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Effect of slow wave structures on scan angles in microstrip

Leaky-Wave Antennas

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Abstract

This paper presents two miniaturized slow wave structures in microstrip leaky-wave antennas (MLWAs) which operate about 8 GHz. The effects of these structures on the scan angles have been compared in the paper. The designed interdigital capacitors and folded-back line have been investigated with ADS Momentum software. It has been shown that the interdigital capacitors (IDCs) yield to a broad scan angles from +53 to -74 degree, while the folded-back line inductor scans only the positive angles.

***Index Terms*—leaky-wave antenna (LWA), scan angle, slow wave structure, periodic structure.**

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- Introduction
- History
- Classification
- Recent attention
- Introduction to Slow wave structure
- Topologies of proposed LWAs
- Properties of proposed LWAs
- Effects of slow wave structure on scan angles and Results
- Conclusion
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Introduction

Definition of Leaky Wave Antennas (LWA)

- LWA is guiding structure that supports wave propagation along it.
- Waves are leaking along it continuously.
- Application: light and speedy vehicle, missile, plane and automotive Radar.
- LWA is travelling wave and non-resonant antenna.

Introduction

Advantages of LWAs

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- High directivity.
- Simple and cheap structure.
- Not-complicated feed network.
- **Ideally suits for frequency beam scanning applications (Beam scans with frequency inherently).**

- *So popular in Microwave and millimeter bands.*

Introduction

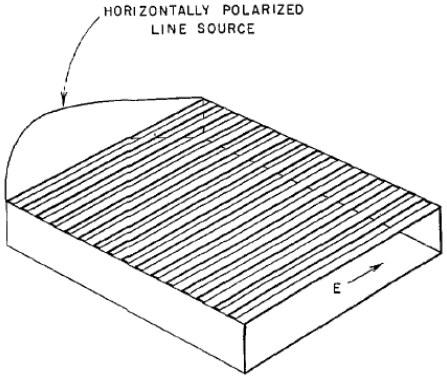
Disadvantages of LWAs

- Narrow pattern beam width ≈ (1% to 10%).

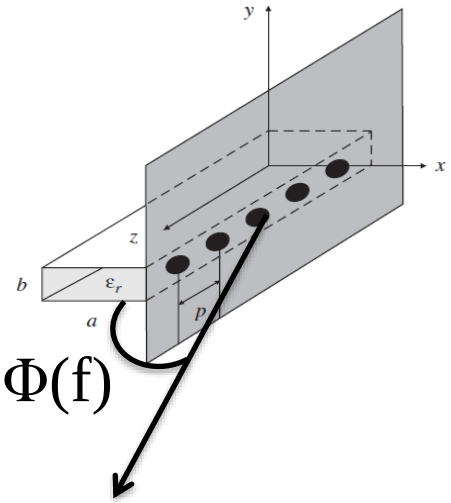
- *So, not appropriate for Point-to-Point communication.*

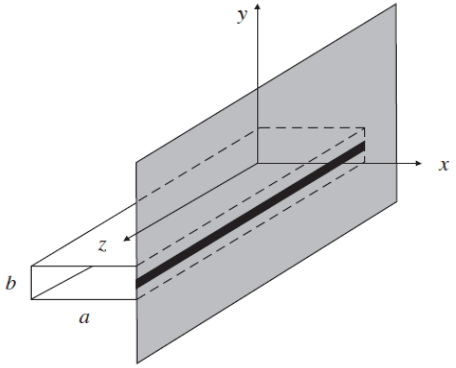
History of LWAs

- Started at 1940s.
- Introducing as slotted rectangular waveguide.
- Some prototype LWA structures, See below!



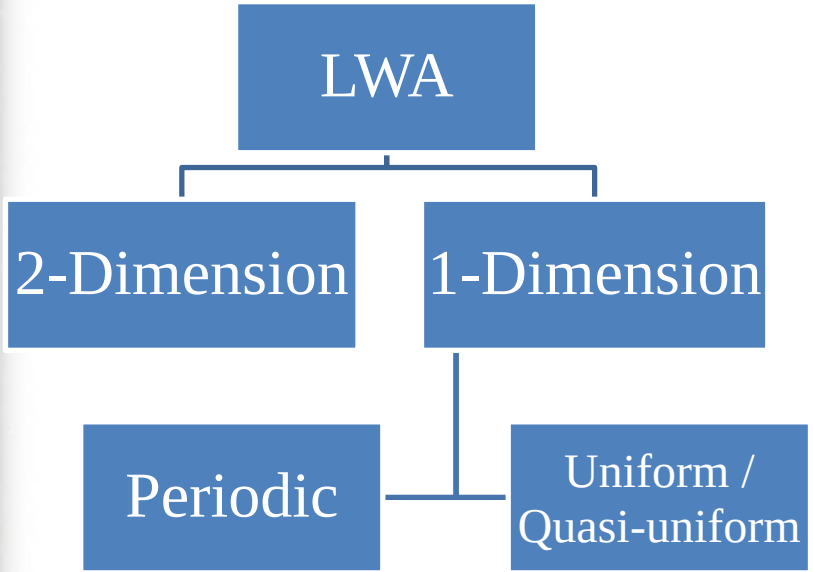
Honey LWA-1959
Dimensions: 46-61 cm
7-13 GHz
Transverse resonance method

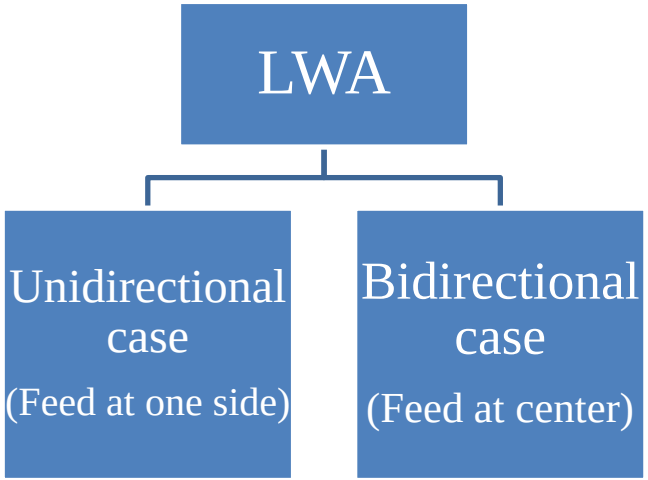




Classification of LWAs

- Classification based on feed location (Right chart)
- Classification based on wave propagating (Left chart)





Classification of LWAs

Based on feed location

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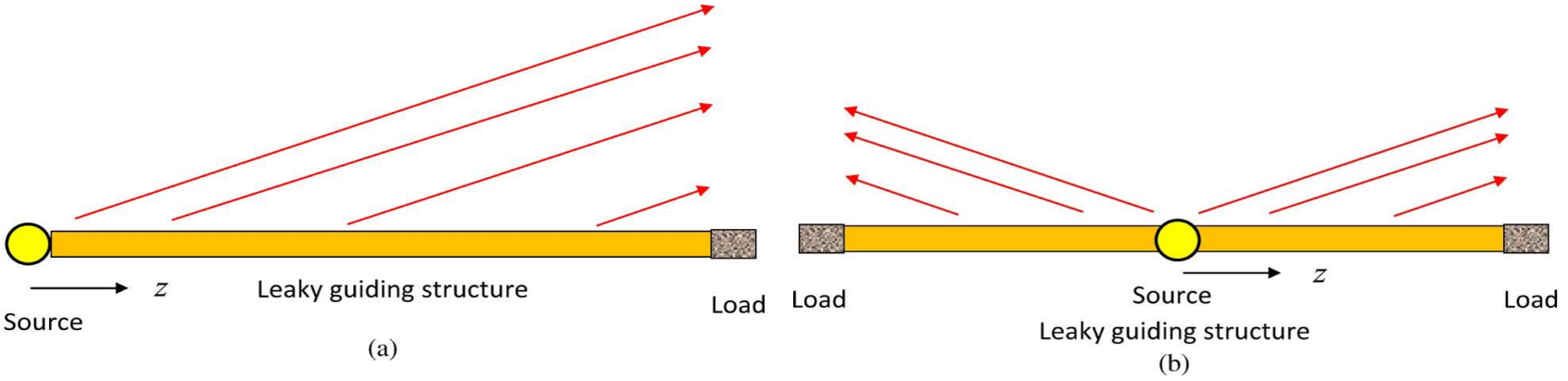
- **Figure (a):** Unidirectional case (Feed at one side)
- **Figure (b):** Bidirectional case (Feed at center): So useful because of creating beam at broadside.



Classification of LWAs

Based on wave propagating

- 1D: Wave is guided in 1 directional.

  1) Uniform (or Quasi-uniform): Guiding structure is uniform along length (support fast waves, $0 < \beta < k_0$).

  2) Periodic: Non-radiating changes to radiating by periodic structures (support slow wave, $\beta > k_0$).

- 2D: Wave is propagated on 2D guiding surface.

Recent Attention on LWA

- Full space scanning continuously.
  - ✓Means: full-space continuous beam scanning, from backfire to endfire, including the broadside direction.
- Create broadside beam by bidirectional LWA.
- Overcoming the “open stop band” problem.
- Power recycling to avoid wasting non-radiated power.
- LWA for curved surface.

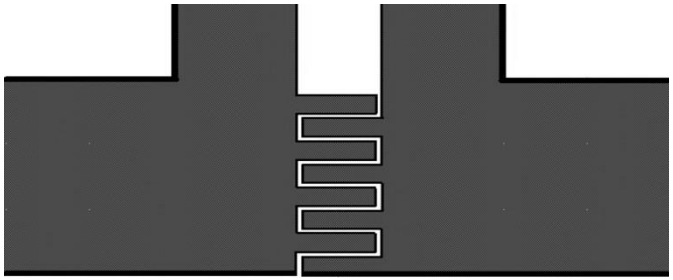
Slow wave structures (SWSs)

- Controlling and handle the wave velocity in certain direction.
- SWS is non-resonant circuit.
- SWS is designed for producing large gain antennas.

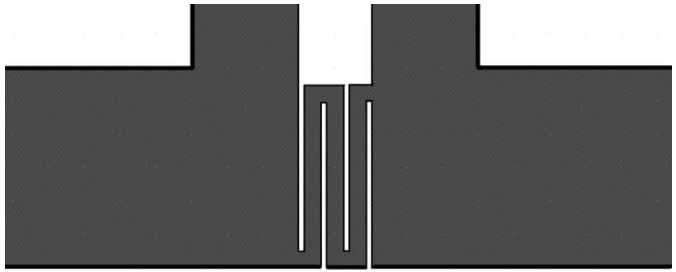
Some slow wave structures

- Zigzag line
- Corrugated waveguide
- Helical line
- Folded-back line inductor
- Interdigital capacitor (IDC)

Effects of them on scan angles in LWA will be investigated.

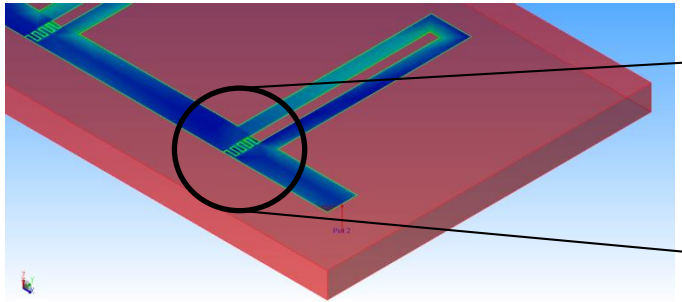


Interdigital Capacitor (typical IDC)



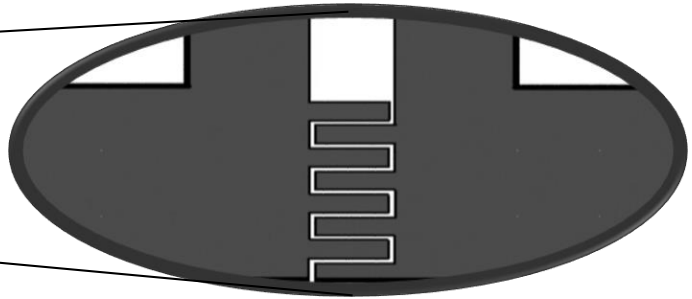
Folded back line inductor

Unit cell of each proposed LWAs

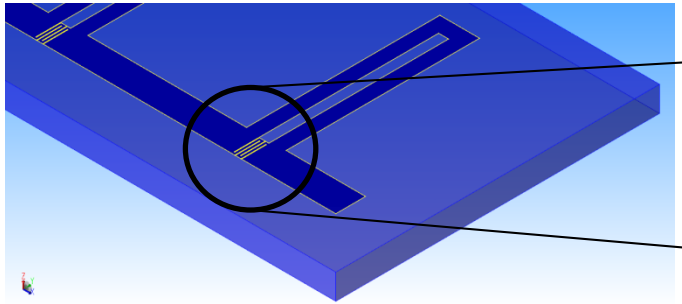


3D view of proposed LWA with periodic IDC.

Zoom in

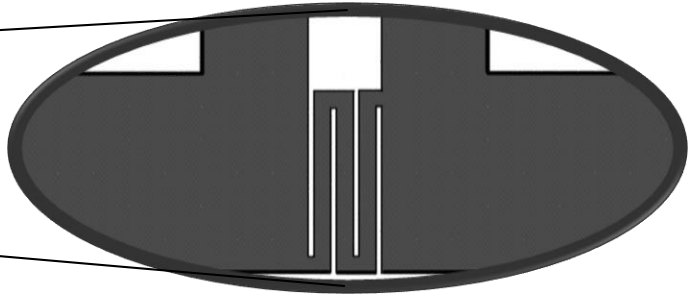


Unit cell of IDC



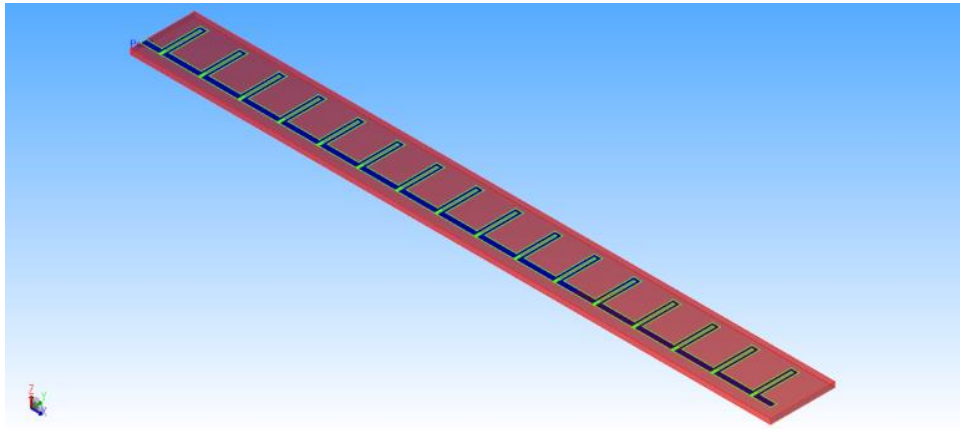
3D view of proposed LWA with periodic folded-back line.

Zoom in

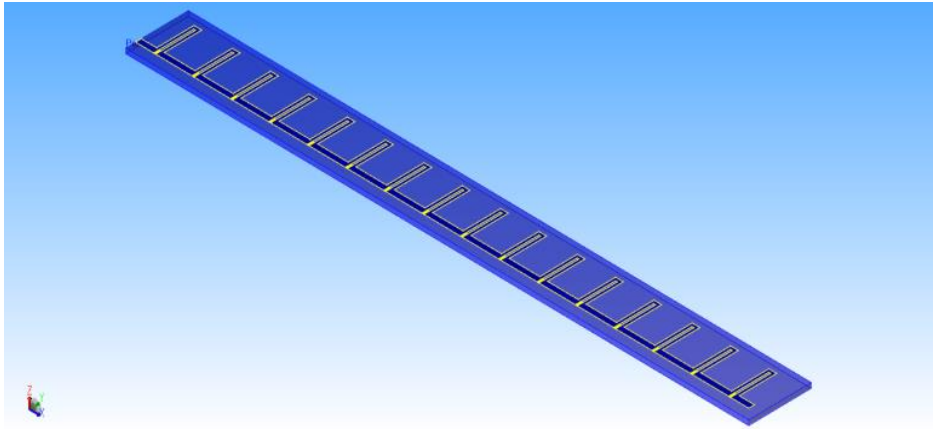


Unit cell of folded-back line

3D view of 16-cell periodic LWAs



3D view of LWA with IDCs formed by 16 cells.



3D view of LWA with folded-back line formed by 16 cells.

Properties of proposed LWAs

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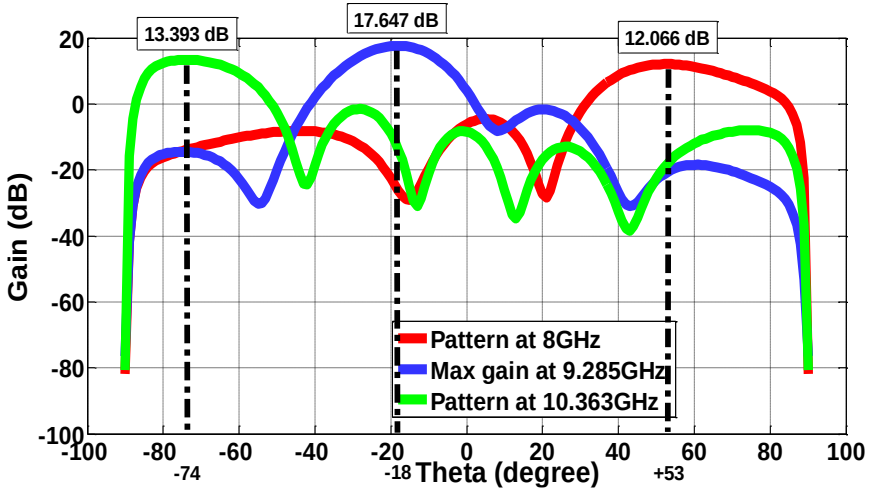
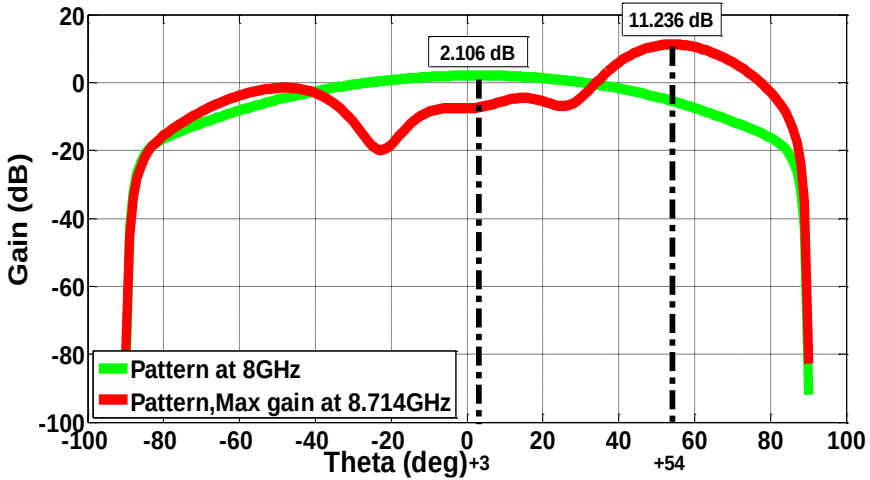
Property	LWA with IDCs	LWA with folded back
Type of LWA	CRLH	RH
Fabrication Technology	Microstrip	Microstrip
Number of cells	16	16
Frequency band analyzing	X-band	X-band
Dimensions of unit cell	4.5mm * 4mm	4.5mm * 4mm
Dimensions of 16-cell	4.5mm * 64mm	4.5mm * 64mm
Substrate and height	Rogers 5880, h = 0.508mm	Rogers 5880, h = 0.508mm
ε_r of substrate	10.2	10.2

Results of radiation pattern and scan angles for both MLWAs

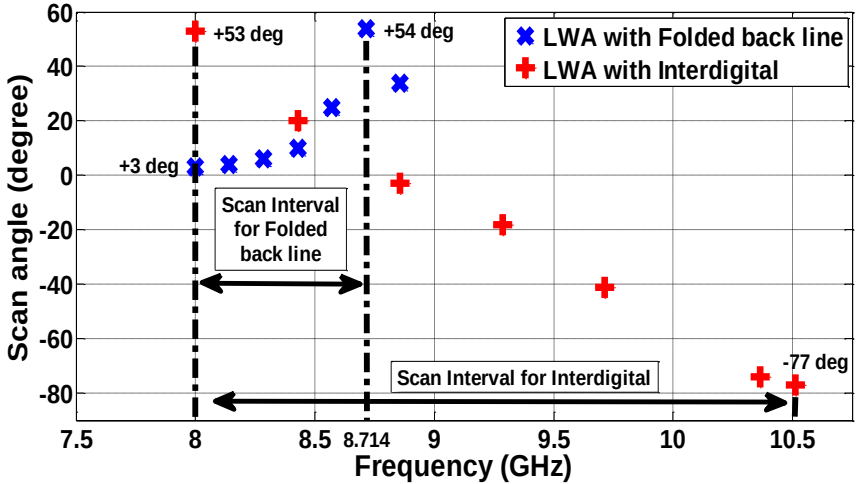


Radiation pattern of LWA with IDC

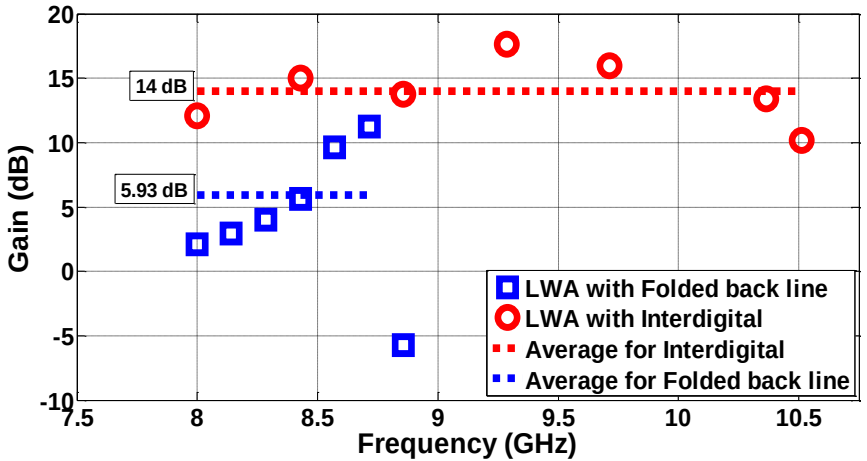


Radiation pattern of LWA with folded back

Other Results



Details of scan angles in both proposed LWAs when frequency changes.



Details of magnitude of the gain in both proposed LWAs when frequency changes and the average of gains in interval of scan.

Magnitude of S-parameter

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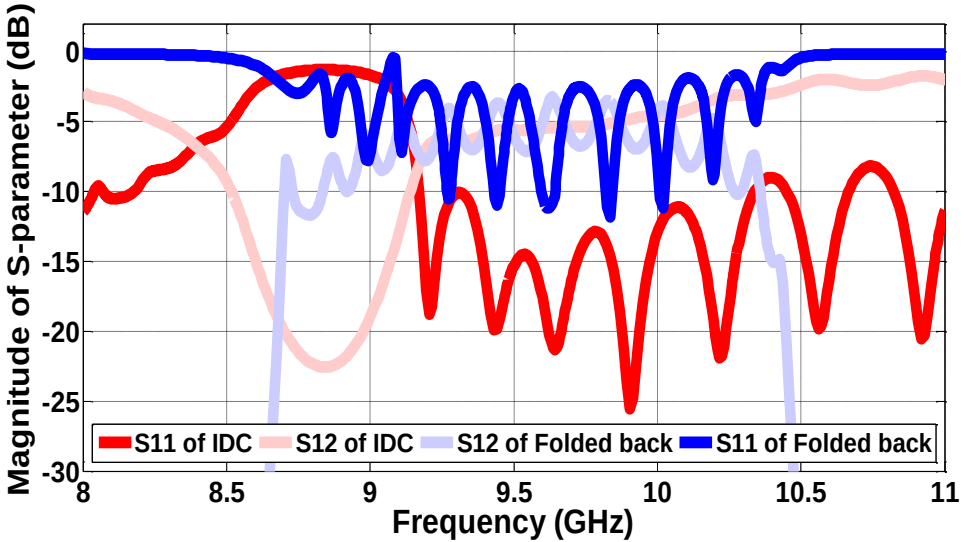

Red lines: S-Parameter for LWA with IDCs
Blue lines: S-Parameter for LWA with folded-back line

Comparative results and conclusion

✓Replacing an Interdigital capacitor with a folded back line inductor in this letter.

✓LWA with Folded back line scans only positive angles (Forward radiation).

Name of antenna	Scan Freq (GHz)	Scan angles (deg) in Φ= 0° plane	Max gain (dB)	Forward / backward radiation	descriptions
LWA with IDC	8 to 10.36	-74 to +53	17.64	Yes / Yes	CRLH
LWA with folded back	8 to 8.71	+3 to +54	11.23	Yes / No	RH

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