Oral of Fractal Based Muti-Band Reject Filter

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Aim of Work

- The aim of this work is to design and fabricate a bandstop filter based on Minkowski-like fractal geometry in the range of useful frequency extending from 1 to 6 GHz. And also, to design and fabricate microstrip BSF structures to operate as a means in the microwave oven for radiation leakage reduction [1].
Fractal Geometry

- The properties of fractal geometry [2]:-
  a) Space-Filling.
  b) Self-Similarity.
  c) Fractal Dimension.
Fig. 1: a) Minkowski-like pre-fractal [3], b) Koch fractal [4], c) Hilbert fractal[5], d) Peano fractal [6], e) and f) Sierpinski fractal [7-8], and g) H-fractal elements [9].
The Minkowski-like Geometry

Fig. 2: Layout of Minkoski- Like Geometry. a) zero iteration, b) 1st iteration, and c) 2nd iteration [3].

\[ L_0 = L_1 = L_2, \text{ where } L_0, L_1, \text{ and } L_2 \text{ are perimeters of zero, 1st and 2nd resonators, respectively.} \]
Fig. 3: Layout of a) Conventional BSF, b) Proposed Triple BSF [1,10,11].
Triple-band BSF

- Single-band BSFs.

\[ L = 0.639 \lambda_g \]

Fig. 4: a) Layout of conventional square open-loop b) Frequency response [1,11].

Where \( \lambda_g \) is waveguide wavelength
Fig. 5: a) The layout of BSF with three 1st iteration Minkowski-like resonators b) Its frequency response \([1,11]\).
Triple-band BSF

- Single-band BSFs.

Fig. 6: a) The layout of the 2\textsuperscript{nd} iteration Minkowski-like BSF b) Its frequency response [1,11].
Triple-band BSF

- Dual-band BSFs.

Fig. 7: First filter a) Layout b) Frequency response [1,11].
Triple-band BSF

- Dual-band BSFs.

Fig. 8: Second filter a) Layout of filter b) Frequency response [1,11].
Triple-band BSF

- Dual-band BSFs.

Fig. 9: Third filter a) Layout of BSF b) Frequency response [1,11].
Fig. 10: Triple-bands BSF a) Layout b) Frequency response [1,11].
Table 1: Summary of the triple-bands BSF properties [1,11].

<table>
<thead>
<tr>
<th>No.</th>
<th>$f_0$ (GHz)</th>
<th>Insertion loss (dB)</th>
<th>-3 dB bandwidth (GHz)</th>
</tr>
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<tbody>
<tr>
<td>Band 1</td>
<td>1.68</td>
<td>-17.27</td>
<td>0.02</td>
</tr>
<tr>
<td>Band 2</td>
<td>2.07</td>
<td>-14.75</td>
<td>0.025</td>
</tr>
<tr>
<td>Band 3</td>
<td>3.05</td>
<td>-38.73</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Fig. 11: Current distributions on the surface of the triple-band BSF at (a) 1.1 GHz (b) 1.68 GHz (c) 1.9 GHz (d) 2.07 GHz (e) 2.4 GHz, and (f) 3.05 GHz [1,11].
Fig. 12: A photo of the fabricated triple band BSF prototype [1,11].
Fig. 13: Measured and Simulated responses of the fabricated filter depicted in Fig. 4. a) $S_{11}$, b) $S_{21}$ [1,11].
A BSF with Controlled Characteristics Using Open Stub

Fig. 14: Square open-loop BSF a) Layout of BSF b) Response of BSF [1].

\[ L = 0.605 \lambda_g \]
A BSF with Controlled Characteristics Using Open Stub

Fig. 15: a) Layout of BSF with Minkowski-like resonators b) Frequency response of it [1].

\[ \mathcal{L} = 0.687 \lambda_g \]
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Fig. 16: a) Implementation of equivalent circuit b) Frequency response using MWO [1].
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- Modify design.

Fig. 17: Geometry of modified filter [1].
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- Parametric Study of the New Design

Fig. 18: The effect of varying the length of stub a) $S_{11}$, b) $S_{21}$ [1].
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Final design.

Fig. 19: The modeled BSF based on the 1st iteration Minkowski-like open loop resonators with open shunt stub a) Layout of BSF b) Frequency response [1].
A BSF with Controlled Characteristics Using Open Stub

- The specification of this filter are: the center frequency is at 2.4 GHz, two zeros at 2.2 GHz and 2.6 GHz, the rejection level of insertion loss at center frequency is -37dB, the -3dB bandwidth is between 2.35 GHz and 2.435 GHz and overall size is 24×23 mm² [1].

- The last filter is suitable for the dimensions of the microwave oven but can't be used for it because the 2.45 GHz isn't inside bandwidth; therefore, in the next the filter dimensions will be scaled to shift center frequency to 2.45 GHz to be inside the filter stopband [1].
A BSF with Controlled Characteristics Using Open Stub

Fabricated Model and the Measured Results.

Fig. 20: (a) A photograph of the fabricated BSF prototype. (b) Frequency response of fabricated BSF [1].
A BSF with Controlled Characteristics Using Open Stub

The measured results are found in good agreement with the simulation results. However, some shift in center frequency to 2.38 GHz, -3dB bandwidth is between 2.362 GHz and 2.432 GHz and there are little differences in the return loss and insertion loss, as shown in Fig.(20). The differences are also because of limitations of the fabrication dimensional tolerances that might affect the mismatch of the input and output ports [1].
Application of the Proposed Filter as a Leakage Reduction of Microwave Oven

Fig. 21: a) Layout and dimensions of BSF b) Frequency response [1].
Application of the Proposed Filter as a Leakage Reduction of Microwave Oven

In this case, the filter properties are: center frequency at 2.45 GHz, insertion loss -21.26dB, -3dB bandwidth equal to 0.2 GHz, and two zeros at 2.333 GHz and 2.766 GHz [1].

To make the proposed filter dimensions suitable for the frame of the microwave oven, we need two pairs of rulers; the dimensions of first pair are 198×24 mm²; therefore a 1-D BSF array consisting of 8 elements is required. The spacing between the two adjacent elements is 24×2 mm². The second pairs have dimensions of 288×24 mm² and consist of 11 elements with the same spacing between adjacent elements and with two spaces' at the edge having the dimensions of 24×7.5 mm² to entirely cover the frame of oven [1].
Application of the Proposed Filter as a Leakage Reduction of Microwave Oven

Fig. 22: A Photograph of the fabricated filter prototype for radiation leakage reduction of microwave oven [1].
Application of the Proposed Filter as a Leakage Reduction of Microwave Oven

Before fixing the proposed filter, the RF field out from the microwave oven has been measured using RF field strength meter shown in Fig.(23.b). It has been found that the value of field strength leakage is $506\mu\text{W/cm}^2$, which doesn’t exceed the Australian Standard 3301 [1,12].
Application of the Proposed Filter as a Leakage Reduction of Microwave Oven

Fig. 23: a) Photograph of used microwave oven., b) The use of the RF field strength meter to measure leakage from the microwave oven without using the proposed BSF arrays [1].
Application of the Proposed Filter as a Leakage Reduction of Microwave Oven

Fig. 24: The use of the RF field strength meter to measure leakage from the microwave oven with the existence of the proposed BSF arrays [1].
Application of the Proposed Filter as a Leakage Reduction of Microwave Oven

Table 2: Comparison between the proposed work and that reported in [13].

<table>
<thead>
<tr>
<th></th>
<th>Thickness of substrate</th>
<th>Complexity</th>
<th>Leakage ($\mu$w/cm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference [13]</td>
<td>10 mm</td>
<td>More complexity (used mushroom, posts)</td>
<td>350 of QWC</td>
</tr>
<tr>
<td>Proposed Work</td>
<td>1.5 mm</td>
<td>Used single layer</td>
<td>257</td>
</tr>
</tbody>
</table>
Recommendations for Future Work

- Search for new fractal-based structures which are both more compact and more selective. A suggested technique is to adopt the multi-layer filter structure to achieve such a task [1].

- Conducting research to integrate the BSF within the structure of the UWB antenna design without increasing its physical size by investigating the current distribution on the surface [1].

- Conducting a research work to design dual-band and multiband BPFs by integrating the multiband BSF within the structures of broadband and UWB BPF structures [1].
List of Publications


Fabrication Process of the Proposed Microstrip BSFs

Fig. 25: Photograph of ProtoMat S100 [1].
Fabrication Process of the Proposed Microstrip BSFs
Fabrication Process of the Proposed Microstrip BSFs

Fig. 26: Vector analyzer Anritsu MS4642A Vector Network Analyzer (VNA) [1].
Fabrication Process of the Proposed Microstrip BSFs
References


THANK YOU VERY MUCH