Abstract

In this paper, a wideband cylindrical dielectric resonator antenna (DRA) with an improved gain is proposed. The presented antenna is designed considering a superstrate and parasitic sheet behind the DRA. To obtain the proper $50\Omega$ matching, the resonant frequency is calculated as $7.9\, \text{GHz}$ using eqn. (1), which further signifies the excitation of hybrid mode. To reach the proper $50\Omega$ matching near $7.9\, \text{GHz}$, the dimension of slots are varied between $1\, \text{mm}$ to $7\, \text{mm}$ and fixed at $3\, \text{mm}$ for an air gap of $20\, \text{mm}$. This model is first simulated using standard economic engineering process. The electric field characteristics are presented for the proposed antenna. The proposed antenna model is depicted in Figure 1. A FR4 ground plane substrate needs high precision and becomes costlier. In case of [8], the weight of metal sheet may cause application restraints behind the DR. The proposed antenna is simple in terms of performance and economic fabrication. However, the reported one [9] was considered as simple in terms of performance and these techniques, superstrate approach, like [9], is probably effective in terms of improving the gain, still they deal with some lacunas like, stacking [6], EBG [7], surface mounted horn [8], etc.

1. Introduction

Recently dielectric resonator antenna (DRA) has become popular due to its popularity. From the day of inception in 1983 to now, it has been updated a lot for various applications [3]. The low loss, high radiation efficiency, wideband, three dimensional design as well as excitation flexibility, etc. are the main advantages of DR [6]. DR has been used to improve the far-field characteristics by a narrow dielectric superstrate. The outcome of this approach is depicted in a gain of $45\, \text{dB}$ with cross pol and cross pol ratio of $>45\, \text{dB}$, the DR shows fairly good performance of the antenna. In [6], the authors have proposed and designed a cylindrical shape DR in HEM$_{11\delta}$ mode. To reach the proper $50\Omega$ matching near $7.9\, \text{GHz}$, the DR is fed by a microstrip feed line. A dielectric resonator (DR) at an air gap of $20\, \text{mm}$ is made on the top side of the ground plane substrate. One square slot ($l_1 = 17\, \text{mm}$) is made on either side of the slot. A set of parasitic sheet of thickness $3\, \text{mm}$ is made on the top side of the ground plane substrate. One square slot ($l_1 = 3\, \text{mm}$) is made on the opposite side of the slot. A set of parasitic sheet of thickness $3\, \text{mm}$ is made on the top side of the ground plane substrate. DR is made on the opposite side of the slot. A set of parasitic sheet of thickness $3\, \text{mm}$ is made on the top side of the ground plane substrate.

2. Proposed Antenna Configuration

The proposed antenna model is depicted in Figure 1. A FR4 ground plane substrate needs high precision and becomes costlier. In case of [8], the weight of metal sheet may cause application restraints behind the DR. The proposed antenna is simple in terms of performance and economic fabrication. However, the reported one [9] was considered as simple in terms of performance and these techniques, superstrate approach, like [9], is probably effective in terms of improving the gain, still they deal with some lacunas like, stacking [6], EBG [7], surface mounted horn [8], etc. The proposed antenna model is depicted in Figure 1. A FR4 ground plane substrate needs high precision and becomes costlier. In case of [8], the weight of metal sheet may cause application restraints behind the DR. The proposed antenna is simple in terms of performance and economic fabrication. However, the reported one [9] was considered as simple in terms of performance and these techniques, superstrate approach, like [9], is probably effective in terms of improving the gain, still they deal with some lacunas like, stacking [6], EBG [7], surface mounted horn [8], etc.
\[
f_{r, \text{HEM}_{1/2}} = \frac{c}{\pi r} \sqrt{\delta_{w_1} + \left( \frac{r}{h} \right) + \left( \frac{r}{h} \right)^2}
\]

The parametric study of \( l_1 \) and \( w_1 \) for matching as well as gain are not shown here for brevity. At this condition antenna operate over 13.56% bandwidth (7.01 - 8.03 GHz) and 5.4 dBi gain [Figure 2]. This antenna is considered as Antenna #1. Next to this, the dimensions of the ground plane are also varied just to cross verify that, the antenna resonance only depends upon DR dimension. However, these results are not included for brevity.

4. Prototype and Characterization

Eccostock HiK dielectric rod (\( \varepsilon_r = 10, \tan \delta = 0.002 \)) is used for shape out the required DR. The required ground plane and superstrate substrate are made from FR4 sheet of (\( \varepsilon_r = 4.4, \tan \delta = 0.04 \)). Copper removal technique is applied to create the feed, slot, and other requisites of the proposed superstrate. After properly placing of all the parts, the model is characterized for \( S_{11} \), gain total and radiation patterns. The measured results shows fairly good matching with their respective simulated ones [Figure 3(a), Figure 3(b)]. The measured \( S_{11} \) was found to operate over (6.95 - 8.3) GHz (i.e. 17.71% BW) with ~8 dBi peak gain. The reason behind the variation between the simulated and measured results could be; variation of loss tangent between the simulated and the fabricated ones, and effect of unconsidered soldering and foam spacers. The simulated radiation patterns are shown in Figure 10. A separation of about 45 dB between the co-pol and cross-pol is obtained in H-plane, while this is 20 dB in E-plane. It can be noted that, during the operation the antenna promises ~ 90% radiation efficiency [Figure 3(b)]. The performance comparison of all antennas are shown in Table 1.

<table>
<thead>
<tr>
<th>Antenna</th>
<th>Bandwidth</th>
<th>Gain</th>
<th>Effi.</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>(7.01 - 8.03) GHz, 13.56%</td>
<td>5.4 dBi</td>
<td>~90%</td>
</tr>
<tr>
<td>#2</td>
<td>(6.84 - 8.21) GHz, 18.21%</td>
<td>6.72 dBi</td>
<td>~90%</td>
</tr>
<tr>
<td>#3</td>
<td>Sim. (6.95 - 8.23) GHz, 16.86%</td>
<td>7.85 dBi</td>
<td>~90%</td>
</tr>
<tr>
<td>Mea.</td>
<td>(6.95 - 8.3) GHz, 17.71%</td>
<td>~8 dBi</td>
<td>NA</td>
</tr>
</tbody>
</table>
5. Conclusion

A wideband dielectric resonator antenna is investigated for gain improvement. The effect of superstrate and parasitic sheet on gain is properly addressed. It can be noted that, the superstrate has more influence on gain when it is oriented in the direction of antenna polarization. The measured results shows 17.71% wide impedance bandwidth and ~8dBi peak gain. The fabrication and implementation of this proposed one is quite simple and economic than those existing ones. This antenna can be suitable one for X-band applications, once appropriate scope is created.

6. References