TH03A-1

Low Delay and Loss Variation Reflection Type Phase Shifter With Sequentially Controlled Varactor Diodes

G. Yang, D. Lee, and B. –W. Min

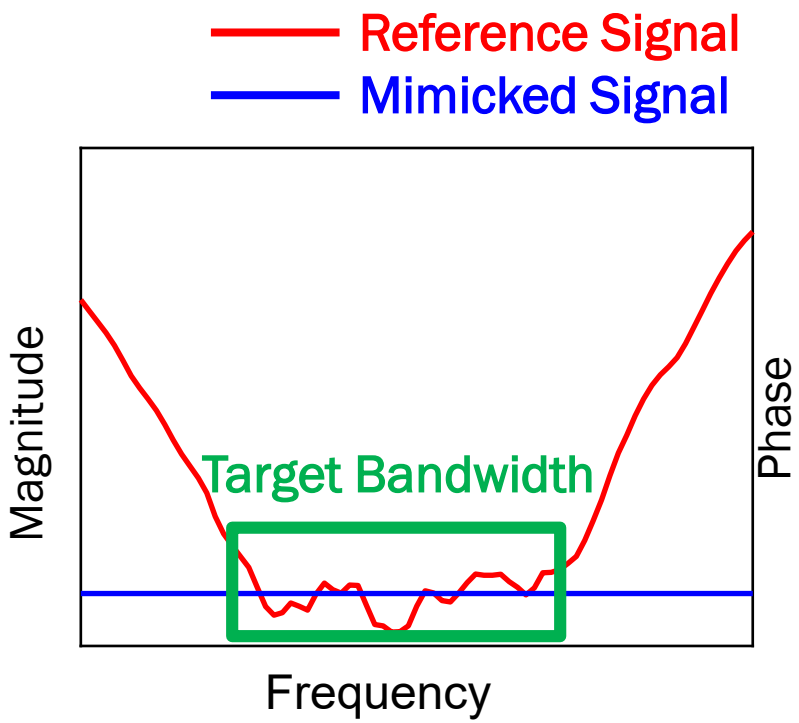
School of Electrical & Electronic Engineering,
Yonsei University, Seoul, Republic of Korea

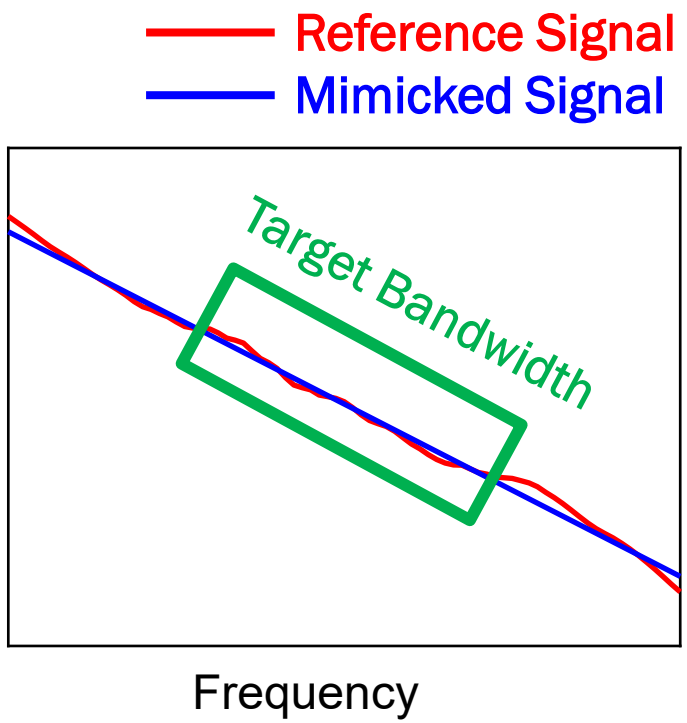
YONSEI UNIVERSITY

Outline

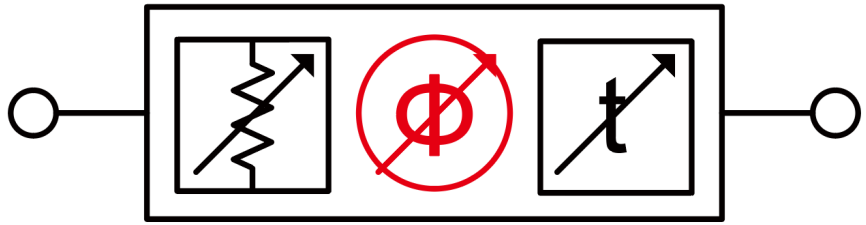
- Motivation
- 360° Phase shifting
- Bias Control Scheme
- Measurement
- Conclusion

Motivation





[Example of mimicked signal]

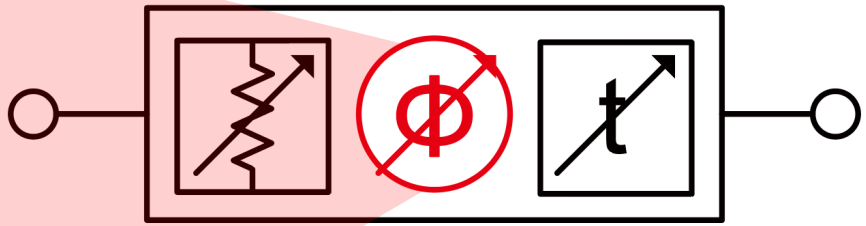


[Mimicked signal generator]

Motivation

[Condition for Phase Shifter]

1. 360° Full Coverage
2. High Resolution
3. High linearity
4. Low loss and delay variation

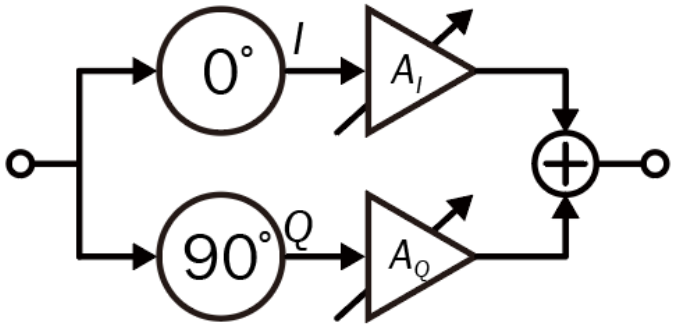


[Mimicked signal generator]

RTPS Fit for Purpose

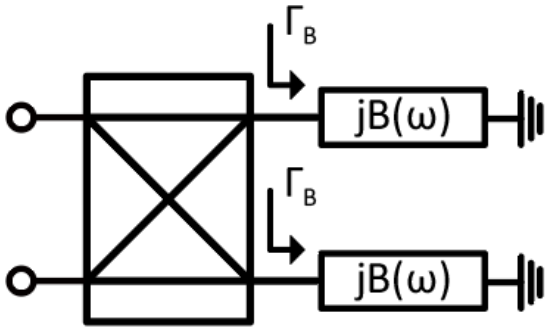
[STPS]

Resolution ☹
Linearity ☺



[VSPS]

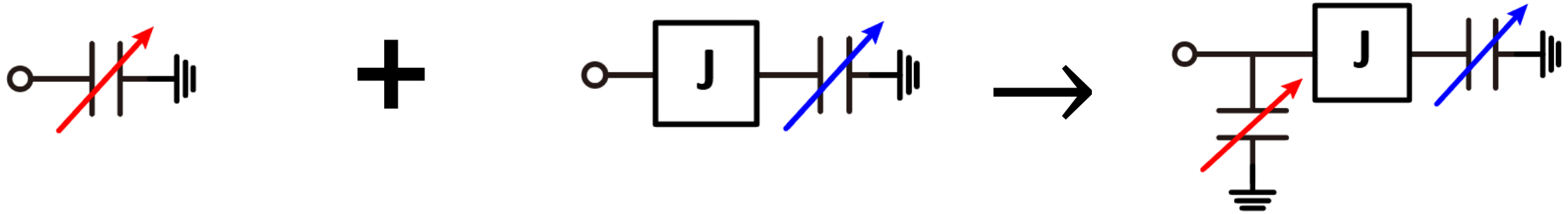
Resolution ☺
Linearity ☹

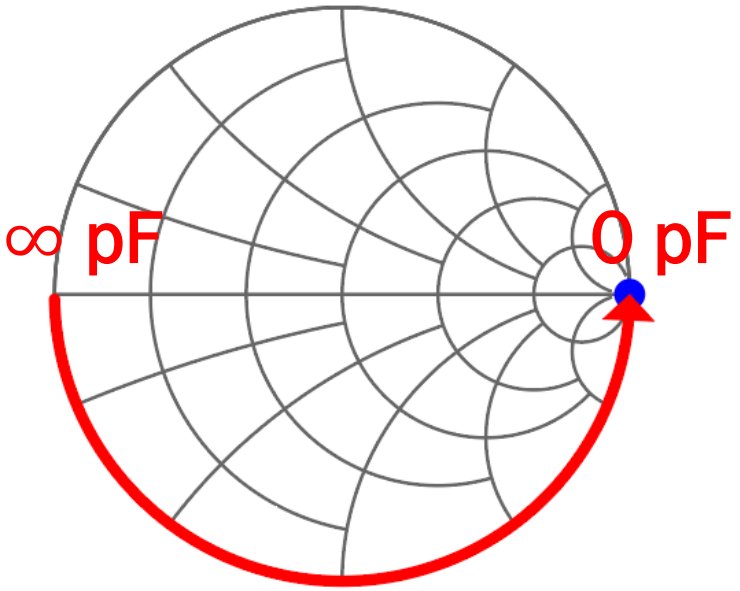


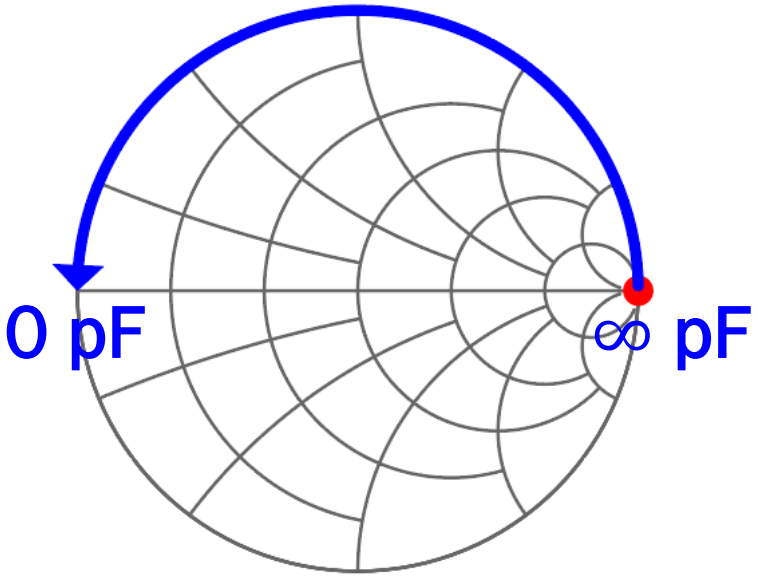
[RTPS]

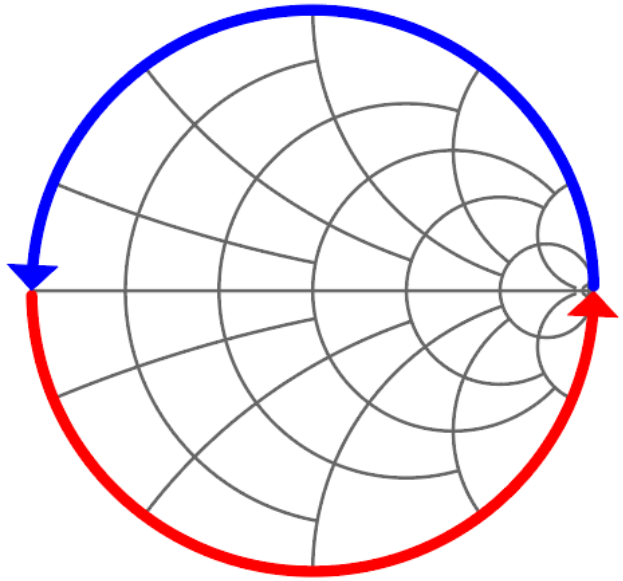
Resolution ☺
Linearity ☺

Need for Two Variable Capacitor

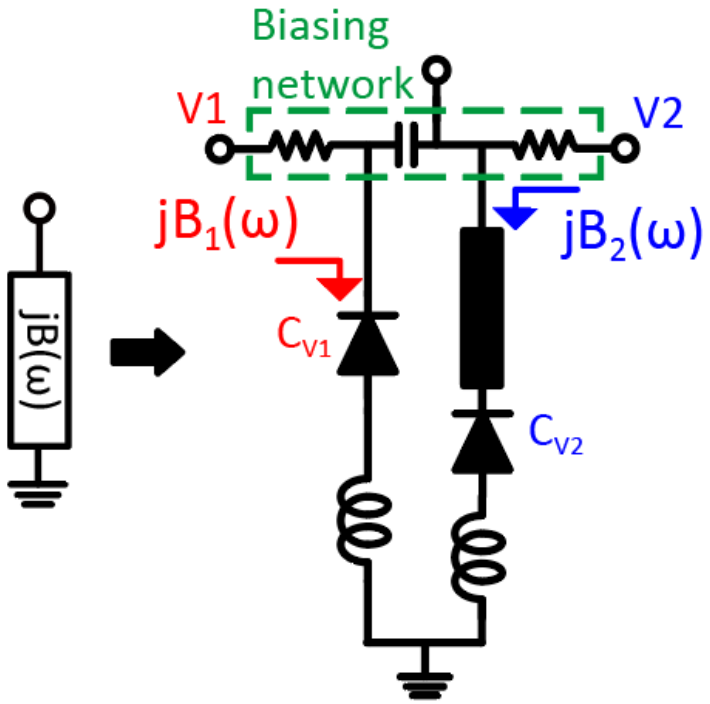




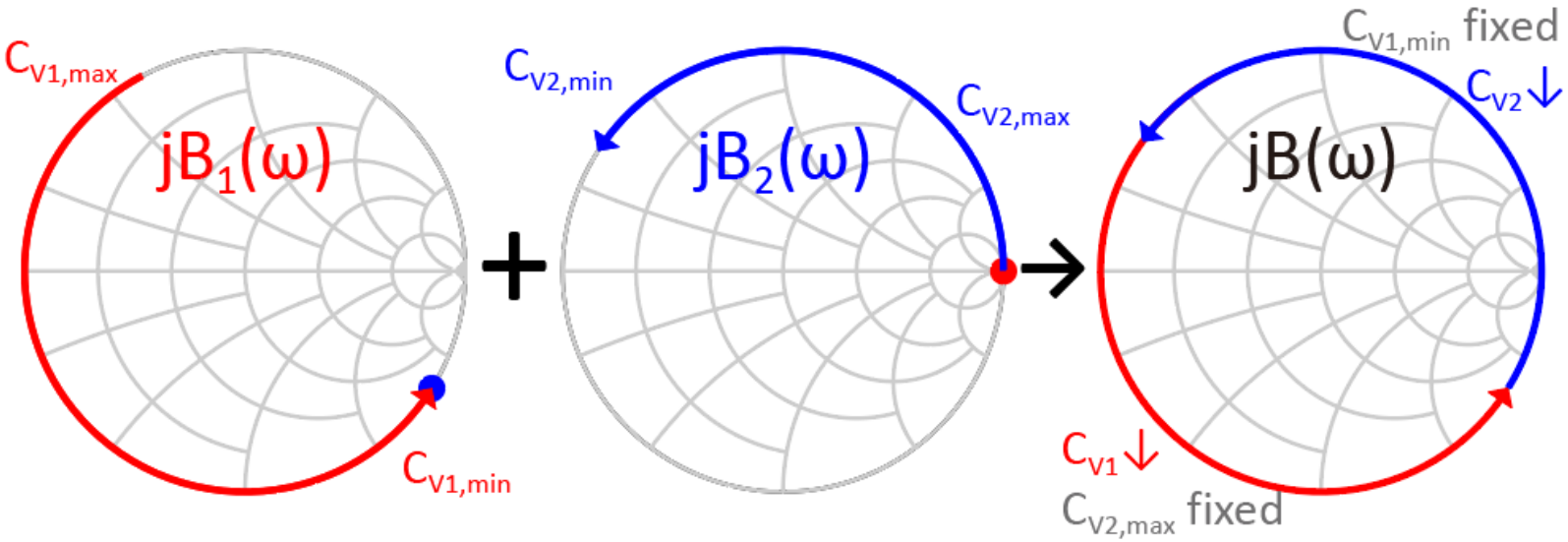




Proposed Reflective Loads

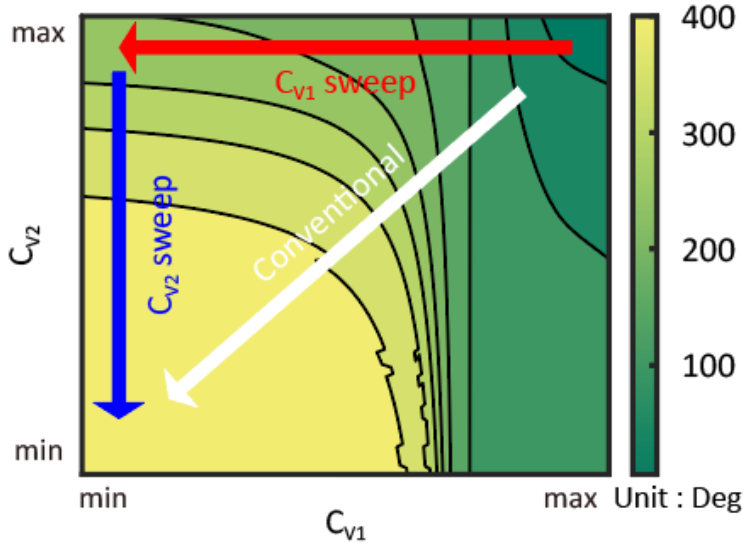


[Reflective load]

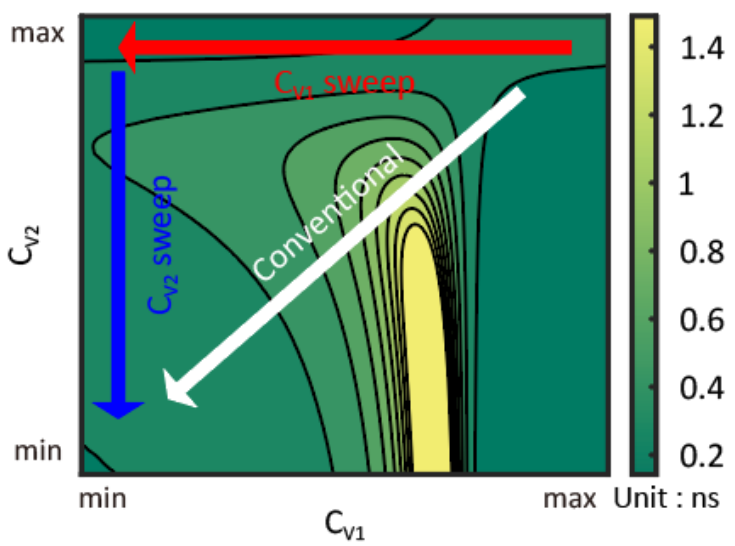


[360° Full Coverage]

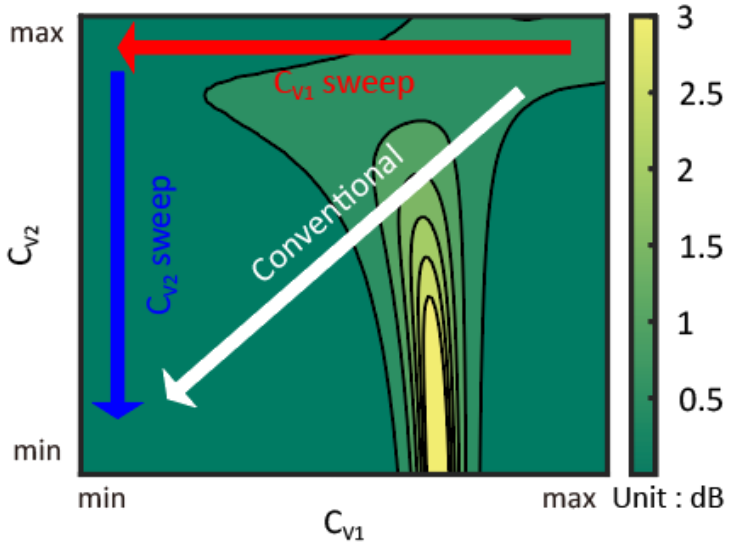
Bias Control Scheme



[Phase Contour]



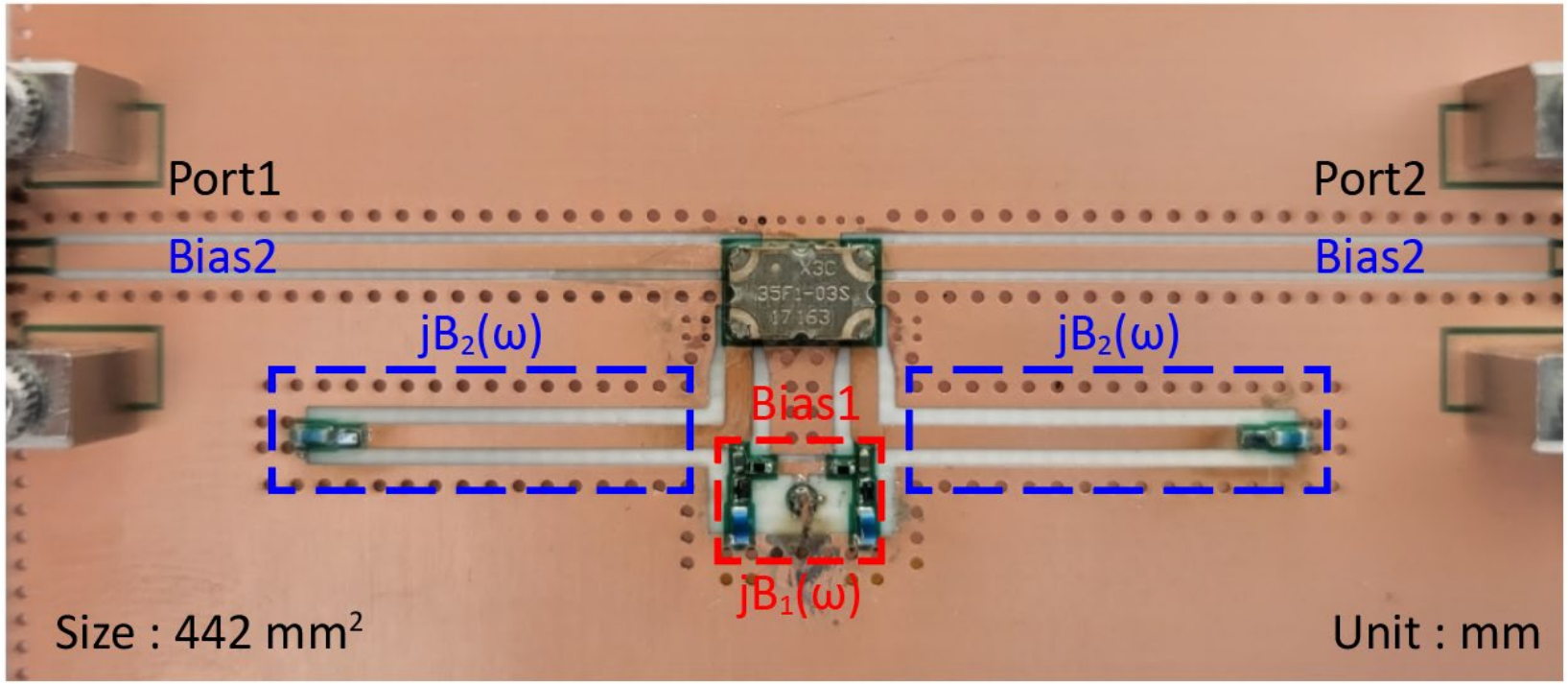
[Delay Contour]



[Loss Contour]

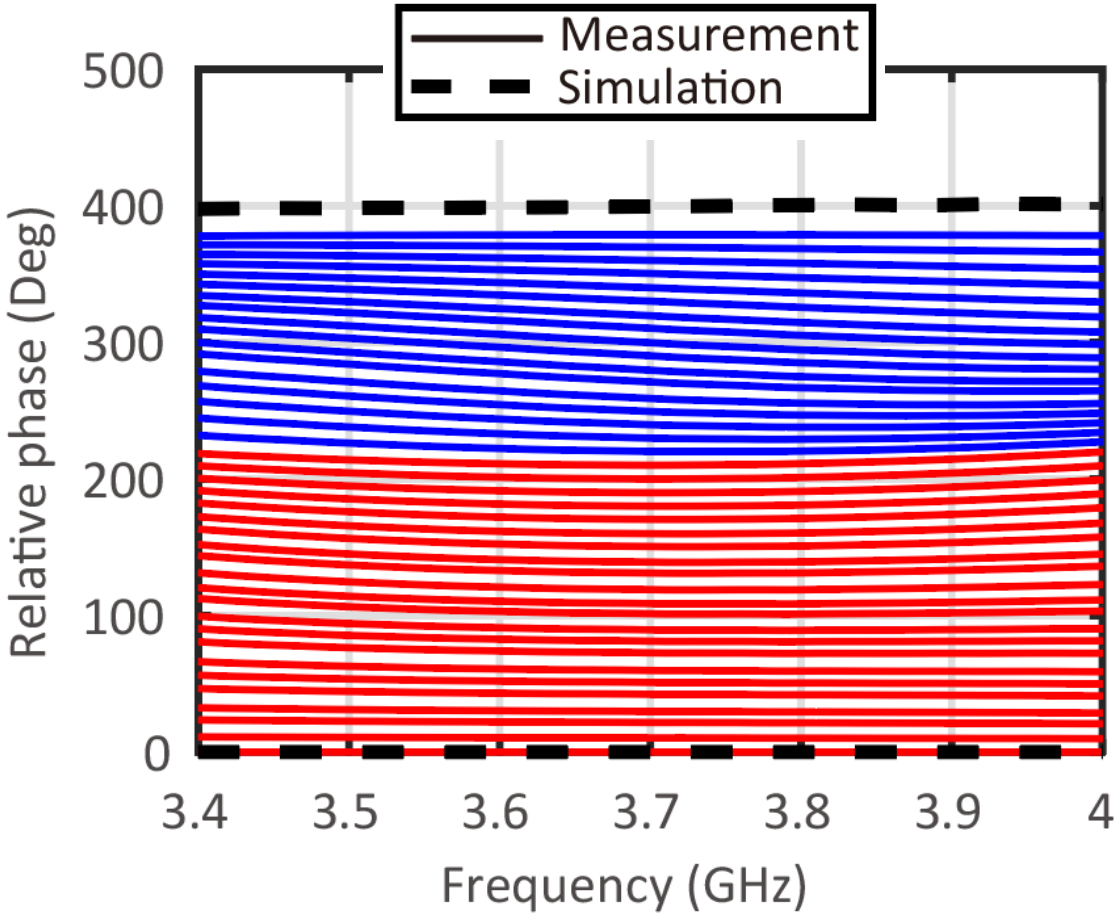
Sequentially control method can avoid delay and loss peak point

Proposed RTPS

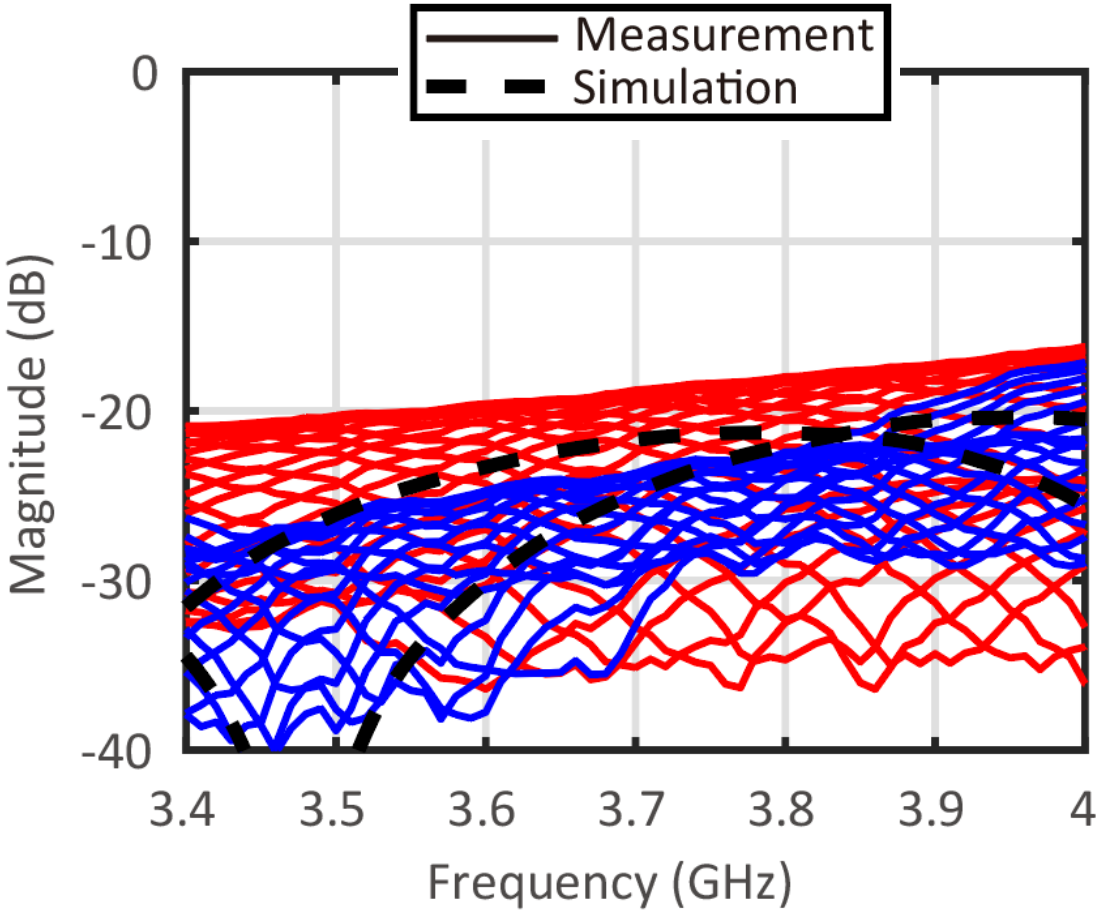


[Photograph of the Manufactured RTPS]

Result

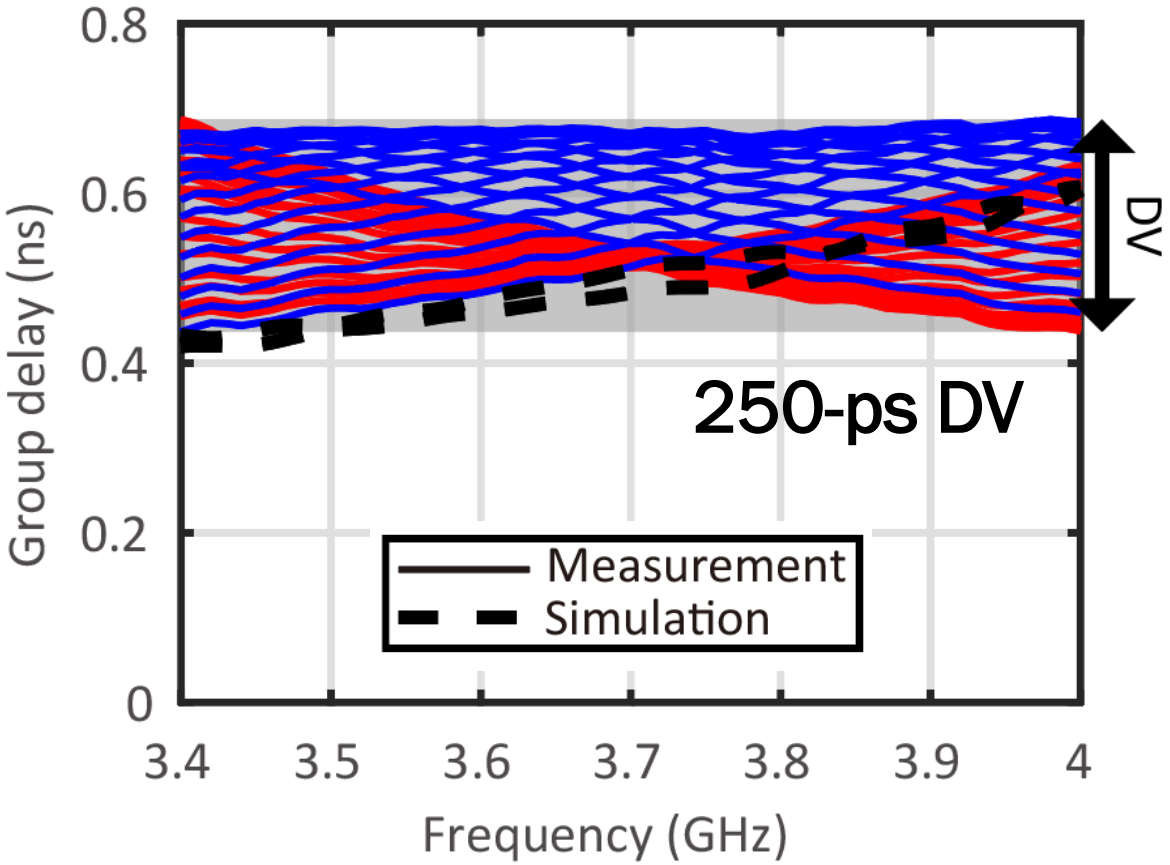


[360° Full Coverage]

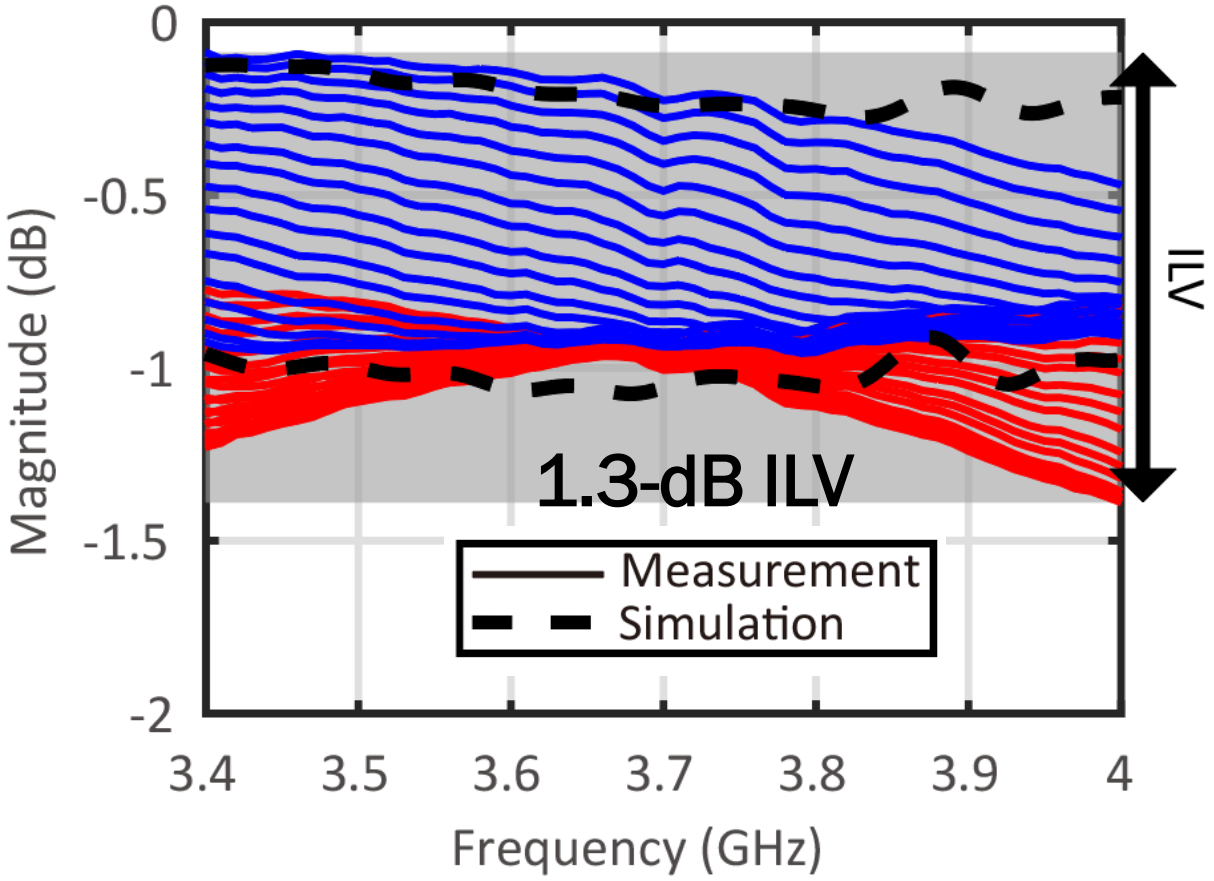


[Well Impedance Matched]

Results



[Low Delay Variation]



[Low Loss Variation]

Figure of Merit

$$FoM = \frac{FBW\ (\%)}{f_c(Hz) \times DV(sec) \times ILV(dB)}$$

- Trade-off relation between FBW and DV, ILV
- DV compared with f_c

$$Phase\ error = f_c(Hz) \times DV(sec)$$

The factors that *actually affect* the system

Performance Comparison

Reference	f_c (GHz)	FBW (%)	DV†† (ns)	ILV (dB)	IL (dB)	FoM (% / λ_c·dB)
Seq. ctrl.†	**3.7**	**16.2**	**0.25, 0.9λ_c**	**1.3**	**0.7**	**13.5**
Conv. ctrl.‡	3.7	16.2	1.32, 4.9λ_c	3.0	1.6	1.1
[2]	4.0	25	0.69, 2.8λ_c	3.1	6.3	2.9
[3]	33	6.9	0.11, 3.8λ_c	4.0	10	0.5
[4]	28	7.1	0.17, 4.7λ_c	0.6	7.8	2.5
[5]	2.0	10	2.48, 5.0λ_c	1.2	1.0	1.7
[6]	10	20	0.83, 8.3λ_c	4.6	2.7	0.5
[7]	2.0	10	2.62, 5.2λ_c	2.2	4.7	0.9
[8]	1.5	66.7	4.08, 6.1λ_c	5.6	3.1	1.9

The Highest Performance

Conclusion

[Condition for Phase Shifter over 600-MHz bandwidth at 3.7 GHz]

1. 360° Full Coverage → 377° phase shift range ☺
2. High Resolution → Continuous resolution ☺
3. High linearity → Use only passive component ☺
4. Low ILV and DV → 250-ps DV and 1.3-dB ILV ☺

Reference

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[2] W. Li, J. Tsai, M. Huang and T. Huang, “A 3.5–4.5-GHz ultra-compact 0.25mm2 reflection-type 360° phase shifter," in IEEE Radio Freq. Integr. Circuits Symp., Baltimore, MD, Jun, 2011, pp. 1-4.

[3] A. Basaligheh, P. Saffari, S. Rasti Boroujeni, I. Filanovsky and K. Moez, “A 28–30 GHz CMOS Reflection-Type Phase Shifter With Full 360° Phase Shift Range," in IEEE Trans. Circuits Syst. II: Express Briefs, vol. 67, no. 11, pp. 2452-2456, Nov. 2020.

[4] R. Garg and A. S. Natarajan, “A 28-GHz Low-Power Phased-Array Receiver Front-End With 360° RTPS Phase Shift Range," in IEEE Trans. Microw. Theory Techn., vol. 65, no. 11, pp. 4703-4714, Nov. 2017.

[5] F. Burdin, Z. Iskandar, F. Podevin and P. Ferrari, “Design of Compact Reflection-Type Phase Shifters With High Figure-of-Merit," in IEEE Trans. Microw. Theory Techn., vol. 63, no. 6, pp. 1883-1893, June 2015.

[6] J. J. P. Venter, T. Stander and P. Ferrari, “X-Band Reflection-Type Phase Shifters Using Coupled-Line Couplers on Single-Layer RF PCB," in IEEE Microw. Wirel. Compon. Lett., vol. 28, no. 9, pp. 807-809, Sept. 2018.

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[9] T.-W. Yoo, J.-H. Song and M.-S. Park, “360° reflection-type analogue phase shifter implemented with a single 90° branch-line coupler,” in Electron. Lett., vol. 33, no. 3, pp. 224-226, Jan. 1997.

Thank you