

WE1F-2

Miniaturized 7-12 GHz 1-to-4 Differential Power Splitter With Low Amplitude/Phase Imbalances Using Broadside-Coupled CPW/SIDGS Scheme and Embedded CPW Spur-Line

Qiqi Luo, Yunbo Rao, Yiyang Shu, and Xun Luo

University of Electronic Science and Technology of China, Chengdu, China

Outline

Motivation & Introduction & Challenges

1-to-4 Differential Power Splitter Design

Measurement and Comparison

Conclusion

Outline

Motivation & Introduction & Challenges

1-to-4 Differential Power Splitter Design

Measurement and Comparison

Conclusion

- Applications

- High date-rate for SATCOM
- Low radiation loss for anti-interference
- Multifunction for miniaturization

- Applications

- High date-rate for SATCOM
- Low radiation loss for anti-interference
- Multifunction for miniaturization



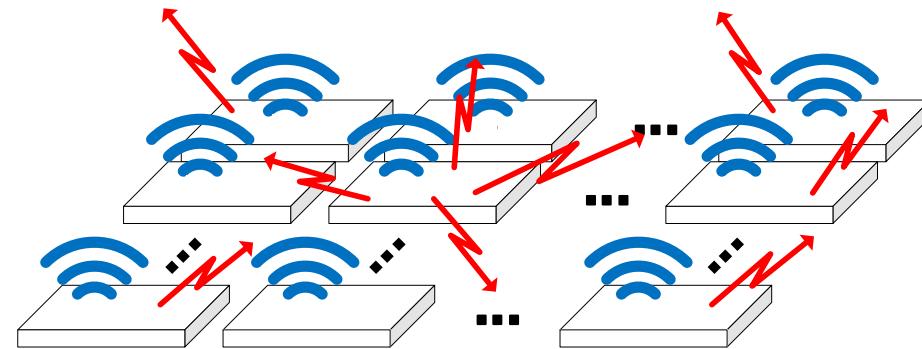
60

- Applications

- High date-rate for SATCOM
- Low radiation loss for anti-interference
- Multi-function for miniaturization



SATCOM



Anti-interference

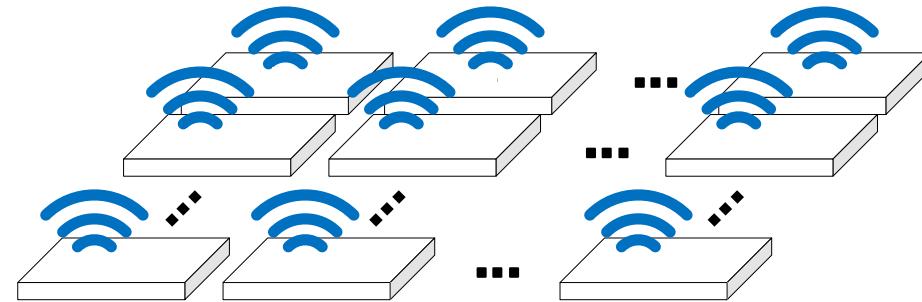
60

- Applications

- High date-rate for SATCOM
- Low radiation loss for anti-interference
- Multi-function for miniaturization



SATCOM



Anti-interference

60

IMS Motivation & Introduction & Challenges

Connecting Minds. Exchanging Ideas.

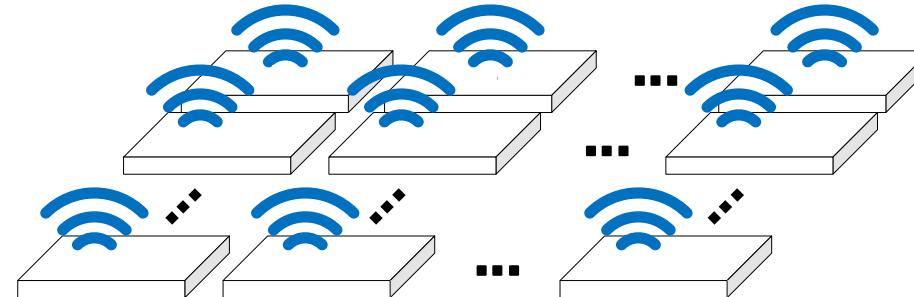


• Applications

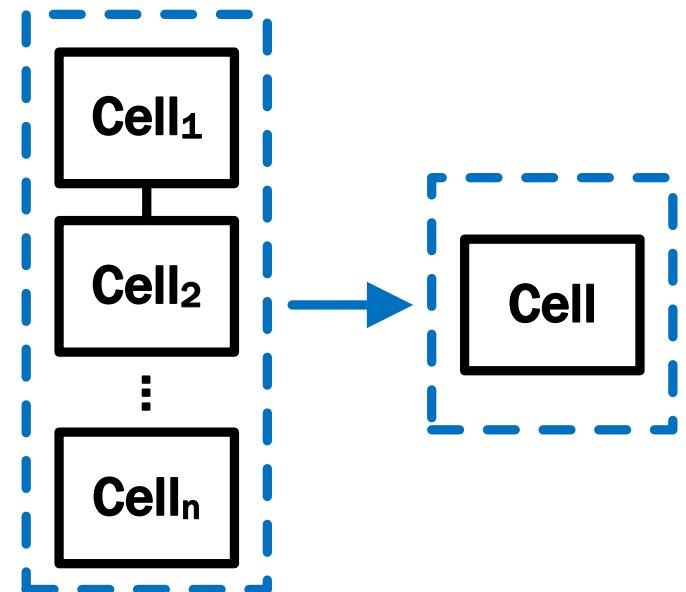
- High date rate for SATCOM
- Low radiation loss for anti-interference
- Multi-function for miniaturization



SATCOM



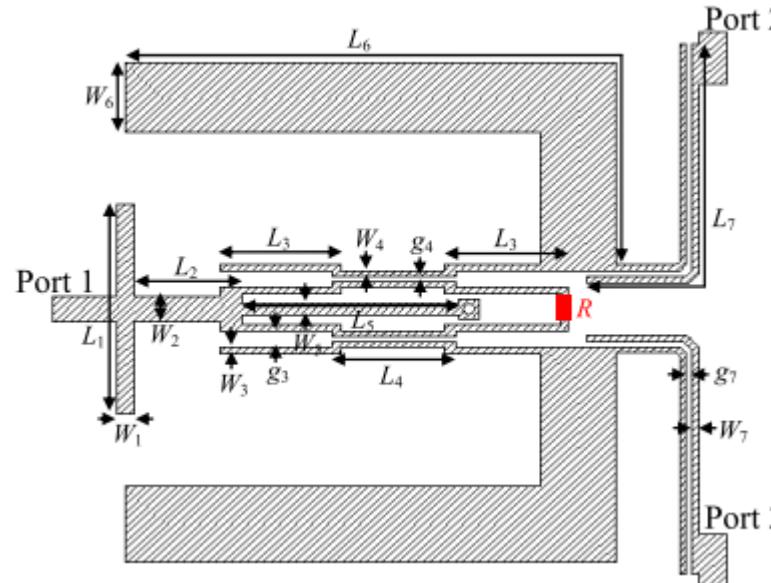
Anti-interference



Miniaturization

- Challenges

- Microstrip power divider^[1]

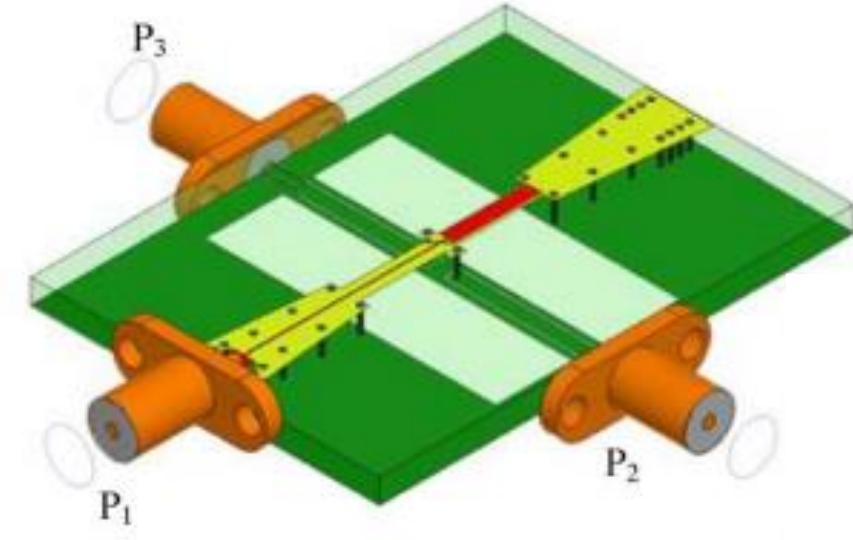


😊 Wide stopband

😢 Relatively large size

😢 High radiation loss

- Microstrip balun^[2]



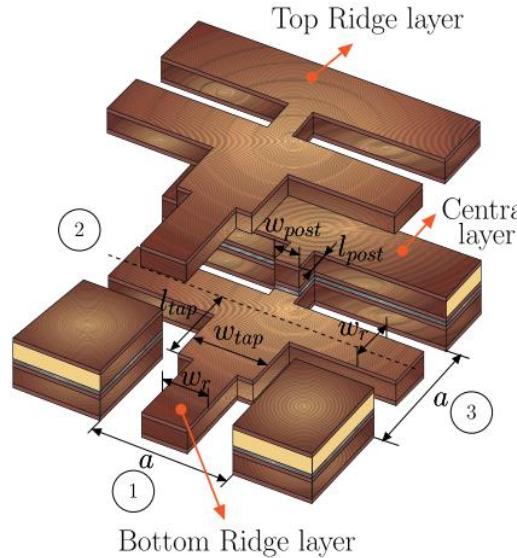
😊 Wide FBW

😢 High phase imbalance

😢 High radiation loss

- Challenges

- SIW power divider^[3]

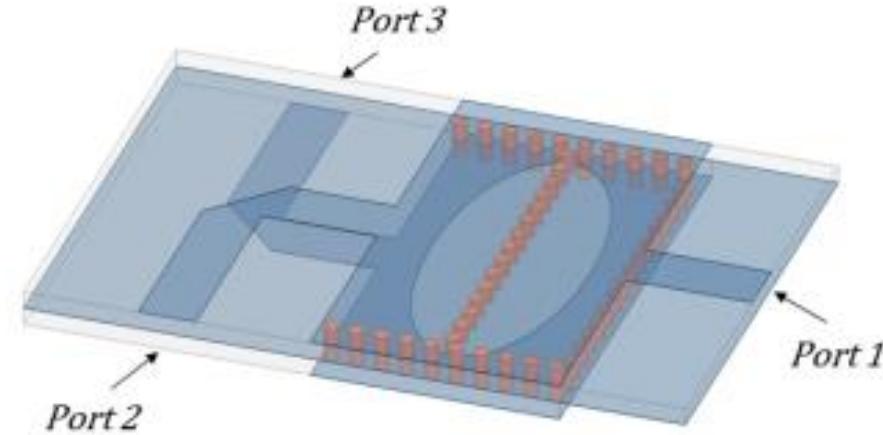


😊 Wide FBW

😐 Medium radiation loss

😢 Narrow stopband

- SIW balun^[4]



😊 Low phase imbalance

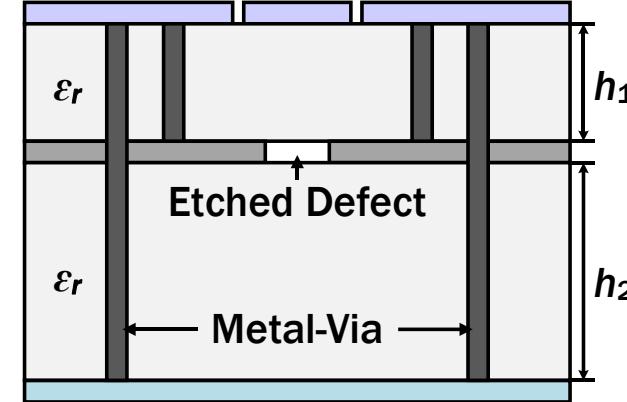
😐 Medium radiation loss

😢 Relatively large size

- Hybrid CPW/SIDGS scheme

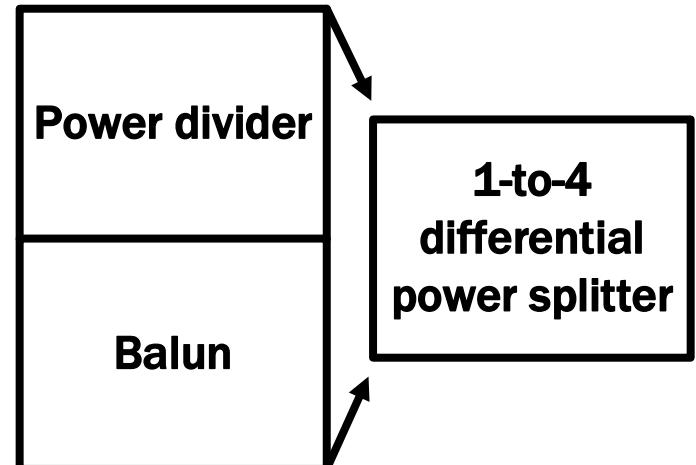
- Miniaturized size
- Wide stopband
- Low radiation loss

■ CPW	■ Ground I
■ Substrate	■ Ground II



- Combine power divider with balun

- Miniaturized size
- Multi-function



Outline

Motivation & Introduction & Challenges

1-to-4 Differential Power Splitter Design

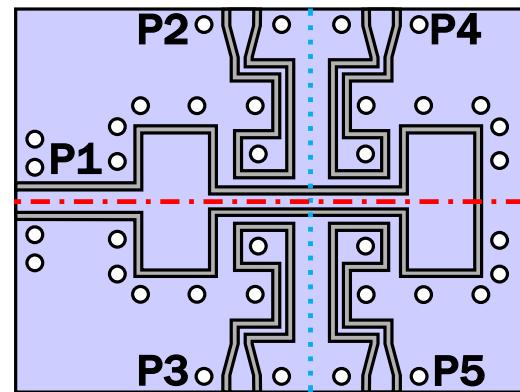
Measurement and Comparison

Conclusion

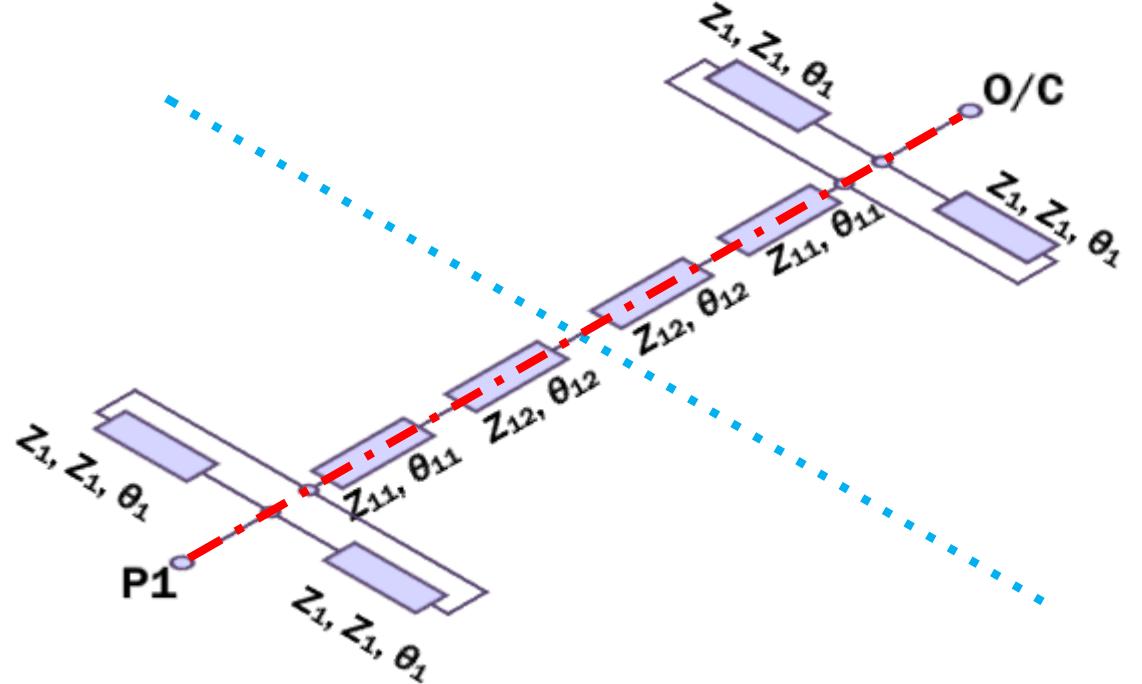
- Transmission-line model

- Transmission-line model
 - CPW resonator

	Top Metal		Symmetrical plane-I (x-axis)
	SIDGS		Symmetrical plane-II (y-axis)



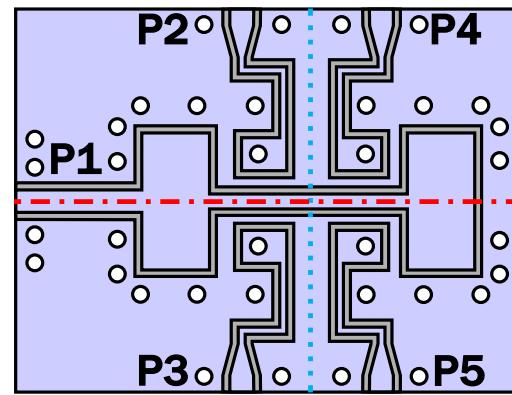
CPW layer



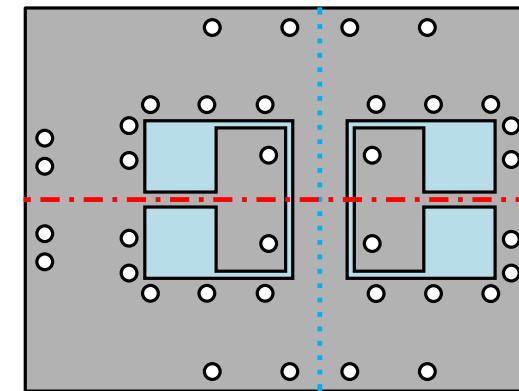
CPW layer transmission-line model

- Transmission-line model

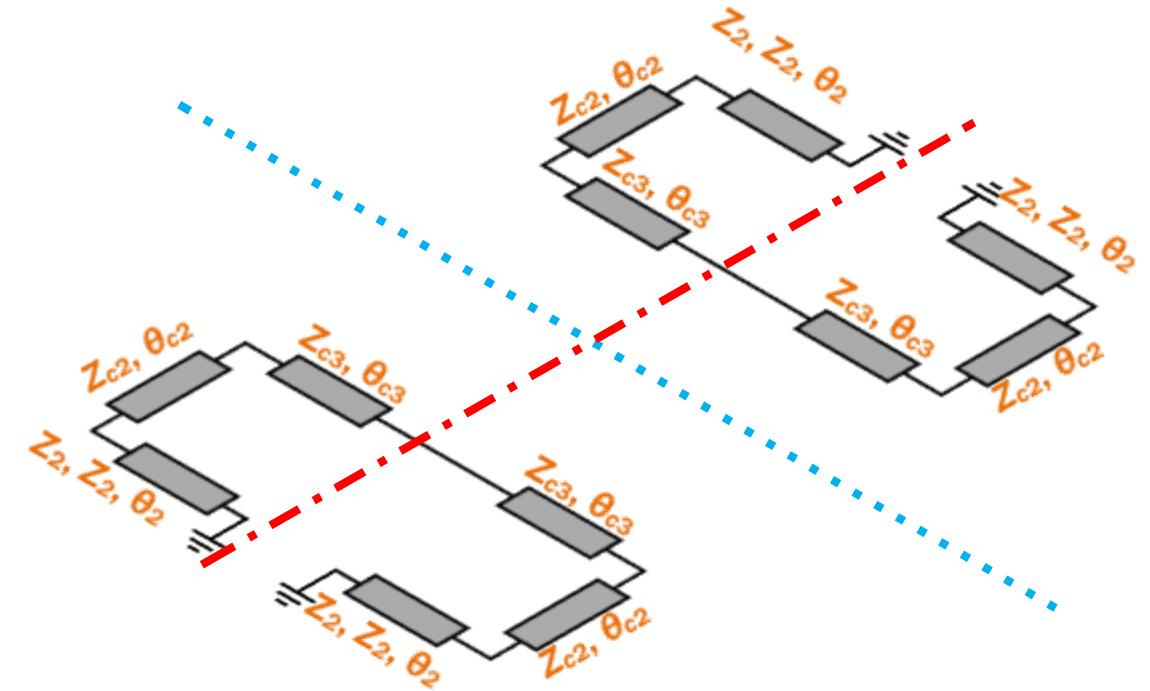
- CPW resonator
- Two SIDGS resonators



CPW layer



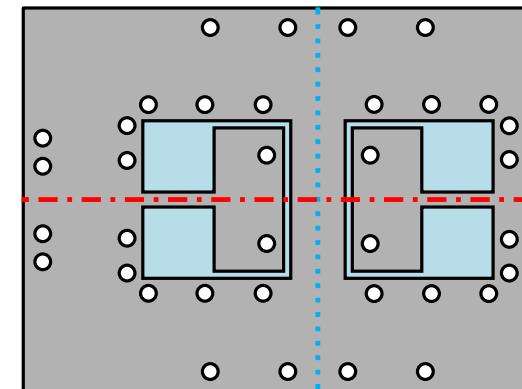
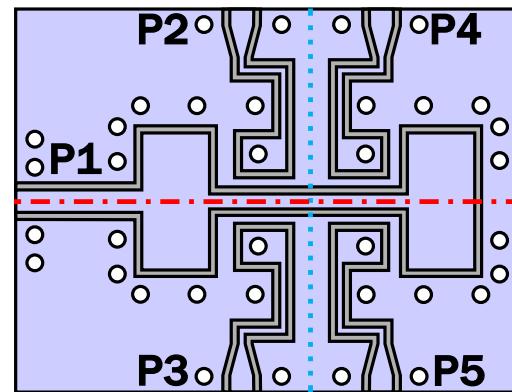
SIDGS layer



SIDGS layer transmission-line model

- Transmission-line model

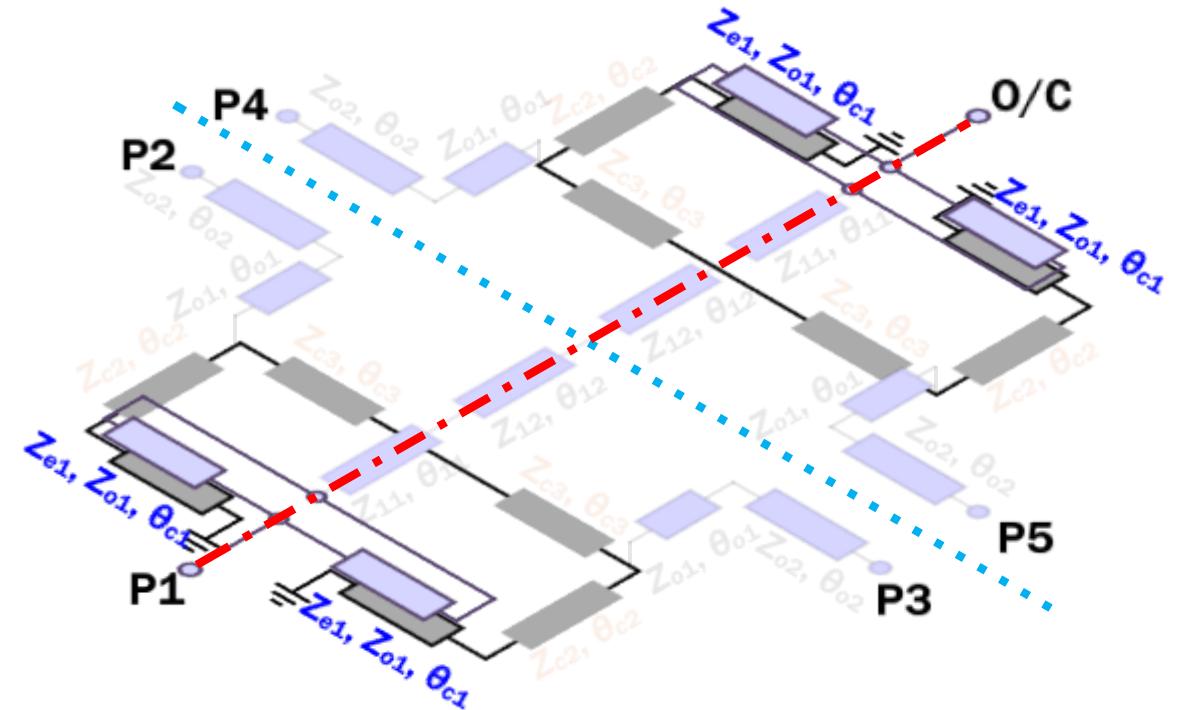
- CPW resonator
- Two SIDGS resonators
- Broadside-coupled



CPW layer

SIDGS layer

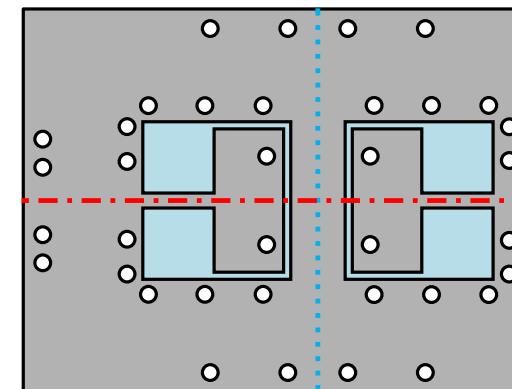
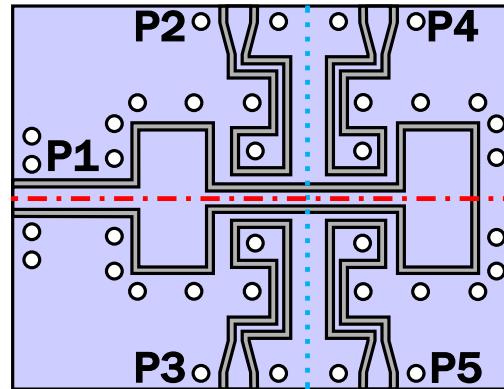
	Top Metal		Symmetrical plane-I (x-axis)
	SIDGS		Symmetrical plane-II (y-axis)



Broadside-coupled

- Transmission-line model

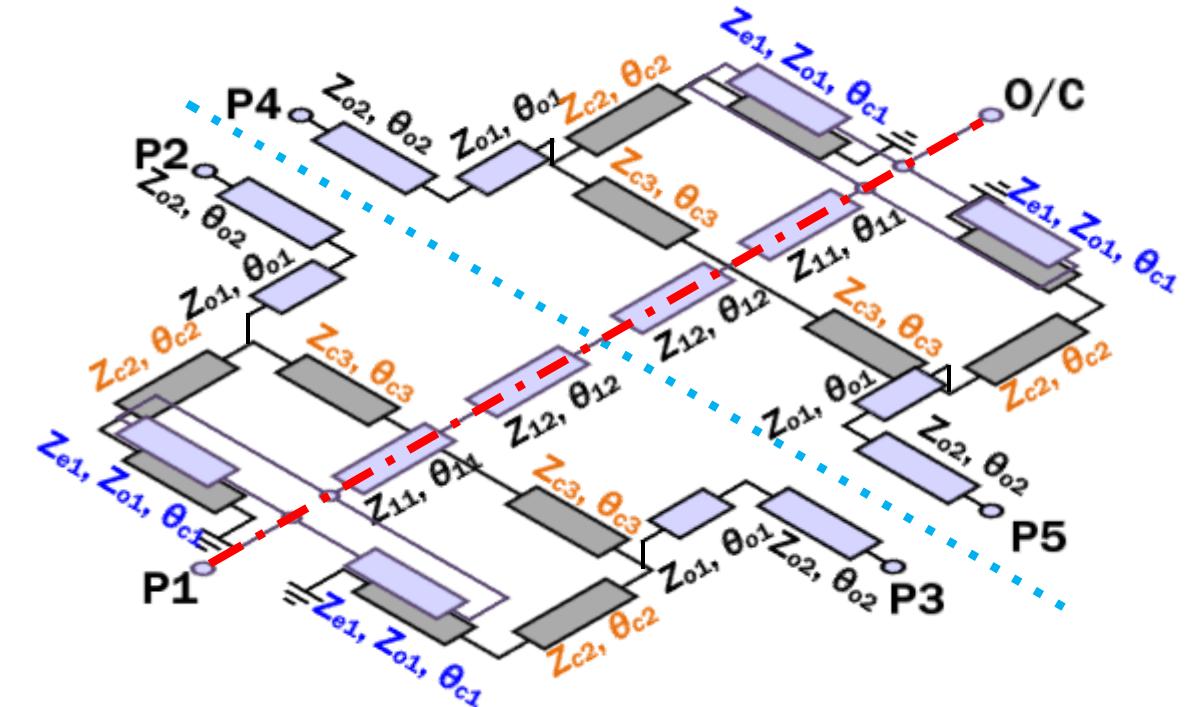
- CPW resonator
- Two SIDGS resonators
- Broadside-coupled
- Hybrid CPW/SIDGS scheme



CPW layer

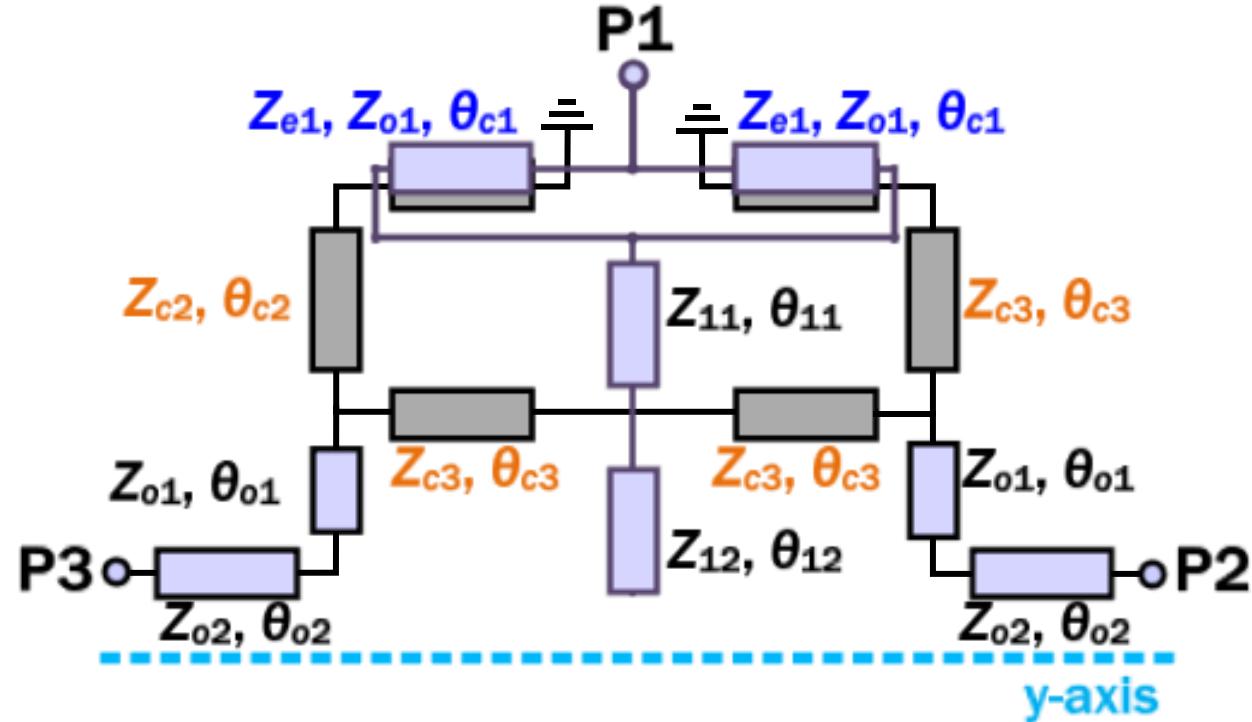
SIDGS layer

	Top Metal		Symmetrical plane-I (x-axis)
	SIDGS		Symmetrical plane-II (y-axis)



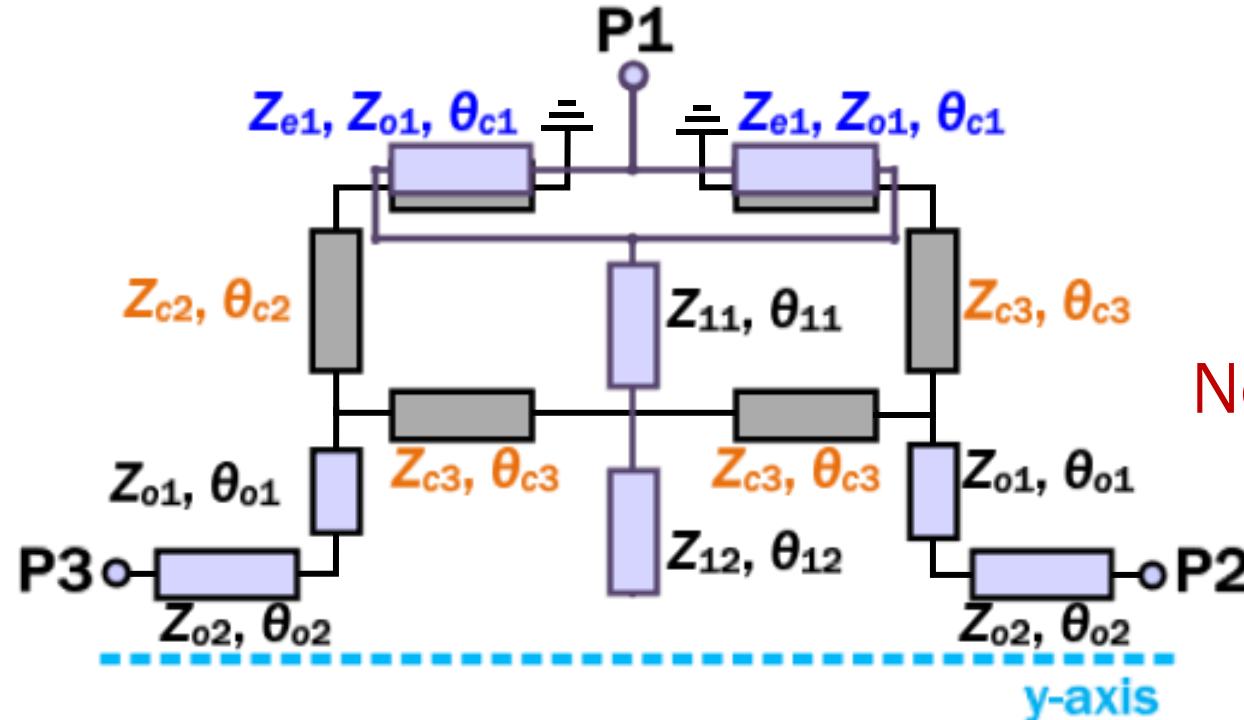
Transmission-line model

- Transmission-line model of 0° power splitter (P2/P3 or P4/P5)
 - Even-mode excitation



Note: P2/P3 are used as example, and P4/P5 are the same.

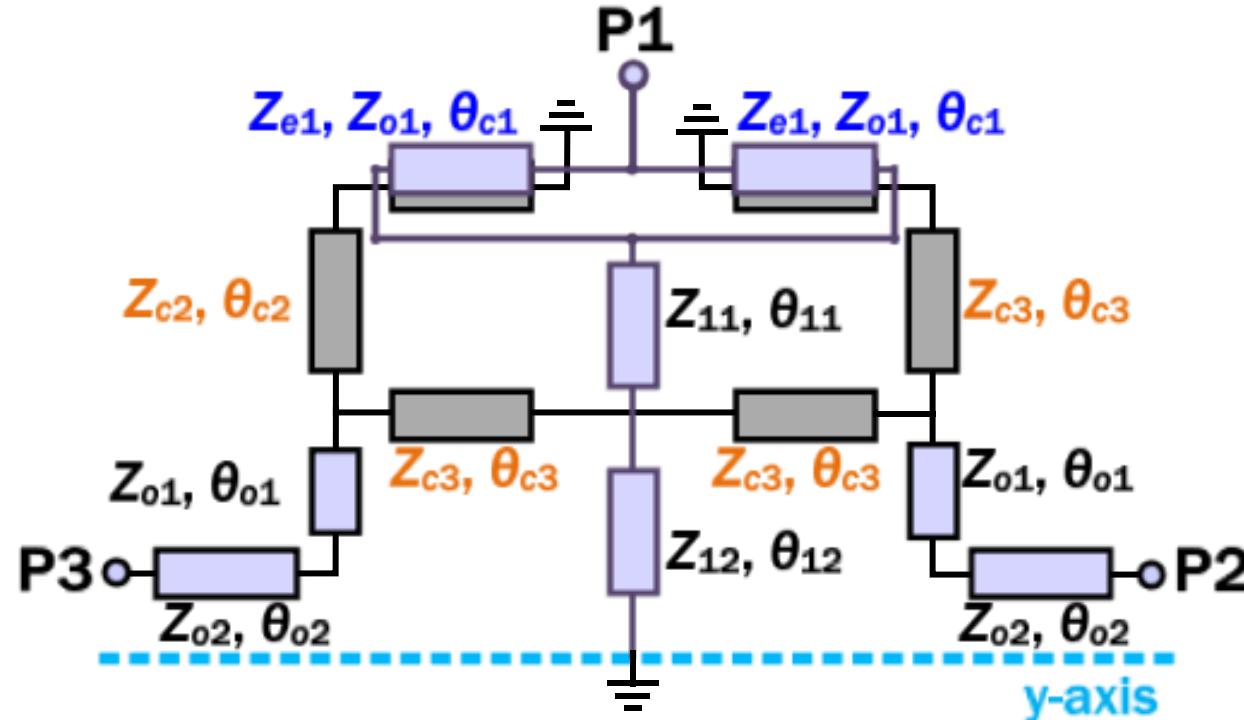
- Transmission-line model of 0° power splitter (P2/P3 or P4/P5)
 - Even-mode excitation



No power transfer from P1 to P2 and P3

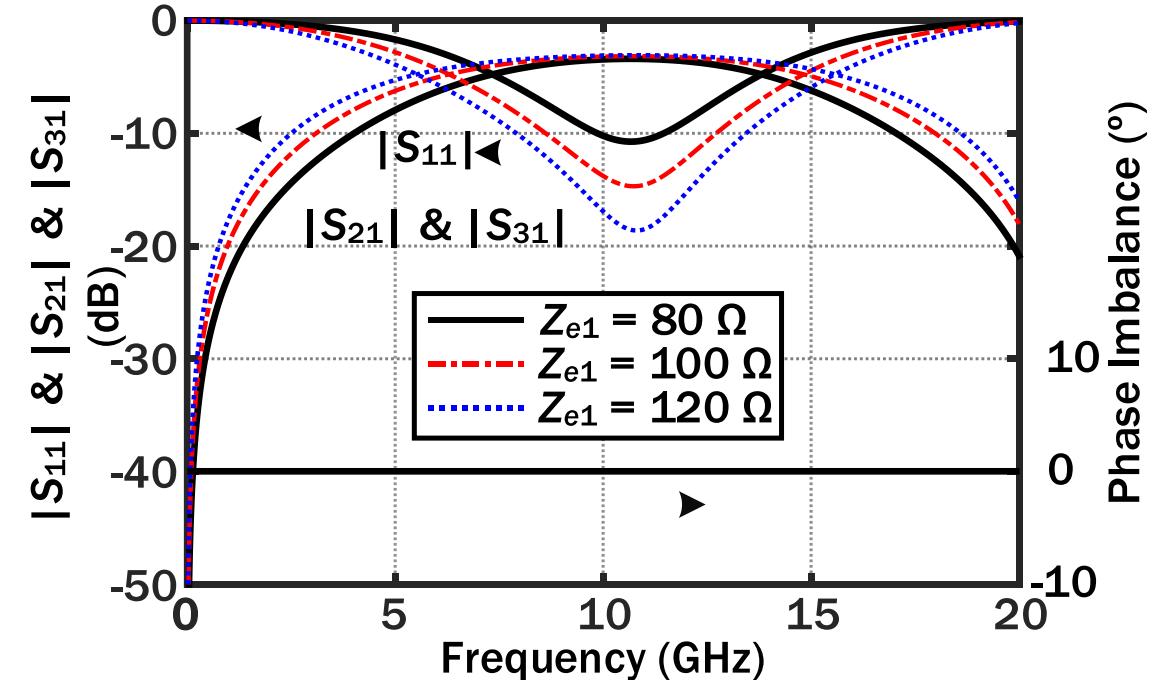
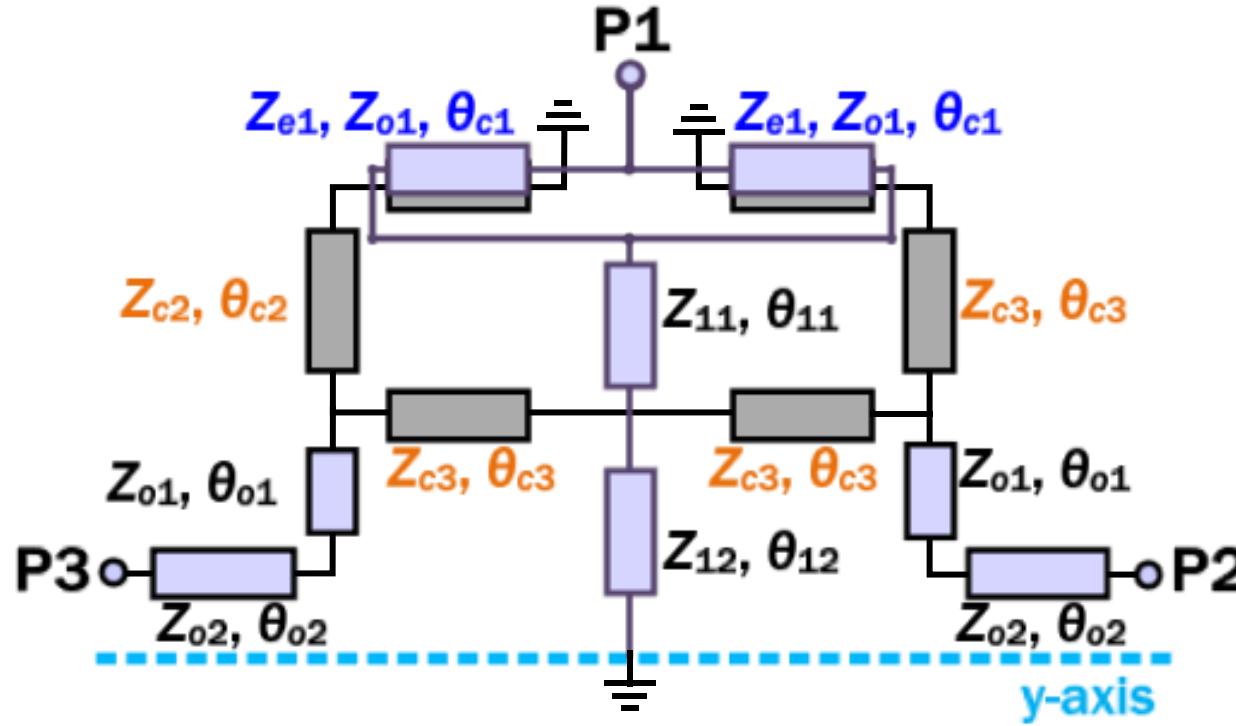
Note: P2/P3 are used as example, and P4/P5 are the same.

- Transmission-line model of 0° power splitter (P2/P3 or P4/P5)
 - Odd-mode excitation



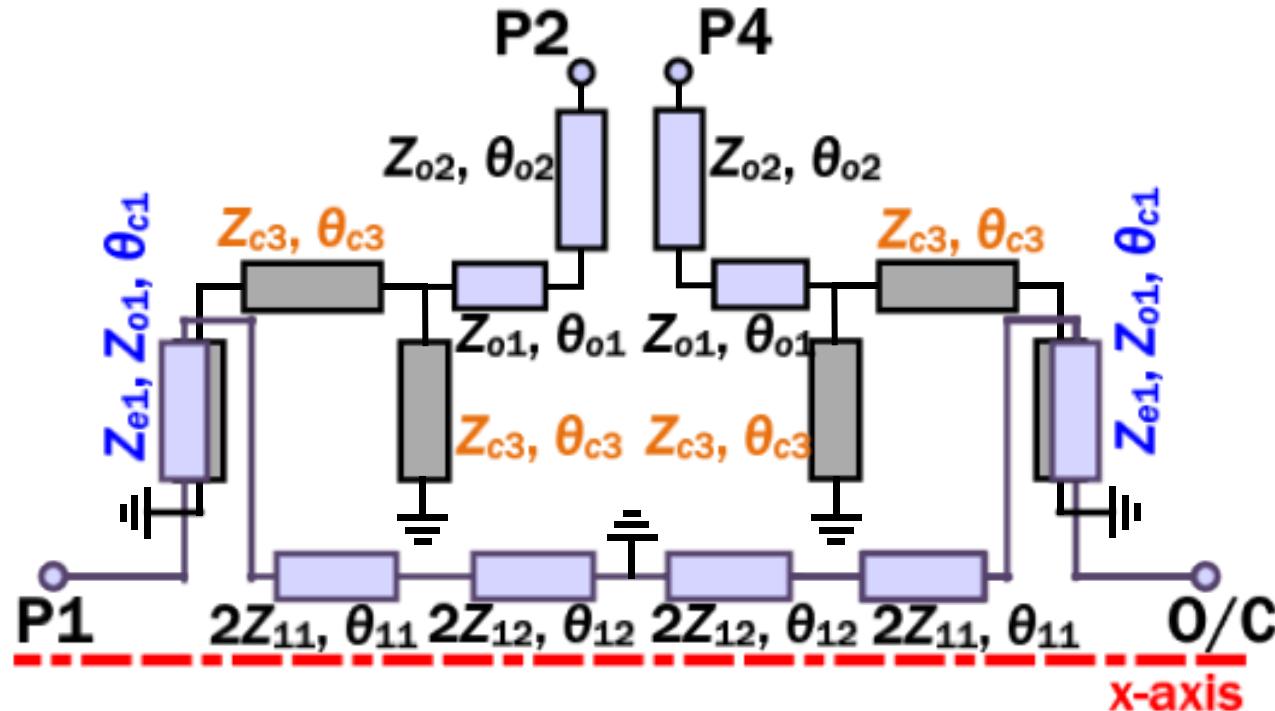
Note: P2/P3 are used as example, and P4/P5 are the same.

- Transmission-line model of 0° power splitter (P2/P3 or P4/P5)
 - Odd-mode excitation



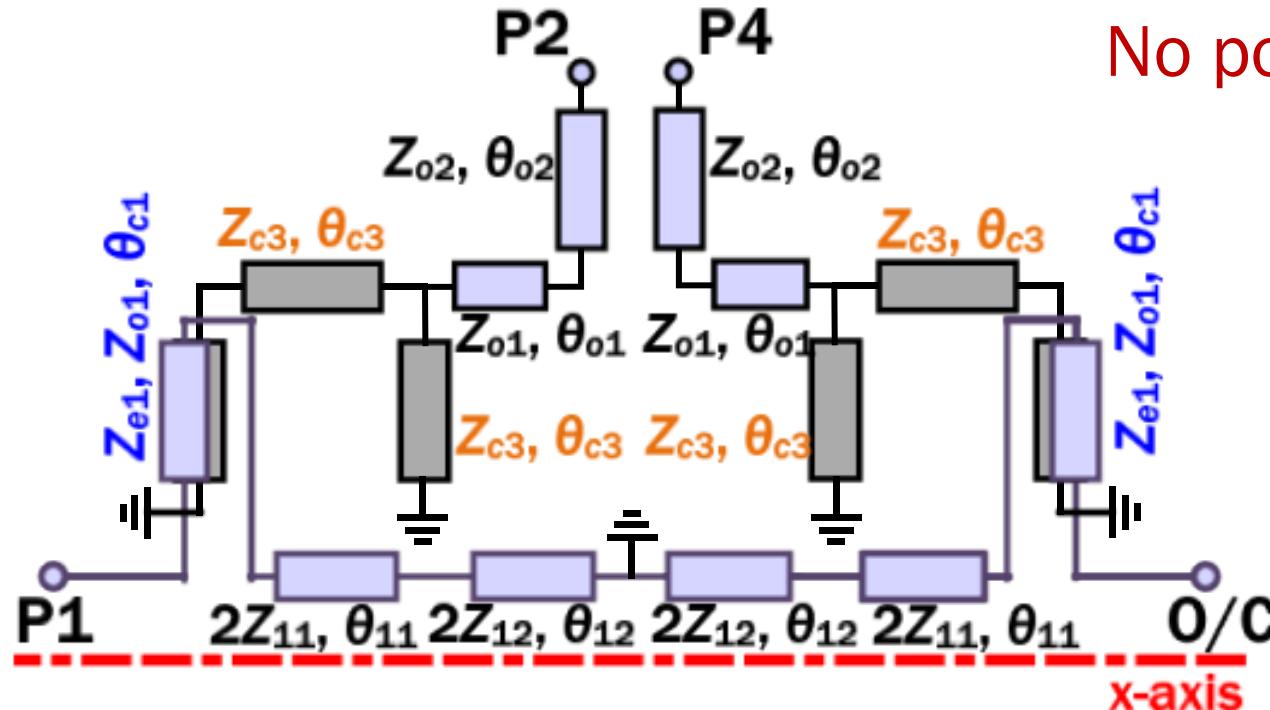
Note: P2/P3 are used as example, and P4/P5 are the same.

- Transmission-line model of 180° power splitter (P2/P4 or P3/P5)
 - Odd-mode excitation



Note: P2/P4 are used as example, and P3/P5 are the same.

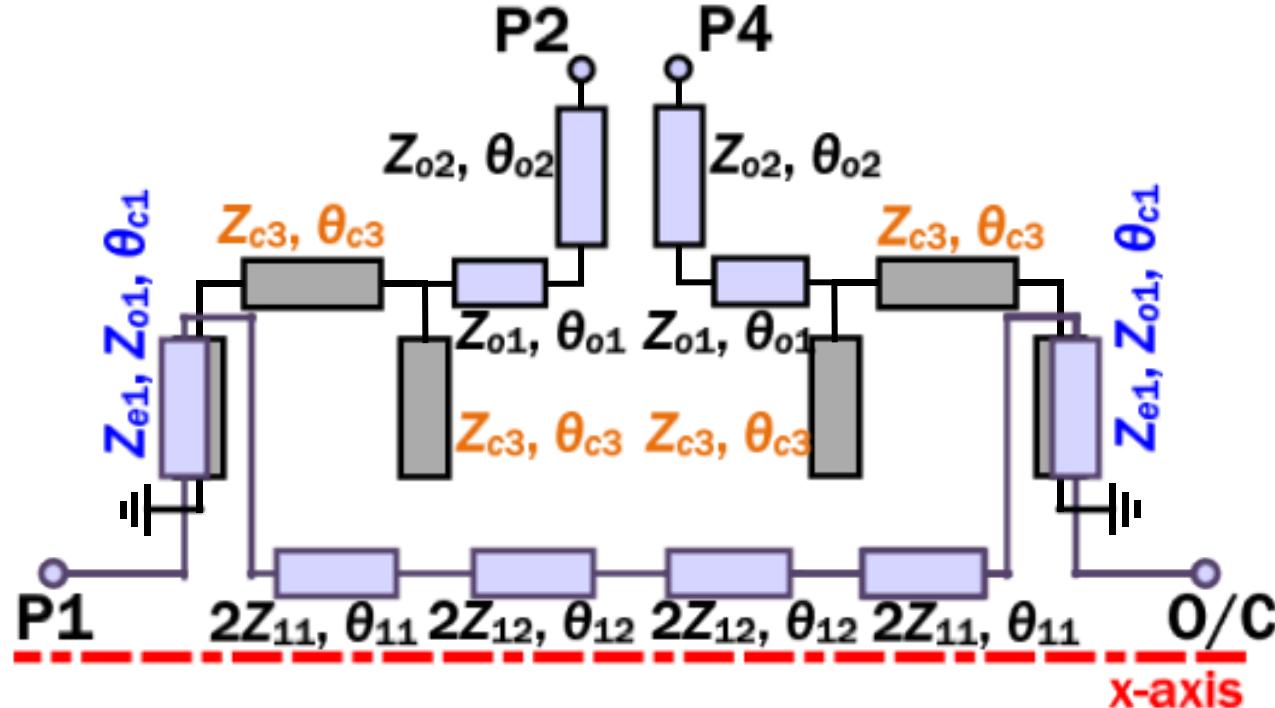
- Transmission-line model of 180° power splitter (P2/P4 or P3/P5)
 - Odd-mode excitation



No power transfer from P1 to P2 and P4

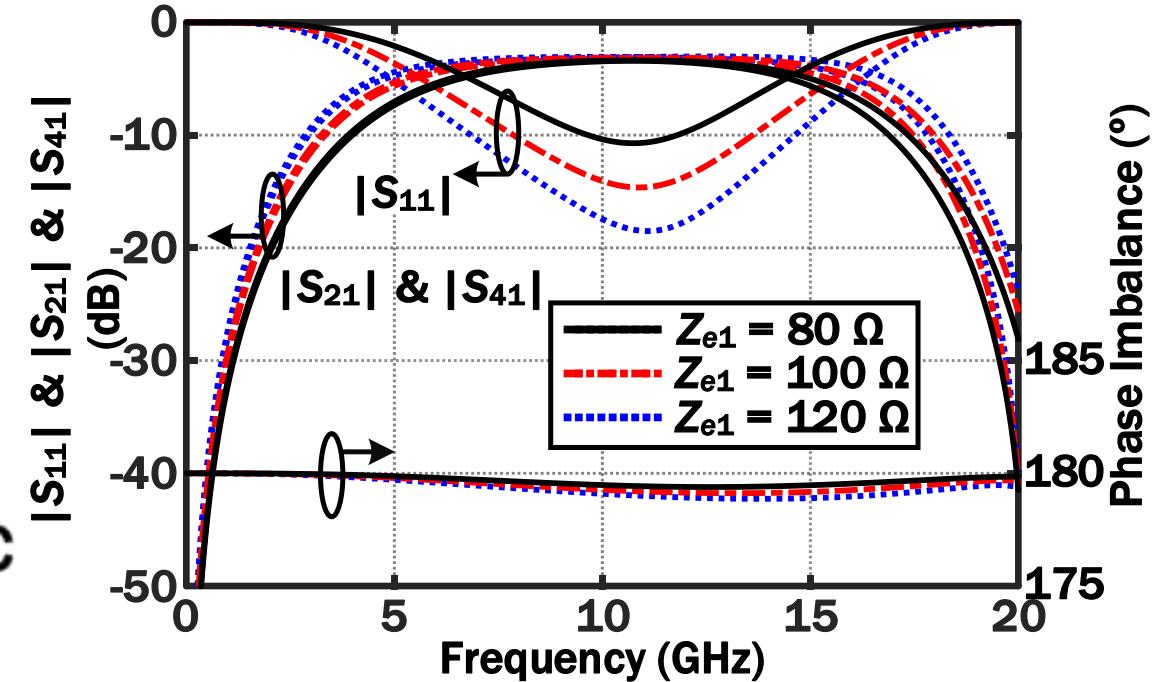
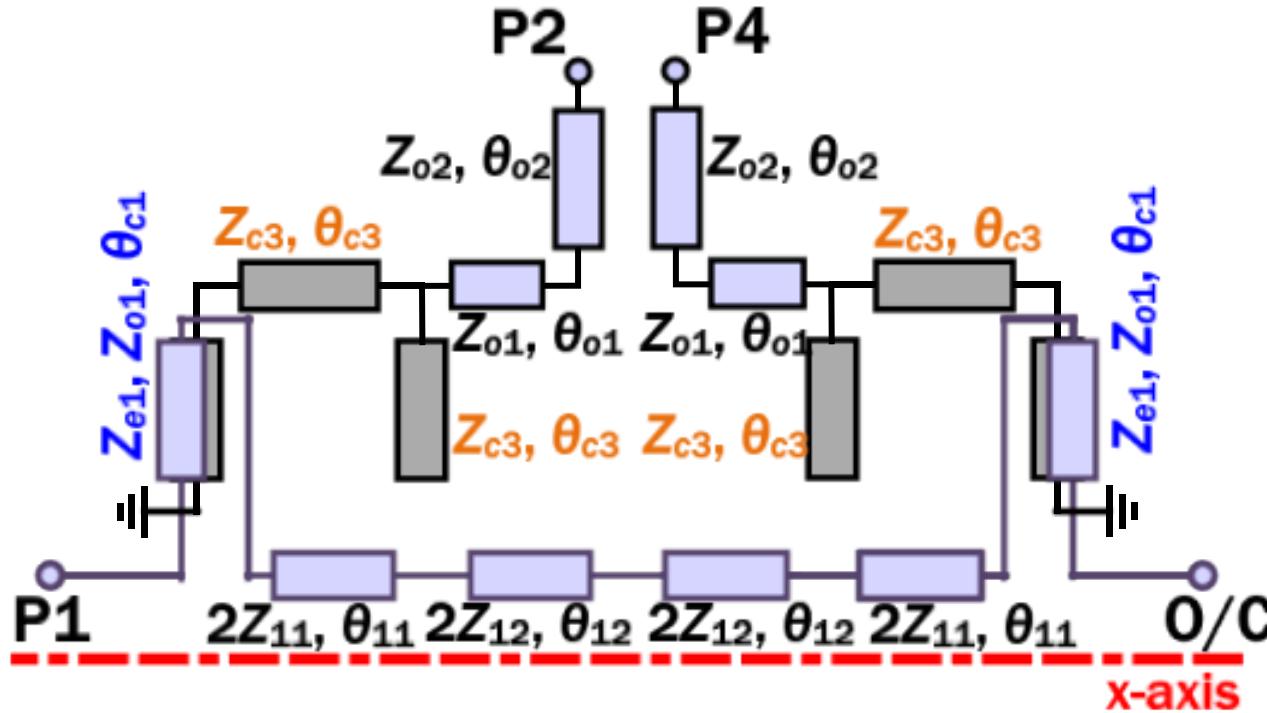
Note: P2/P4 are used as example, and P3/P5 are the same.

- Transmission-line model of 180° power splitter (P2/P4 or P3/P5)
 - Even-mode excitation



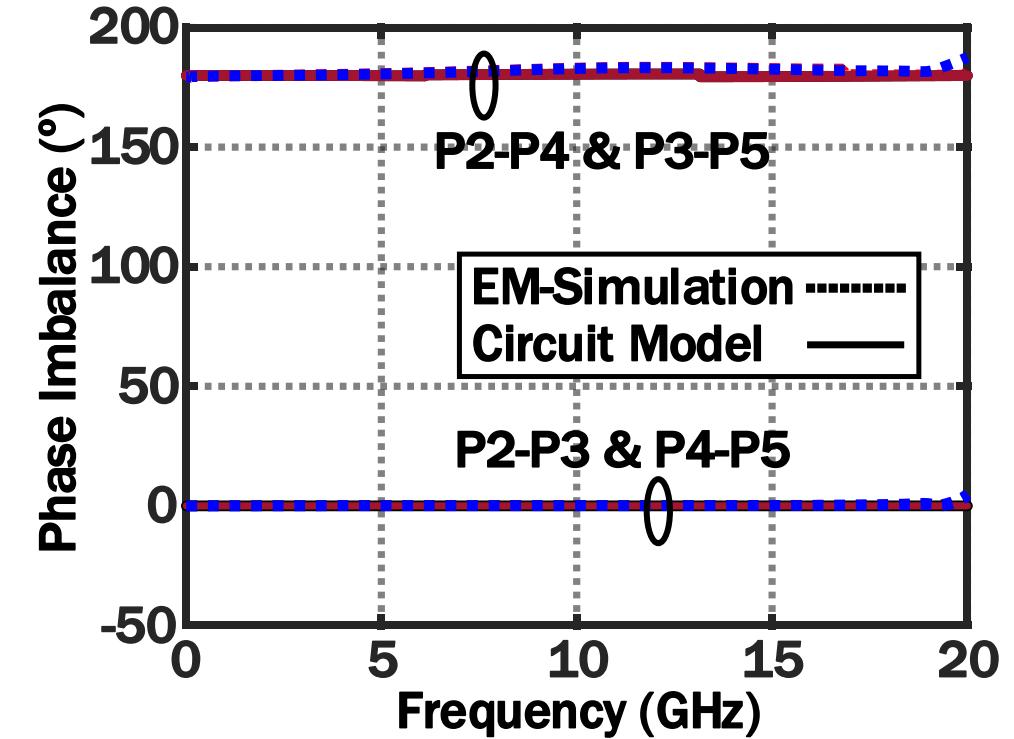
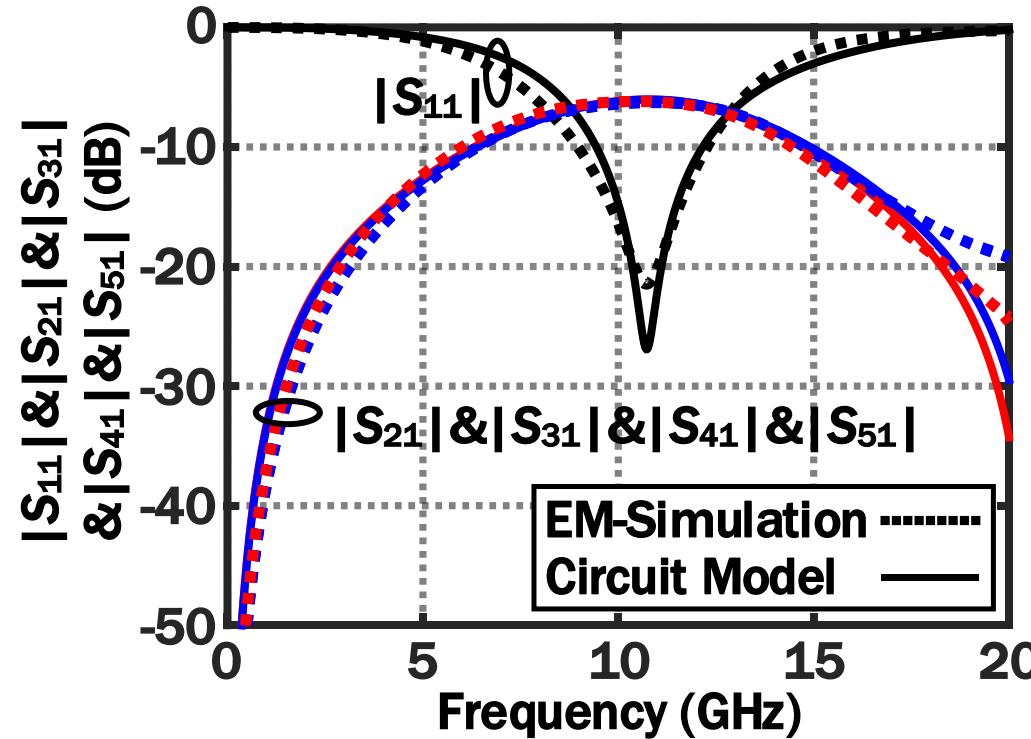
Note: P2/P4 are used as example, and P3/P5 are the same.

- Transmission-line model of 180° power splitter (P2/P4 or P3/P5)
 - Even-mode excitation

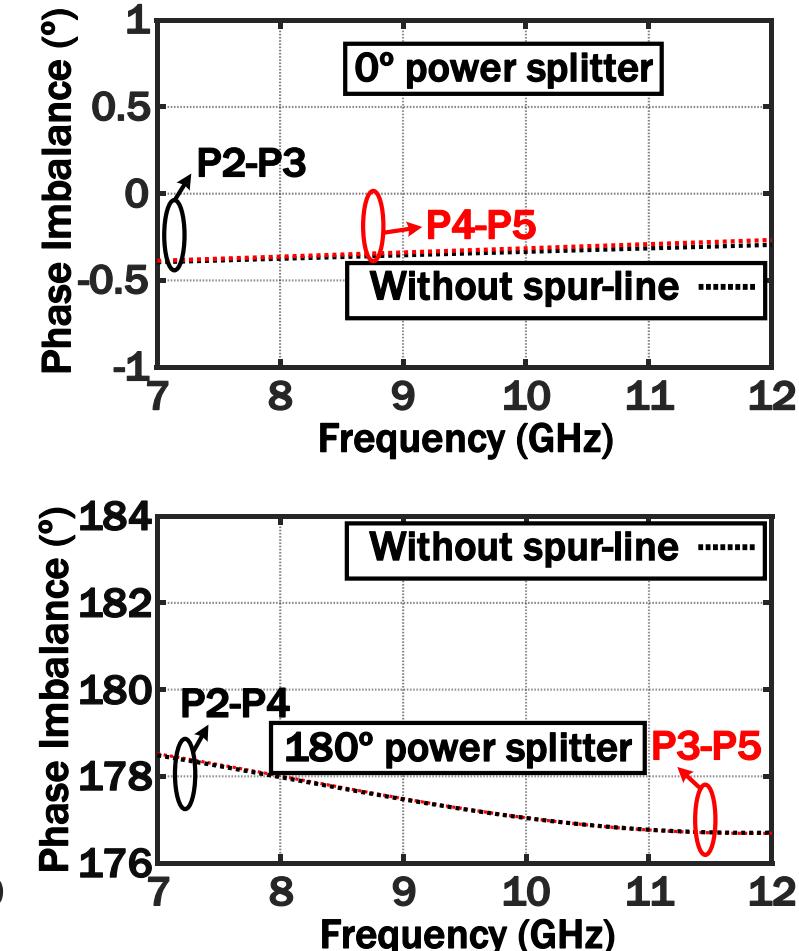
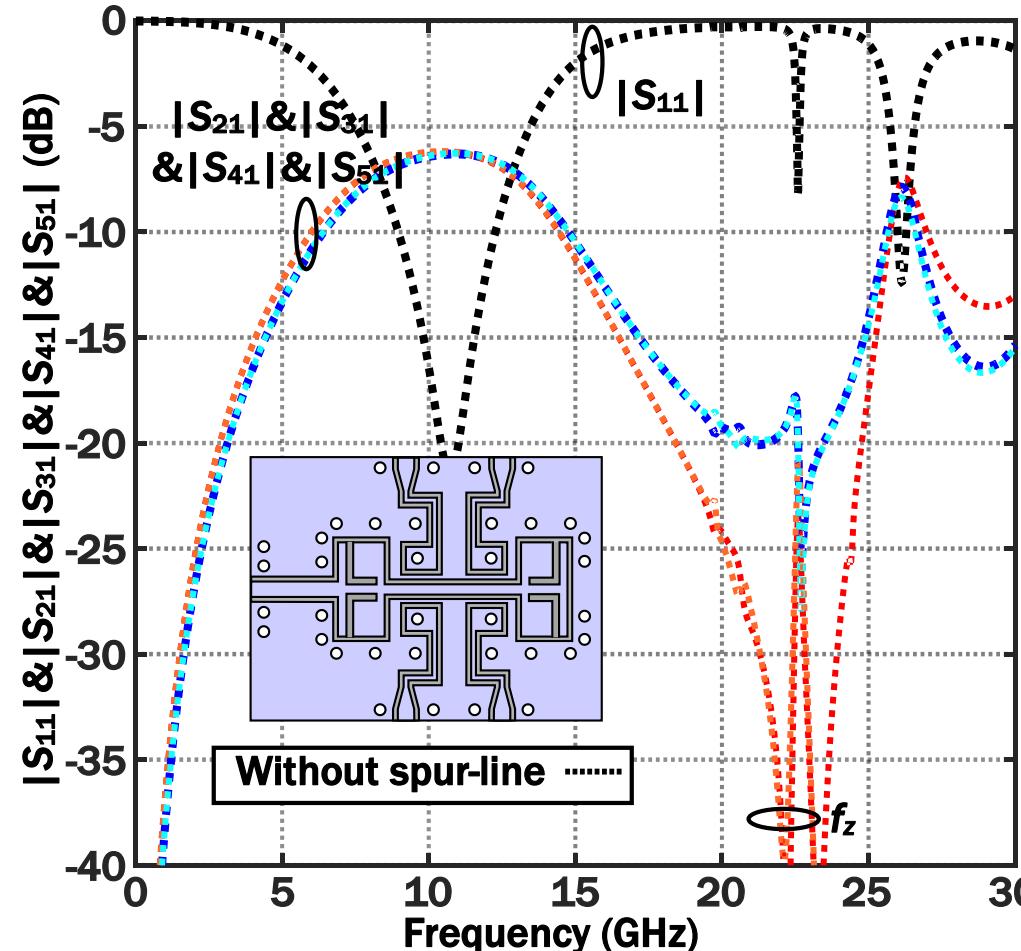


Note: P2/P4 are used as example, and P3/P5 are the same.

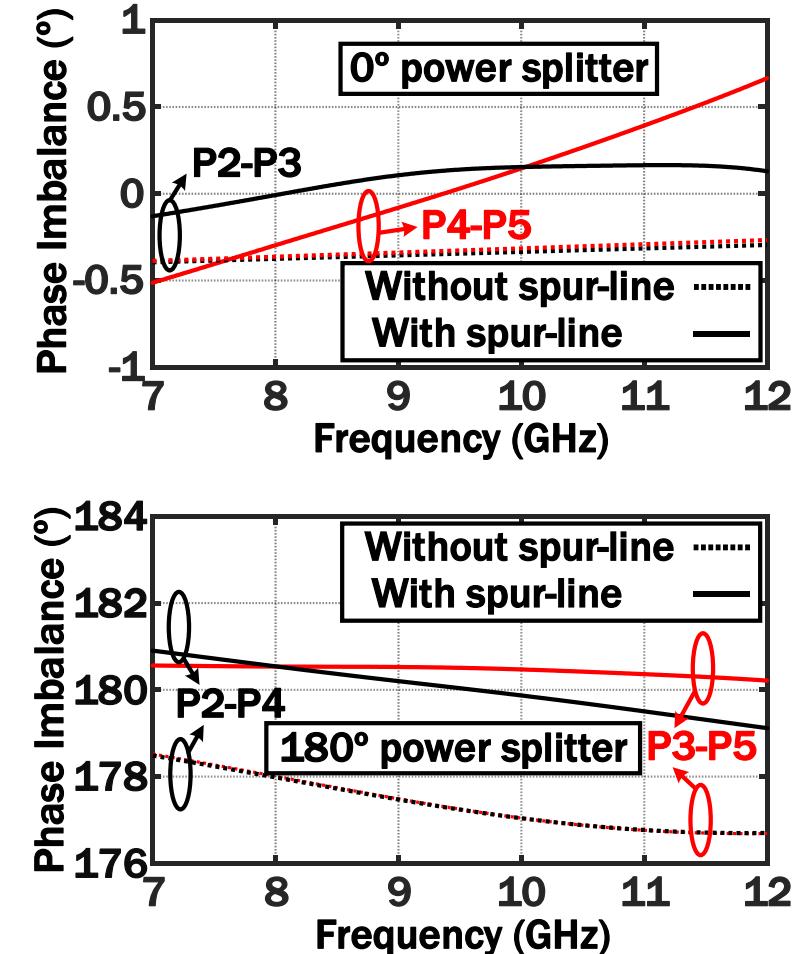
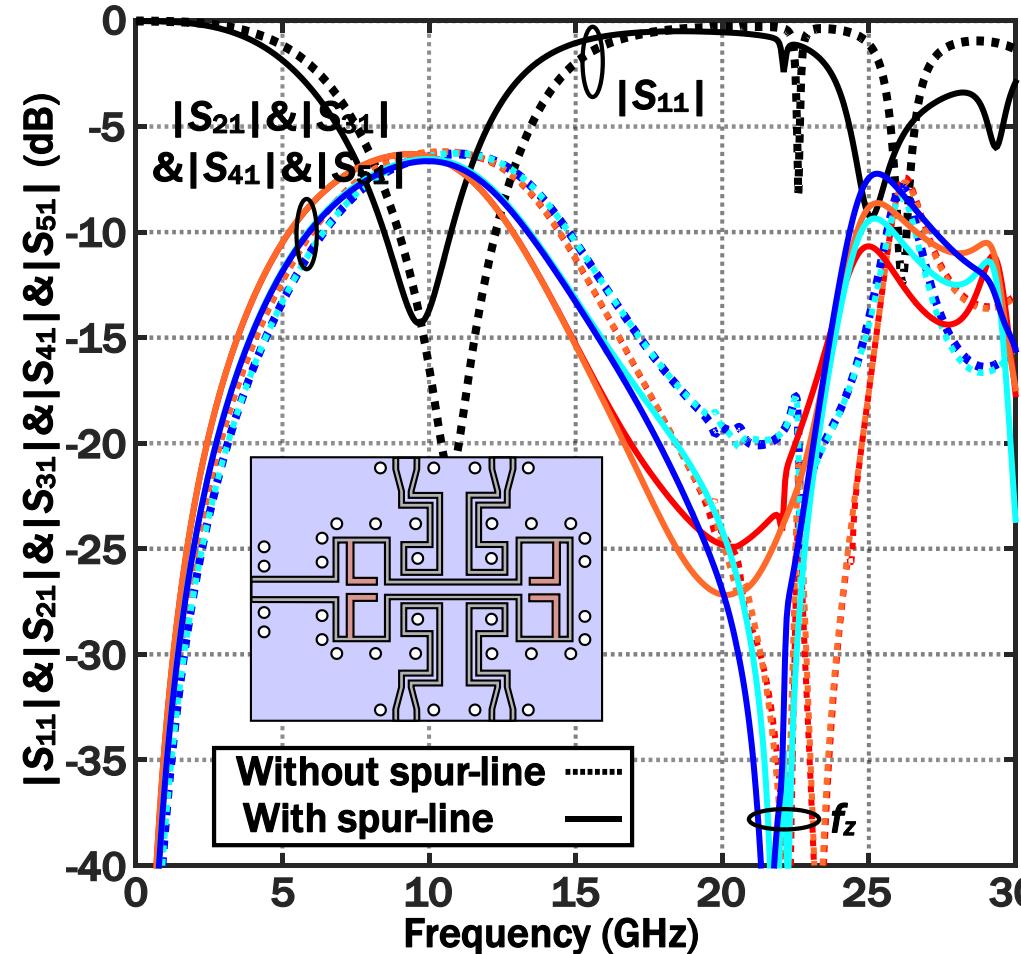
- Frequency response of 1-to-4 differential power splitter
 - S-parameters
 - Phase Imbalance



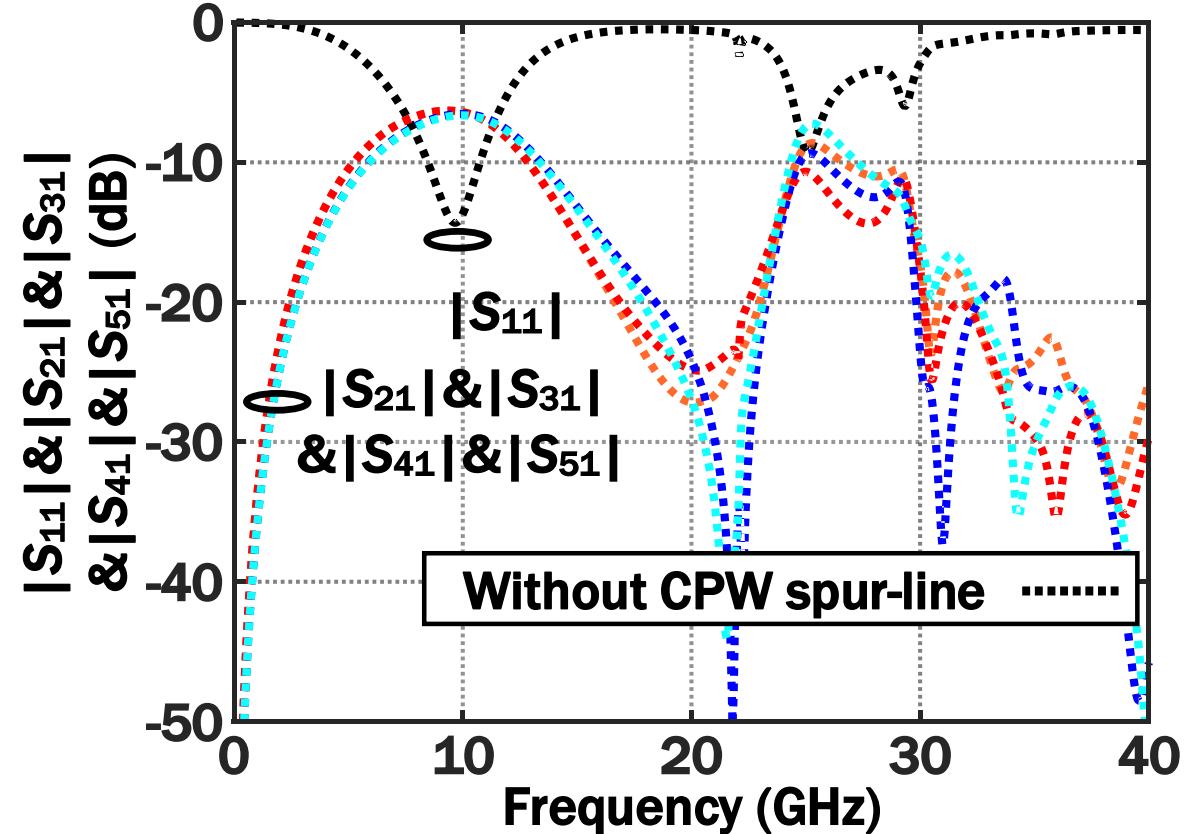
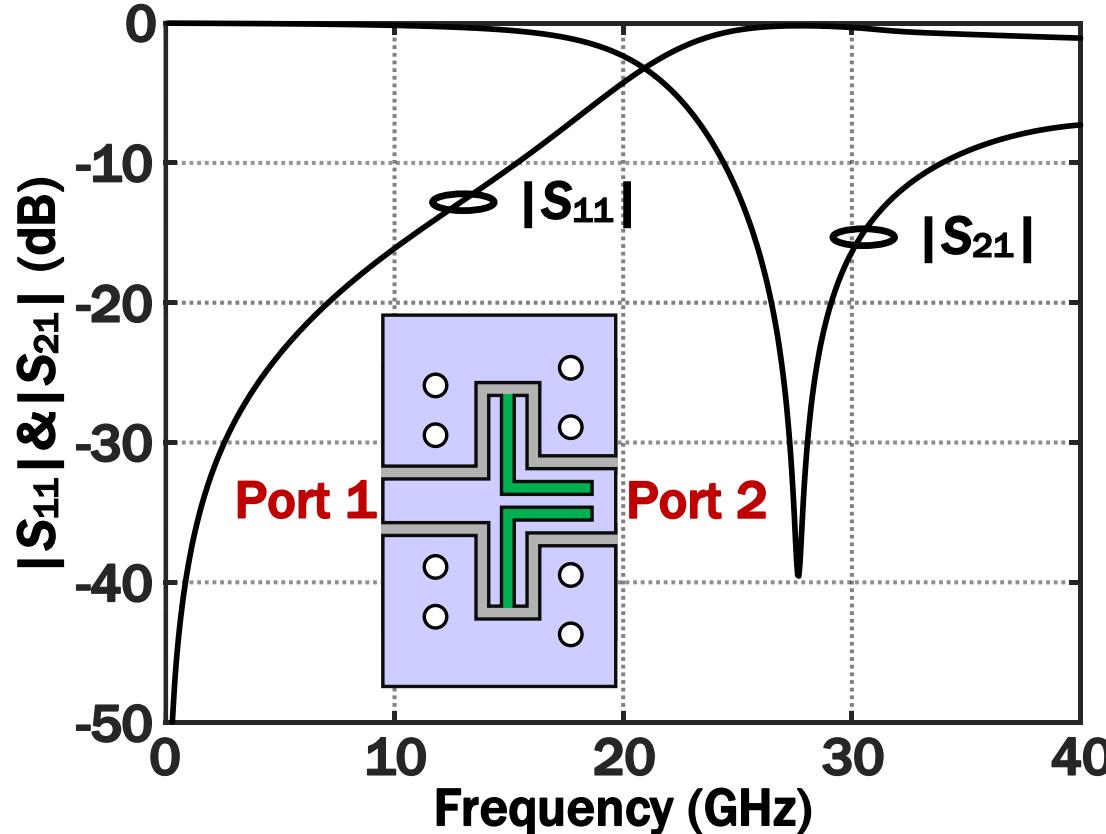
- Embedded CPW spur-lines
 - Broadside-coupled CPW/SIDGS spur-line



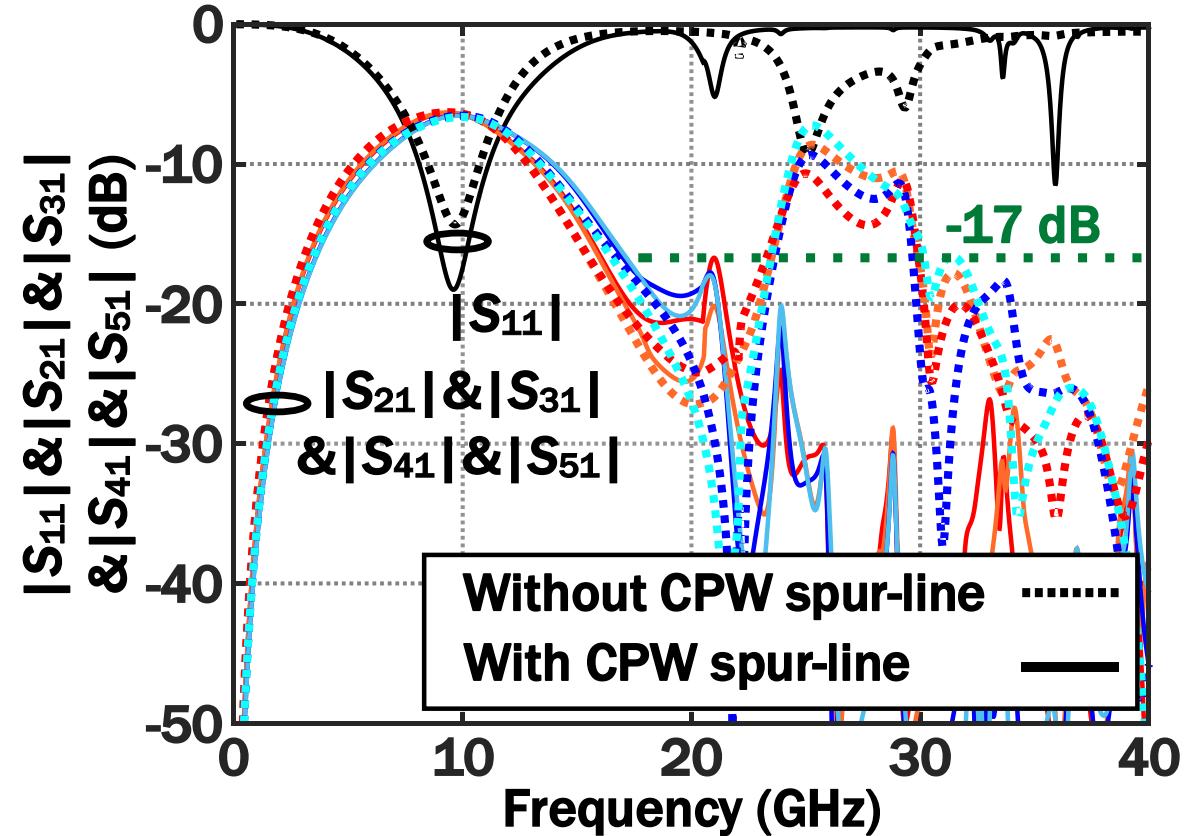
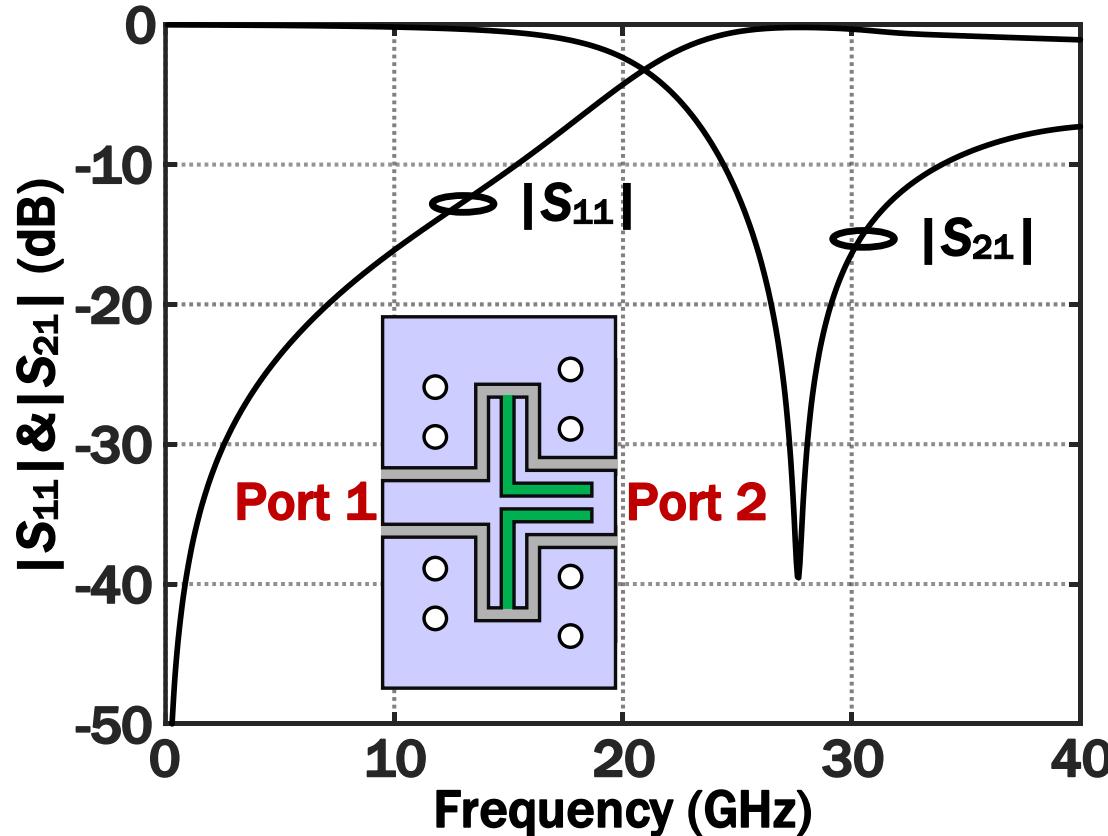
- Embedded CPW spur-lines
- Broadside-coupled CPW/SIDGS spur-line



- Embedded CPW spur-lines
 - Input/output CPW spur-line

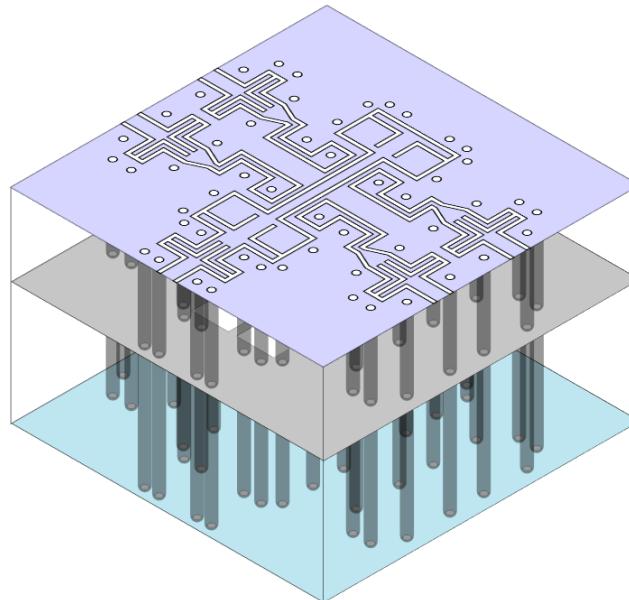


- Embedded CPW spur-lines
 - Input/output CPW spur-line

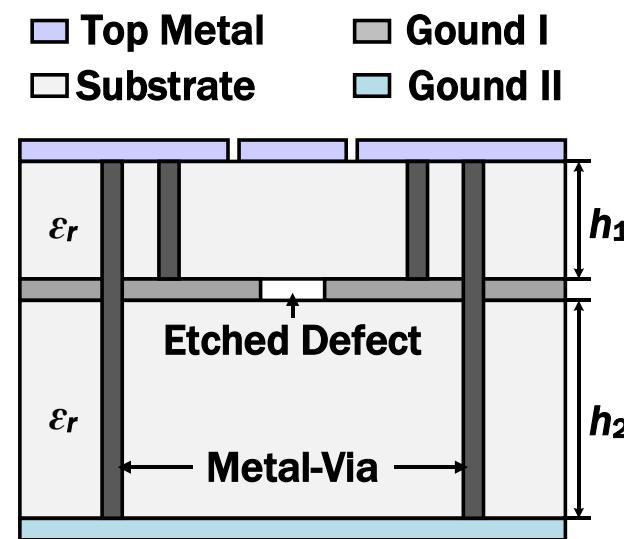


- Configuration

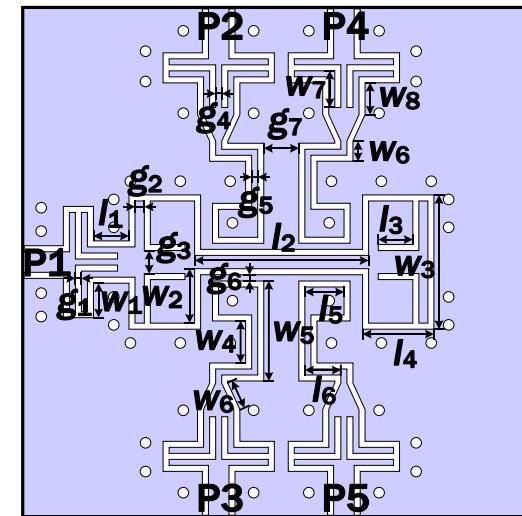
- 3-D structure (Core circuit size: 5.31mm × 7.68mm)
- Layer diagram
- Circuit details of top layer and ground I layer



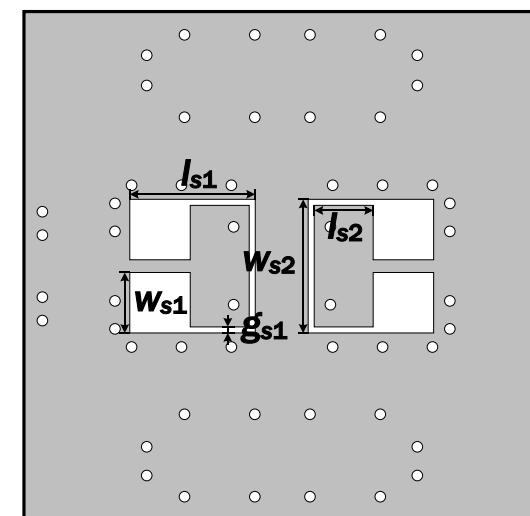
3D-view



Layer diagram



Top layer



Ground I layer

Outline

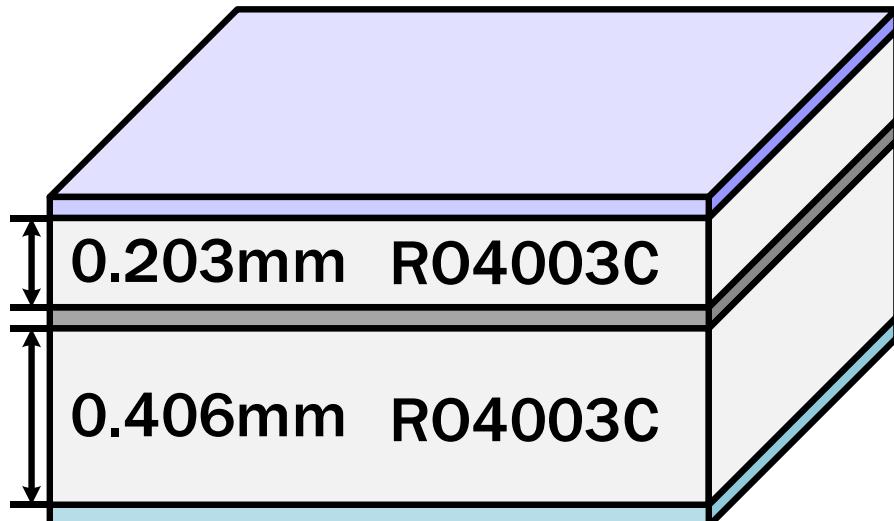
Motivation & Introduction & Challenges

1-to-4 Differential Power Splitter Design

Measurement and Comparison

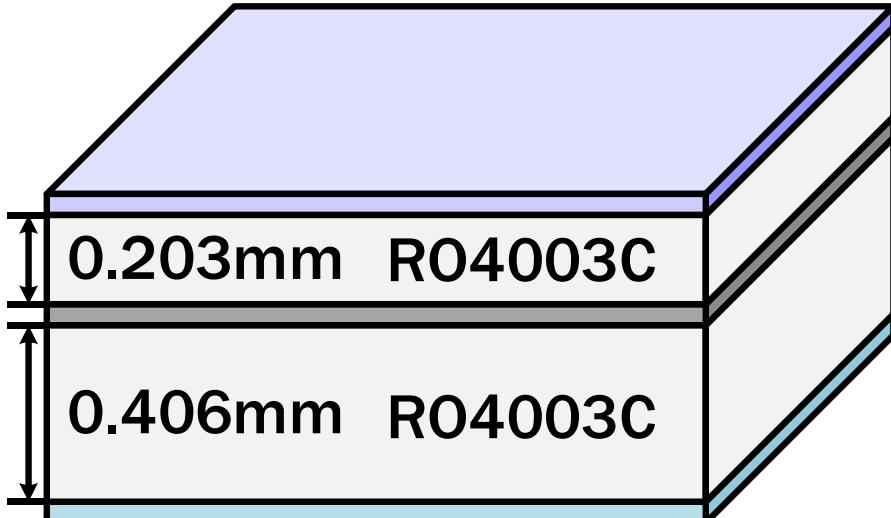
Conclusion

- Three-layer commercial PCB fabricated technology
 - RO4003C is selected as the substrate ($\epsilon_r = 3.55$)
 - Thicknesses of each substrate are 0.203mm and 0.406mm
 - $\tan\delta = 0.0027@10 \text{ GHz}/300 \text{ K}$

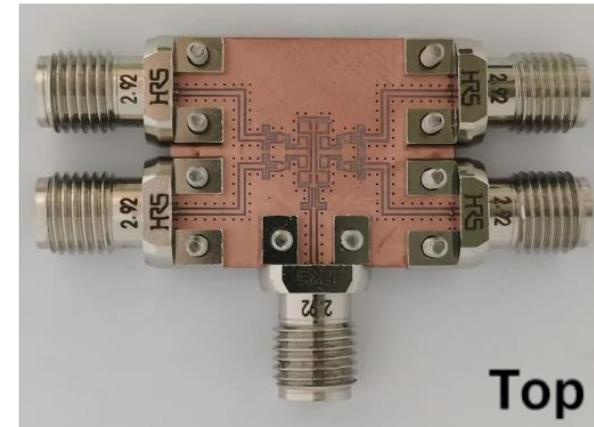


Layer configuration

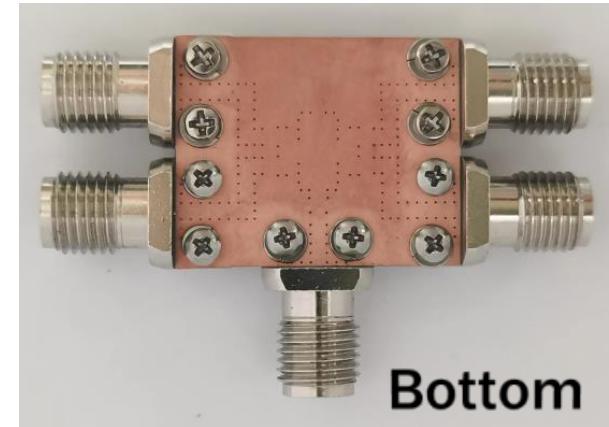
- Three-layer commercial PCB fabricated technology
 - RO4003C is selected as the substrate ($\epsilon_r = 3.55$)
 - Thicknesses of each substrate are 0.203mm and 0.406mm
 - $\tan\delta = 0.0027@10 \text{ GHz}/300 \text{ K}$
- Photograph of fabricated 1-to-4 differential power splitter



Layer configuration



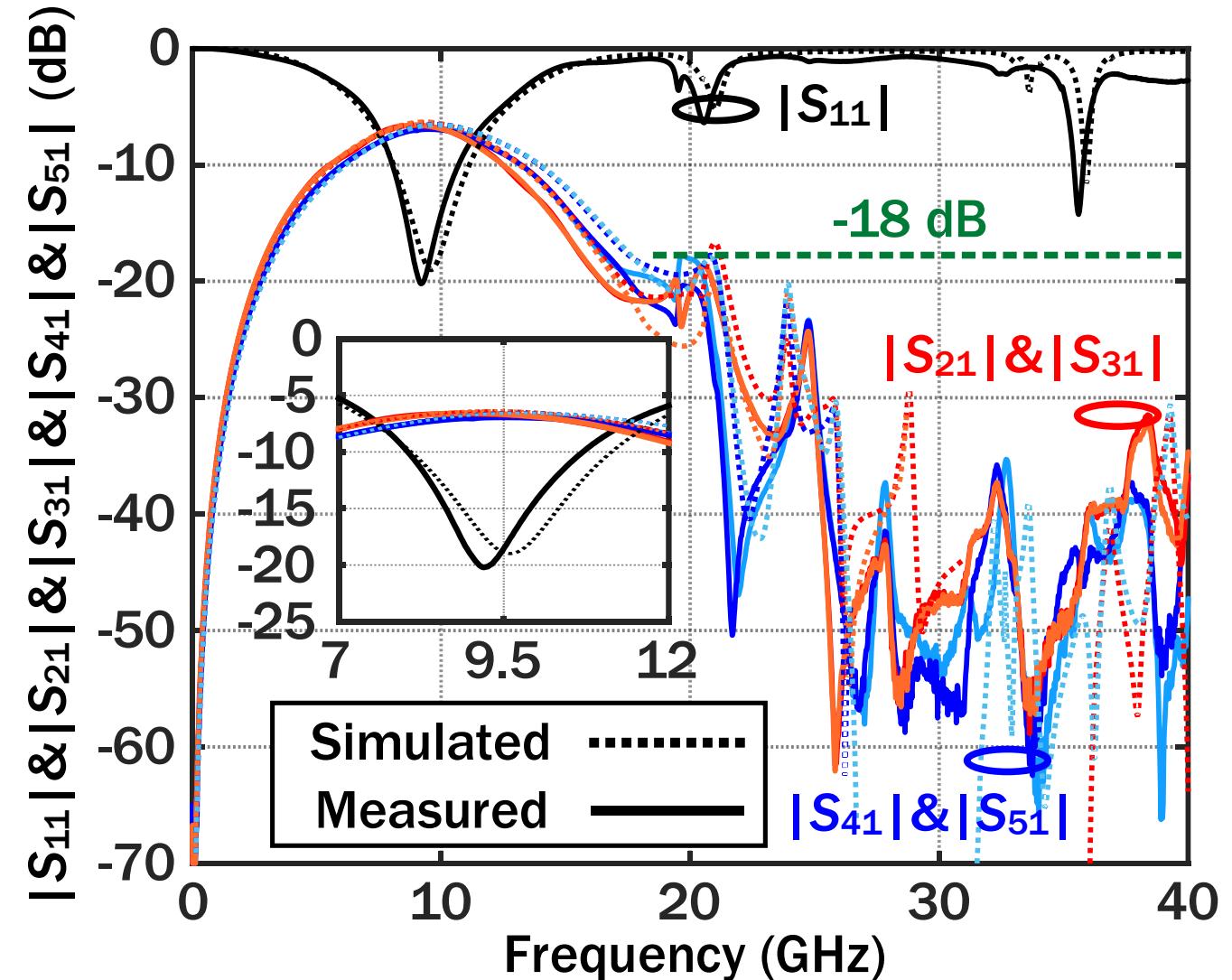
Top



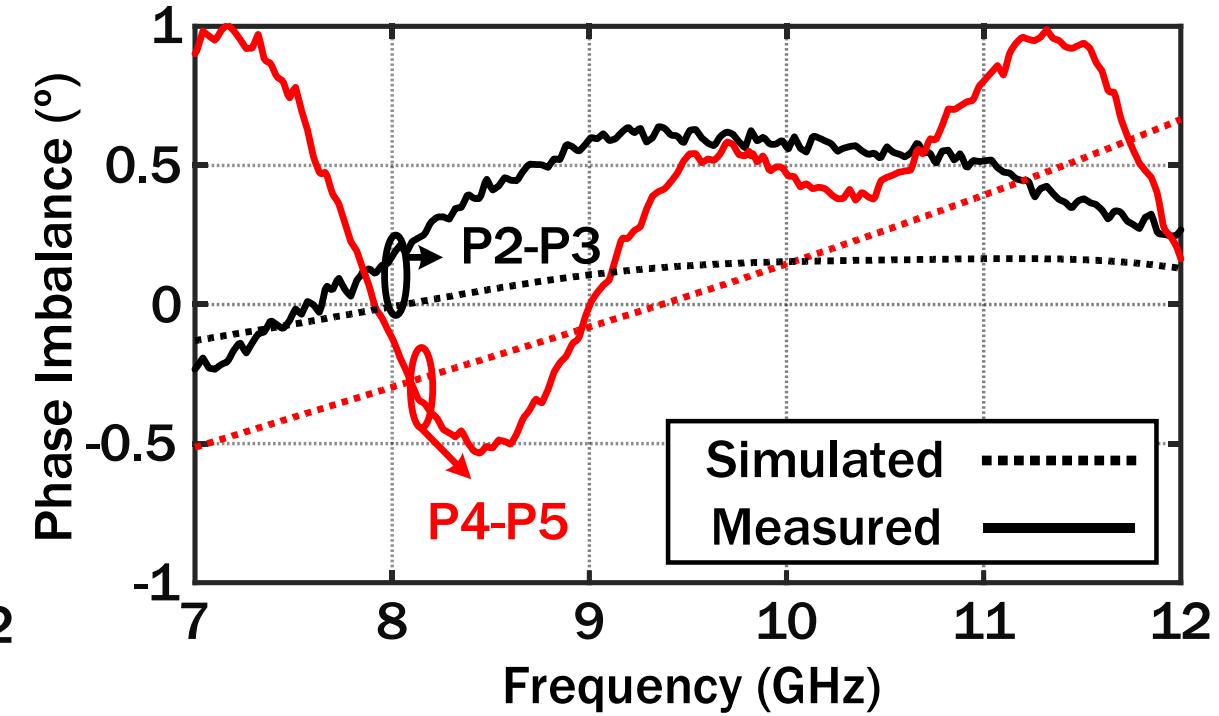
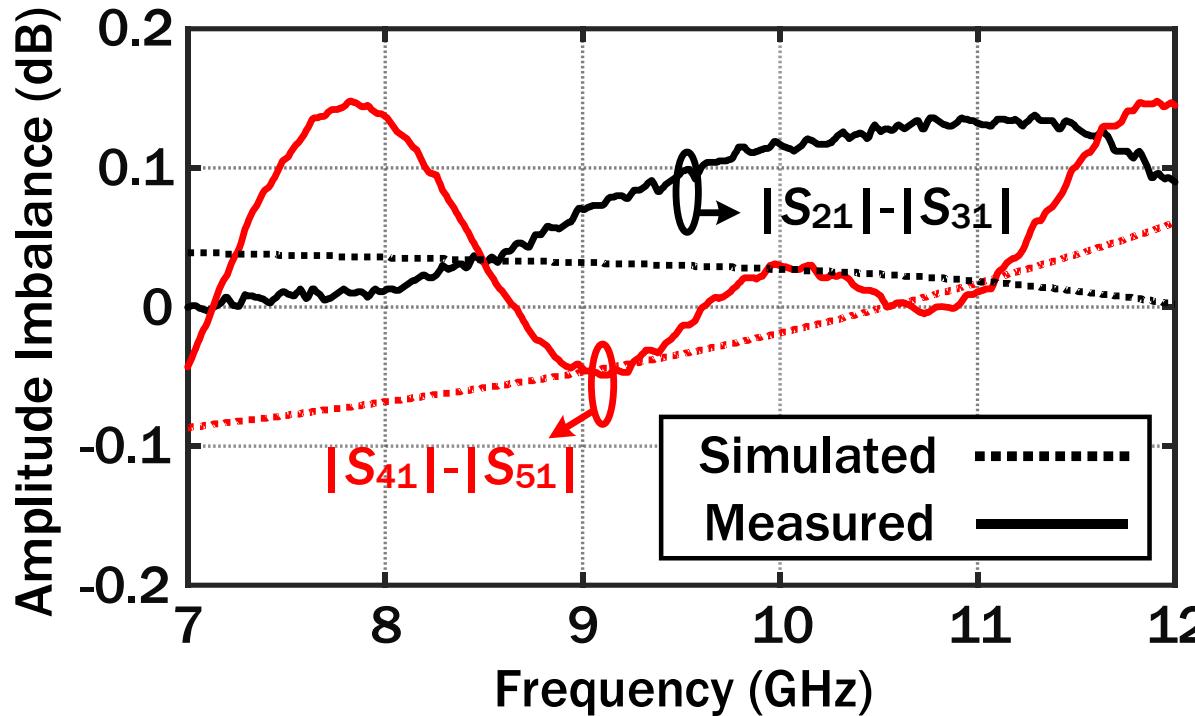
Bottom

Photograph

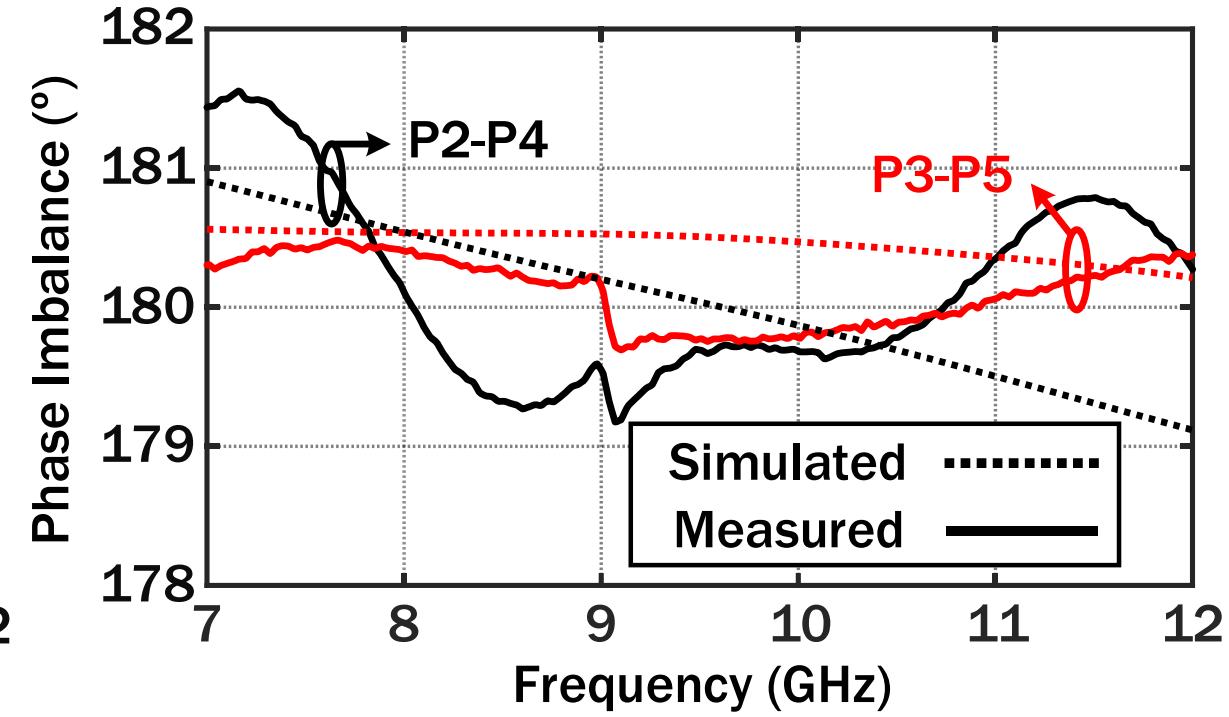
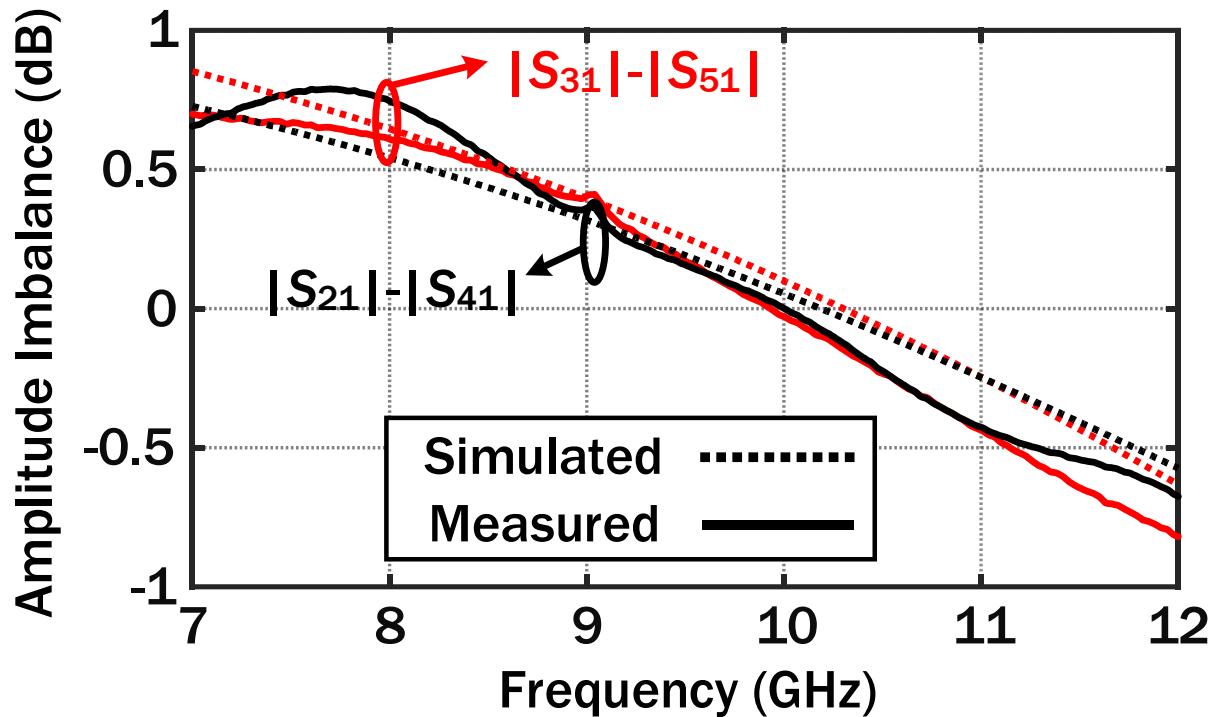
- Passband performance
 - Center frequency: 9.5 GHz
 - FBW: 52.6%
 - Return loss: >15 dB
 - Insertion loss: 0.75 dB
- Stopband performance
 - Stopband: up to $4.2 f_0$
 - Rejection level: <-18 dB



- 0° power splitter
 - Amplitude imbalance: ± 0.15 dB
 - Phase imbalance: $\pm 1^\circ$



- 180° power splitter
 - Amplitude imbalance: ± 0.75 dB
 - Phase imbalance: $\pm 1.5^\circ$



- Comparison table

Ref.	[1]	[2]	[3]	[4]	[5]	[6]	This work
Technology	Microstrip		SIW		Microstrip/SIDGS		CPW/SIDGS
Passive components	Power divider	Balun	Power divider	Balun	Power divider	Balun	1-to-4 differential power splitter
f_0 (GHz)	2.02	3.65	13.65	15.1	2.87	3.08	9.5
IL** (dB)	1*	0.5*	0.98	1.1	1	0.6	0.75
FBW (%)	49.5	175	99	50.3	23	45	52.6
0° A.-Im (dB)/P.-Im# (°)	0.1/1.5	N/A	0.57/6.2	N/A	N/A	N/A	0.15/1
180° A.-Im (dB)/P.-Im# (°)	N/A	0.5/10	N/A	0.35/1.9	N/A	0.5/0.4	0.75/1.5
Stopband Rejection	<-12 dB up to $4.63 f_0$	N/A	N/A	N/A	<-28 dB up to $8.71 f_0$	<-20 dB up to $5.8 f_0$	<-18 dB up to $4.2 f_0$
Radiation Loss	High	High	Medium	Medium	Low	Low	Low
Size (mm ²)	1443	570	N/A	138.5*	444.0	91.7	40.8

*: estimated from the figures of measured results. IL**: insertion loss. A.-Im (dB)/P.-Im#: amplitude/phase imbalance.

- Comparison table

Ref.	[1]	[2]	[3]	[4]	[5]	[6]	This work
Technology	Microstrip		SIW		Microstrip/SIDGS		CPW/SIDGS
Passive components	Power divider	Balun	Power divider	Balun	Power divider	Balun	1-to-4 differential power splitter
f_0 (GHz)	2.02	3.65	13.65	15.1	2.87	3.08	9.5
IL** (dB)	1*	0.5*	0.98	1.1	1	0.6	0.75
FBW (%)	49.5	175	99	50.3	23	45	52.6
0° A.-Im (dB)/P.-Im# (°)	0.1/1.5	N/A	0.57/6.2	N/A	N/A	N/A	0.15/1
180° A.-Im (dB)/P.-Im# (°)	N/A	0.5/10	N/A	0.35/1.9	N/A	0.5/0.4	0.75/1.5
Stopband Rejection	<-12 dB up to $4.63 f_0$	N/A	N/A	N/A	<-28 dB up to $8.71 f_0$	<-20 dB up to $5.8 f_0$	<-18 dB up to $4.2 f_0$
Radiation Loss	High	High	Medium	Medium	Low	Low	Low
Size (mm ²)	1443	570	N/A	138.5*	444.0	91.7	40.8

*: estimated from the figures of measured results. IL**: insertion loss. A.-Im (dB)/P.-Im#: amplitude/phase imbalance.

Outline

Motivation & Introduction & Challenges

1-to-4 Differential Power Splitter Design

Measurement and Comparison

Conclusion

- A compact 7-12 GHz 1-to-4 differential power splitter using **hybrid CPW/SIDGS scheme** is proposed for SATCOM.
- The hybrid CPW/SIDGS scheme introduces **wide stopband** and **low radiation loss**.
- Combine 0° power divider with 180° balun to generate multi-function component.
- The spur-lines are used to achieve **low amplitude/phase imbalances** and **upper stopband** with **low radiation loss**.
- The measured results show that the proposed 1-to-4 differential power splitter has the merits of **low amplitude/phase imbalances**, **low loss**, **compact size**, and **wide stopband**.

- A compact 7-12 GHz 1-to-4 differential power splitter using **hybrid CPW/SIDGS scheme** is proposed for SATCOM.
- The hybrid CPW/SIDGS scheme introduces **wide stopband** and **low radiation loss**.
- Combine 0° power divider with 180° balun to generate multi-function component.
- The spur-lines are used to achieve **low amplitude/phase imbalances** and **upper stopband** with **low radiation loss**.
- The measured results show that the proposed 1-to-4 differential power splitter has the merits of **low amplitude/phase imbalances**, **low loss**, **compact size**, and **wide stopband**.

- A compact 7-12 GHz 1-to-4 differential power splitter using **hybrid CPW/SIDGS scheme** is proposed for SATCOM.
- The hybrid CPW/SIDGS scheme introduces **wide stopband** and **low radiation loss**.
- Combine 0° power divider with 180° balun to generate **multi-function component**.
- The spur-lines are used to achieve **low amplitude/phase imbalances** and **upper stopband** with **low radiation loss**.
- The measured results show that the proposed 1-to-4 differential power splitter has the merits of **low amplitude/phase imbalances**, **low loss**, **compact size**, and **wide stopband**.

- A compact 7-12 GHz 1-to-4 differential power splitter using **hybrid CPW/SIDGS scheme** is proposed for SATCOM.
- The hybrid CPW/SIDGS scheme introduces **wide stopband** and **low radiation loss**.
- Combine 0° power divider with 180° balun to generate **multi-function component**.
- The spur-lines are used to achieve **low amplitude/phase imbalances** and **upper stopband with low radiation loss**.
- The measured results show that the proposed 1-to-4 differential power splitter has the merits of **low amplitude/phase imbalances**, **low loss**, **compact size**, and **wide stopband**.

- A compact 7-12 GHz 1-to-4 differential power splitter using **hybrid CPW/SIDGS scheme** is proposed for SATCOM.
- The hybrid CPW/SIDGS scheme introduces **wide stopband** and **low radiation loss**.
- Combine 0° power divider with 180° balun to generate **multi-function component**.
- The spur-lines are used to achieve **low amplitude/phase imbalances** and **upper stopband with low radiation loss**.
- The measured results show that the proposed 1-to-4 differential power splitter has the merits of **low amplitude/phase imbalances**, **low loss**, **compact size**, and **wide stopband**.

- The authors thank the support of National Key R&D Program of China under Grant 2021YFE0205600 and National Natural Science Foundation of China under Grant 61934001 and 62161160310.

- [1] M.-T. Chen and C.-W. Tang, "Design of the filtering power divider with a wide passband and stopband," *IEEE Microw. Wireless Compon. Lett.*, vol. 28, no. 7, pp. 570–572, Jul. 2018.
- [2] K.-C. Lin and Y.-C. Lin, "A simple printed compensated balun for enhanced ultra-wideband performances," *IEEE Microw. Wireless Compon. Lett.*, vol. 24, no. 1, pp. 5–7, Jan. 2014.
- [3] D. Herraiz, H. Esteban, D. Herraiz, A. Belenguer, and V. E. Boria, "Wideband H-plane T-junction power divider with compensation elements using double ridged empty substrate integrated waveguide," *IEEE Microw. Wireless Techn. Lett.*, vol. 33, no. 3, pp. 255–258, Mar. 2023.
- [4] M. Jia, J. Zhang, and Y. Dong, "A compact and broadband balun based on multilayer SIW," *IEEE Microw. Wireless Compon. Lett.*, vol. 32, no. 2, pp. 105–108, Feb. 2022.
- [5] C. Han, D. Tang, Z. Deng, H. Qian, and X. Luo, "Filtering power divider with ultrawide stopband and wideband low radiation loss using substrate integrated defected ground structure," *IEEE Microw. Wireless Compon. Lett.*, vol. 31, no. 2, pp. 113–116, Feb. 2021.
- [6] D. Tang and X. Luo, "Compact filtering balun with wide stopband and low radiation loss using hybrid microstrip and substrate-integrated defected ground structure," *IEEE Microw. Wireless Compon. Lett.*, vol. 31, no. 6, pp. 549–552, Jun. 2021.

Thank you very much for your attention!