DESIGN OF HYBRID COUPLER CONNECTED HEXAGONAL FRACTAL PATCH FOR VARIOUS WIRELESS APPLICATIONS

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Abstract  
Generator and turbine units are the major machineries used in the wind energy conversion system. The efficiency of such system depends greatly on the generators performance. Switched Reluctance Generator (SRG) is slowly replacing conventional induction and permanent magnet synchronous generators in the area of wind energy generation system. This paper presents the fuzzy logic based inductance profile evaluation technique for SRG. The main objective of this work is to determine the suitable fuzzy membership function for inductance profile estimation. The various membership functions such as Trapezoidal, Gbell, Gaussian, Psigmoid and Triangular functions are used to develop the non linear inductance pattern for SRG. The results of inductance profiles estimated from all these membership functions are compared, analyzed and presented in detail. From the analysis of results, it has been proved that the triangular membership function has developed a good inductance profile
compared with the other functions. The high non-linearity nature of SRG is well handled by triangular membership function. The developed FIS for SRG is certain to be a prospective candidate in real time wind energy conversion system.

**Keywords**: Fractal Antenna, HFSS, Hybrid Coupler, Patch Antenna, Radiation pattern, Return loss.

# 1 INTRODUCTION

Fractals are a bend or geometrical figure, which has similar patterns happen again at progressively smaller scales. Fractal has compact physical shape with electrically long curves due to space filling property. Different types of fractal shapes are available for example Koch curve [1], Minkowski [2], Hilbert Curve [3], M. Susila [4] etc. Hybrid Minkowski fractal antenna for GPS system with dual frequency is achieved by Thanh Nghia Cao and Wojciech J. Krzysztofik [5] and miniaturization is done. The iteration order is limited to the complexity of the design because as the number of iterations increases a more complex structure that is difficult to fabricate is formed [6]-[11]. With the evolution of antenna theory new design concepts of antenna have been introduced. By using fractal geometry multiband antenna can be constructed and this is known as Fractal Antenna. It is more than a decade, fractal geometries are being applied in the design of passive components in the RF (radio frequency) and microwave domain. This geometry came in to its existence due to B.B. Mandelbrot in the year 1975 [12]. This intensive study was being conducted in 1970s. Later in the mid of 1990s, it was seen that the properties of such geometry could be used to design frequency selective surface, multiband antenna and also new configurations of antenna array. Several fractal based antenna geometries have been reported in recent years [13, 14].

Coupler is one of the most popular passive circuits used in microwave and millimeter-wave applications. It gives equal amplitude and phase outputs within the designed operating frequencies. These passive components are commonly used in variety of application such as mixers, phase shifters, power amplifiers and bridging many microwave circuits [15]. The hybrid couplers are designed using three main topologies. They are branch-line, coupled line and
patch-line structure. Each topology has its own advantages and disadvantages. In a branch-line structures stubs are loaded on the conventional branch line sections to realize dual-band operation. In other way, additional pairs of cross coupling and transmission line sections are to be added to the conventional branch line coupler to enable dualband operation [16-21]. In this paper we proposed a novel techniques that fractal antenna is fed by hybrid coupler and analysed for wireless applications.

2 ANTEenna DESIGN

The dual fed circular polarized microstrip patch antenna is etched on a FR4 epoxy with a height of 1.6mm. Ground plane length
and width is taken as 37.9x47.6mm². The operating frequency is chosen to be 2.4 GHz. The proposed hybrid coupler along with the dimensions is shown in Figure 1. The geometrical configuration of the suggested antenna is shown in figure 2. The antenna is fed by dual feed by using hybrid coupler. By adding the fractal geometry the resonant frequencies are being shifted towards right side.

The design procedure for fractal structure is shown in figure 3. The basic unit of fractal structure is a hexagon. The primary hexagonal shaped patch is having a side length of 8mm. From the hexagonal patch, six equilateral triangles of side 4mm is taken out to obtain first iteration. Then six equilateral triangles of side length 2mm is taken out which results in second iteration. Then six equilateral triangle of side 1mm is taken out which results in third iteration.

![Figure 3: Various iterations of hexagonal shaped fractal antenna](image)

Figure 3: Various iterations of hexagonal shaped fractal antenna
3 SIMULATION AND MEASURED RESULTS

The simulated return loss characteristics of the proposed antenna are shown in figure 4. From the return loss plot it is observed that the proposed design is resonating at five different frequencies for all the iterations. A comparison has been made for different parameters like resonant frequency, return loss and gain for all the iterations and it is shown in table 1. The minimum return loss obtained from all the bands is found to be -27dB. By adding the fractal geometry to the hexagonal patch it is observed that the frequency is slightly being shifted towards lower frequency side. For the first three iterations it is clear from the plot that there is poor impedance matching and for the final iteration the impedance matching is improved. Apart from that a wider band has been obtained in between the frequencies 3-4 GHz. Gain plots and radiation patterns of the proposed antenna are shown in figure 5 and 6. Comparing the gains of all the iterations it was observed that the gain has been improved for the final iteration at all the resonating frequencies.

![Return loss plot for the proposed design](image-url)
Figure 5: Gain plots for the proposed antenna at (a) 2.5 GHz, (b) 3.27 GHz, (c) 3.8 GHz, (d) 5.16 GHz and (e) 5.8 GHz.
<table>
<thead>
<tr>
<th>Iteration</th>
<th>Resonating frequencies (GHz)</th>
<th>Return loss (dB)</th>
<th>Gain (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0th Iteration</td>
<td>2.59</td>
<td>-12.62</td>
<td>3.56</td>
</tr>
<tr>
<td></td>
<td>3.33</td>
<td>-19.86</td>
<td>1.48</td>
</tr>
<tr>
<td></td>
<td>3.95</td>
<td>-15.24</td>
<td>2.02</td>
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<tr>
<td></td>
<td>5.32</td>
<td>-9.81</td>
<td>5.87</td>
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<tr>
<td></td>
<td>5.94</td>
<td>-7.30</td>
<td>5.94</td>
</tr>
<tr>
<td>1st Iteration</td>
<td>2.57</td>
<td>-12.17</td>
<td>3.72</td>
</tr>
<tr>
<td></td>
<td>3.22</td>
<td>-19.42</td>
<td>1.58</td>
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<tr>
<td></td>
<td>3.88</td>
<td>-15.00</td>
<td>3.21</td>
</tr>
<tr>
<td></td>
<td>5.28</td>
<td>-9.97</td>
<td>5.54</td>
</tr>
<tr>
<td></td>
<td>5.91</td>
<td>-6.71</td>
<td>5.62</td>
</tr>
<tr>
<td>2nd Iteration</td>
<td>2.55</td>
<td>-12.10</td>
<td>4.12</td>
</tr>
<tr>
<td></td>
<td>3.29</td>
<td>-19.43</td>
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<td>3.87</td>
<td>-15.64</td>
<td>2.27</td>
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<td>-10.66</td>
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<tr>
<td></td>
<td>5.88</td>
<td>-7.32</td>
<td>5.85</td>
</tr>
<tr>
<td>3rd Iteration</td>
<td>2.50</td>
<td>-20.70</td>
<td>5.78</td>
</tr>
<tr>
<td></td>
<td>3.27</td>
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<td></td>
<td>5.16</td>
<td>-14.31</td>
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<tr>
<td></td>
<td>5.79</td>
<td>-10.12</td>
<td>7.46</td>
</tr>
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</table>

Figure 6: Comparison of simulation results for all the iterations of proposed design
Finally the prototype model is developed using Chemical vapour deposition (CVD) method and the results are measured using Vector Network Analyser shown in figure 7. The measured results are shown return loss at 2.8 GHz = -11.3 dB, at 4.16 GHz = -11.9 dB and at 5.24 GHz = -22.07 dB. Then comparison between measured...
and simulated result is done. These results are having very good agreement between them which is shown in figure 8.

![Figure 8: Measured return loss](image)

Figure 8: Measured return loss

![Figure 9: Comparision between Simulated and Measured return loss](image)

Figure 9: Comparision between Simulated and Measured return loss

4 CONCLUSION

In this paper a novel microstrip fractal antenna fed with hybrid coupler for different wireless applications is reported. Three iterations of antenna are designed and various parameters such as return loss and gain are observed and on comparision with each other it shows that impedance matching was improved for final iteration and along
with it gain has been improved. So the proposed antenna is attractive and can be practical for various wireless applications.

References


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