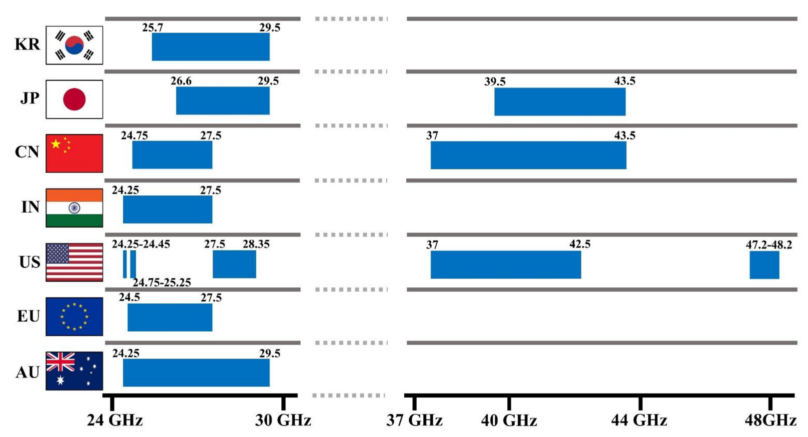
KAIST

A 28/37-GHz Frequency-Reconfigurable Front-End IC for Millimeter-Wave 5G Handsets

Gyuha Lee*, Jaehun Lee**, Hyoungkyu Jin**, and Songcheol Hong*
*Department of Electrical Engineering, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea
**System LSI Business, Samsung Electronics, Hwaseong, Republic of Korea

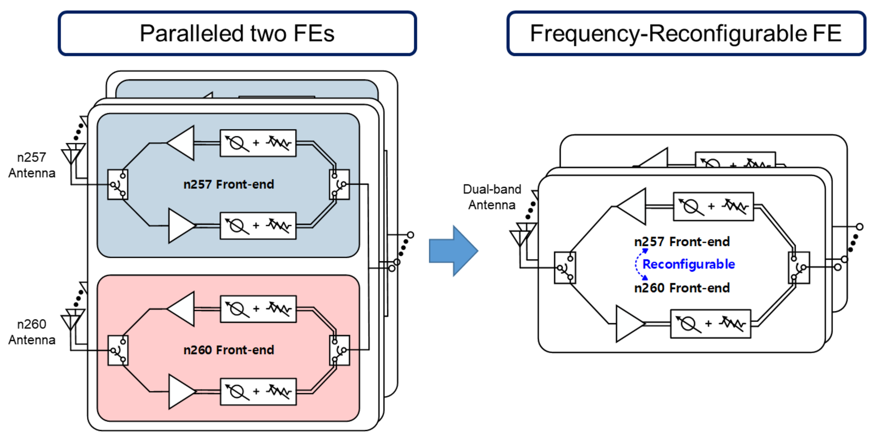
Introduction



[Global 5G Spectrum]

- Different countries use different frequency bands.

→ Dual-band front-end IC is needed for global usage & roaming service.

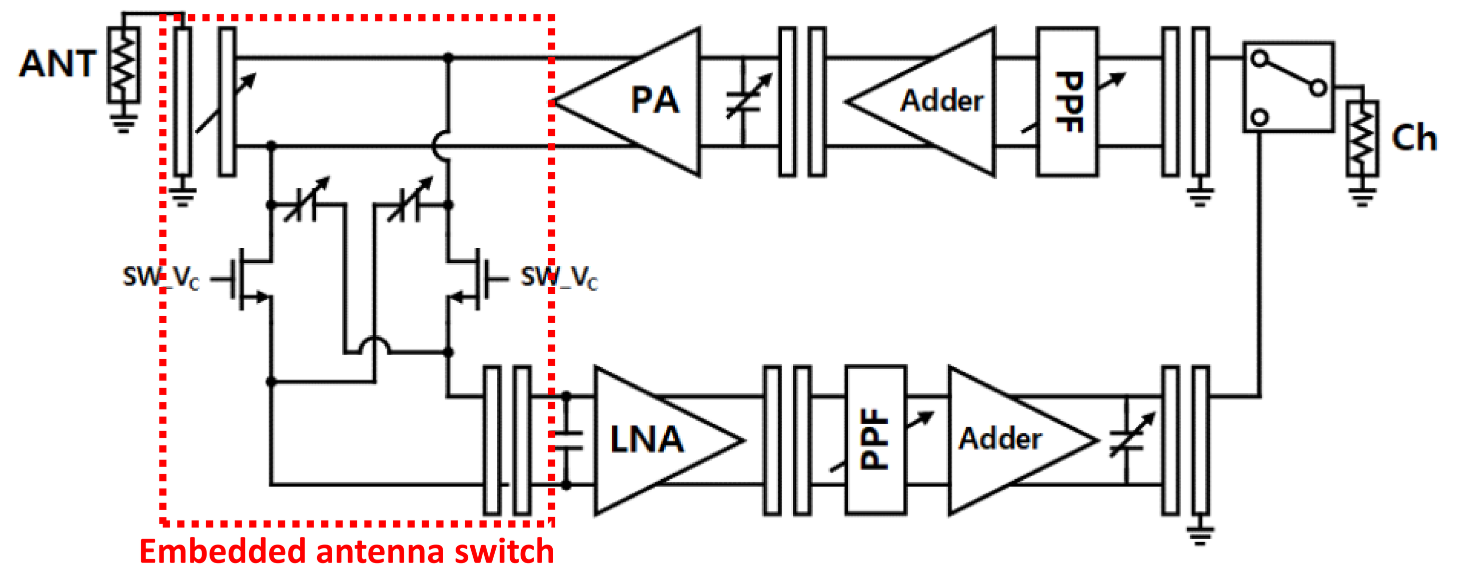


[Dual-band front-end structure]

- Frequency-reconfigurable (FR) front-end can halve the form factor compared to conventional structure (paralleled two single-band front-ends).

Schematic Design

- **Proposed FR dual-band front-end IC**

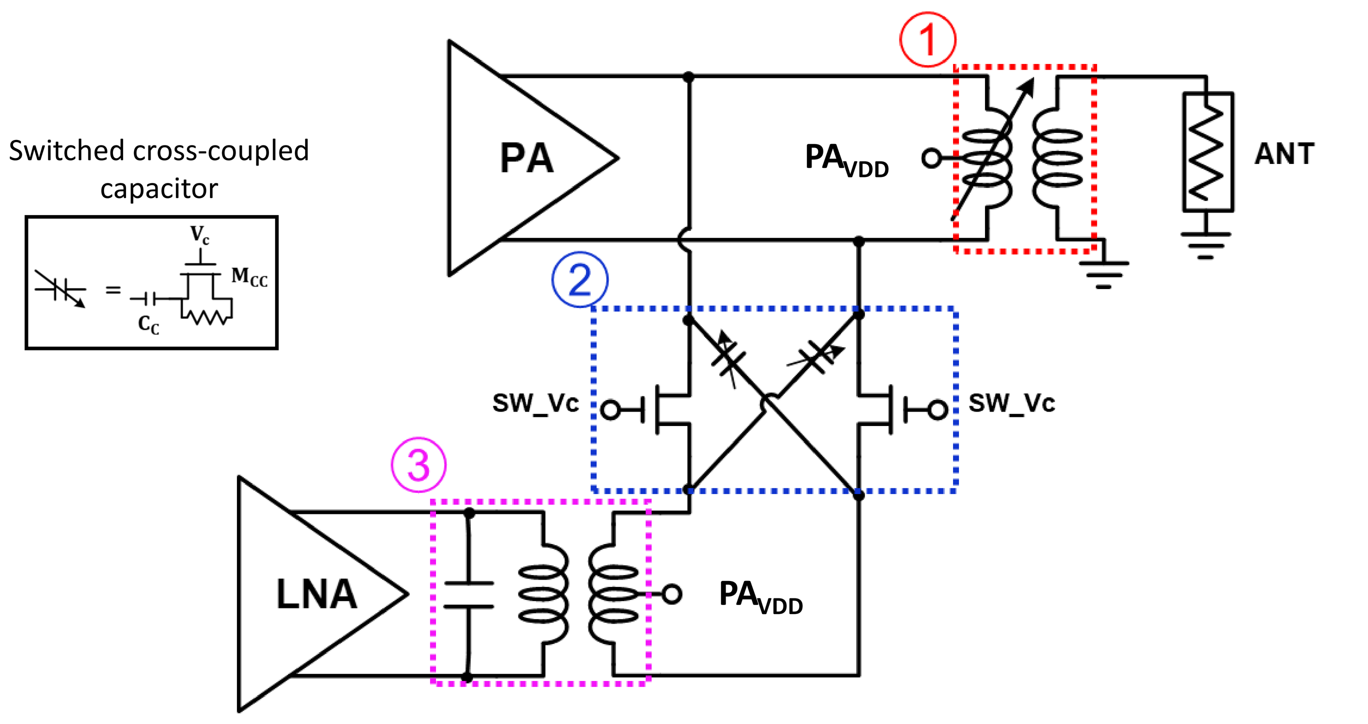


[Block diagram of FR front-end IC]

- Proposed IC consists of dual-band LNA, channel switch, and FR PA variable-gain phase shifter, embedded antenna switch [1].
- Embedded antenna switch consists of FR TLT for TX mode impedance matching, SPST switch for TRx mode change, and TLT for RX mode impedance matching.

[1] RFIC 2023 – A 28/37 GHz Frequency Reconfigurable Dual-Band Beamforming Front-End IC for 5G NR

- **Embedded antenna switch operation**



[Block diagram of the embedded antenna switch]

① TX FR TLT
- PA impedance matching ($Z_{opt,PA}$ ↔ 50Ω).

② SPST switch with switched cross-coupled capacitor
- TX mode: Cancel parasitic off-capacitance of the switch transistor to reduce the leakage.
- RX mode: Act as a matching network (shunt capacitor).

③ RX TLT with shunt capacitor
- RX impedance matching ($Z_{opt,PA}$ ↔ $Z_{opt,LNA}$).

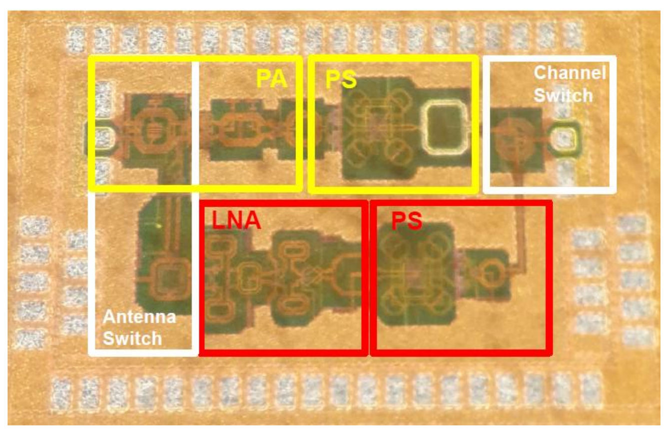
- Bias condition
  - TX mode: PA_{VDD}=2.2V, SW_Vc=1.1V.
  - RX mode: PA_{VDD}=1.1V, SW_Vc=2.2 V.

Acknowledgement

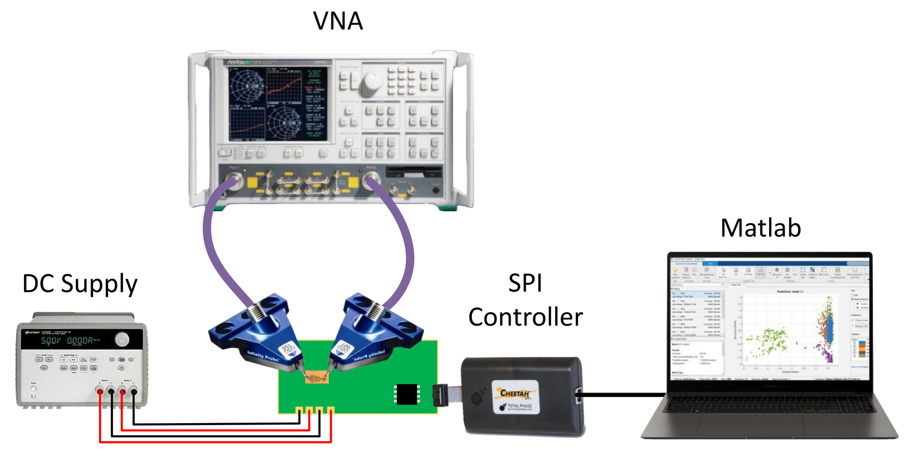
The chip fabrication and EDA tools were supported by Samsung Co. Ltd., and IC Design Education Center(IDEC), respectively.

Implementation and Measurement Results

- **Chip implementation & Measurement Setup**



[Chip photograph]

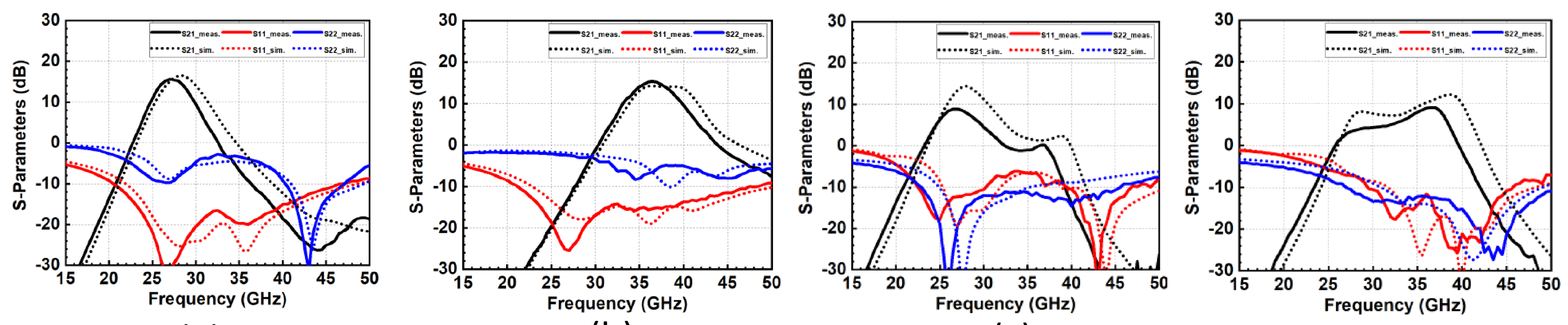


[S-Parameter measurement setup]

- Process: Samsung 28nm bulk CMOS.
- Size: 1287 x 756 μm² (core), 1886 x 1143 μm² (total).
- Electro-Magnetic field simulated by Keysight ADS Momentum.
- Phase/Gain state is controlled by Cheetah SPI Controller and Matlab.

- **Measurement results**

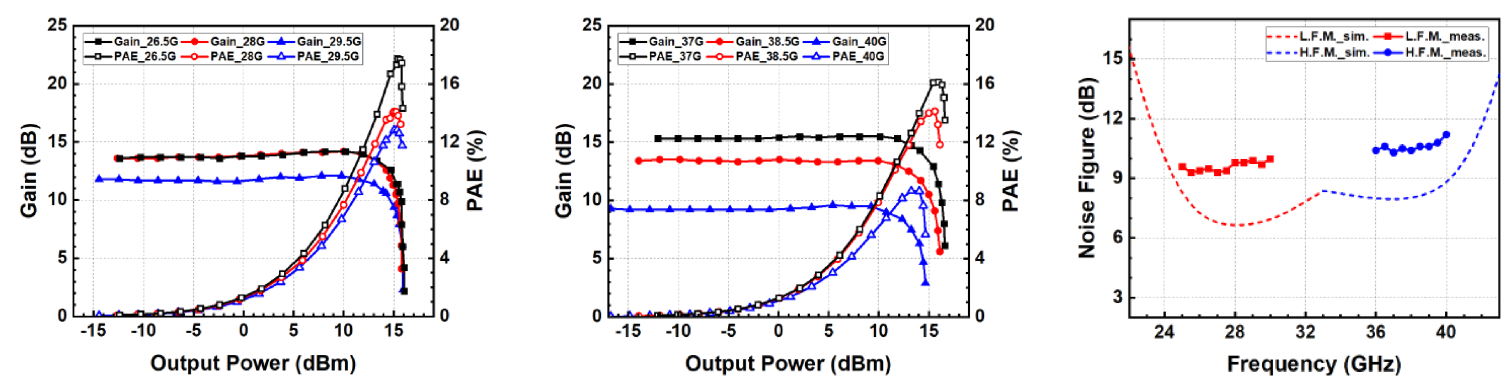
[S-parameter]



(a) (b) (c) (d)

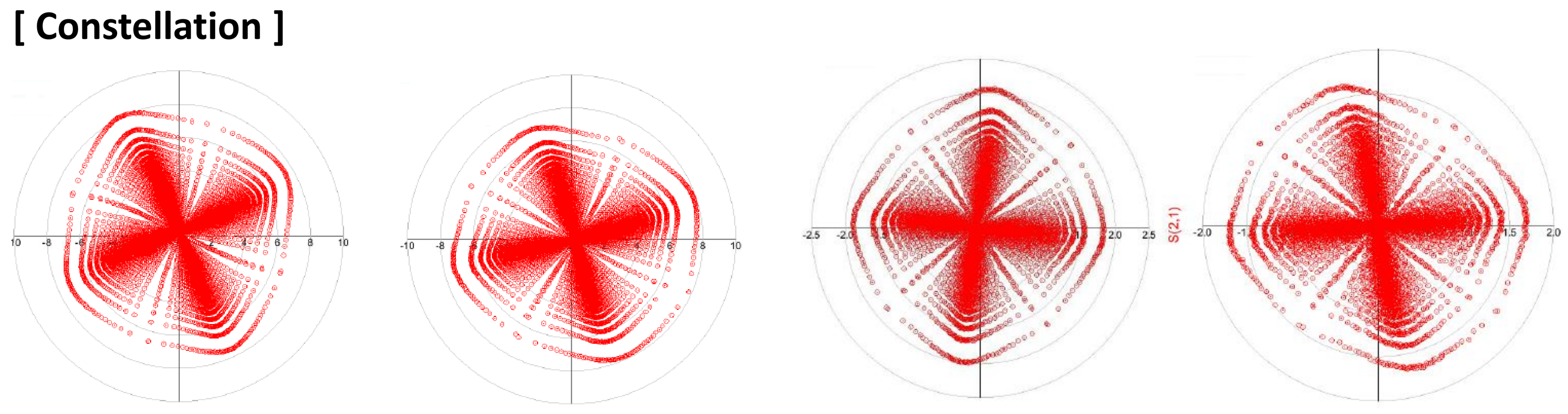
- TX mode gain of 15.1/15.1 dB and RX mode gain of 8.9/9.2 dB at 28/37 GHz.

[TX 1-tone measurement and RX noise figure]



- TX OP1dB of 14.3/14.1 dBm and TX Psat of 15.8/16.6 dBm at 28/37 GHz.
- Peak PAE of 14.1/16.1% at 28/37 GHz.
- Noise figure of 9.3/10.3 dB at 28/37 GHz.

[Constellation]



(a) (b) (c) (d)

- The overall gain/phase states (a) TX 28 GHz, (b) TX 37 GHz, (c) RX 28 GHz, and (d) RX 37 GHz.
- 6-bit gain control, 7-bit phase control, and 16 dB gain dynamic range.

[Comparison table]

			RX		TX				
	Technology	Freq. (GHz)	Gain (dB)	NF (dB)	Gain (dB)	Psat (dBm)	P1dB (dBm)	PAE (%)	Core area (mm^2)
RFIC 2024	65 nm CMOS	27	16	6.7*	24*	17.6	13*	19	0.78
		37	15	8.1	27	16.4	13.6	12.2	
ISSCC 2020	65 nm CMOS	28	44	8.5*	43.5	15.5	14	21	1.05
		37	37	9.5*	40	15.6	14.2	21.5	
TMTT 2020	45 nm CMOS	28	19.3	< 4	17.6	19.2*	16*	18	-
		36			13.6	18.8*	15*	14.1	
ISSCC 2019	65 nm CMOS	28	16.1	7.4*	28.5	15.8	14.1	20	-
		37	10.9	7*	26.2	16.8	15.2	21.6	
		39	8.3	7.9*	20.3	16.7	13.5	22.2	
This work	**28 nm CMOS**	**28**	**8.9**	**9.3**	**15.1**	**15.8**	**14.3**	**14.1**	**0.97**
		37	**9.2**	**10.3**	**15.1**	**16.6**	**14.1**	**16.1**	

*Graphically estimated

Conclusions

A 28/37 GHz transmitter-optimized FR front-end IC utilizing an embedded antenna switch is implemented and verified. The antenna switch is integrated in TX matching network with TLTs and an SPST switch. The proposed dual-band front-end IC shows high TX performance, as the output power for PA directly connected to antenna.