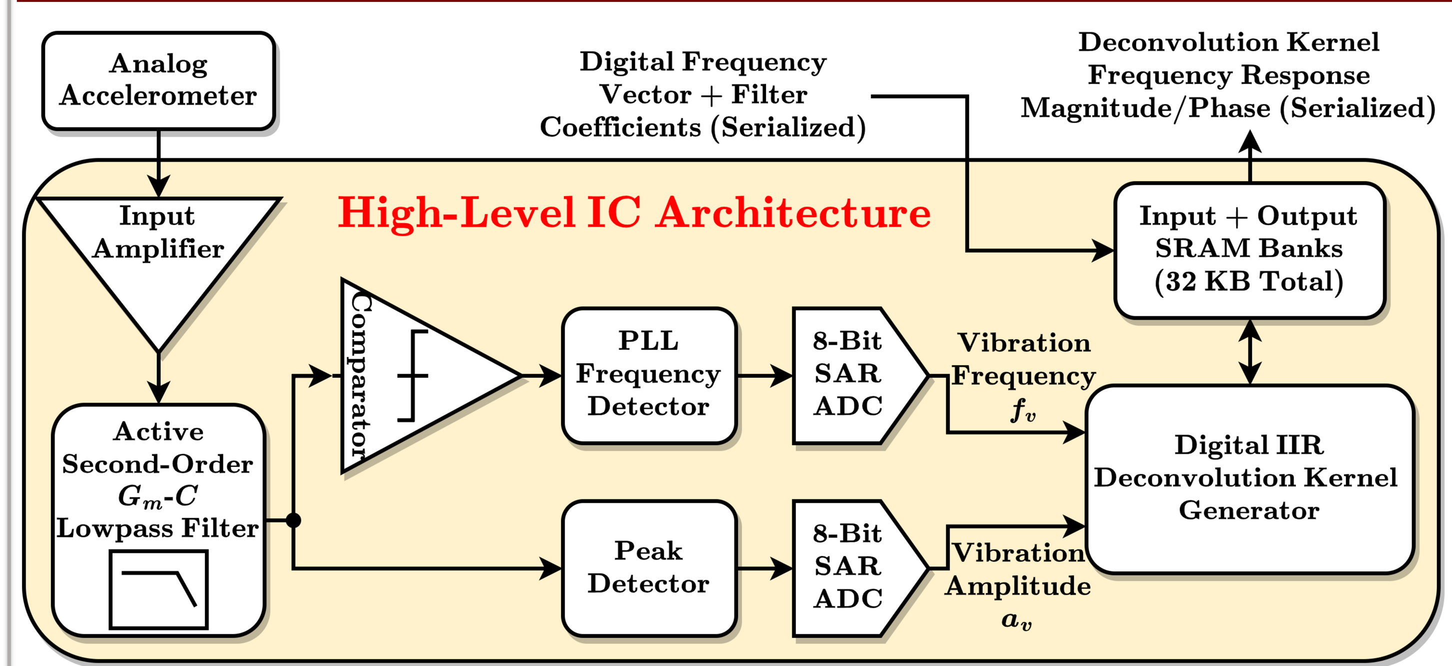
- Process: 130-nm Google SkyWater technology (fully open-source)
- Real-time: 95-ms processing intervals → **no compute-heavy post-processing**.
- Accelerometer fusion: chip detects frequency and amplitude of vibration.
- Assumptions: single-mode vibration + single target.



OPEN-SOURCE / COMMERCIAL TOOLS FLOW



CHIP ARCHITECTURE



Input

- High-pass-filtered x-axis signal from an analog accelerometer.

Analog Front-End

- Process the frequency and amplitude of the accelerometer-detected platform vibration and digitize the results via separate SAR ADCs.
- External frequency-detect circuitry to bypass a non-functional PLL.

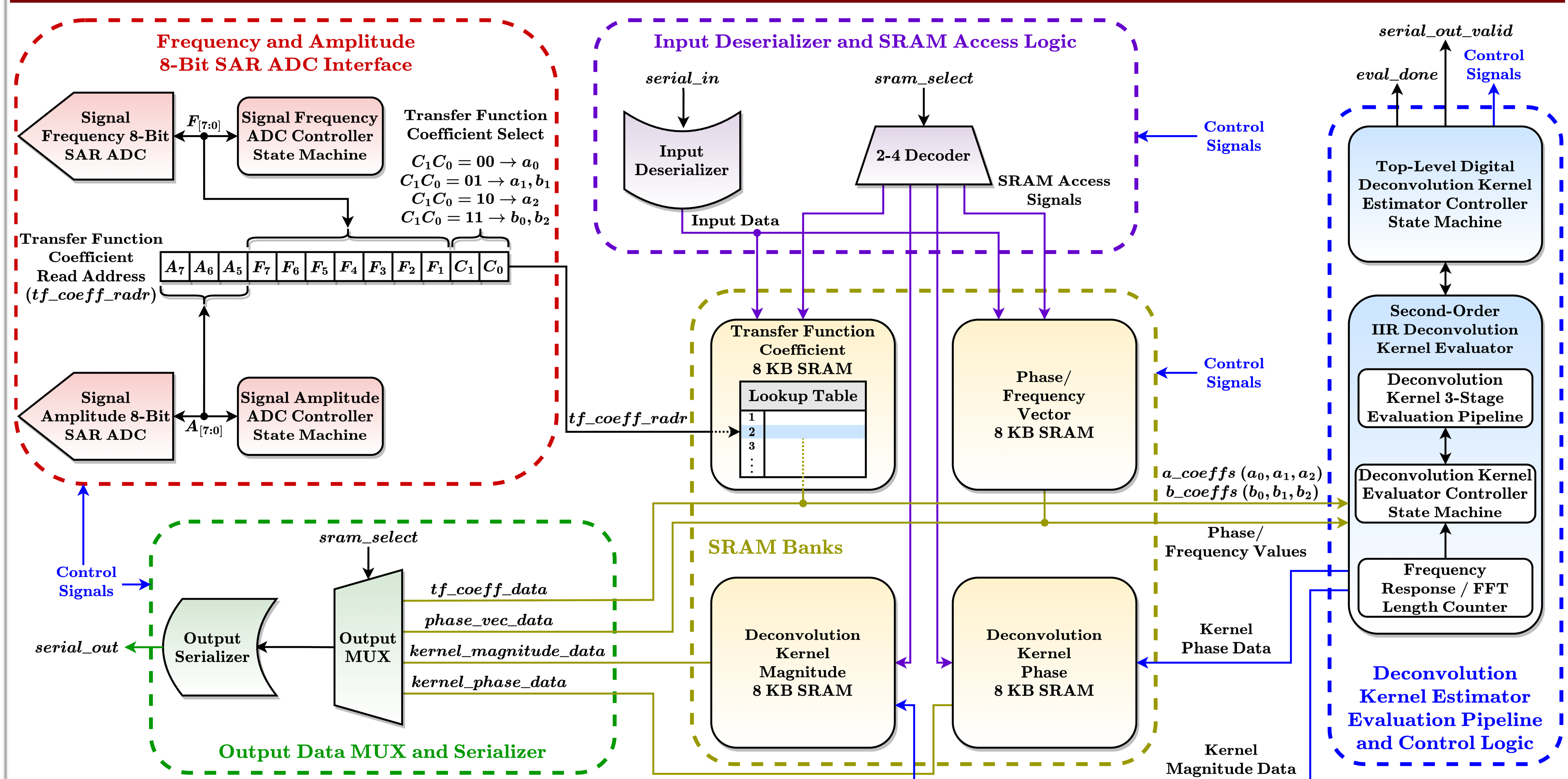
DSP Back-End

- Formulate + store in memory the estimated deconvolution kernel.
- Transfer function coefficient lookup + an optimized frequency response evaluation pipeline yield **time- and energy-efficient** kernel estimation.

Output

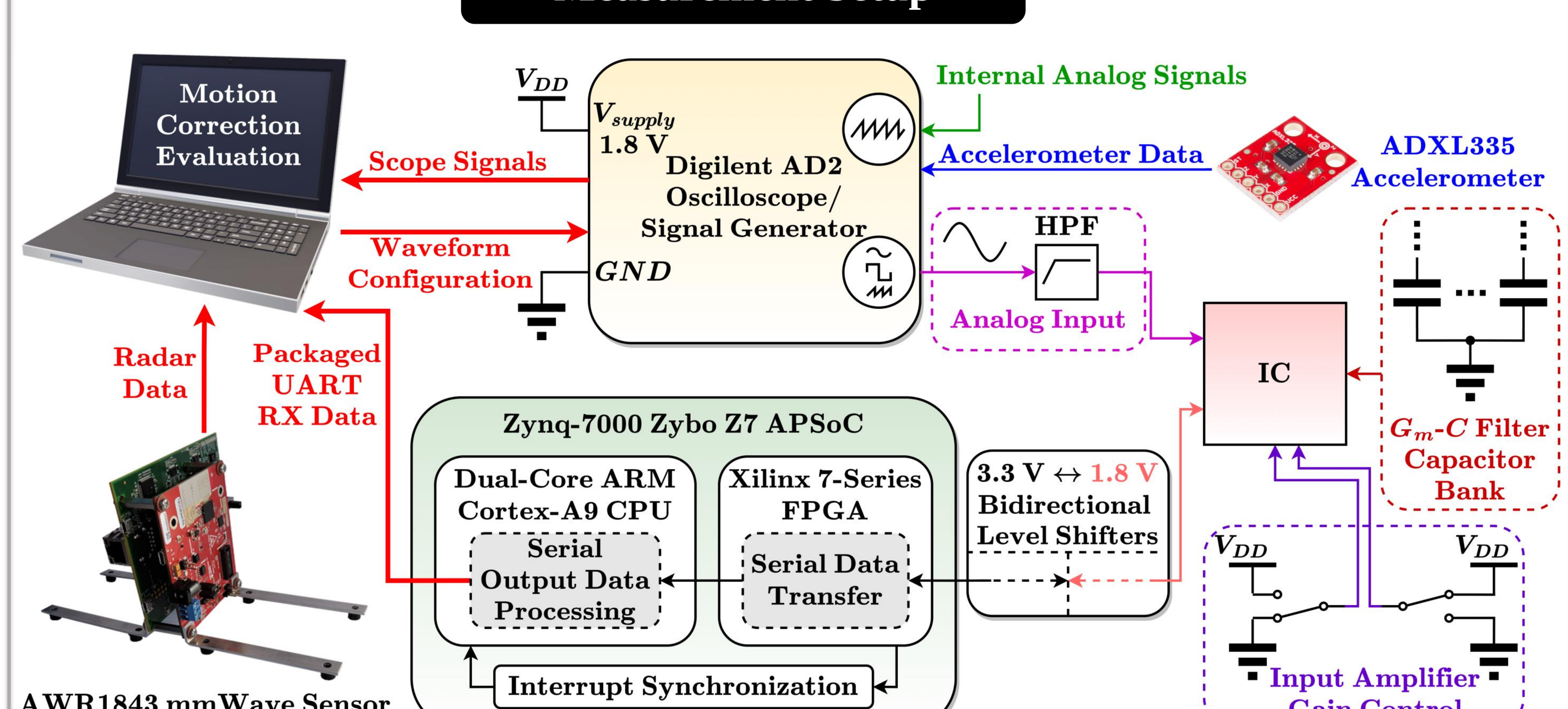
- Digital deconvolution kernel frequency response (phase + magnitude).

DECONVOLUTION KERNEL GENERATION

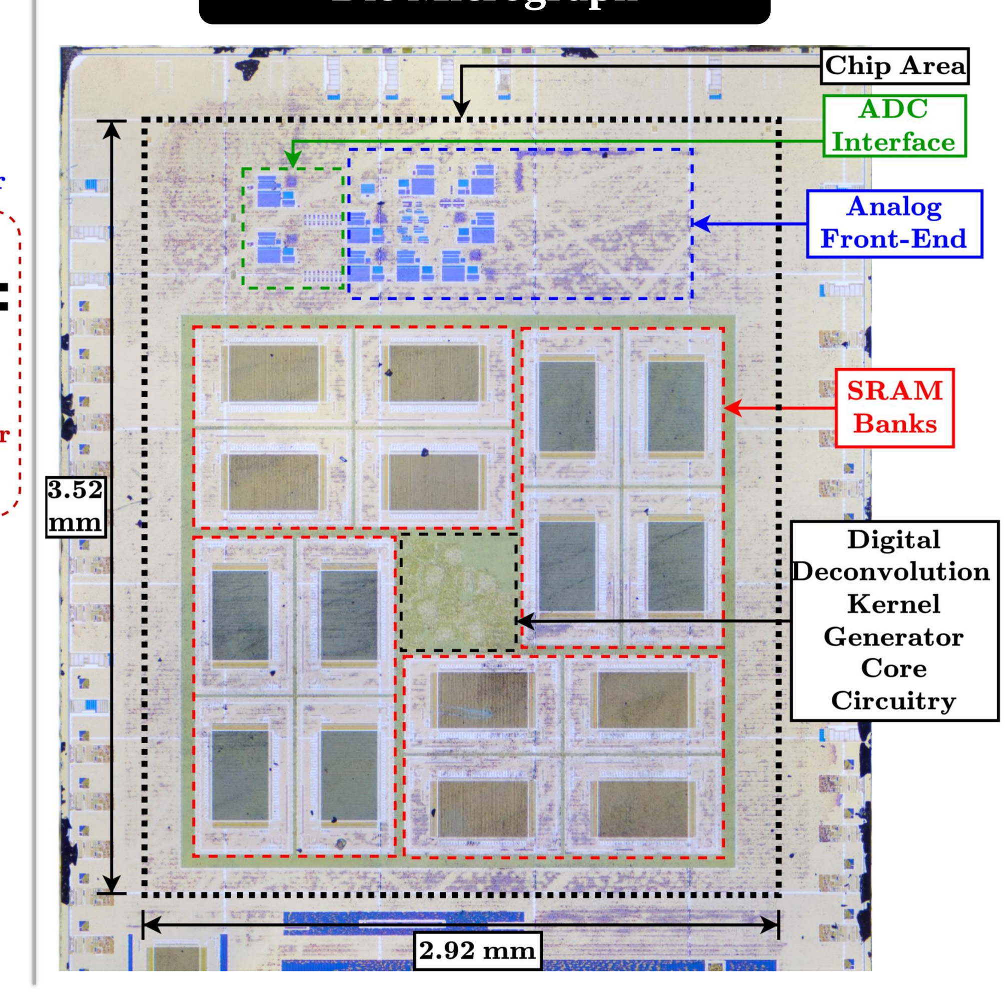


SYSTEM IMPLEMENTATION

Measurement Setup



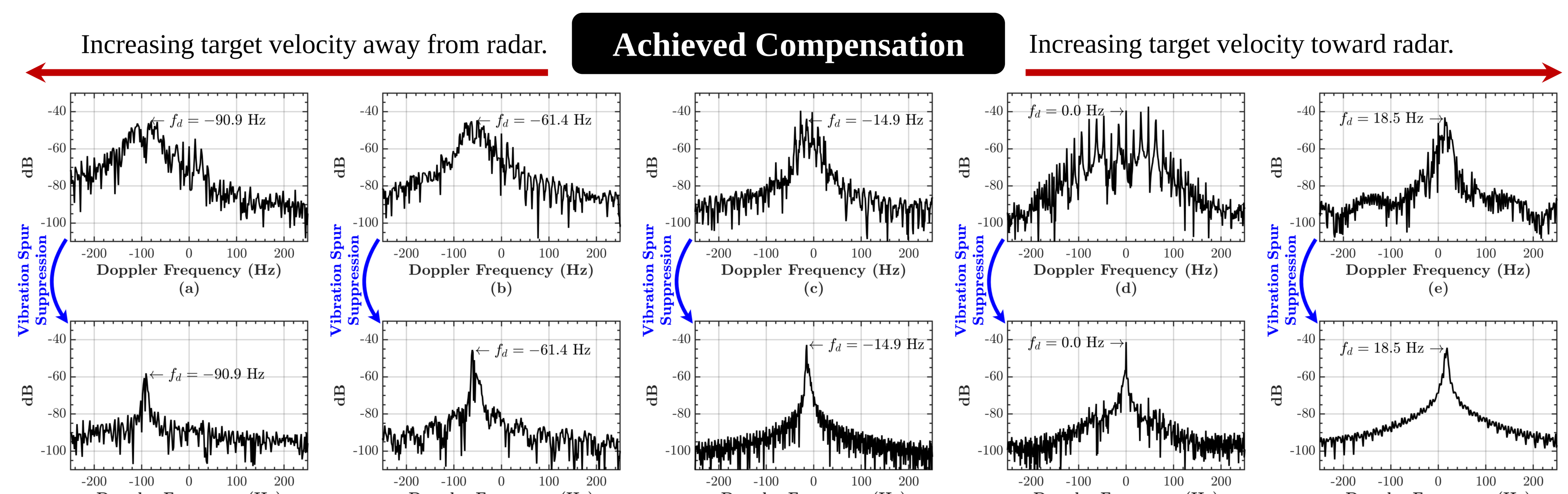
Die Micrograph

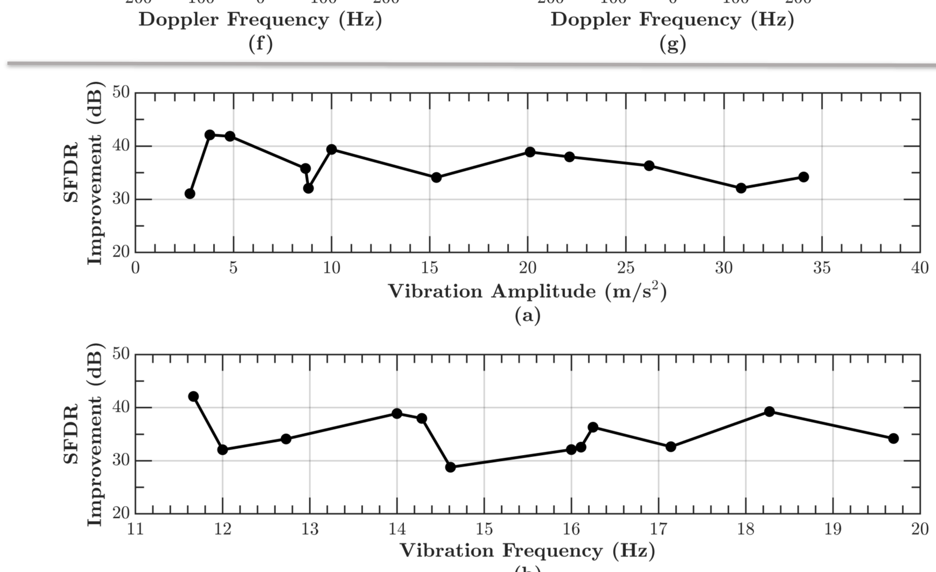


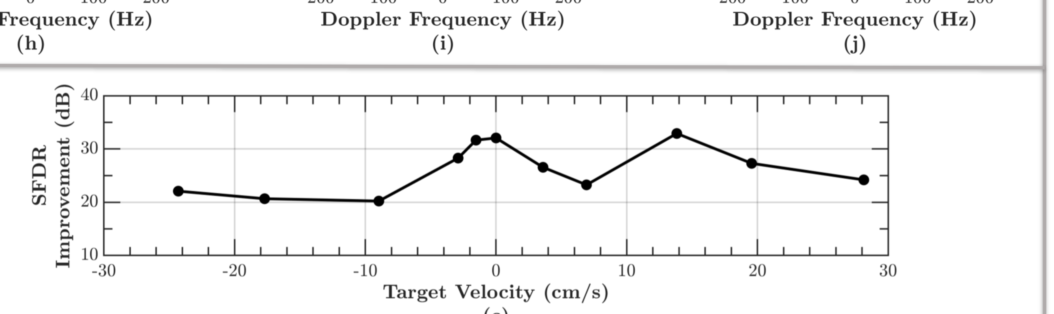
Active Area	Power Consumption	Latency
10.28 mm^2	2.43 mW	38-95 ms

MEASUREMENT RESULTS

Achieved Compensation







- ✓ Average ~35 dB SFDR improvement across vibration frequency / amplitude.
- ✓ Average ~26 dB SFDR improvement across target velocity.

Performance Summary

	This Work	[1]	[2]	[3]	[4]
Key Features	Fusion-aided real-time platform compensation for FMCW mmWave radar.	Wideband analog/RF SIC via LMS with autonomous adaptation to time-varying interference channels.	Continuous-time LMS adaptive filter of TX leakage in CDMA receivers.	Broadband SIC via Hilbert transform equalization (HTE) implemented in baseband.	RF + analog BB on-chip SIC via adaptive adjustment of cancellation signal + off-chip nonlinear digital BB cancellation.
Suppression Domain	Analog + Digital	Analog	Analog	Analog	Analog + Digital
Interference Suppression	26-35 dB	24 dB	14-21 dB	23 dB	20 dB
Computational Complexity	Second-order digital IIR deconvolution kernel, lookup-based, point-wise mult. correction → *minimal computation.*	Analog LMS adaptive circuitry only – no additional off-chip digital calibration, single tap per canceller → *minimal computation.*	Analog LMS adaptive circuitry only – no additional off-chip digital calibration → *minimal computation.*	Minimal number of equalizer taps via baseband HTE after RF downconversion + LPF → *minimal computation.*	Adaptive transmit interference cancellation; gradient descent to adapt amplitude, phase, and delay → *computationally complex.*
Bandwidth	12.5 MHz†	20 MHz	1 MHz	80 MHz	20 MHz
Canceller Power Consumption	2.43 mW	66 mW	30.5 mW	13 mW	80 mW
Technology	130-nm CMOS	65-nm CMOS	250-nm CMOS	130-nm CMOS	65-nm CMOS
Active Area	10.28 mm^2	3 mm^2	1.3 mm^2 §	0.72 mm^2	3.24 mm^2
# Channels	1 TX, 1 RX	1 TX, 1 RX	1 TX, 1 RX	1 TX, 1 RX	1 TX, 1 RX

References

[1] Y. Cao, *JSSC*'20.
[2] V. Aparin, *JSSC*'06.
[3] A. El Sayed, *TCAS-I*'19.
[4] S. Ayati, *TCAS-I*'21.