Design and simulation of a 2-shaped Slotloaded Rectangular Microstrip Patch Antenna

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KEYWORDS:  
- 2-slot  
- HFSS  
- VSWR  
- FR4-epoxy  
- band width

ABSTRACT

A design of 2-slot loaded rectangular microstrip patch antenna was worked out. The aim of this design is to improve the parameters of microstrip antenna. This design shows that there is an increase in the bandwidth, which may distinguish it for the use in communication purposes especially in military and civil applications. The antenna has been designed selecting FR4-epoxy substrate with dielectric constant of 4.4 and optimal dimensions of $60 \times 60 \times 1.66 \text{ mm}^3$. The design requirements for this antenna should include a VSWR less than 2 for 50 $\Omega$ reference impedance and return loss is less than -10 dB. The simulation of this design is carried out using a high frequency simulation structure (HFSS). The 2-slot microstrip patch antenna was then fabricated using microstrip coaxial probe feed technique. The return loss, VSWR, real and imaginary impedance, radiation pattern and gain results were calculated. The 2-slot impedance bandwidth of the proposed antenna is 9.06 - 13.86 GHz, which is about 51.06% broader. The proposed antenna has an average gain of 6.3 dB and the peak is 8.239 dB at resonance frequency 9.42 GHz. Compared with the original one, the average gain of the proposed antenna improve about 1.7 dB.

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تصميم ونمذجة هوائي شريطي يقطع على شكل 2 من سطح المشع المستطيل

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الخلاصة

تم العمل على تصميم ودراسة هوائي المستطيل المحمل يقطع على شكل رقم 2. الخروج من التصميم هو تصميم هوائي ذو دعم 2. تم استخدام هذه الملكية لتحسين إدماج الخوارزمية في مجالات الاستخدام من خلال التقلبات وآذان الحذرية لتفسير التصميم المقترح لاستخدامه في مجالات الاستخدام. تم الحصول على القيم الاشتقاقات من قلاب FR4-epoxy (4.4) ورسم الخرائط في الظروف المحيطة. تم إجراء المحاكمة للهوائي ذو 2-النقطة ورصد النتائج. تناسب النتائج HFSS عند المعايير 50 أم. تتم تصميم وحساب النتائج باستخدام برنامج RFsim. المبرمجة عبر عن نمذج محوري. تم قياس كمية الخروج في الخرائط التي كانت 2-النقطة من خلال حساب VSWR وواحدة مدى الاشتقاقية في النتائج. حيث كانت معظم المحاكمة 32/89 عند التردد 9.06 $\text{GHz}$ وعند التردد 9.42 $\text{GHz}$. اسمن معدل التحسين كان 6.3 $\text{dB}$ عند التردد 9.4 $\text{GHz}$، مقارنة بالهوائي البياني فإن الزيادة في التحسين بلغت 1.7 $\text{dB}$ للخط.
1. Introduction

The microstrip antennas are characterized by having small size, low profile, and light weight, conformable to planar and non-planar surfaces. It demands a very little volume due to its structure, when mounted. They are simple and cheap to manufacture using modern printed circuit technology [1].

However, the main disadvantages of the microstrip antennas are: low efficiency, narrow bandwidth of less than 5%, and low RF power due to the small separation between the radiation patch and the ground plane (not suitable for high-power applications) [1].

Microstrip antennas are used in a wide range of applications from communication systems (radars, telemetry, and navigation) to biomedical systems [3]. Basic microstrip antenna consist of two thin metallic layers (t << λ₀) separated by a dielectric substrate of thickness (h << λ₀) usually 0.003 λ₀ ≤ h ≤ 0.05 λ₀ [4-5]. Microstrip patches have several shapes such as rectangular, circular, triangular, semi-circular, sectoral and annular [6-7]. An antenna is characterized by its center frequency, bandwidth (B.W), polarization, radiation pattern, gain, and impedance [8]. The bandwidth of the antenna depends on the patch shape, resonant frequency, dielectric constant, and the thickness of the substrate. The bandwidth improvement of a microstrip antenna has been directed towards improving the impedance bandwidth of the antenna element [9].

Due to the widely used in different application of microstrip antennas, this causes a demand to improve antenna efficiency. A number of theoretical and experimental researches have been done to improve the bandwidth of this antenna [10]. Loading of shorting pins and stacking of patches are some techniques to increase the bandwidth of microstrip antennas [11].

Different shapes of slot loading in feed patch can also enhance the antenna bandwidth [12].

In this study, a 2-slot patch antenna was designed with coaxial - probe feed, to improve antenna efficiency, using software which is the industry standard for simulating high-frequency electromagnetic fields (HFSS).

In this paper, a microstrip antenna with higher gain and wider band is proposed. The configuration of the initial antenna at Resonance frequency is 2.3 GHz, FR4-epoxy material has been used as substrate having thickness 1.6 mm, and the dielectric constant of substrate is 4.4, with dimension of patch 30*37 mm². The bandwidth of that antenna is from 2.26 to 2.4 GHz at 2.3 GHz where S₁₁ is -24.40 dB, and from 9.0 to 9.25 at 9.13 GHz where S₁₁ is -28.21 dB, the VSWR is 1.11 at 2.32 GHz, and the average gain is 4.6 dB with the peak is 6.21 dB.

2. Antenna design

The configuration of the proposed antenna is shown in Fig. (1)

The antenna is of single layer configuration along with its current distribution, in which 2-shape slot is incorporated in feed rectangular patch. The design of the antenna is a rectangular microstrip antenna with patch size of 29.44*38.04 mm². The substrate chosen for the proposed antenna is FR4-epoxy with dielectric constant of 4.4 and a thickness of 1.66 mm.
The dimensions of slot, are shown in Fig(1), were $L_S$ represents the length of the slot, the width is $W_S$, and $T_S$ is the thickness of the slot.

$B_1$ represent the height of the lower edge of the slot from lower edge of the patch.

$B_2$ represents the distance between right side of the slot from the right side of the patch, $B_3$ represent the distance between left side of the slot from the left side of the patch.

$B_4$ represents the distance between the upper edge of the slot to the upper edge of the patch at y-plane direction, $B_5$ represent the distance between the feed position and the slot in x direction and $B_6$ represent the distance between the position of feed and the lower edge of the slot in y direction.

The value of these dimensions of the proposed antenna are presented in table (1).

### Table 1: Dimensions of proposed antenna

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size the substrate ($L \times W$)</td>
<td>60 mm $\times$ 60 mm</td>
</tr>
<tr>
<td>Dielectric constant ($\varepsilon_r$)</td>
<td>4.4 (FR4-epoxy)</td>
</tr>
<tr>
<td>Thickness of substrate ($h$)</td>
<td>1.66 mm</td>
</tr>
<tr>
<td>Size of the patch ($L_p \times W_p$)</td>
<td>29.44 mm $\times$ 38.04 mm</td>
</tr>
<tr>
<td>Feed position ($X_f, Y_f$)</td>
<td>(1.8 mm, -1.8 mm)</td>
</tr>
<tr>
<td>Frequency</td>
<td>9.4 GHz</td>
</tr>
<tr>
<td>Dimension of the slot $L_5 \times W_5$</td>
<td>19 mm $\times$ 10 mm</td>
</tr>
<tr>
<td>thickness of the slot $T_5$</td>
<td>3 mm</td>
</tr>
<tr>
<td>$B_1, B_2$</td>
<td>15.02 mm, 16.72 mm</td>
</tr>
<tr>
<td>$B_3, B_4$</td>
<td>2.6 mm, 4.02 mm</td>
</tr>
<tr>
<td>$B_5, B_6$</td>
<td>7.2 mm, 5.8 mm</td>
</tr>
<tr>
<td>$L_{S1}, L_{S2}$</td>
<td>11 mm, 5 mm</td>
</tr>
</tbody>
</table>

3. Results and Discussion

Fig.(3) shows the simulated and measured return loss of the 2-slot antenna. The measured impedance bandwidths for -10 dB return loss ranging from 9.06 to 13.86 GHz or 51% for the 2-slot microstrip antenna. The VSWR value is 1.008 for the antenna at resonant frequencies 9.42 GHz as shown in Fig. (4). The resonant frequency was determined from Fig(5) that
shows that the real part of impedance which is approximately equal to 50 Ω , and the imaginary part is approximately equal to zero .

Figure (3): Return loss of the proposed antenna.

Figure (4): VSWR of the proposed antenna.

Figure (5): The real and imaginary part of input impedance with the Frequency.

The radiation patterns of proposed antenna shown in Figs (6) and (7) it was shown that the E-plane and H-plane at 9.42GHz , by the polar coordinates fig (8) show the evaluation pattern for proposed antenna at 9.42GHz .
4. Conclusions

The simulation design of 2-slot loaded rectangular microstrip patch antenna using Ansoft HFSS Microsoft was presented. The design requirements for the antennas include a VSWR < 2 for 50 Ω reference impedance and return loss is less than to -10 dB. The shape of the proposed microstrip patch antenna was then fabricated using coaxialprobe feed arrangement with VSWR values of 1.008 which is corresponding to the resonance frequency 9.42 GHz. The slot in proposed antenna in the patch area of low fields, led to increasing fringing fields, this will be resulting in a clear increase in bandwidth and gain compare to initial antenna.

References


