Compact Bandpass Filter with Wide Stopband and Low Radiation Loss Using Substrate Integrated Defected Ground Structure

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• Substrate Integrated DGS Filter
  – Substrate integrated DGS cell
  – Filter design using substrate integrated DGS cell
  – Radiation
• Experimental Results & Comparison
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Motivation & Introduction & Challenges

• Motivation
  – Future wireless system
    • Implement with high integration level
    • Cancel interference from different devices
    • Simplify the wireless system
Motivation & Introduction & Challenges

• Air-Filled SIW Bandpass Filter
  – High passband selectivity
  – Low insertion loss and low radiation loss
  – Narrow stopband bandwidth

Motivation & Introduction & Challenges

- Bandpass Filter Using Stepped-Impedance Resonators
  - Wide stopband to $10.6f_0$ with the rejection of -23.7 dB
  - Good passband selectivity
  - High radiation and insertion loss

Motivation & Introduction & Challenges

• Bandpass Filter Using Hybrid Microstrip T-Stub/DGS Cell
  – Wide stopband to $12.1f_0$ with the rejection of -30.1 dB
  – Extra requirement for packaging
  – High radiation loss

Motivation & Introduction & Challenges

- Challenges

- Low insertion loss
- Compact size
- Wide stopband
- Low radiation loss
- High selectivity
Substrate Integrated DGS Filter

- Configuration of Substrate Integrated DGS Filter
  - Layer introduction
    - Top layer: microstrip line and metal-vias
    - Middle layer: ground I with DGSs
    - Bottom layer: ground II serves as the surrounding ground
Substrate Integrated DGS Filter

- Configuration of Substrate Integrated DGS Filter
  - Microstrip feed-lines
  - Substrate integrated DGS cell
    - DGS (Middle layer)
    - Surrounding ground (Bottom layer)
    - Surrounding metal-vias (Though 3 layers)
Substrate Integrated DGS Filter

- SIDGS Cell
  - Resonance
    - Resonances of the two separate resonators and the cell
Substrate Integrated DGS Filter

- SIDGS Cell
  - Stopband frequency response in two cases

A strong-coupled feed-line with a patch (Case B) enhances the harmonic suppression
Substrate Integrated DGS Filter

- SIDGS Cell
  - Enhanced slow-wave effect to extend stopband bandwidth

![Diagram showing frequency response and regions](image)

- Reg. I: Strong effective capacitance
- Reg. II: Strong effective inductance

Enhanced slow-wave effect
Substrate Integrated DGS Filter

• Filter Design
  – Coupling-node diagram of the proposed BPF
Substrate Integrated DGS Filter

• Filter Design

– The extraction of the couplings of the main paths

\[ k_{12} \quad \downarrow \quad k_{34} \quad \downarrow \]

\[ w_4 \quad \uparrow \quad w_6 \quad \uparrow \quad l_t \quad \uparrow \quad Q \quad \downarrow \]
Substrate Integrated DGS Filter

- Radiation
  - Simulated radiation loss under the case of lossless substrate and metal
  - The surrounding ground and metal-via minimize the radiation level

\[ R_r = 1 - |S_{11}|^2 - |S_{21}|^2 \]
Photograph – Constructed on an RO4003C dielectric substrate with $\varepsilon_r = 3.55$ and thickness of $h_1 = 0.203\text{ mm}$, $h_2 = 0.303\text{ mm}$.

– Core size is 12.2 mm $\times$ 12.3 mm ($0.16\ \lambda_g \times 0.16\ \lambda_g$).
Experimental Results & Comparison

- Experimental result
- Center frequency: 2.4 GHz
- 3-dB FBW: 24.6%
- Minimum insertion loss: 1.66 dB
- Stopband rejection: >29 dB up to 19.3 GHz
- Radiation Loss: <6% up to 19 GHz
- Total loss (including radiation, metal, and substrate loss): <30% up to 19 GHz
Experimental Results & Comparison

- Comparison

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<tbody>
<tr>
<td>Technology</td>
<td>SIW</td>
<td>Microstrip</td>
<td>DGS</td>
<td>SIDGS</td>
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<tr>
<td>$f_0$ (GHz)</td>
<td>4.83</td>
<td>1.5</td>
<td>2.48</td>
<td>2.4</td>
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<tr>
<td>Insertion Loss (dB)</td>
<td>1.2</td>
<td>2.52</td>
<td>1.081</td>
<td>1.66</td>
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<tr>
<td>FBW (%)</td>
<td>1.4</td>
<td>8.9</td>
<td>10.8</td>
<td>24.6</td>
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<td>Stopband Rejection</td>
<td>&gt;15 dB up to 1.4$f_0$</td>
<td>&gt;23.7 dB up to 10.6$f_0$</td>
<td>&gt;30 dB up to 12$f_0$</td>
<td>&gt;29 dB up to 8$f_0$</td>
</tr>
<tr>
<td>Radiation Loss$^\dagger$</td>
<td>Low</td>
<td>High</td>
<td>30% at 19 GHz</td>
<td>&lt;6% to 19 GHz</td>
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<tr>
<td>Peak Total Loss*</td>
<td>≈37%** at 6.25 GHz</td>
<td>≈98%** at 4.1 GHz</td>
<td>≈60%** at 19 GHz</td>
<td>30% at 19 GHz</td>
</tr>
<tr>
<td>Total Loss &lt;30%</td>
<td>Up to 6.1 GHz**</td>
<td>Up to 4 GHz**</td>
<td>Up to 14 GHz**</td>
<td>Up to 19 GHz</td>
</tr>
<tr>
<td>Core Size</td>
<td>1000 mm$^2$</td>
<td>0.0192 (μ$m^2$)</td>
<td>0.1122 (μ$m^2$)</td>
<td>0.0256 (μ$m^2$)</td>
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<td>777 mm$^2$</td>
<td>847 mm$^2$</td>
<td>150 mm$^2$</td>
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</table>

$^\dagger$: Calculated radiation loss under case of lossless substrate and metal.
*: Including radiation, metal, and substrate loss.
**: Estimated from the paper.
Conclusion

• Substrate integrated defected ground structure is firstly introduced for a wide stopband characteristic and low radiation loss.
• A filter is designed using SIDGS cells inherits the merits of DGS including the wide upper stopband with a compact size. Moreover, it exhibits a strong advantage in the suppression of radiation.
• With such good performance and flexibility of integration, the miniaturized SIDGS cells and BPF are attractive for the practical applications.
ACKNOWLEDGMENT

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Thank you for your attention!