



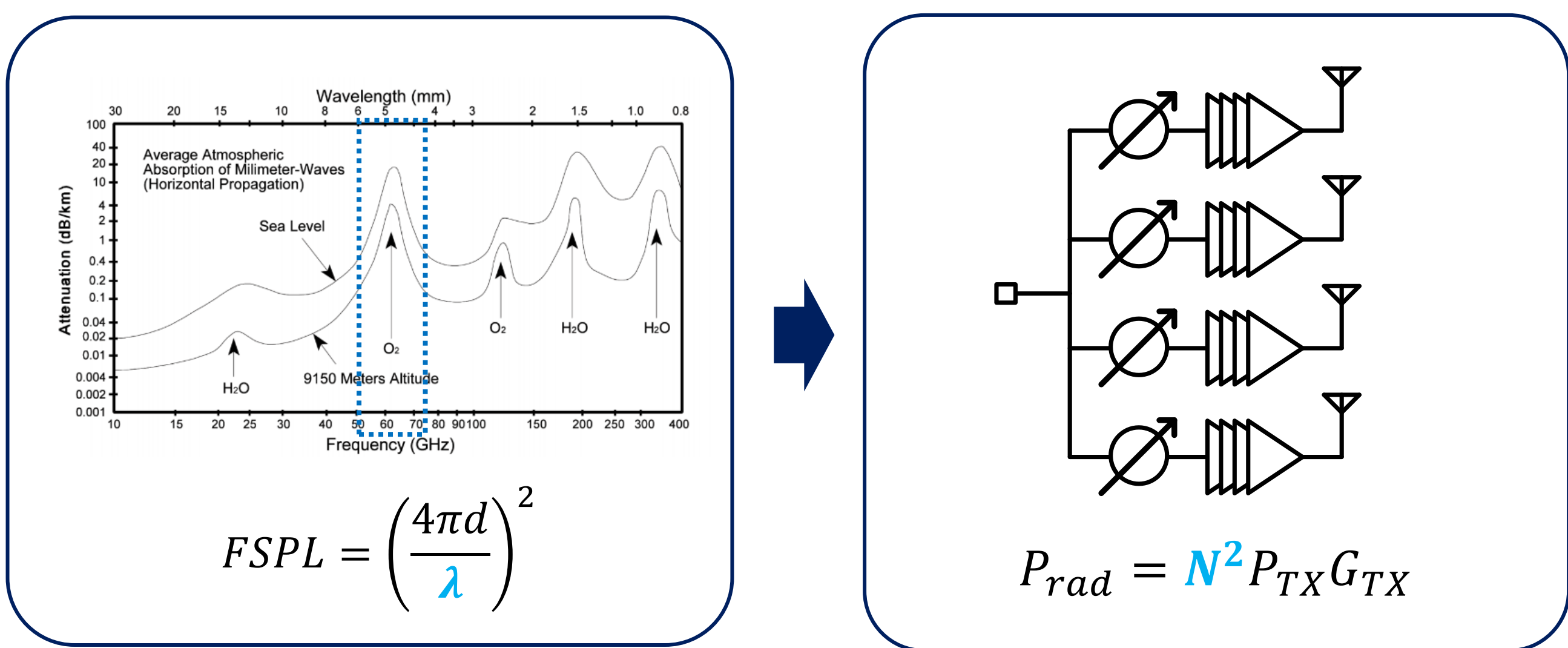
A V-band Four-Channel Phased-Array Beamforming Transmitter with Integrated Antenna Array

Hyun-Sik Hwang*, Cheol So**, Songcheol Hong*

*Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea

**Kyungpook National University, Daegu, Republic of Korea

Introduction

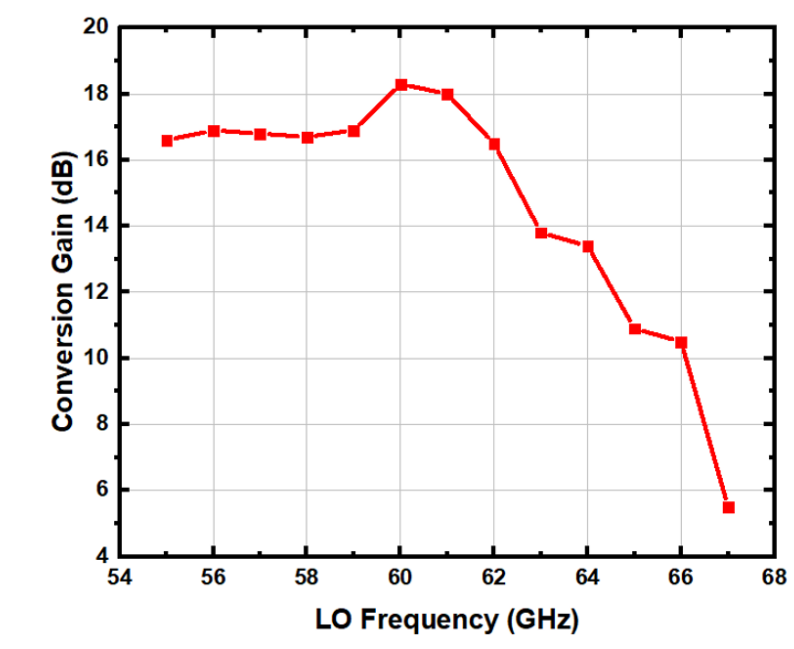
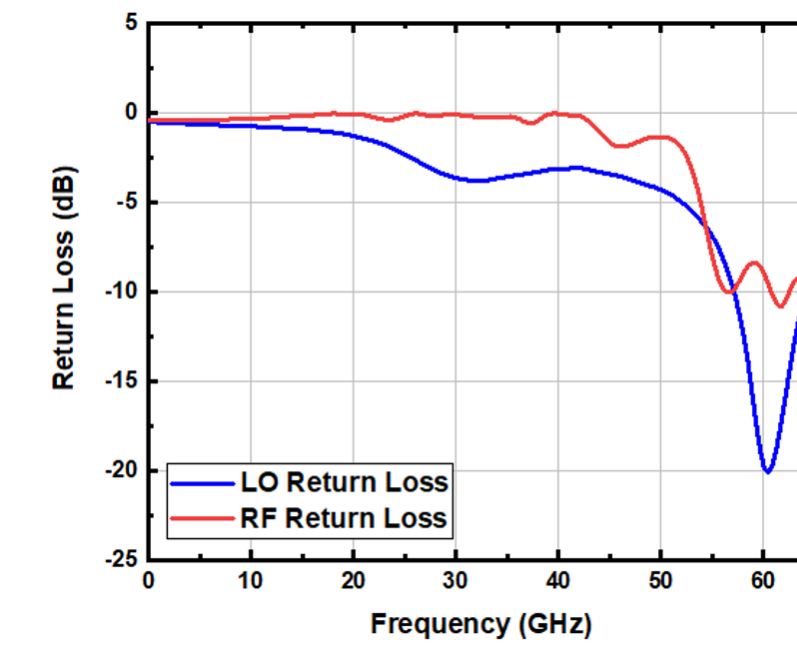
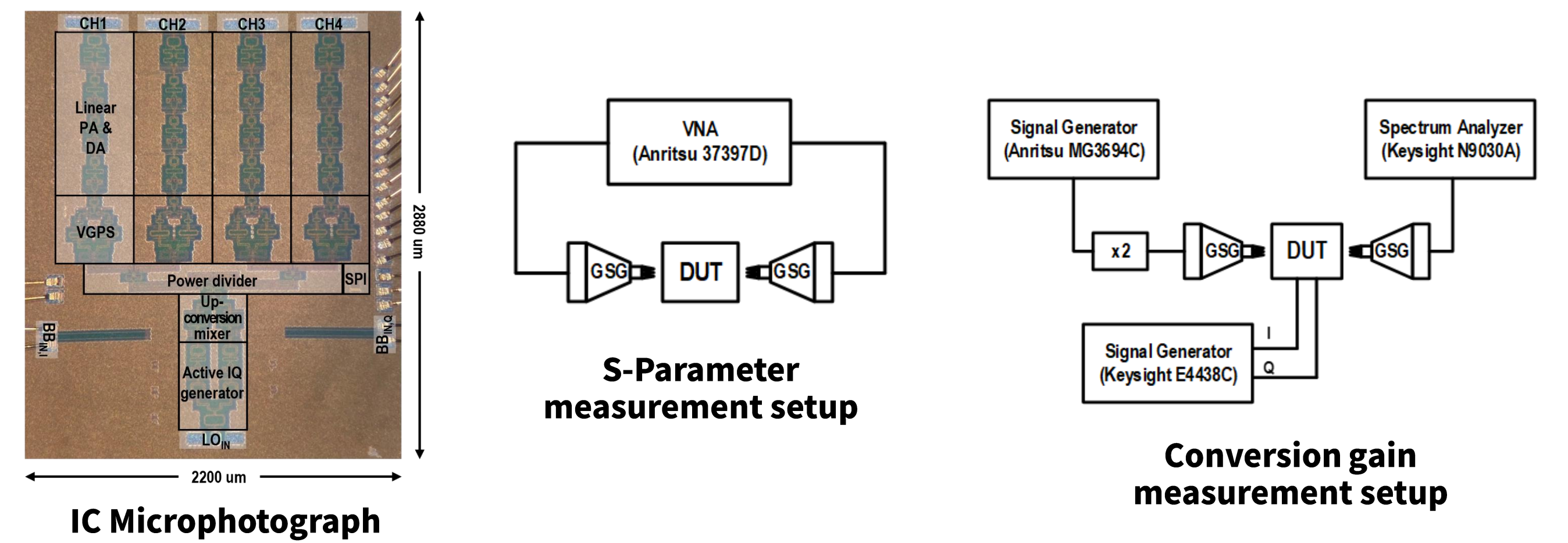


High path loss at 60 GHz

Beamforming at phased-array system

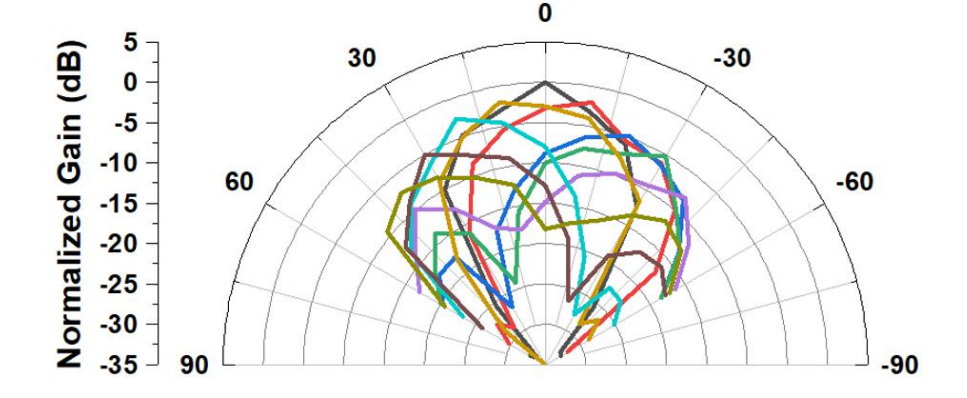
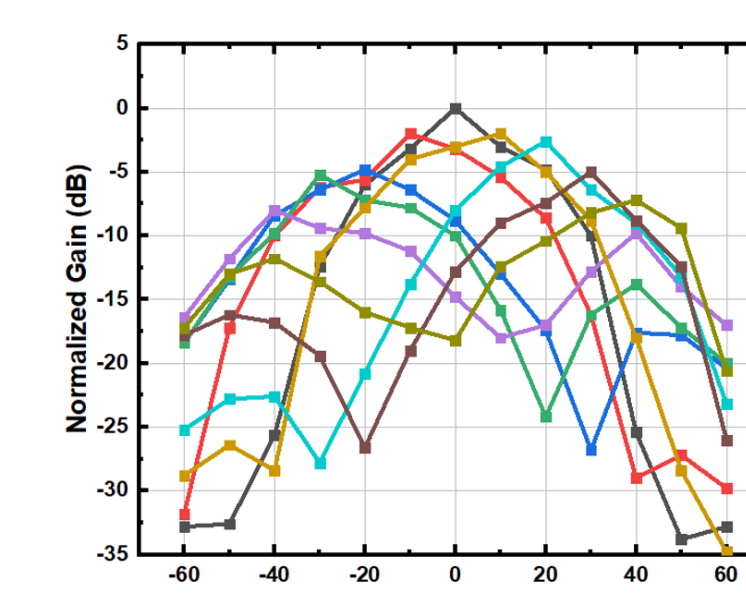
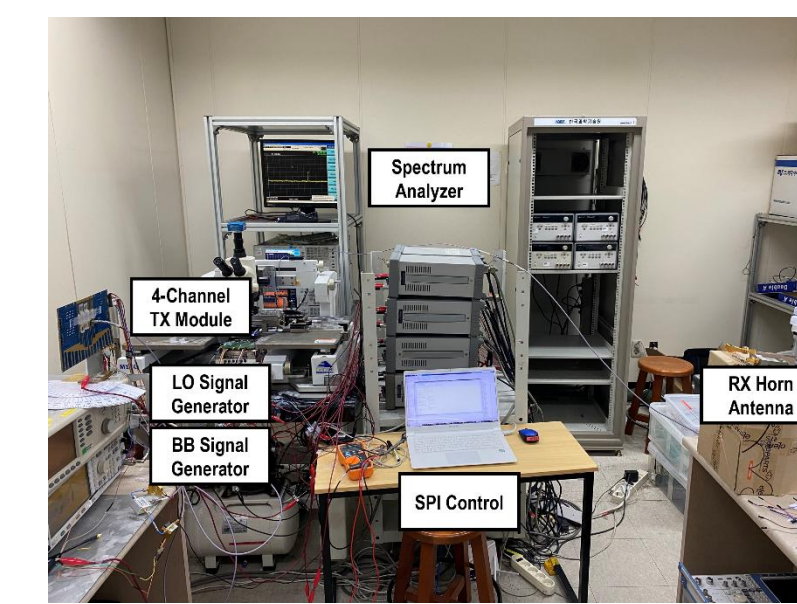
- 60 GHz Unlicensed band with **wide bandwidth**
- Wide bandwidth is suitable for high data-rate communication and high-resolution radar
- High path loss at 60 GHz → **Phased-array system**

Measurement Results



Measurement of S-parameter and conversion gain

- The proposed IC was fabricated using a 28-nm bulk CMOS process, and the chip area is 2200 μm × 2880 μm.
- The peak conversion gain was 18.3 dB, and the 3-dB bandwidth was 8 GHz.



Far-field radiation measurement setup

Far-field radiation pattern

- For far-field beamforming, a series-fed patch antenna fabricated on a Teflon substrate was integrated into the PCB.
- Over-the-air (OTA) beamforming operation, beam steering from -40° to 40° was achieved, and the sidelobe level was suppressed to -20 dB through chebyshev windowing.

	TMTT 2019	TCASI 2025	TMTT 2024	This work
Process	65nm	65nm	65nm	28nm
Freq.(GHz)	60	47.2-51.2	60	60
Elements	4	256	4	4
Phase res.(°)	22.25	5.625	11.25	1.4
Up-conv.	No	Yes	Yes	Yes
P _{DC} (mW)	403	78.5	371	387
Die size(mm ²)	2.88	19.1	3.38	6.34

Conclusion

A V-band 4-channel beamforming transmitter IC with integrated antenna module was implemented. The gm-boosted mixer enables frequency up-conversion over a wide LO frequency range. The VGPS includes a vector modulator that is controlled with a phase resolution of 1.4°. The antenna module integrates a 4-channel series-fed patch antenna array. The far-field beam pattern was measured through the test setup.

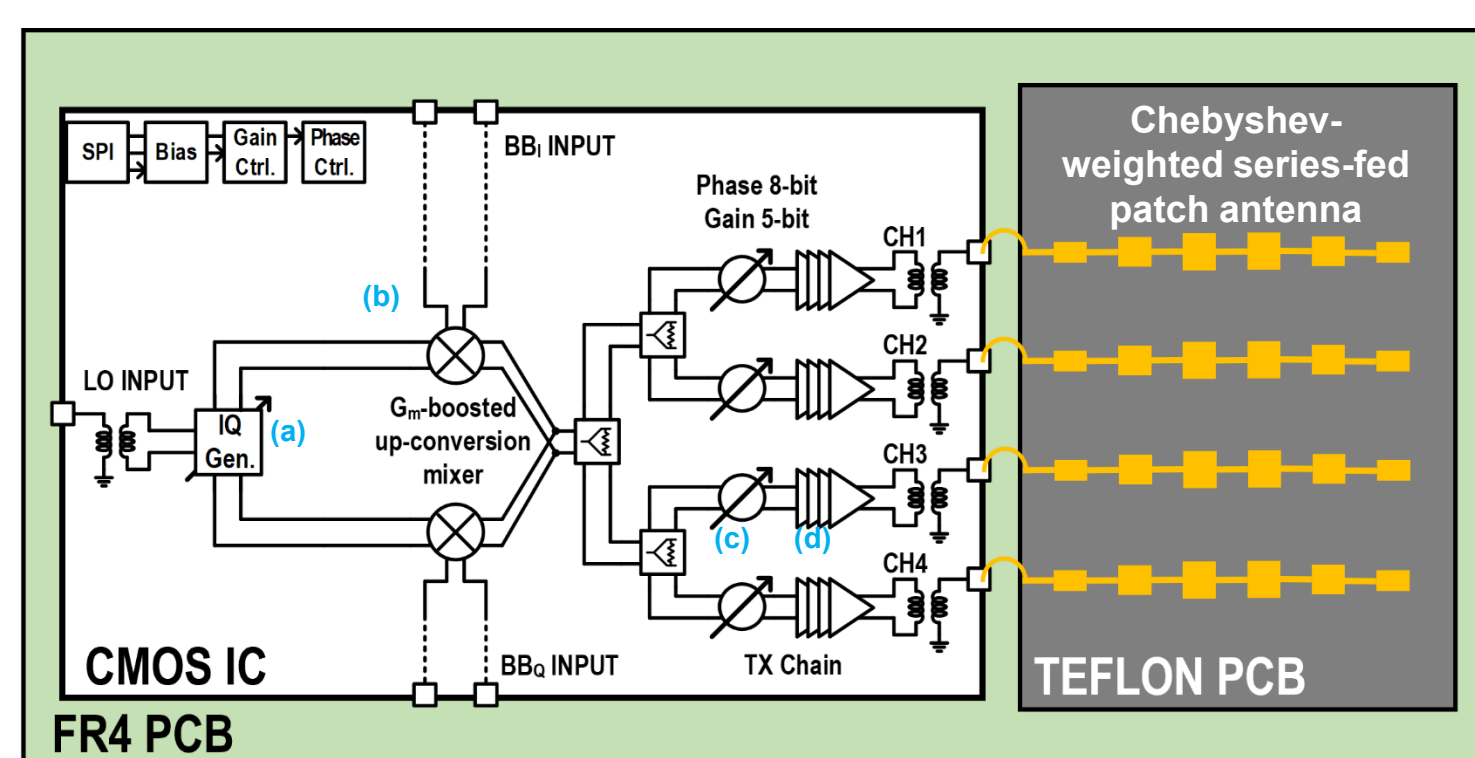
References

- [1] C. So, E. -T. Sung and S. Hong, "A V-Band Four-Channel Phased Array Transmitter Front-End With 0.7° Phase Step and 20 dB Gain Dynamic Range," in IEEE Transactions on Microwave Theory and Techniques, vol. 72, no. 5, pp. 2799-2808, May 2024.
- [2] E. -T. Sung, S. Wang and S. Hong, "A 60-GHz Polar Vector Modulator With Lookup Table-Based Calibration," in IEEE Microwave and Wireless Components Letters, vol. 31, no. 6, pp. 572-574, June 2021.

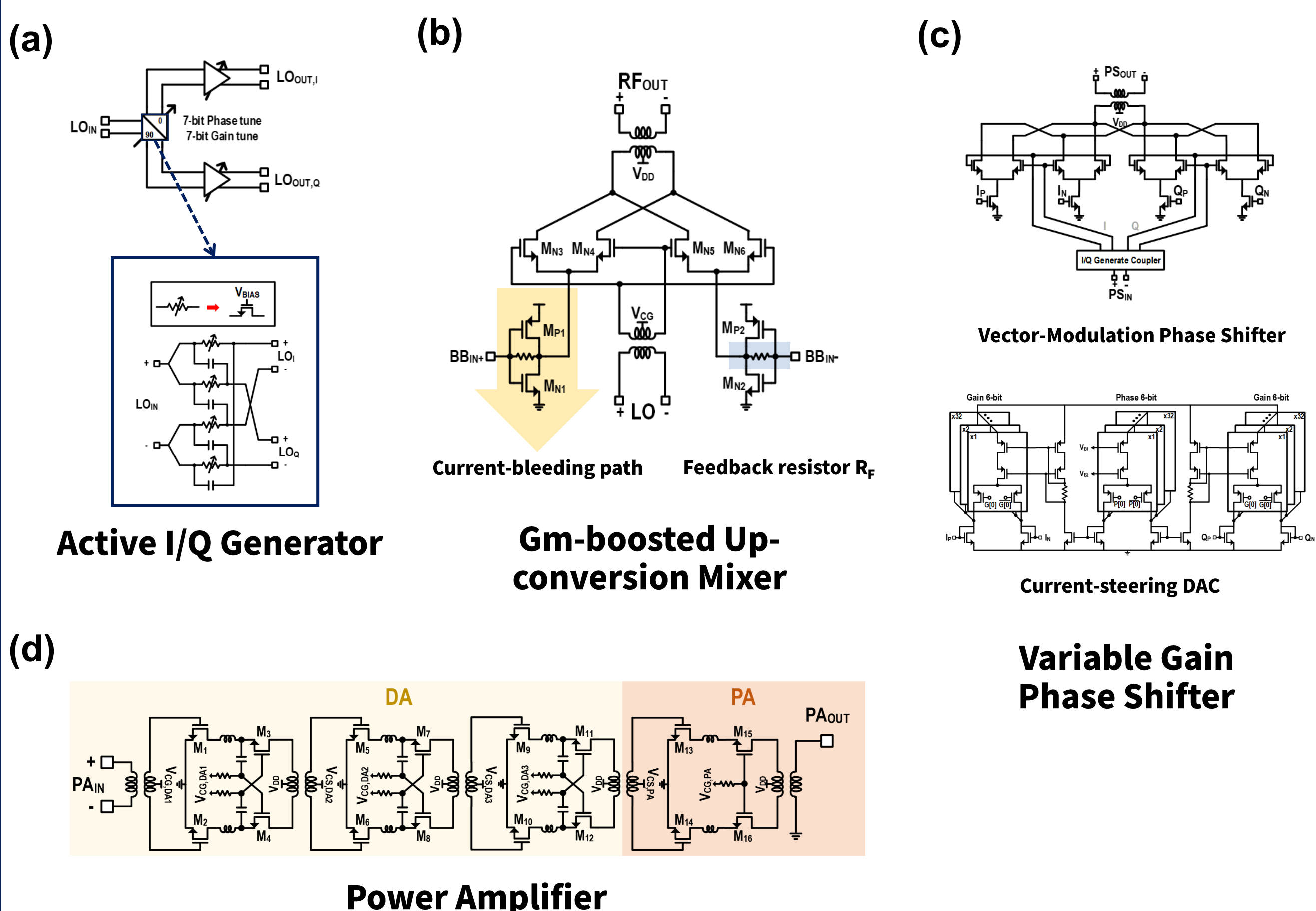
Acknowledgement

The chip fabrication and EDA tools were supported by Samsung Co. Ltd., and IC Design Education Center(IDEC), respectively.

Schematic Design



Block Diagram of Proposed V-band 4-Channel Beamforming Transmitter



- The active I/Q generator can support wideband LO frequency. It consists of a 7-bit tunable variable polyphase filter and 7-bit tunable variable-gain buffer for phase and gain compensation across frequency. It enables high image rejection ratio over a wide LO frequency range.
- The up-conversion mixer adopts a gilbert-cell-based topology, in which a PMOS current-bleeding path is incorporated to boost g_m, thereby increase the conversion gain.
- Additionally, a feedback resistor is connected between the drain and gate of the gm stage. It increase input impedance of baseband port, which consequently mitigates the insertion loss.
- The variable-gain phase shifter is controlled by a current-steering DAC, providing 5-bit gain control and 8-bit phase control with a phase resolution of 1.4°.
- The power amplifier consists of a three-stage driver amplifier and a power amplifier.