A CMOS Cascode VGA for X-Band Phased-Array Applications With Reduced Phase Error

Min Song
School of Electronic Engineering,
Soongsil University, 06978
Seoul, Korea, Republic of
sm2001@soongsil.ac.kr

Hyeonhui Roh
Dept. of Intelligent Semiconductors
Soongsil University, 06978
Seoul, Korea, Republic of
yeshyuni@soongsil.ac.kr

Changkun Park
Dept. of Intelligent Semiconductors
Soongsil University, 06978
Seoul, Korea, Republic of
pck77@ssu.ac.kr

A. *Introduction*

Accurate beamforming in phased-array front-ends requires a variable gain amplifier (VGA) with low phase error over the entire gain-control range (GCR). The proposed CMOS cascode VGA for X-band (7–9 GHz) that employs inductive loads to achieve high gain with low phase error, and explain the reason of phase error remains small by analyzing output-phase variation to Vctrl variation.

B. *Design of Variable Gain Amplifier*

The proposed VGA is a single-ended, two-stage cascode structure, and both stages employ inductive loads at their outputs. Gain control is confined to the first stage via Vctrl, while the second stage operates with a fixed bias to maintain consistent output return loss and provide additional gain. LC matching is applied at both the input and output. For comparison, a resistive-load topology is evaluated under identical conditions. The proposed inductive-load topology maintains comparably low phase error while achieving higher gain, without additional compensation.

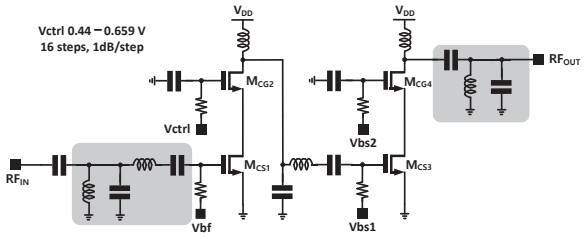


Fig 1. Schematic of the proposed VGA

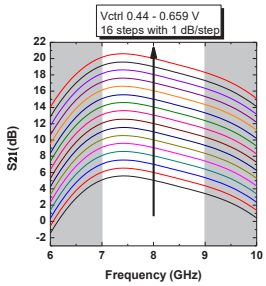
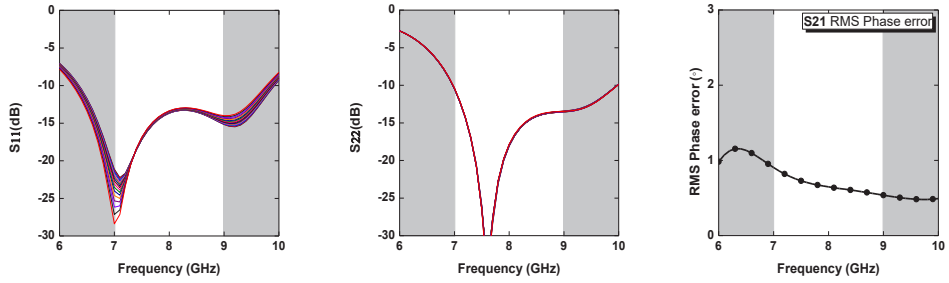


Fig 2. Simulated S_{21} results of VGA

C. *Design Results*

Simulation results show that the input return loss (S_{11}) and output return loss (S_{22}) are ≤ −10 dB across 7–9 GHz. Within Vctrl = 0.44–0.659 V, a total of 16 steps with 1 dB/step achieves a 5–20 dB gain-control range. Over 7–9 GHz, the RMS phase error is maintained at an average of 0.672° with a maximum of 0.905°, and the total power consumption is 17.4 mW.



(a) (b) (c)

Fig 1. Simulated results of VGA: (a) S11, (b) S22, (c) RMS phase error

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