Experimental Investigations on DGS Monopole Antenna for LTE Applications by few Iterative Techniques for Achieving Stable Gain.

Raghava Yathiraju, P.Pardhasaradhi, B.T.P.Madhav

Abstract: The tremendous growth of modern wireless communication devices enabling the design of compact microstrip patch with wideband behavior is becoming more attractive. The challenge is always put to the engineers to design a simple antenna that is low cost, compact and efficient for simultaneous communication in multiple frequency bands. The four proposals in this paper provide the best investigations for attaining the open challenges in the field of communications in LTE with an acceptable range of results. Iteration-1 works for dual wide bands operating from 8.8 – 14.7 GHz and 20.7 – 25 GHz respectively, which has the wide band notch in between those two bands to avoid interference problem. The improvements being made to the design in each iteration, to extract much better results in terms of resonating frequencies and operating bandwidths are verified in Iteration-2. Even narrow band operating frequency with best results are attained in Iteration-3. The antenna design in Iteration -3 is a narrow band operating antenna with 2.75 GHz being the resonant frequency. In Iteration-4 a triple band operation is achieved for medical band applications.

Index Terms: LTE, Medical Band Applications, Wireless communication.

I.INTRODUCTION

. Many innovative designs are found attractive in the literature regarding efficient antenna characteristics with probe feeding, microstrip line feeding and coplanar waveguide feeding [1-7]. To design compact size antennas to excite additional resonance frequencies, different methods are proposed by the researchers [8-13]. DGS is one among them, which can provide and excite the additional resonance modes with smaller sizes as well. The Defected ground structures are mainly profound in evolving many gaps from Electromagnetic Band Gap (EBG) structures by which DGS usually exhibits band notch property mostly used in MMICs and antennas [14-16].

A simple DGS procedure for mitigating the different polarized especially X, and its radiation of a patch antenna is presented in [17-18]. Spurious radiations minimization was obtained in [19-20] using the Koch-shaped DGS. The creation of various auxiliary resonances in the operating band and bandwidth improvement has seen in [21-22] with the dual-inverted L-strips and the employed DGS in the monopole antenna. A compact and well defined meander-shaped DGS verified and used in [23] for reducing the coupling which is mutual between elements of the microstrip antenna array with 0.5 λ_0 elements spacing. A DGS which is obtained by etching a structured combination of slots which are shaped as U and L is used in [24] to impart the compactness to the antenna. A spiral shaped DGS is used in [25] to realize the circular polarization at the lower band. Some other DGS procedures are available in the literature [26-28]. To obtain a wide band, compact antennas with effective etching in the ground plane have been discussed and verified. By modifying ground plane with embedding meandered shaped slot in the ground plane, a wideband impedance bandwidth with integrated LTE band can be achieved. The microstrip antennas with defected ground structures have prominent techniques for betterment in improving radiation characteristics, and bandwidth of the antennas are widely used techniques in present-day technology. The microwave circuits, which are embedded with these structures, are highly appreciable [29-30]. There is wide and huge requirement for medical band applications in the market for which a compact wideband antennas are most appreciable. The antennas with variable lengths and notch bands have been verified and many experimental investigations are being carried out in the field of antennas to get best results. One such idea of achieving multiple widebands with good notch bands are addressed in this. The design and analysis of different iterations of the monopole antennas are carried through commercial electromagnetic tools HFSS and CST microwave studio. EM-Tools and Vector network analyzer is utilized for the parametric investigations of the designed antenna models presented in this paper with simulation as well as measurement results.

Revised Manuscript Received on June 07, 2019.

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II. Antenna Geometry and Configuration

The schematic configuration of the proposals is based on standard design parameters. Radiating element is placed on one side of the substrate and on the other side defected ground structure of circular slot is taken. The ground plane under the top side of the radiating element is working like a matching stub for the DGS. The length of the Propagating element is calculated based on the formula in equation (1).

$$L_f = (5/4)\lambda_{eff} \;\ldots\ldots\ldots\; (1)$$

Where

$$\lambda_{eff} = \frac{c}{f_{min}\sqrt{\varepsilon_{eff}}} \;\ldots\ldots\ldots\; (2)$$

'C' is a known term with value $3X10^{8}$ m/sec and ε_{eff} is the effective dielectric constant, which is obtained from $\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2}$. To design the circular slot on the ground plane, we used the equation (3).

$$r = \frac{F}{\left(\left(1+\frac{50h}{\pi \varepsilon_r F}\right)\left[\ln\left(\frac{\pi F}{50h}\right)+1.7726\right]\right)^{1/2}} \;\ldots\ldots\; (3)$$

Where ε_r = dielectric constant

h = height of the substrate.

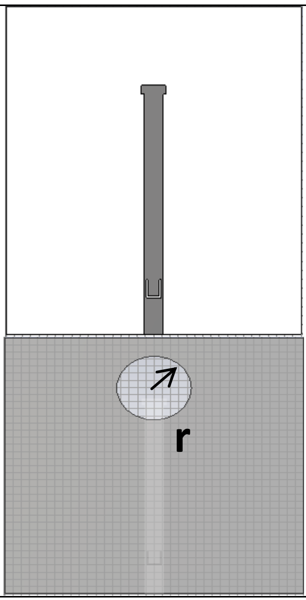
$$F = \frac{8.791\times 10^{9}}{f_{min}\sqrt{\varepsilon_r}} \;\ldots\ldots\; (4) \text{ and}$$

f_{min} = lowest frequency of the design.

Each iteration have particular dimensions in designing the required structure on FR4 substrate as per requirement.

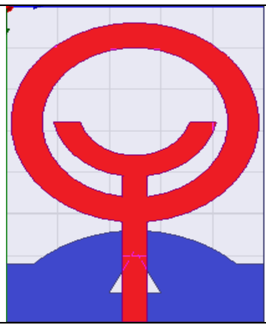
Iteration :I Stub loaded monopole antenna with U-slot

Table 2.1. Design of Iteration-I

Parameter	Antenna design
Prototype	

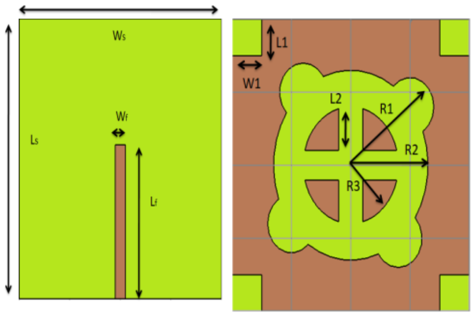
Iteration:II Circular slot Monopole Antenna with Half ring and rectangular patch on ground plane

Table 2.2. Design of Iteration-II

Parameter	Antenna Design-3
Prototype	

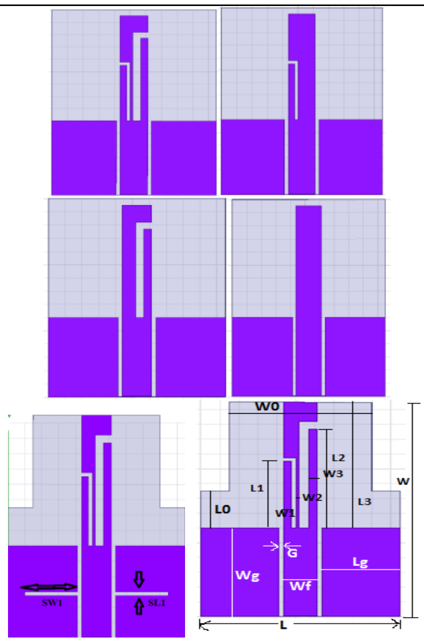
Iteration :III Circular Meandered Wideband Monopole Antenna with DGS

Table 2.3. Design of Iteration-III

Parameter	Antenna Design
Prototype with Rectangular Patch & Circular Meandered Defected Ground Structure	

Iteration:IV Triband DGS with F shaped Monopole Antenna

Table 2.4. Design of Iteration -IV

Parameter	Antenna Design
Iteration wise Design Upgradation of the Proposed Triband Defected Ground Structure F- Shaped Monopole Antenna	

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Blue Eyes Intelligence Engineering
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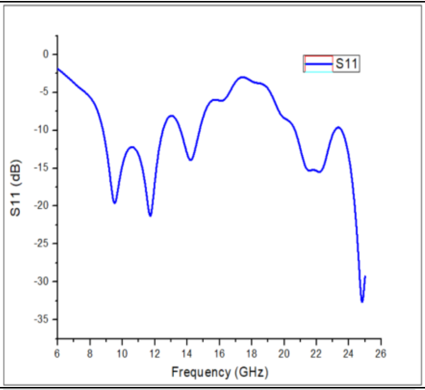
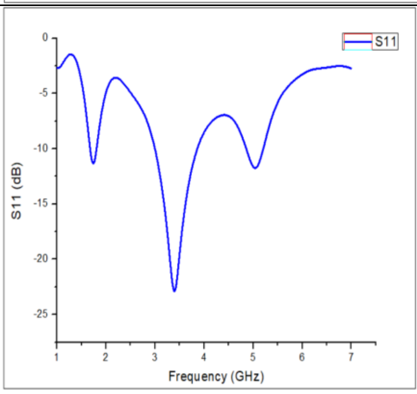
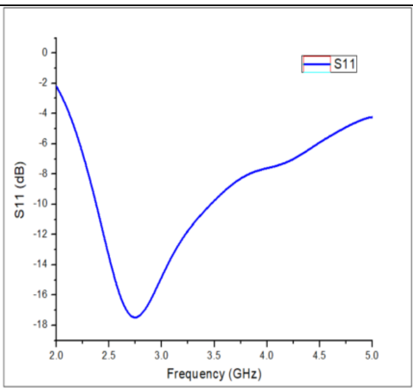
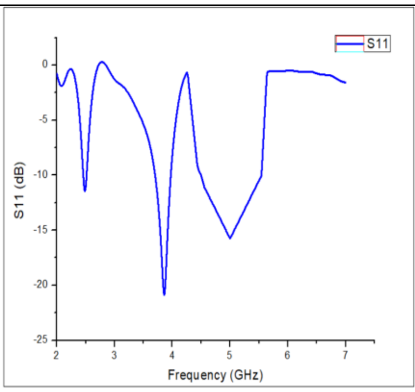
III. KEY RESULTS AND DISCUSSIONS

3.1 Return Loss

<table>
<tr><th>MODES</th><th>CHARACTERISTICS</th></tr>
<tr><td>Iteration I</td><td>
</td></tr>
<tr><td>Iteration II</td><td>
</td></tr>
<tr><td>Iteration III</td><td>
</td></tr>
<tr><td>Iteration IV</td><td>
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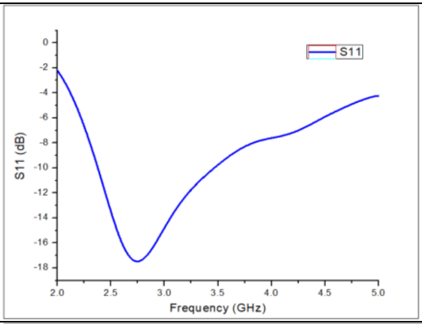
</table>

The final design in Iteration 4 has been extracted through various iterations for achieving its final operating bands with an attractive peak gain. The simulated results have shown up clearly that, the antenna design of Iteration 4 operates at 2.4 GHz, 3.7 – 3.97 GHz with the resonance occurring at 3.8 GHz frequency and 4.5 – 5.5 GHz with the 5GHz centre frequency.

3.2 Voltage Standing Wave Ratio(VSWR)

<table>
<tr><th>MODES</th><th>CHARACTERISTICS</th></tr>
<tr><td>Iteration I</td><td>
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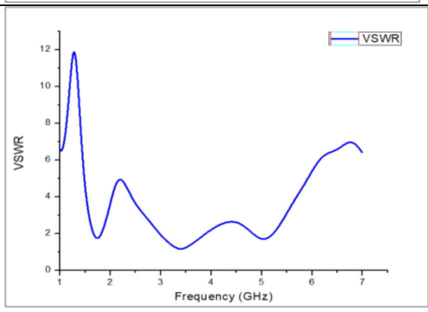
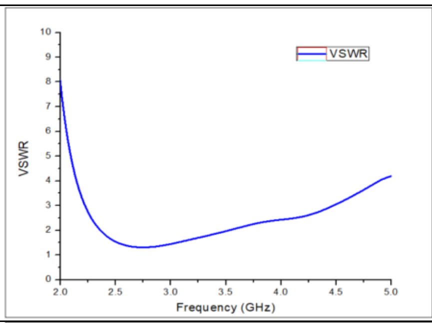
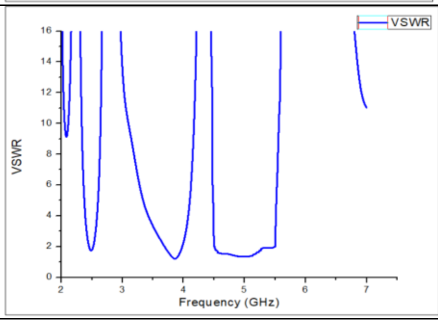
<tr><td>Iteration II</td><td>
</td></tr>
<tr><td>Iteration III</td><td>
</td></tr>
<tr><td>Iteration IV</td><td>
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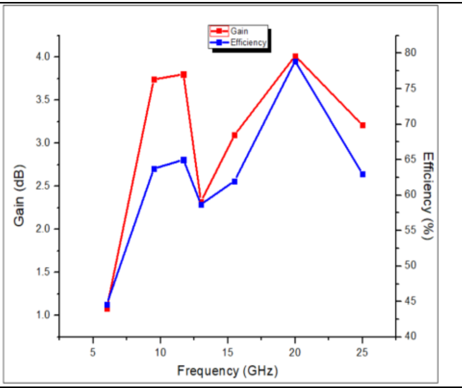
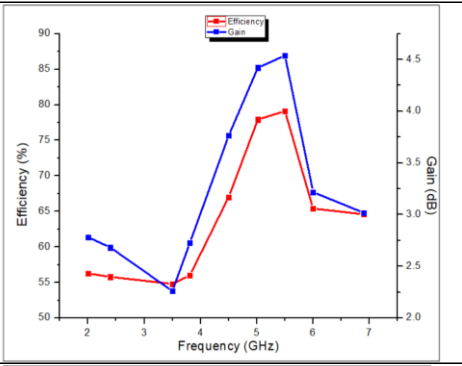
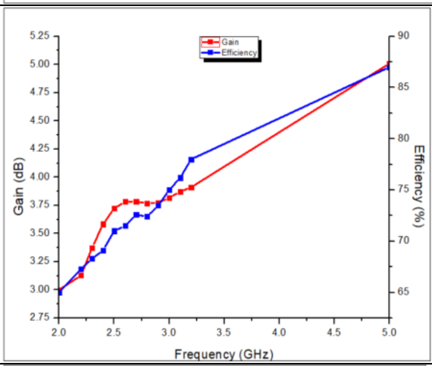
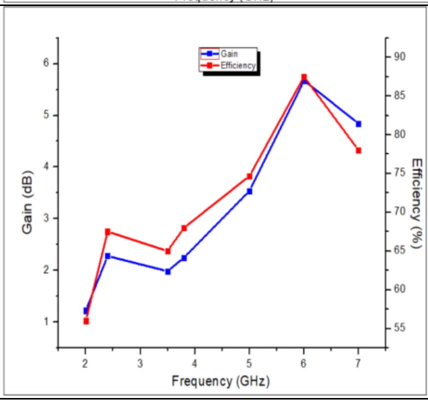
</table>

The VSWR gives us the better picture about the operating bands and helps us to judge the operating frequency range of an antenna with the condition being, VSWR lying under 2. the proposed antenna design in Iteration 4 is operating at 2.4 GHz, 3.7 – 3.97 GHz with the resonance occurring at 3.8 GHz frequency and 4.5 – 5.5 GHz with 5GHz centre frequency. It is very clear from the VSWR plot that, the stopband isolation between the operating bands is very high and hence the proposed antenna design has been given a clean chit from the interference problem.

3.3 Gain and Efficiency

MODES	CHARACTERISTICS
Iteration-I	
Iteration-II	
Iteration-III	
Iteration-IV	

The simulated gain and efficiency plot over the frequency range is as shown in the Table.3.3. Across the operating band of frequencies for all iterations is mentioned , the maximum efficiency of 87.5% is achieved at around 5.5 GHz and the next best efficiency of 78% is achieved at 7 GHz in Iteration 4. The average efficiency of the Iteration 4 throughout the operating frequency band is around 77 – 80%. On the other hand, the gain of the antenna design at 5 GHz is around 3.5 dB, with 5.7 being the peak gain nearer to 6 GHz Frequency.

3.4 Comparision of Parameters in all Iterations

Key Factors	Iteration - I	Iteration - II	Iteration - III	Iteration - IV
Operating Bands in GHz	8.8 – 14.7 and 20.7 – 25	5.2 – 5.72	2.38 – 3.45	2.4 , 3.7 – 3.97 & 4.5 – 5.5
Peak Gain in dB	4	5.5	5	5.7
Average Efficiency	70%	78%	75 – 77 %	77 – 80 %

As the objective of this antenna iterations is to operate in the medical bands, the simulation results have been considered keeping in view of the medical band frequencies. The list of various parameters like a prototype with all iterations, operating bandwidth, peak gain and average efficiency have been included.

IV.CONCLUSION

The objective of this paper has considered by exploring the various types of frequency bands (such as wide band, notch band, single band, multiple bands, etc.), that a Microstrip patch antenna can operate with the inclusion of various defected ground structures. The total work carried out in four phases, where the first phase covers the wideband operation of a microstrip patch antenna with DGS, followed by the analysis of notch band characteristics of a microstrip patch antenna along with defected ground structures, in the second phase. Whereas in third and fourth phases, the focus of the work is shifted exclusively on to the different types of defected ground structures and their significance in obtaining multiple notch bands or wideband characteristics, which suits the best for medical applications.

Acknowledgments and Data

Author is obliged to convey his gratitude to the ECE department and management of St Mary’s group and K L E F for the extended support in this work. Further B T P Madhav like to express his regards to DST for availing the research through ECR/2016/000569.

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