Chapter 9

Common-Mode Noise Suppression of Bended Coplanar Waveguide

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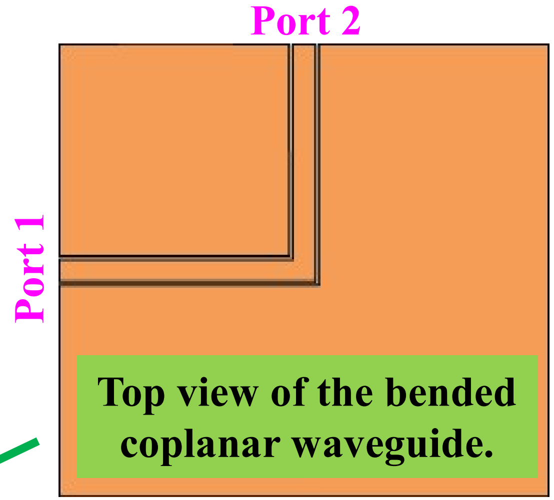
Outline

- Motivation
- Literature Survey
- Conventional Bended Coplanar Waveguide
- Bended Coplanar Waveguide Using U-Shaped Slot
- Bended Coplanar Waveguide Using Inductance-Compensated Slotline
- Conclusion

Motivation

Problem

- **Electrical length difference between the inner and outer slots will induce the even-to-odd mode conversion**



Purpose

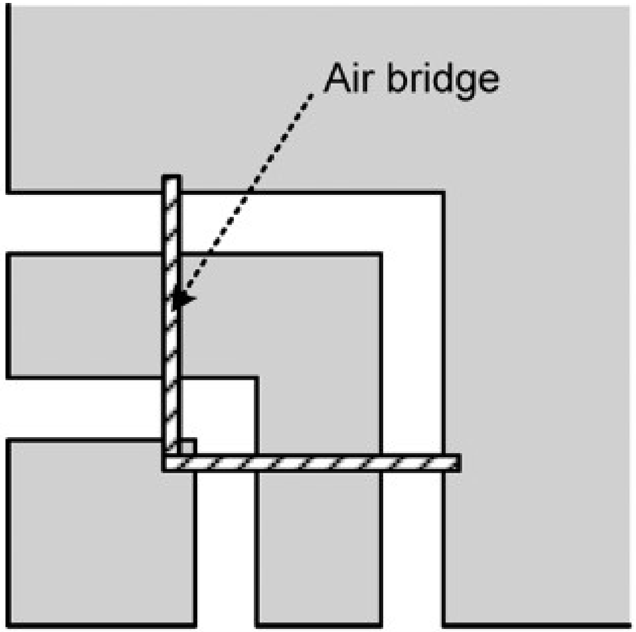
- **Make equal the electrical lengths of the inner and outer slots to eliminate the even-to-odd mode conversion**

Methods

- **Using U-shaped slot or inductance-compensated slotline**

Literature *Survey*

● Conventional bended CPW with air bridges



● **Advantage:**

To suppress coupled slot-line mode effects

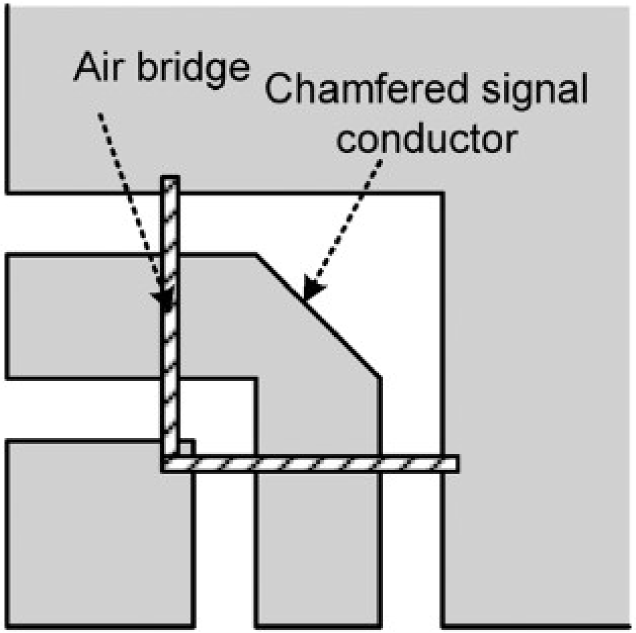
● **Disadvantage:**

Create parasitic capacitance and limit the operating bandwidth of the circuit

* N. H. L. Koster, S. Koblowski, R. Bertenburg, S. A. H. S. Heinen, and I. A. W. I. Wolff, "Investigations on air bridges used for MMICs in CPW technique," in *19th Eur. Microw. Conf.*, pp. 666–671, 1989.

Literature Survey

● Chamfered bended CPW with air bridges



● **Advantage:**

Chamfering provides a simple way to partially compensate for the effects of the air-bridges

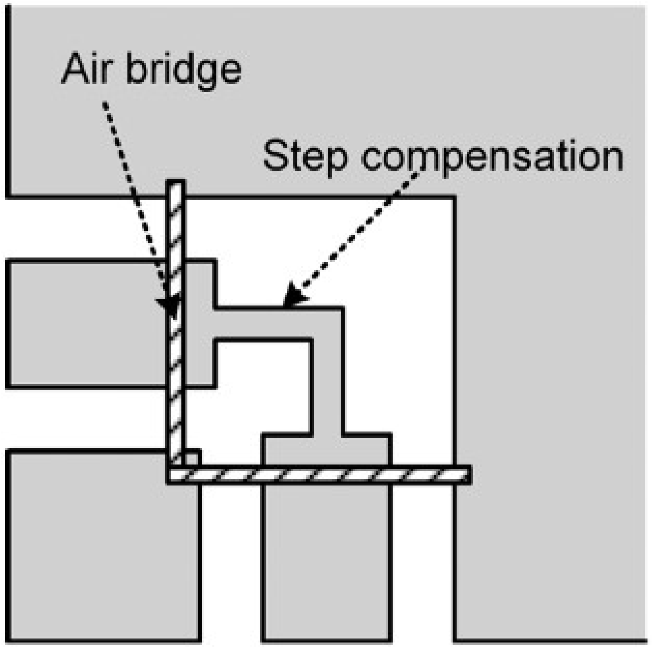
● **Disadvantage:**

Increase fabrication cost

* P. M. Watson and K. C. Gupta, "Design and optimization of CPW circuits using EM-ANN models for CPW components," *IEEE Trans. Microw. Theory Tech.*, vol. 45, no. 12, pp. 2515–2523, Dec. 1997.

Literature Survey

- **Step compensated CPW with air bridges**



- **Advantage:**

To suppress coupled slot-line mode effects more effectively

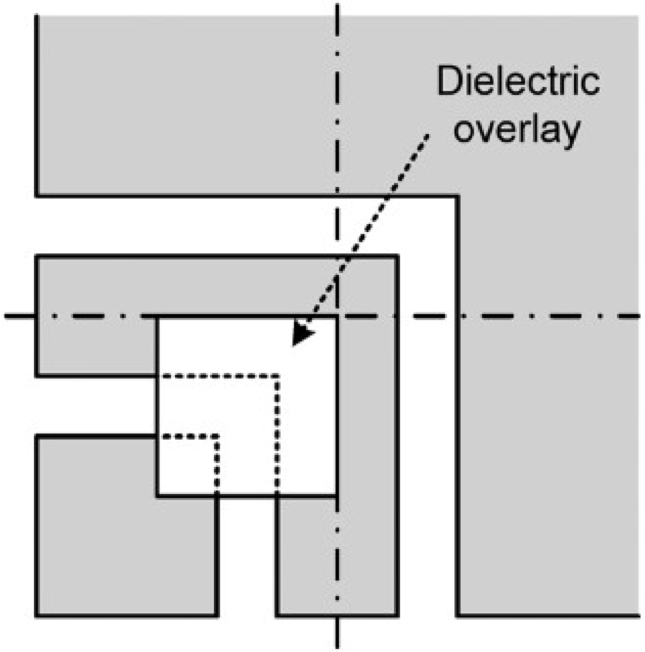
- **Disadvantage:**

A localized narrowing of the center conductor may not provide enough compensation

* T. M. Weller, R. M. Henderson, K. J. Herrick, S. V. Robertson, R. T. Kihm, and L. P. B. Katehi, "Three-dimensional high-frequency distribution networks. I. Optimization of CPW discontinuities," *IEEE Trans. Microw. Theory Tech.*, vol. 48, no. 10, pp. 1635–1642, 2000.

Literature Survey

- **Bended CPW with dielectric overlay on the inner slot**



- **Advantage:**

Bondwire-free

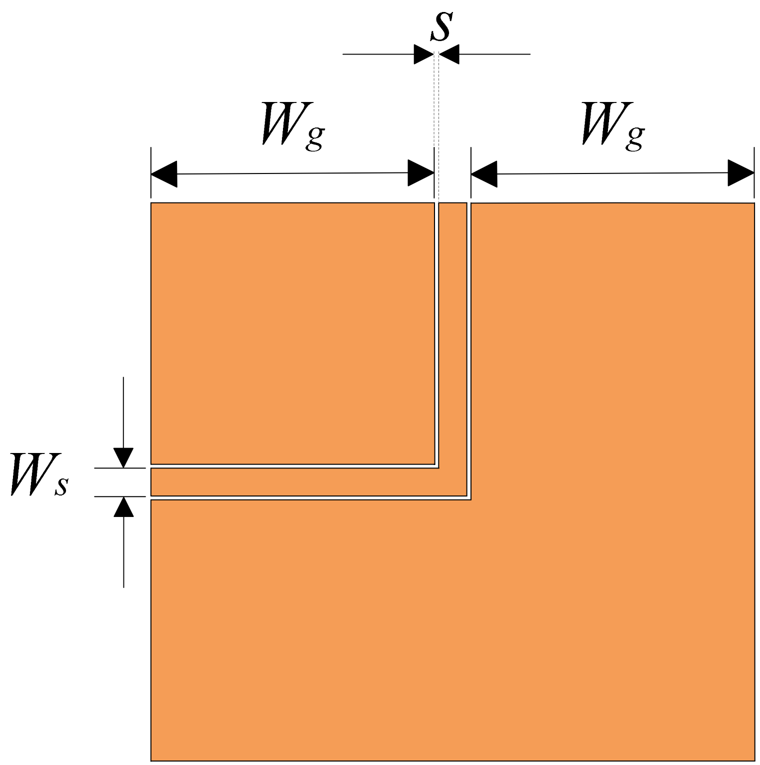
- **Disadvantage:**

Increase fabrication complexity, process steps, and fabrication cost

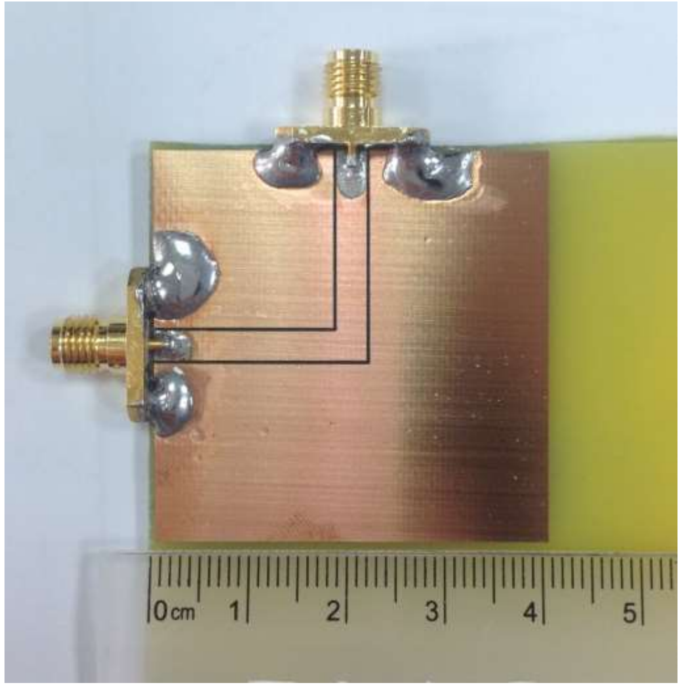
* R. N. Simons and G. E. Ponchak, "Modeling of some coplanar waveguide discontinuities," *IEEE Trans. Microw. Theory Tech.*, vol. 36, no. 12, pp. 1796–1803, 1988.

Conventional Bended Coplanar Waveguide

● Topology

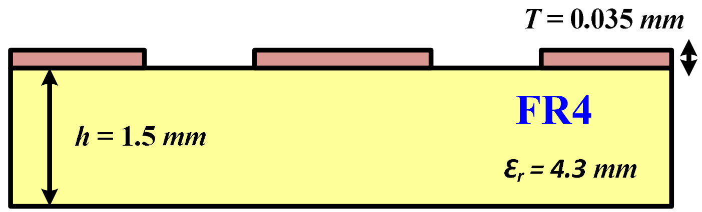


Top view



Implementation

W_s (mm)	W_g (mm)	s (mm)
3.08	18.48	0.35

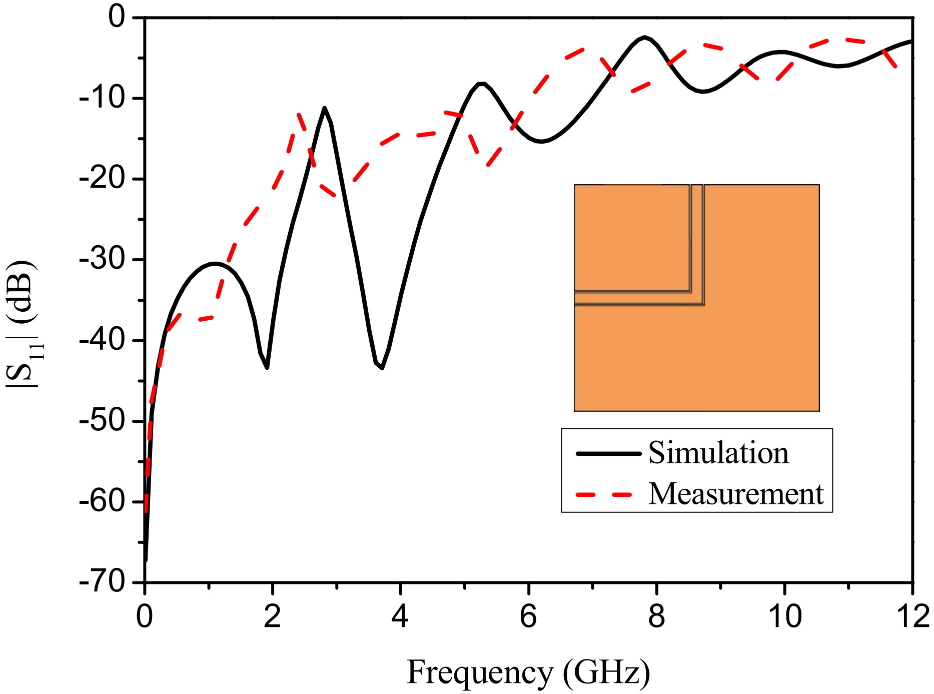


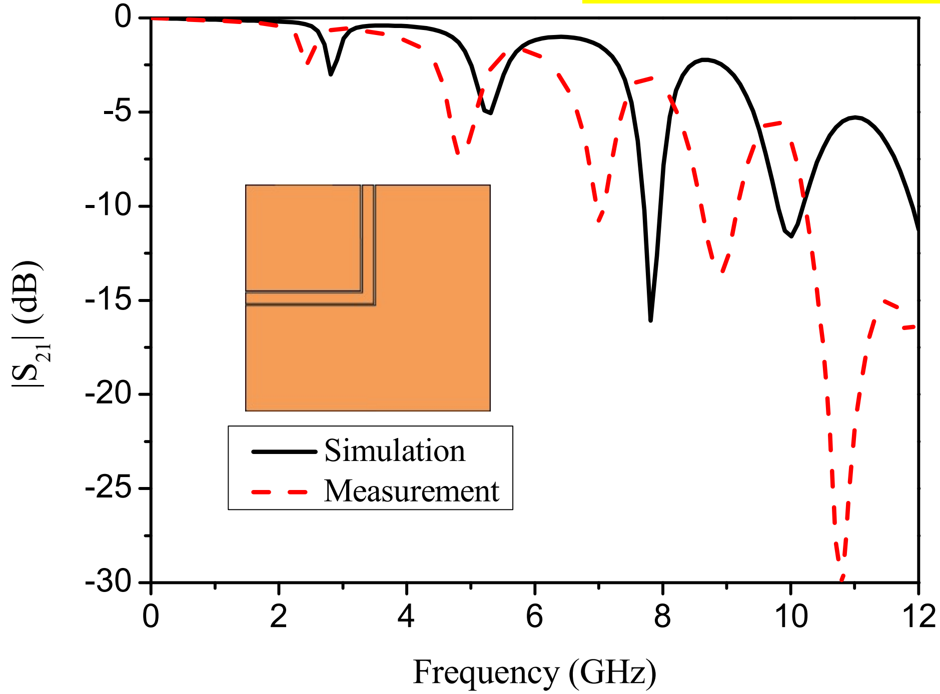
Cross-sectional view

Conventional Bended Coplanar Waveguide

● Reflection & Transmission Coefficients

Simulated by ADS

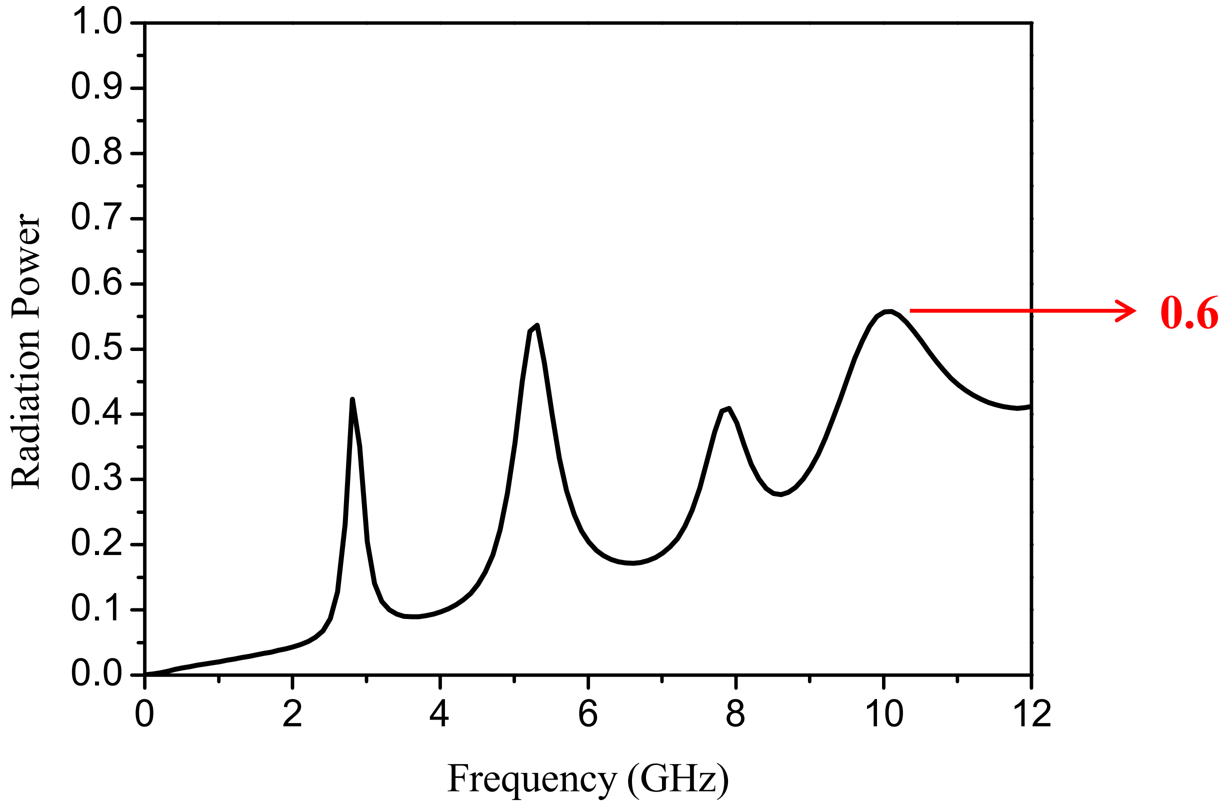




		Maximum Reflection Coefficient (dB)	Minimum Transmission Coefficient (dB)
Bended CPW without Compensation	Simulation	-2.44	-15.75
	Measurement	-2.74	-30.16

Conventional Bended Coplanar Waveguide

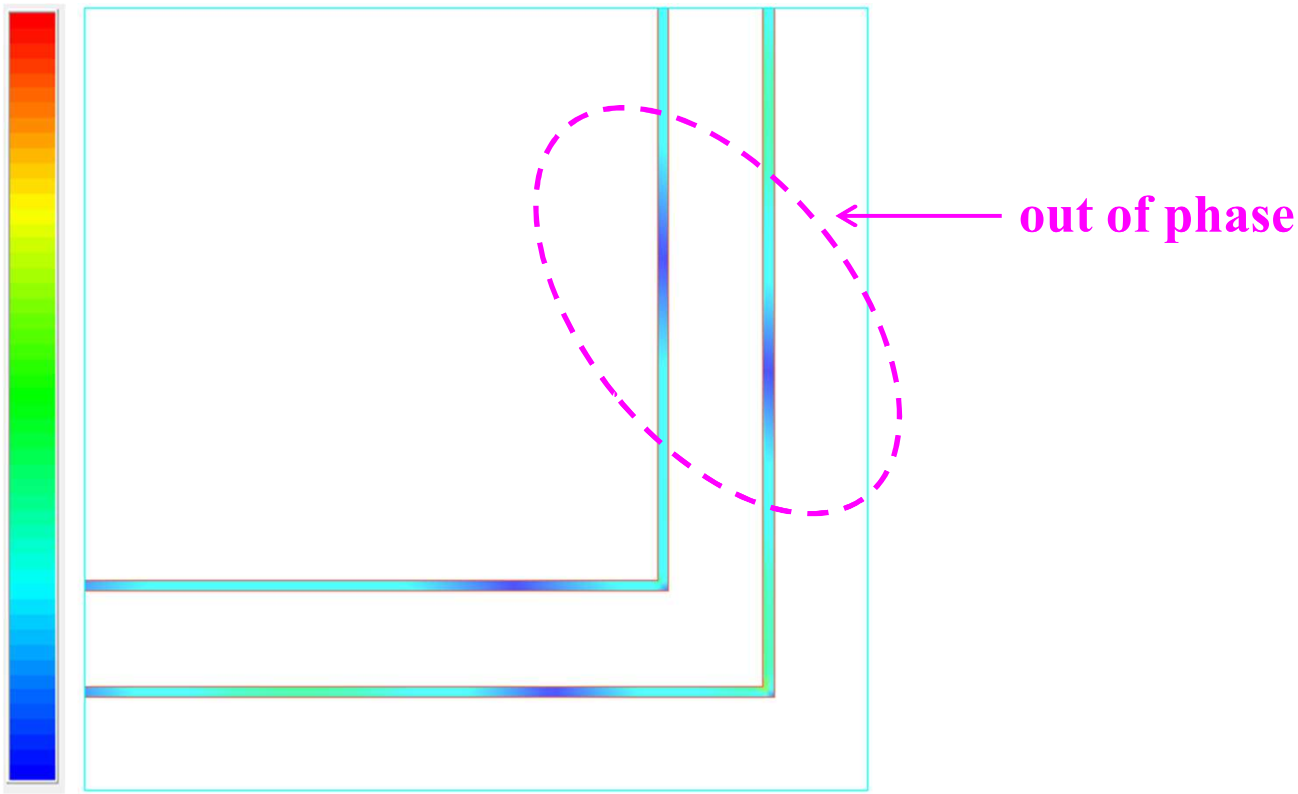
- **Radiation Power ($1-|S_{11}|^2-|S_{21}|^2$)**



Radiation power of the bended coplanar waveguide without compensation.

Conventional Bended Coplanar Waveguide

- ## Electric Field Distribution

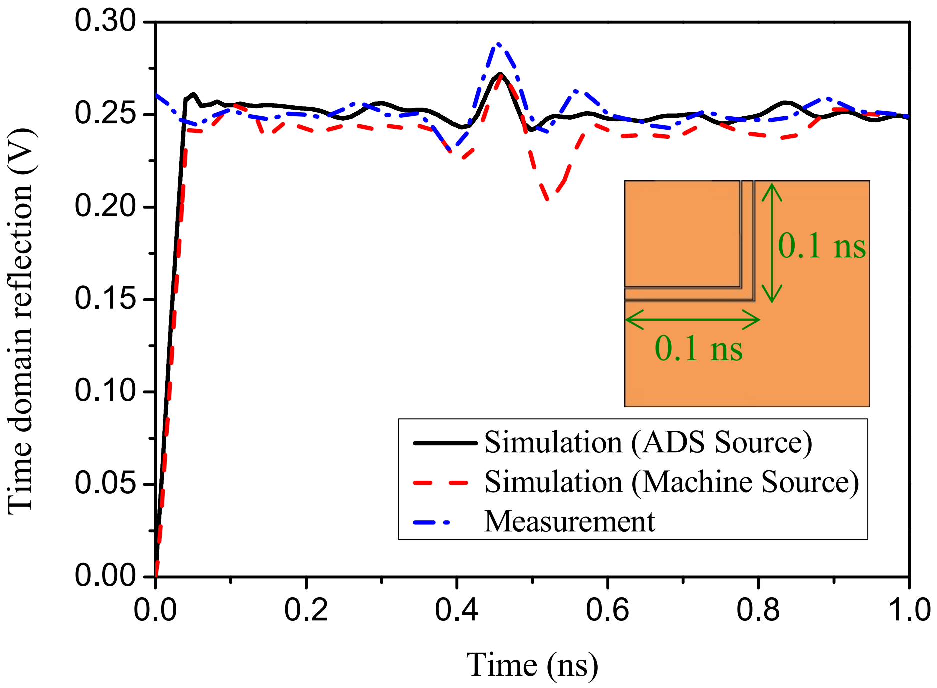


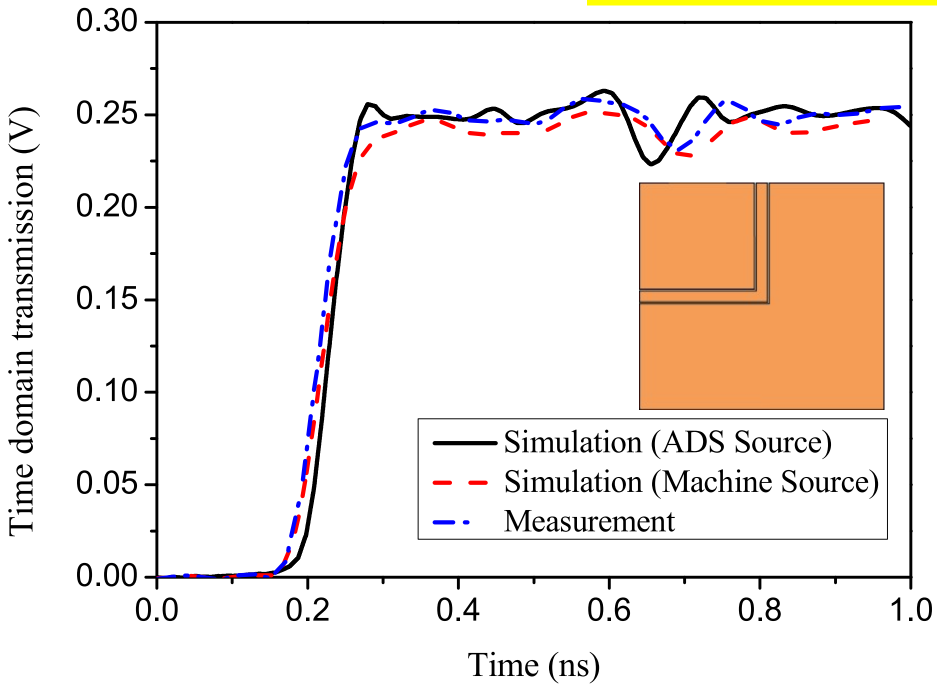
Electric field distribution of the bended coplanar waveguide without compensation.

Conventional Bended Coplanar Waveguide

● TDR & TDT

Simulated by ADS





		Peak-to-peak TDR Noise (V)	Peak-to-peak TDT Noise (V)
Bended CPW without Compensation	Simulation	0.033	0.040
	Measurement	0.050	0.030

Conventional Bended Coplanar Waveguide

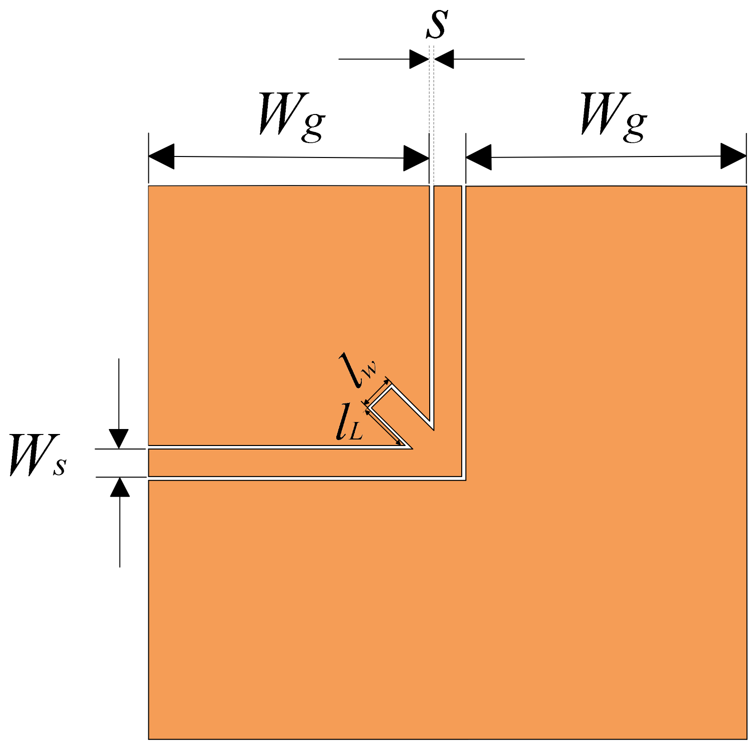
● Eye Height & Eye Width & Jitter

	Eye Height (V)	Eye Width (ps)	Jitter (ps)
Bit Rate= 2 Gbps, t_r = 100 ps	0.233 (93.2%)	496 (99.2%)	4.00
Bit Rate= 4 Gbps, t_r = 50 ps	0.218 (87.2%)	245 (98.0%)	5.00
Bit Rate= 8 Gbps, t_r = 25 ps	0.160 (0.64%)	118.3 (94.6%)	6.75
Bit Rate= 16 Gbps, t_r = 12.5 ps	0.064 (25.6%)	38.88 (62.2%)	22.81

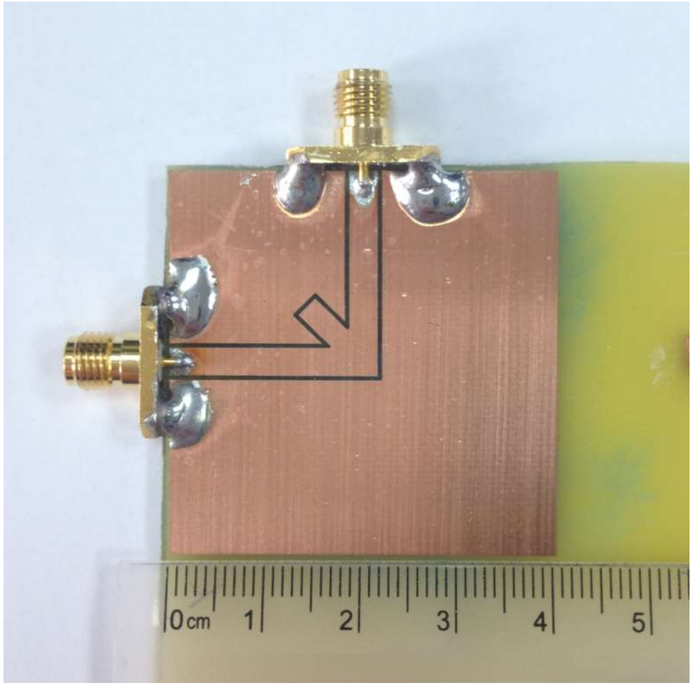
Parameters of the eye diagrams using various bit rates and rise times for the bended coplanar waveguide without compensation.

Bended Coplanar Waveguide Using U-Shaped Slot

- **Topology**

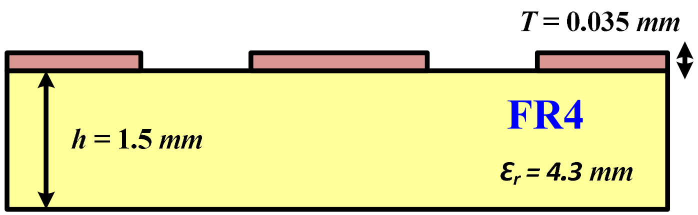


Top view



Implementation

W_s (mm)	W_g (mm)	s (mm)	l_w (mm)	l_L (mm)
3.08	18.48	0.35	3.285	4.545

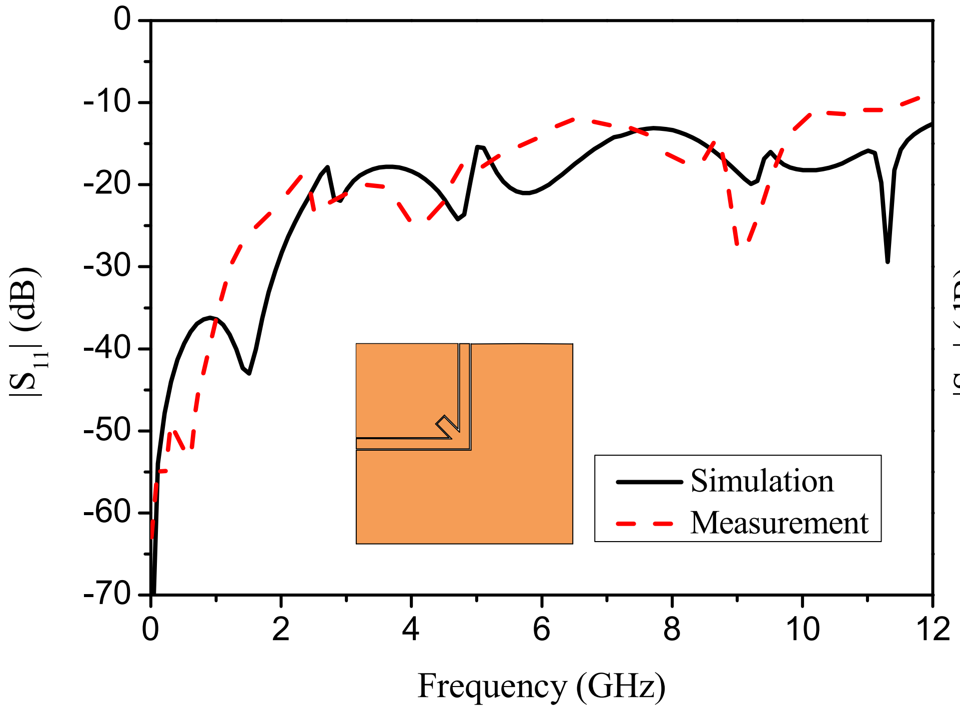


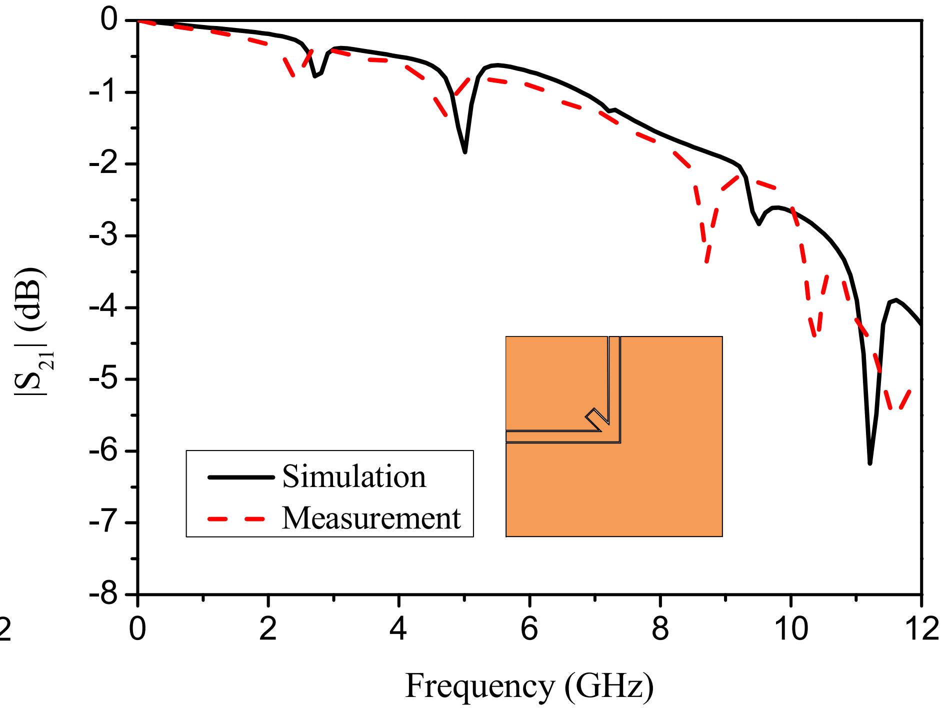
Cross-sectional view

Bended Coplanar Waveguide Using U-Shaped Slot

● Reflection & Transmission Coefficients

Simulated by ADS

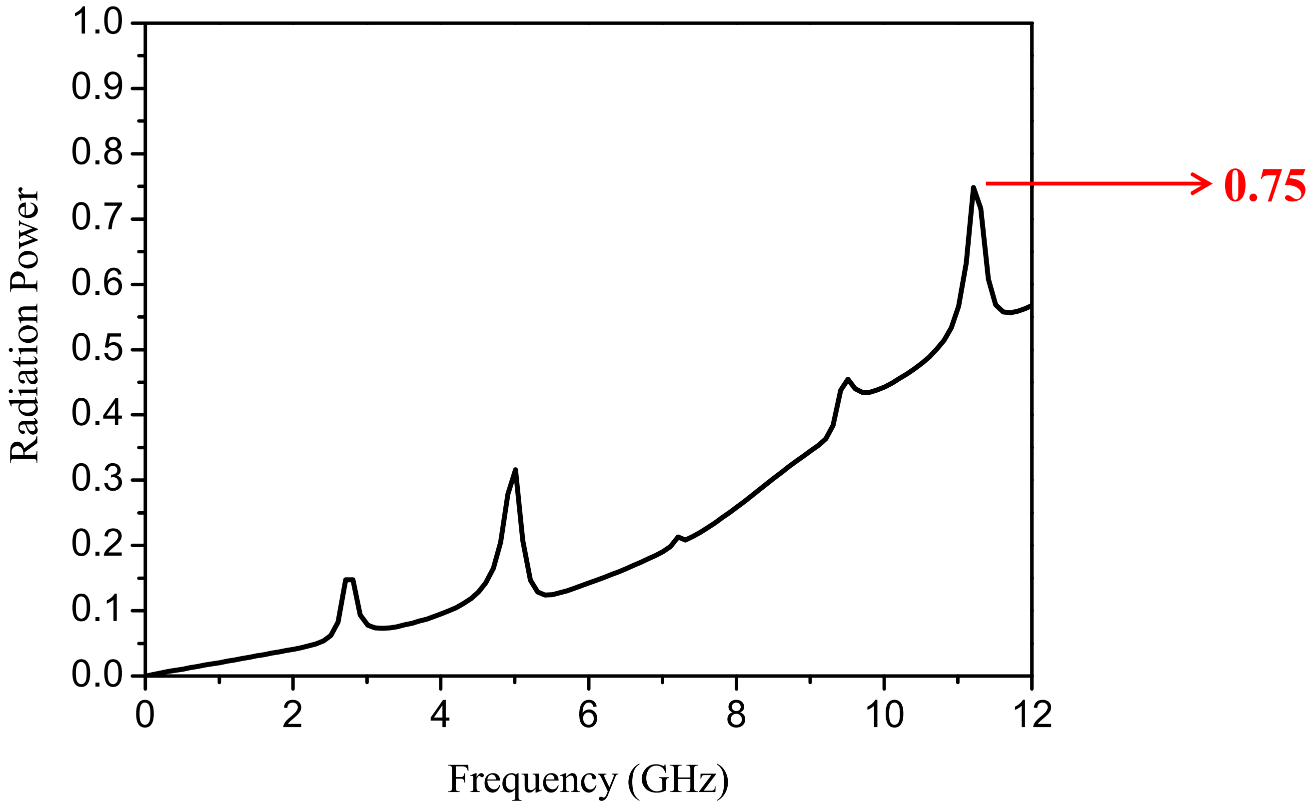




		Maximum Reflection Coefficient (dB)	Minimum Transmission Coefficient (dB)
Bended CPW without Compensation	Simulation	-12.44	-6.24
	Measurement	-9.17	-5.54

Bended Coplanar Waveguide Using U-Shaped Slot

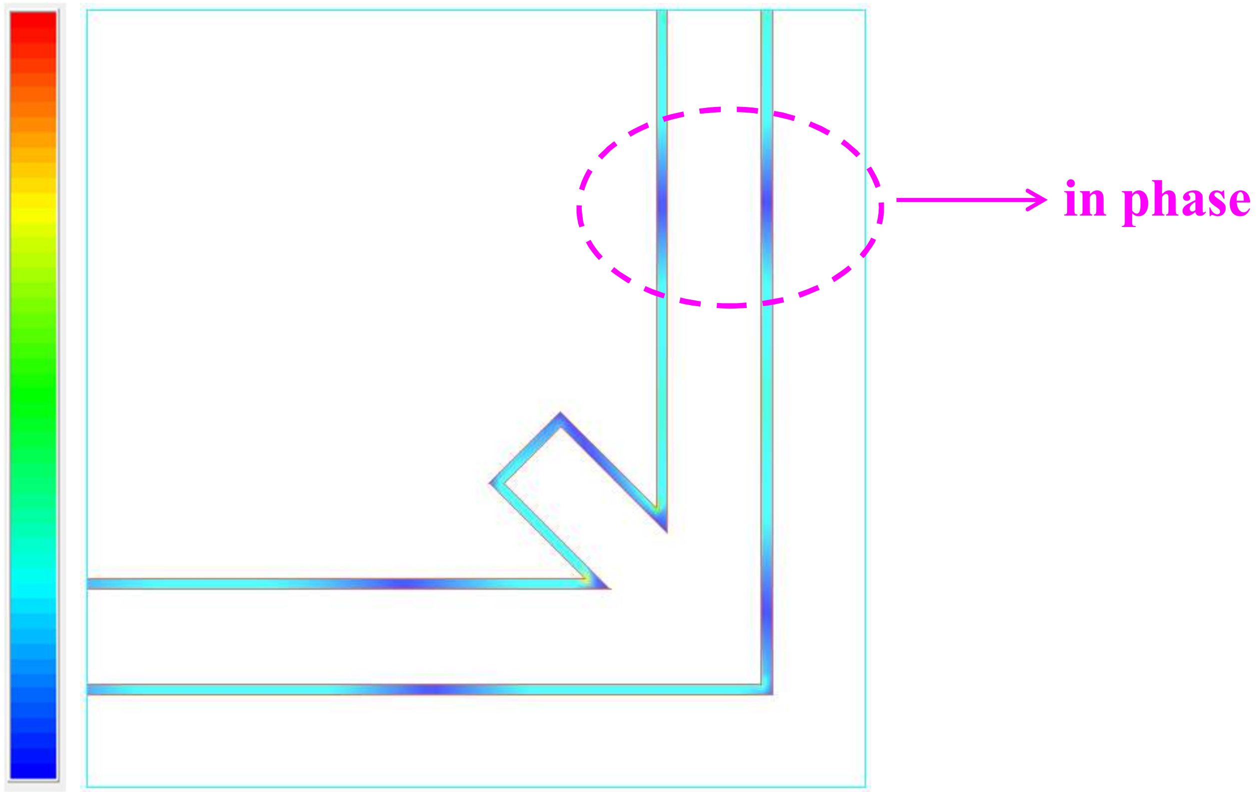
- **Radiation Power (1-$|S_{11}|^2$-$|S_{21}|^2$)**



Radiation power of the bended coplanar waveguide using U-shaped slot.

Bended Coplanar Waveguide Using U-Shaped Slot

● Electric Field Distribution

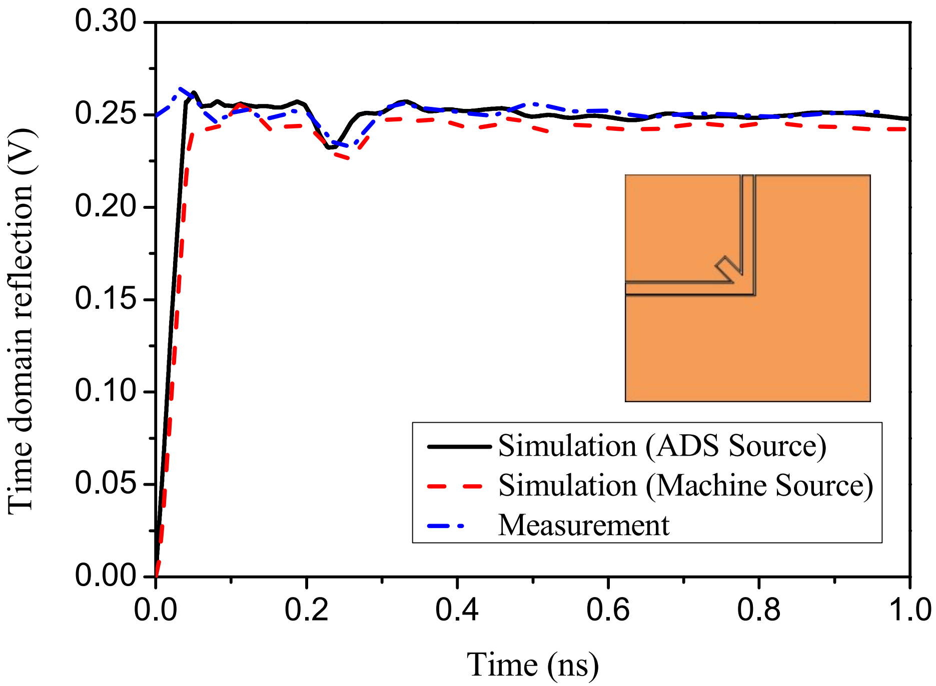


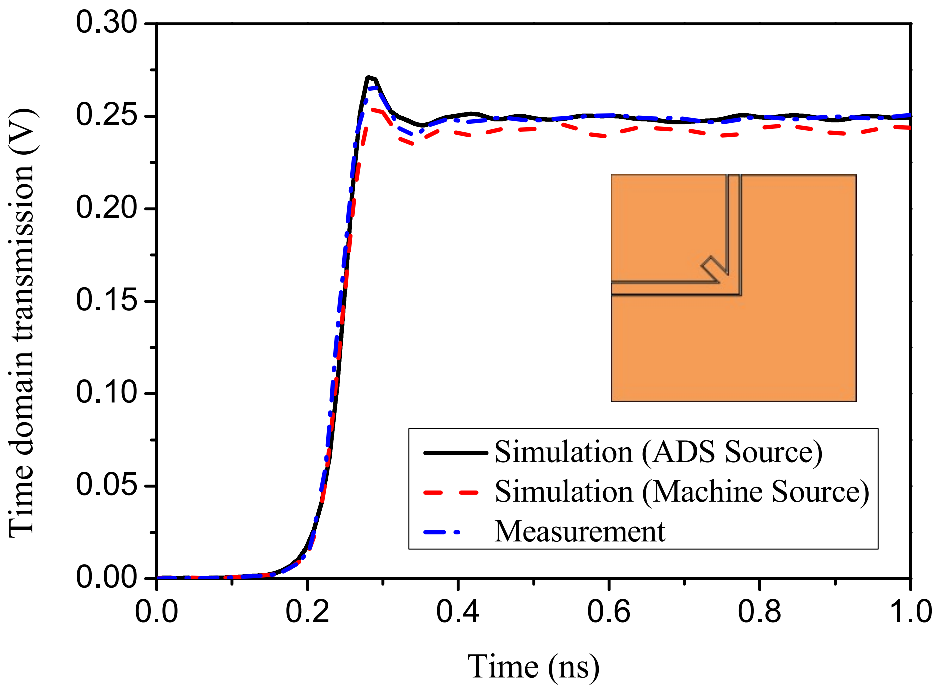
Electric field distribution of the bended coplanar waveguide using U-shaped slot.

Bended Coplanar Waveguide Using U-Shaped Slot

- **TDR & TDT**

Simulated by ADS





		Peak-to-peak TDR Noise (V)	Peak-to-peak TDT Noise (V)
Bended CPW without Compensation	Simulation	0.028	0.027
	Measurement	0.029	0.029

Bended Coplanar Waveguide Using U-Shaped Slot

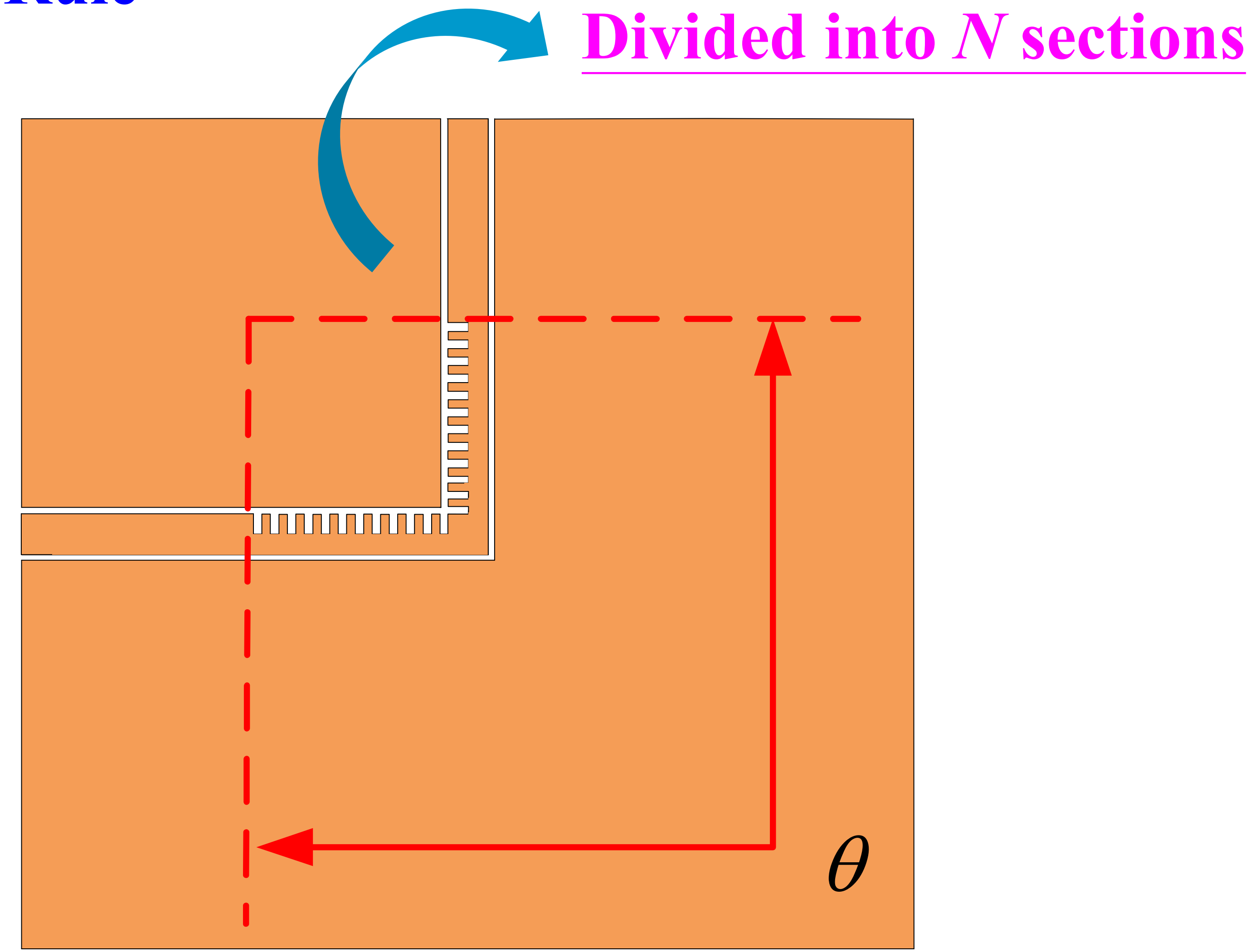
- **Eye Height & Eye Width & Jitter**

	Eye Height (V)	Eye Width (ps)	Jitter (ps)
Bit Rate= 2 Gbps, t_r = 100 ps	0.243 (97.2%)	498 (99.6%)	2.00
Bit Rate= 4 Gbps, t_r = 50 ps	0.234 (93.6%)	248 (99.2%)	1.50
Bit Rate= 8 Gbps, t_r = 25 ps	0.202 (80.8%)	122 (97.6%)	3.00
Bit Rate= 16 Gbps, t_r = 12.5 ps	0.133 (53.2%)	57.87 (92.6%)	4.625

Parameters of the eye diagrams using various bit rates and rise times for the bended coplanar waveguide using U-shaped slot.

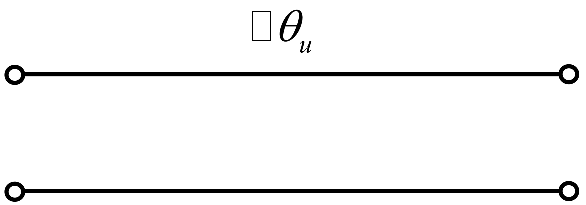
Bended Coplanar Waveguide Using Inductance-Compensated Slotline

- **Design Rule**

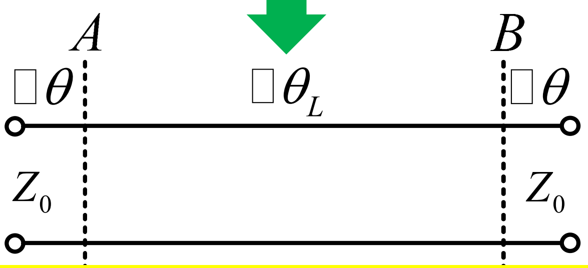


Bended Coplanar Waveguide Using Inductance-Compensated Slotline

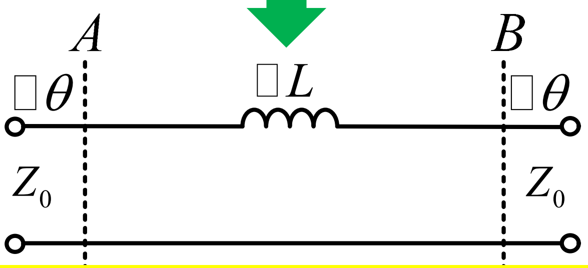
● Design Rule



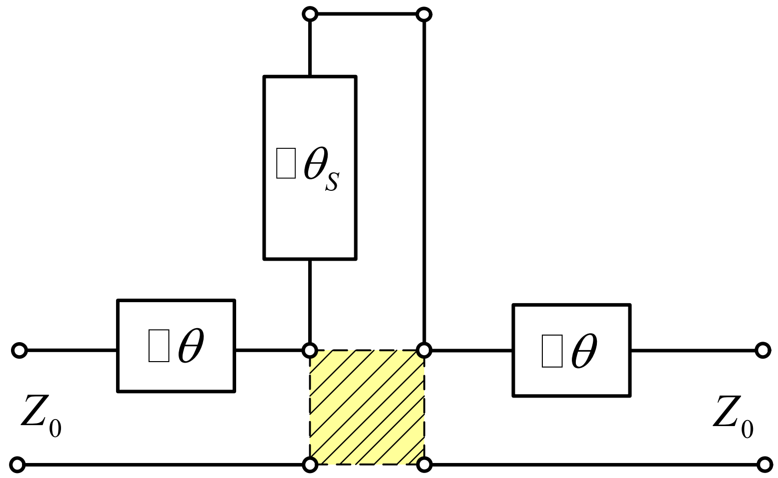
(a) Unit section model



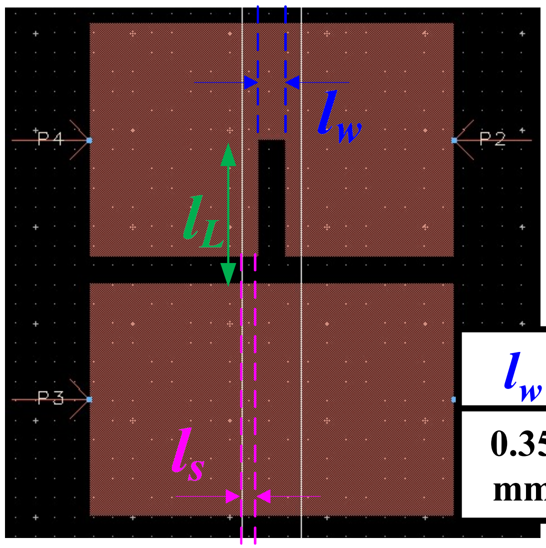
(b) Three subsections model



(c) Equivalent inductance model



(d) Short-circuited stub model



l_w	l_L	l_s
0.35 mm	1.35 mm	0.205 mm

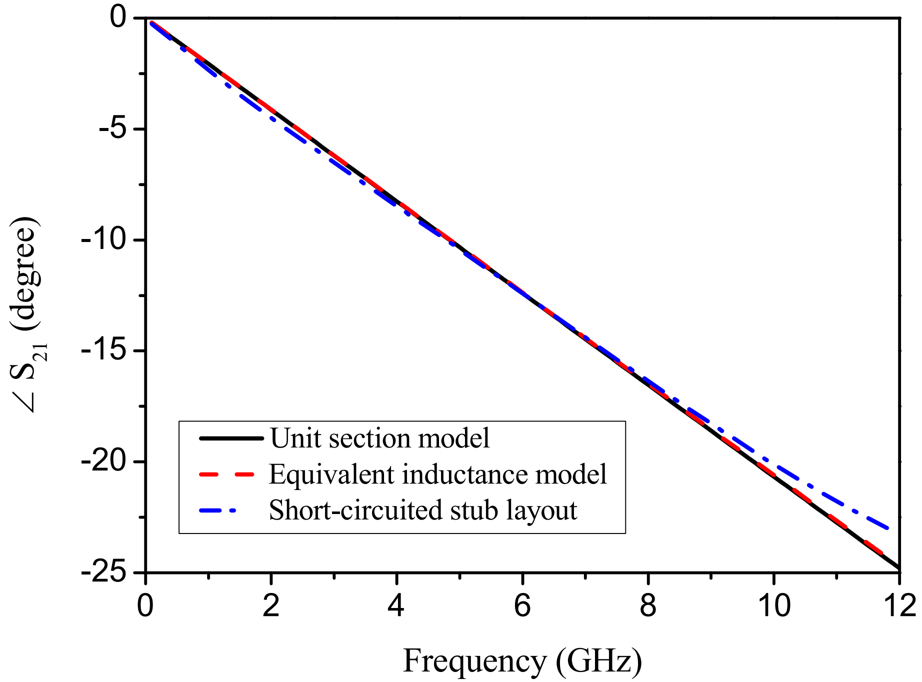
(e) Short-circuited stub layout

Bended Coplanar Waveguide Using Inductance-Compensated Slotline

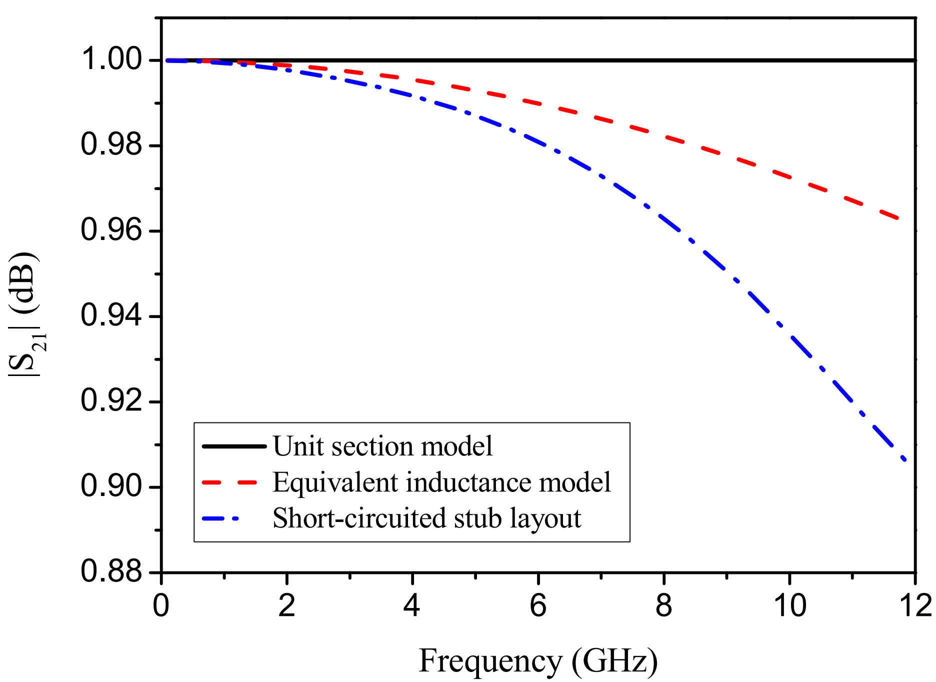
- **Comparison between the frequency responses of S_{21} for various equivalent circuit models for (a), (c) and (e).**

$\Delta\theta_u$	$\Delta\theta$	$\Delta\theta_L$	ΔL	$\Delta\theta_s$
12.4°	2.15°	8.1°	0.7 nH	15.76°

Simulated by ADS



Frequency response of $\angle S_{21}$

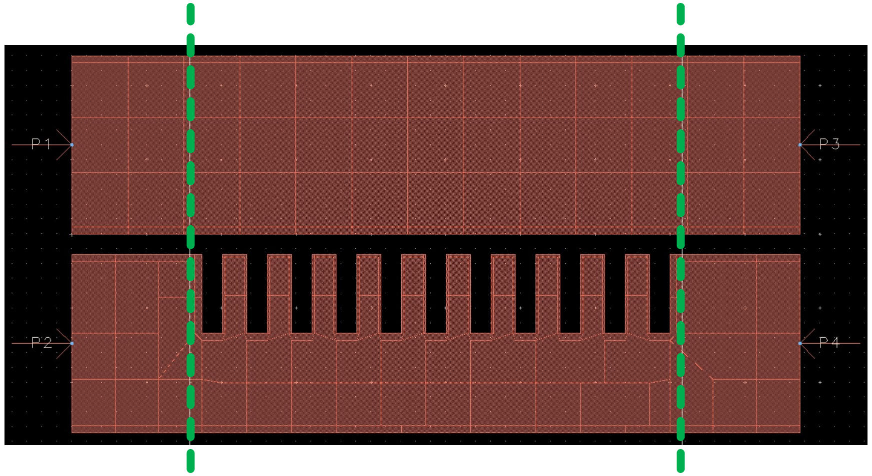


Frequency response of $|S_{21}|$

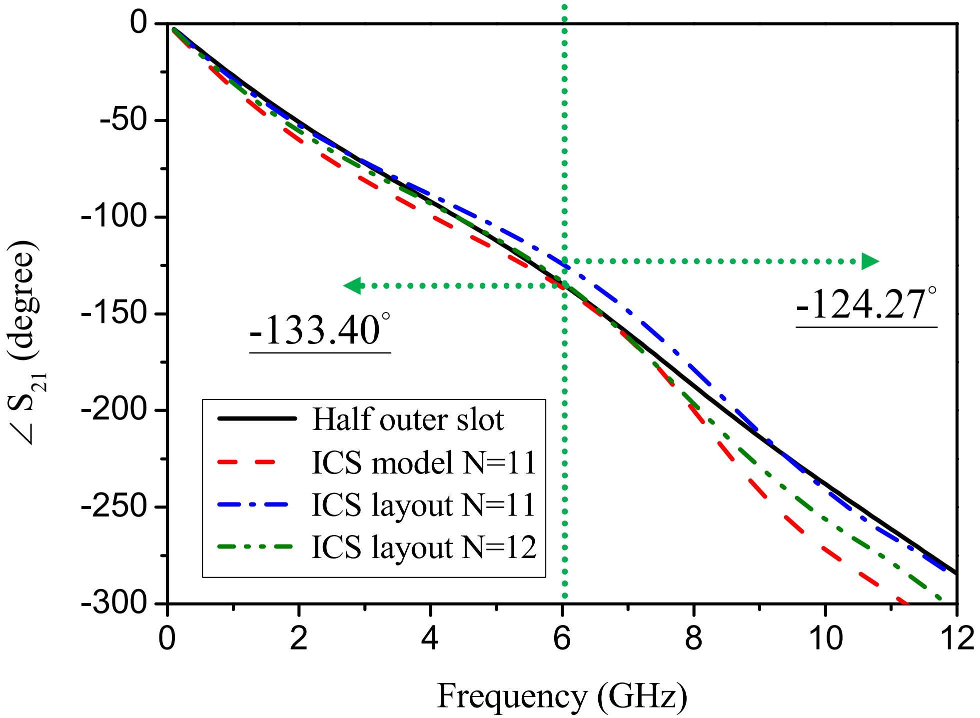
Bended Coplanar Waveguide Using Inductance-Compensated Slotline

- **Inductance-Compensated Slotline**

Simulated by ADS



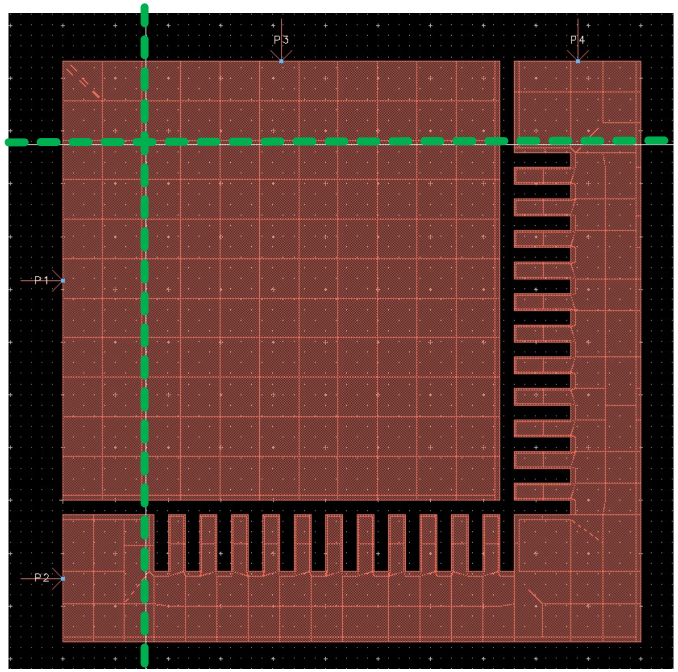
Schematic view of the inductance-compensated slotline layout.



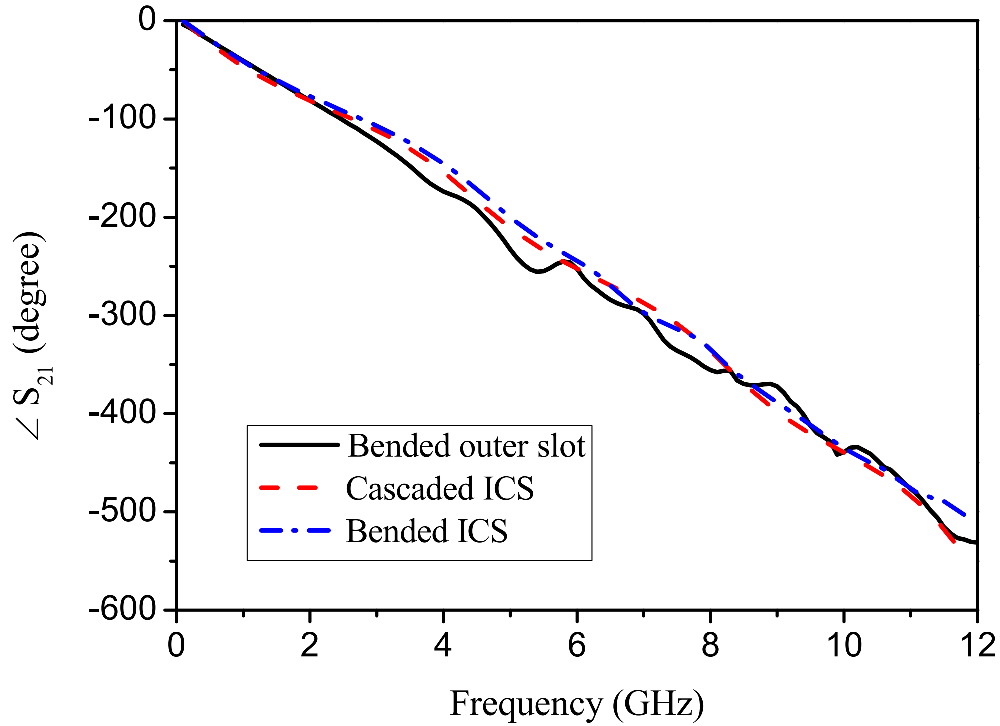
Bended Coplanar Waveguide Using Inductance-Compensated Slotline

● The bended inductance-compensated slotline

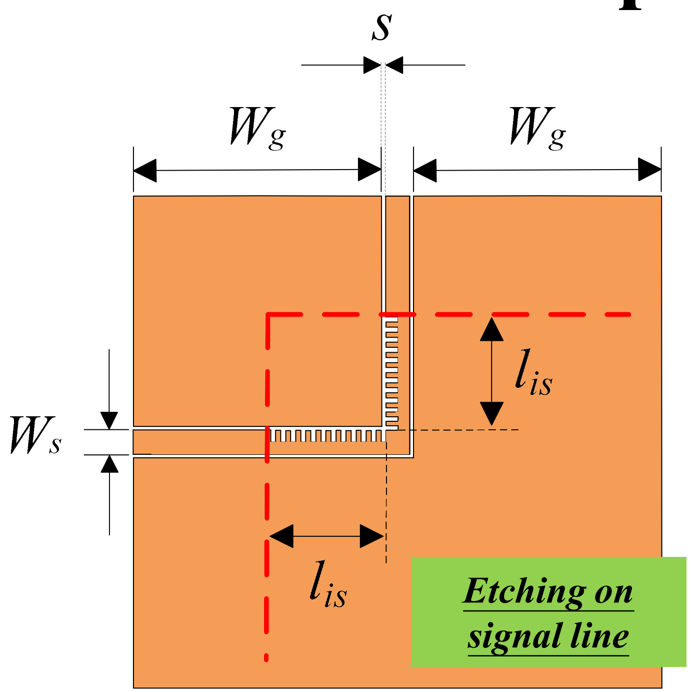
Simulated by ADS

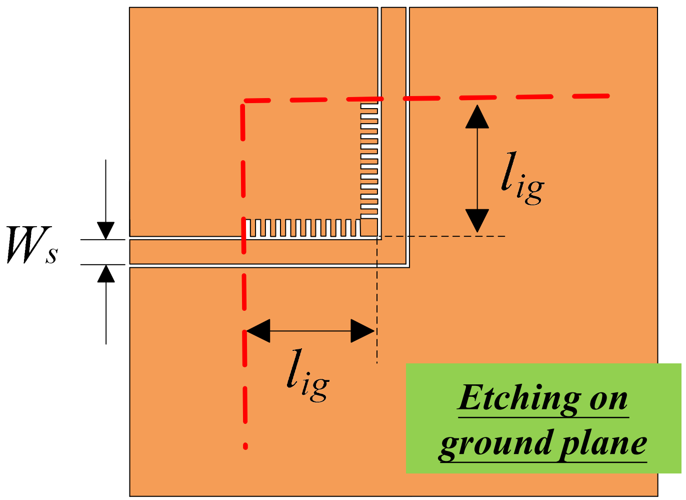


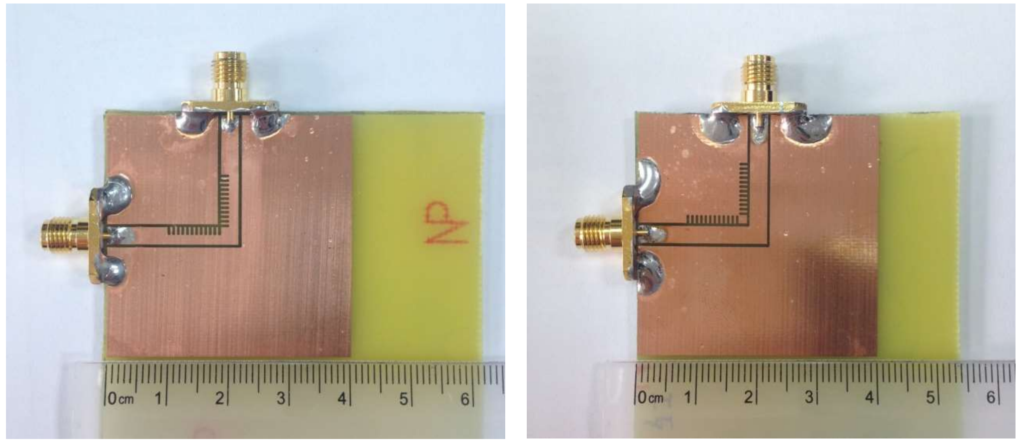
Schematic view of the bended inductance-compensated slotline.



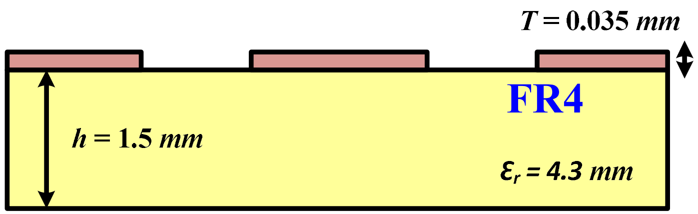
Bended Coplanar Waveguide Using Inductance-Compensated Slotline







Implementation



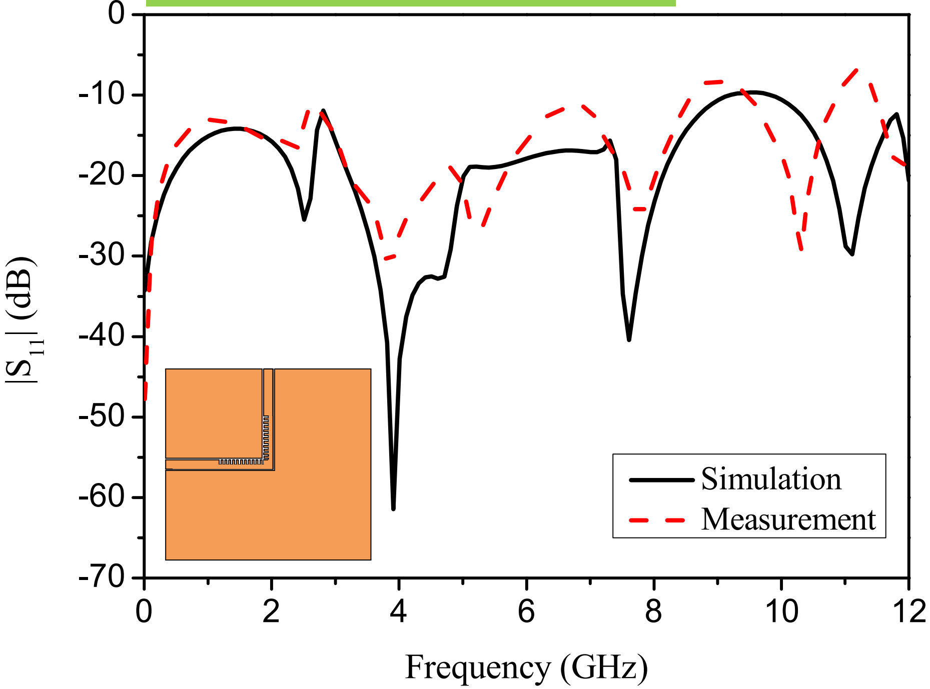
Cross-sectional view

W_s	W_g	s	l_{is}	l_{ig}
3.08 mm	18.48 mm	0.35 mm	8.915 mm	10.79 mm

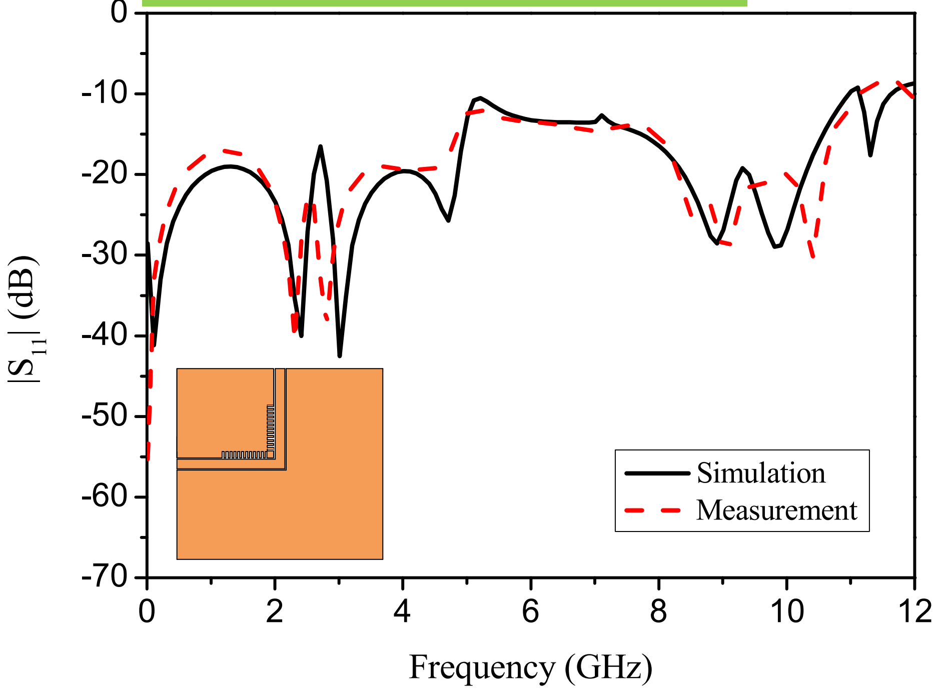
Bended Coplanar Waveguide Using Inductance-Compensated Slotline

- **Reflection Coefficient**

Etching on signal line



Etching on ground plane

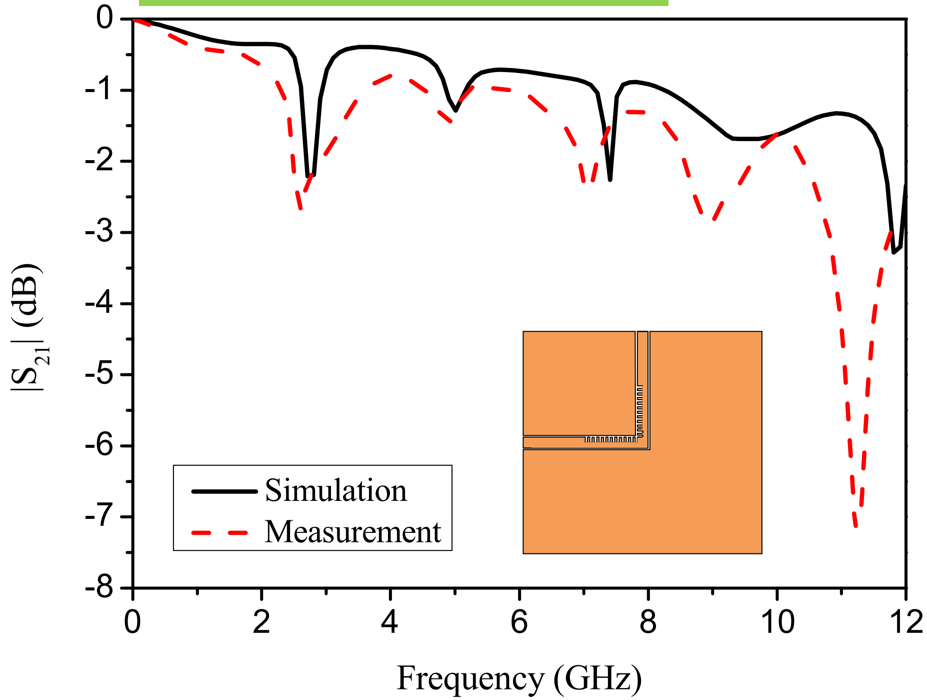


		Maximum Reflection Coefficient (dB)
Etching on the signal line	Simulation	-11.02
	Measurement	-7.76
Etching on the ground plane	Simulation	-9.52
	Measurement	-8.34

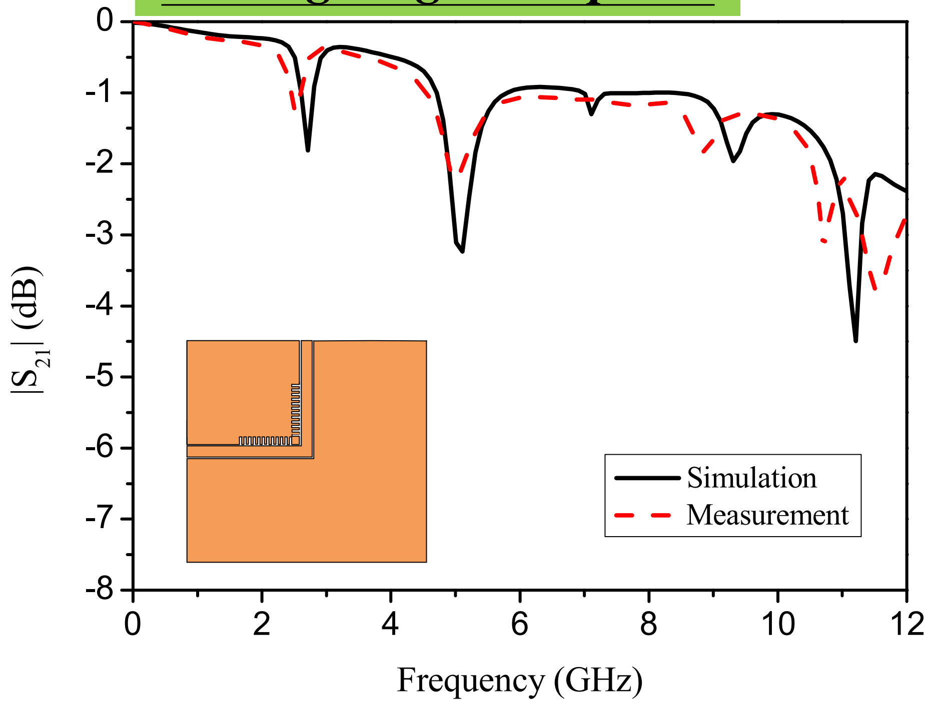
Bended Coplanar Waveguide Using Inductance-Compensated Slotline

● Transmission Coefficient

Etching on signal line



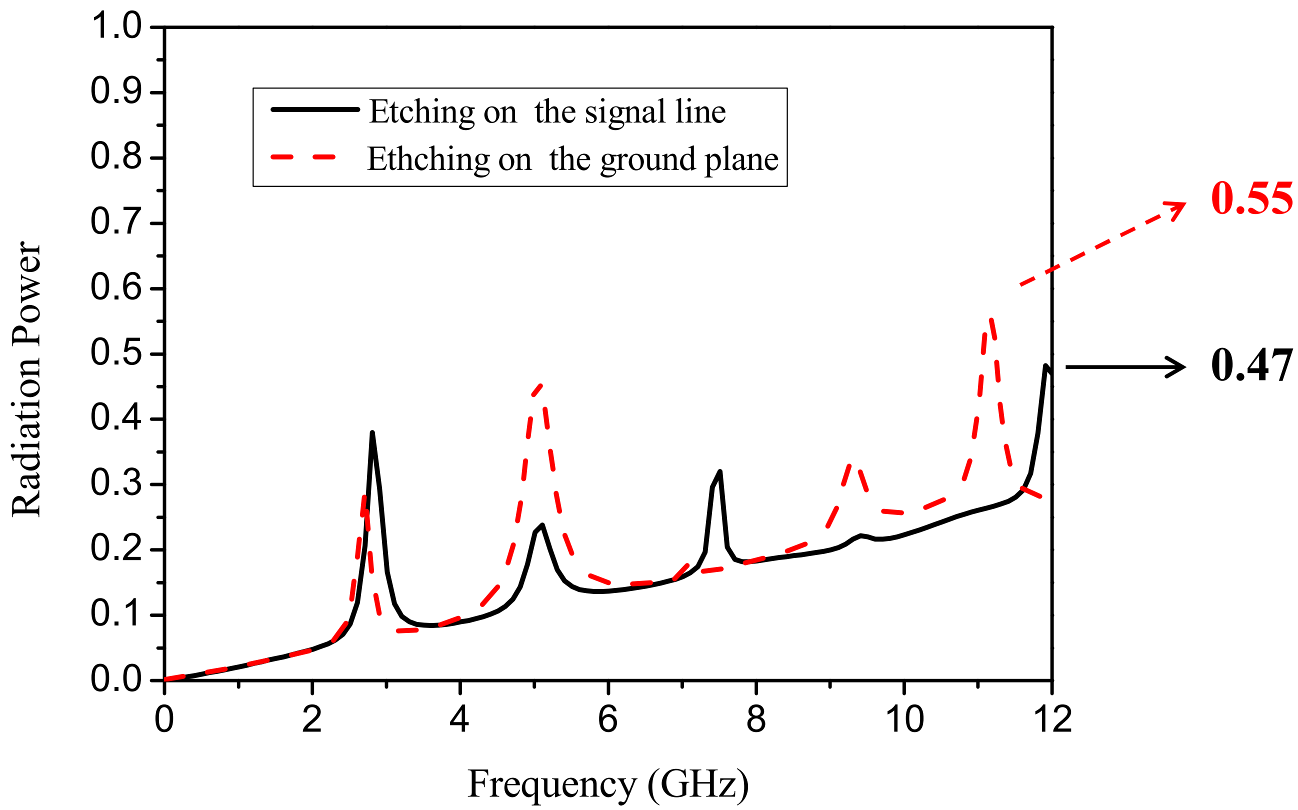
Etching on ground plane



		Minimum Transmission Coefficient (dB)
Etching on the signal line	Simulation	-2.19
	Measurement	-2.39
Etching on the ground plane	Simulation	-3.24
	Measurement	-3.13

Bended Coplanar Waveguide Using Inductance-Compensated Slotline

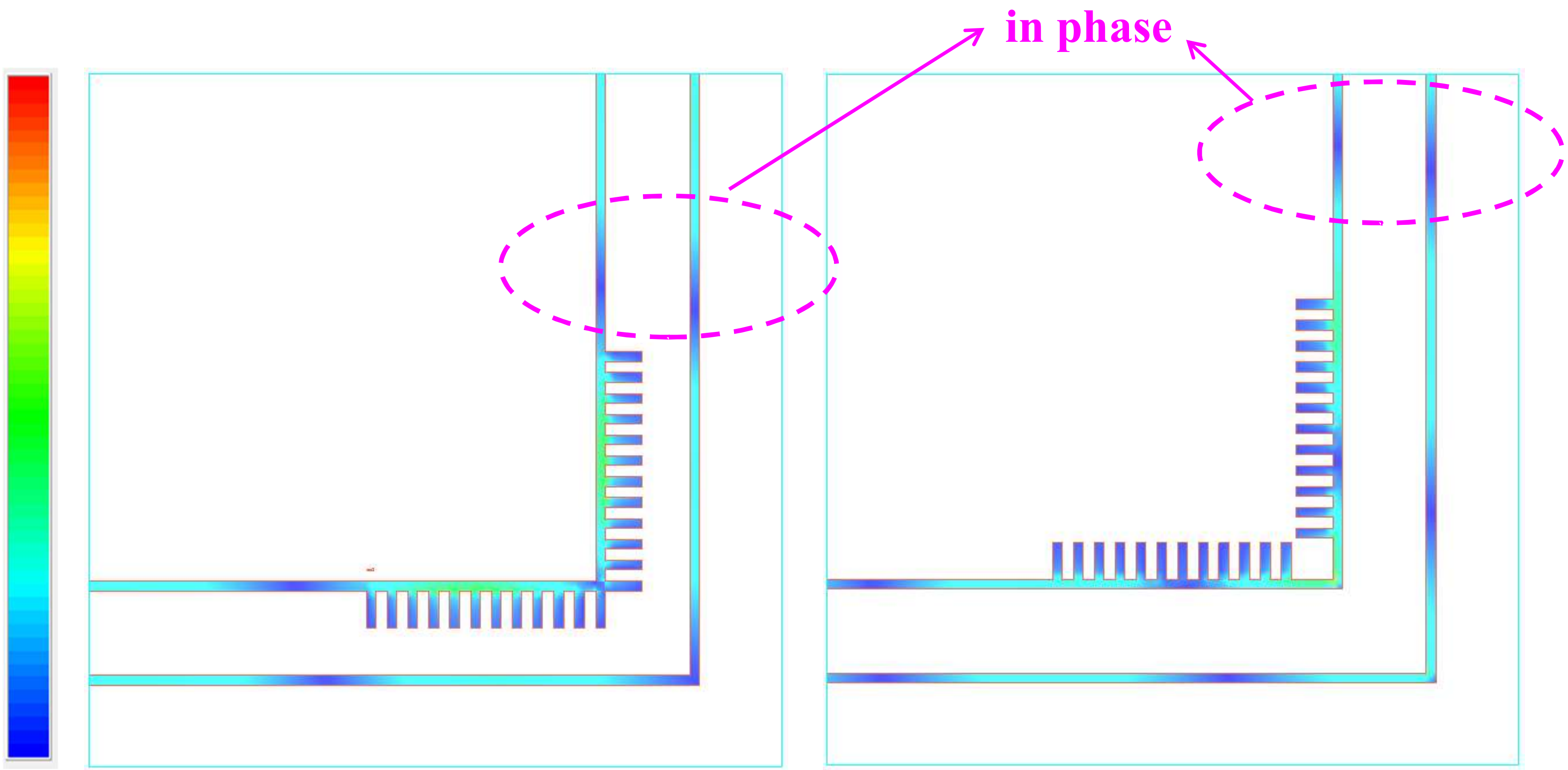
- **Radiation Power ($1-|S_{11}|^2-|S_{21}|^2$)**



Radiation power of the bended coplanar waveguides using the inductance-compensated slotline.

Bended Coplanar Waveguide Using Inductance-Compensated Slotline

- **Electric Field Distribution**

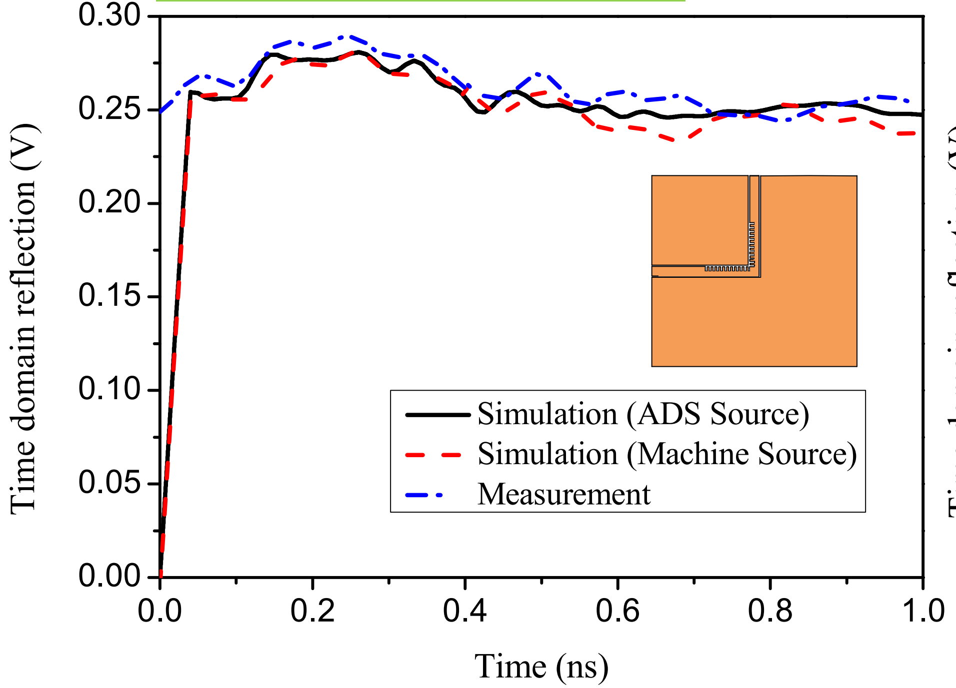


Electric field distribution of the bended coplanar waveguides using the inductance-compensated slotline.

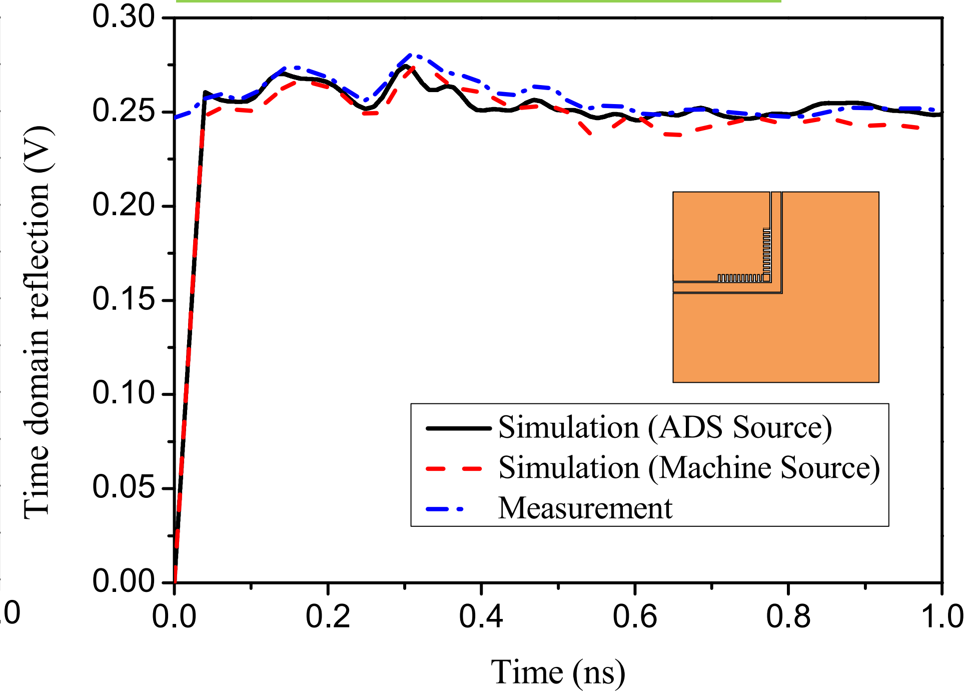
Bended Coplanar Waveguide Using Inductance-Compensated Slotline

- **TDR**

Etching on signal line



Etching on ground plane

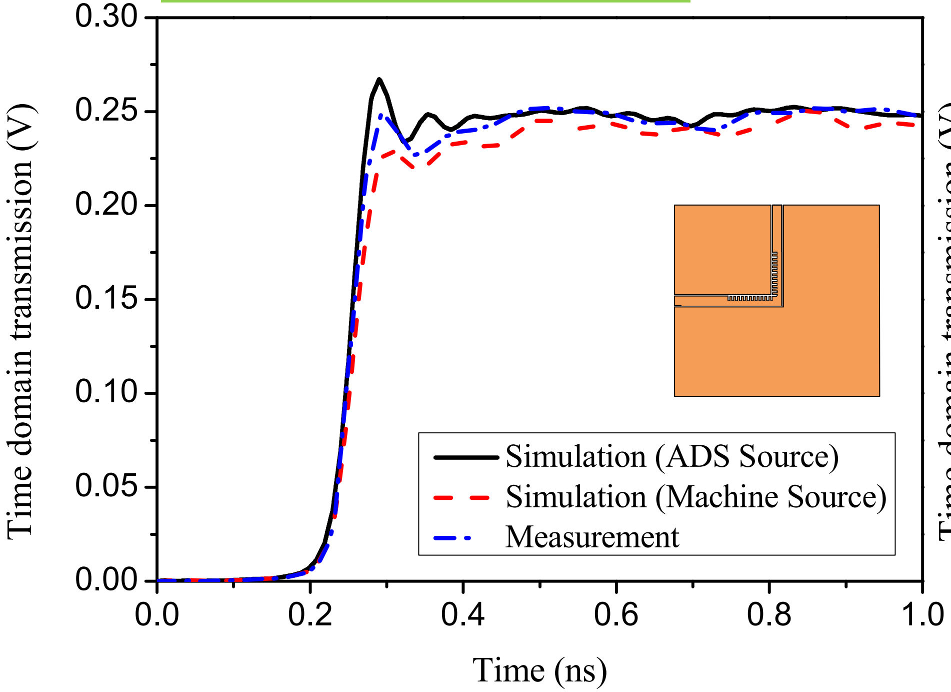


		Peak-to-peak TDR Noise (V)
Etching on the signal line	Simulation	0.029
	Measurement	0.034
Etching on the ground plane	Simulation	0.027
	Measurement	0.027

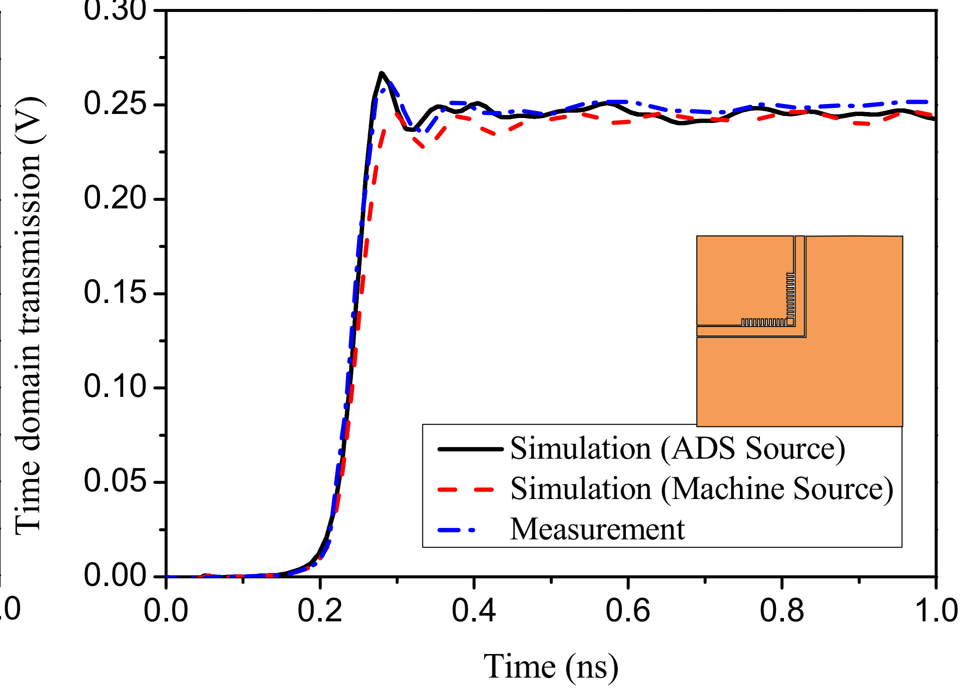
Bended Coplanar Waveguide Using Inductance-Compensated Slotline

- **TDT**

Etching on signal line



Etching on ground plane



		Peak-to-peak TDT Noise (V)
Etching on the signal line	Simulation	0.033
	Measurement	0.029
Etching on the ground plane	Simulation	0.029
	Measurement	0.025

Bended Coplanar Waveguide Using Inductance-Compensated Slotline

- **Eye Height & Eye Width & Jitter**

Etching on signal line	Eye Height (V)	Eye Width (ps)	Jitter (ps)
Bit Rate= 2Gbps, tr= 100 ps	**0.239 (95.6%)**	**496 (99.2%)**	**4.0**
Bit Rate= 4Gbps, tr= 50 ps	**0.224 (89.6%)**	**248 (99.2%)**	**2.50**
Bit Rate= 8Gbps, tr= 25 ps	**0.163 (65.2%)**	**120 (96%)**	**4.5**
Bit Rate= 16Gbps, tr= 12.5 ps	**0.177 (70.8%)**	**56.25 (90%)**	**6.083**

Etching on ground plane	Eye Height (V)	Eye Width (ps)	Jitter (ps)
Bit Rate= 2Gbps, tr= 100 ps	**0.23 (92%)**	**496 (99.2%)**	**4.0**
Bit Rate= 4Gbps, tr= 50 ps	**0.229 (91.6%)**	**248 (99.2%)**	**2.50**
Bit Rate= 8Gbps, tr= 25 ps	**0.166 (66.4%)**	**122 (97.6%)**	**3.00**
Bit Rate= 16Gbps, tr= 12.5 ps	**0.151 (60.4%)**	**53.2 (85.12%)**	**8.981**

Conclusion

Better

		Bended Coplanar Waveguide **Without Compensation**	Bended Coplanar Waveguide **Using U-shaped Slot**	Bended Coplanar Waveguide Using **ICS Slot on the Signal Line**	Bended Coplanar Waveguide Using **CCS Slot on the Signal Line**
Maximum Reflection Coefficient (dB)	Simulation	-2.44	-12.44	-11.02	-14.25
	Measurement	-2.74	-9.17	-7.76	-10.12
Minimum Transmission Coefficient (dB)	Simulation	-15.75	-6.24	-2.19	-1.63
	Measurement	-30.16	-5.54	-2.39	-2.79
Time-Domain Reflection Noise (Peak-to-Peak, V)	Simulation	0.033	0.028	0.029	0.015
	Measurement	0.050	0.029	0.034	0.024
Time-Domain Transmission Noise (Peak-to-Peak, V)	Simulation	0.040	0.027	0.033	0.022
	Measurement	0.030	0.029	0.029	0.015
Radiation Power (Peak, V)	Simulation	0.60	0.75	0.37	0.064