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.
Contents

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• History
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• Recent attention
• Introduction to Slow wave structure
• Topologies of proposed LWAs
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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

- 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.
Narrow pattern beam width $\approx (1\% \text{ to } 10\%)$.

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

- **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.
Unit cell of each proposed LWAs

3D view of proposed LWA with periodic IDC.

Unit cell of IDC

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

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.
<table>
<thead>
<tr>
<th>Property</th>
<th>LWA with IDCs</th>
<th>LWA with folded back</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of LWA</td>
<td>CRLH</td>
<td>RH</td>
</tr>
<tr>
<td>Fabrication Technology</td>
<td>Microstrip</td>
<td>Microstrip</td>
</tr>
<tr>
<td>Number of cells</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Frequency band analyzing</td>
<td>X-band</td>
<td>X-band</td>
</tr>
<tr>
<td>Dimensions of unit cell</td>
<td>4.5mm * 4mm</td>
<td>4.5mm * 4mm</td>
</tr>
<tr>
<td>Dimensions of 16-cell</td>
<td>4.5mm * 64mm</td>
<td>4.5mm * 64mm</td>
</tr>
<tr>
<td>Substrate and height</td>
<td>Rogers 5880, h = 0.508mm</td>
<td>Rogers 5880, h = 0.508mm</td>
</tr>
<tr>
<td>$\varepsilon_r$ of substrate</td>
<td>10.2</td>
<td>10.2</td>
</tr>
</tbody>
</table>
Results of radiation pattern and scan angles for both MLWAs

Radiation pattern of LWA with IDC

Radiation pattern of LWA with folded back
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

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).

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