Effect of Split Ring Resonators Slot Position on Planar Inverted-F Antenna

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Abstract:
Recently, requirement of high speed on cell phones grow day by day. So, the priority of wireless communication is that, it needs high gain and wide band small size antenna. In this paper a small size planar inverted F antenna is designed with split ring resonator loading. Circular shaped double ring with single slit is used as split ring resonator loading on PIFA. The proposed design resonates at the operating frequency of 5GHz with the bandwidth of 1.83 GHz. The proposed antenna has high gain of 5.8dB compared to the conventional PIFA design. The proposed antenna has also low VSWR value of. The size of antenna is 20mm × 20mm with the height of 4mm. The total size of patch of antenna is 8mm × 12mm. Conventional and proposed antenna is designed on FR-4 substrate with dielectric permittivity of 4.4 and thickness of substrate is 1.6mm. High frequency structure simulator (HFSS) software is used for the antenna designing.

Keywords: HFSS, Return loss VSWR, Slots, SRR, WiMAX, WLAN

I. INTRODUCTION
Currently, wireless communication network comes in picture due to widely use of wireless portable and handheld devices such as mobile phones, note books, modems, laptops which requires high data speed for communication. Applications such as WLAN (5.15-5.825GHz) for IEEE 802.11a Wi-MAX (5.25-5.85GHz) systems and wideband systems also needs high data rate and high gain for better performance. So it is required to design an antenna for fulfillment of demands of users [1-4]. Increase in the channel capacity without sacrificing additional spectrum or transmitted power can only obtained by new circuits designs. For obtaining high gain and wide bandwidth different techniques are used such as defected ground, insert slotting or use planar inverted F antenna (PIFA) in case of miniaturized antenna [4-6]. Planar inverted F antenna is extended from a quarter wavelength monopole and a rectangular microstrip patch antenna. Planar inverted F antennas are mainly used in mobile, tablets and other handheld devices due to its low profile, light weight, low cost and low absorption rate (SAR). SAR is defined as rate of energy absorbed by human body exposed in RF electromagnetic field. Planar inverted-F antenna has less interaction with user’s body [6-7]. PIFA is improved form of wired inverted F antenna in which rectangular plate used in place of wires to increase the bandwidth of antenna shown in Figure 1. The planar inverted F antenna has advantage over microstrip patch antenna of compactness due to impedance matching with the shorting plate. The resonating frequency of planar inverted F antenna can be calculated by equation written bellow

\[ L_1 + L_2 - W = \frac{\lambda}{4} \]  
\[ f_r = \frac{c}{4(L-W)} \]  
\[ L = L_1 + L_2 \]

Where, \( L_1 \) and \( L_2 \) are noted as length and width of patch of antenna design. \( W \) is known as the width of shorting plate.

There are limitations in bandwidth and gain enhancement on planar inverted F antenna due to shorting plate height. The height of plate should not be increased more because it increases the volume of antenna. And at certain point of height either gain or bandwidth of antenna degraded [7-9]. So the bandwidth of antenna can be enhanced only by loading split rings/slots or both. Either array of antenna can be used for bandwidth enhancement. But in this case the mutual coupling effect comes in picture due to antenna spacing. Antenna parameters such as gain, bandwidth, and radiation efficiency also degraded when array of antenna is used. So, to solve this issue split ring resonator (SRR) can be used [6, 8,].

A split-ring resonator (SRR) is a structure manufactured with unnatural material which is similar to the metamaterials. Due to composite structure split ring resonator (SRR) designs have a stronger magnetic coupling than conventional material which is found in nature.

Split ring resonator has consists of two concentric rings made up of nonmagnetic material like copper. The radius of inner ring is \( r_i \) and the gap provided between the rings is \( d \). The
width of the rings is c in which i amount of current flow as shown in Figure 2. Split ring resonators have property of negative reflective index.

![Figure 2: Split Ring Resonator Structure](image2)

In this paper, the conventional PIFA design and compare with proposed PIFA design consists of double ring SRR with single slot variation operates at 5GHz frequency. The conventional PIFA performance like gain, bandwidth, return loss and VSWR has been compared with proposed design.

II. USING THIS TEMPLATE

A. Conventional Antenna design

The conventional planar inverted F antenna design has layer of ground, substrate, shorting port and patch. The thickness of FR-4 substrate is 1.6mm with dielectric permittivity of εᵣ=4.4. Height of antenna design is H=4mm from ground plane. The length, width of patch and width of shorting port are calculated from equation (1). Coaxial feed is provided to the antenna design with coax radius of R=0.7mm. The position of feed point is 8mm × 5mm from the centre of antenna. The conventional antenna has air gap of 2.4mm between substrate and patch. The total volume of antenna is 20mm × 20mm × 4mm shown in Figure 3. The dimension of conventional planar inverted F antenna is shown in table 1.

![Figure 3: Conventional PIFA Design](image3)

![Figure 4: Proposed PIFA Design](image4)

### TABLE 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (mm)</th>
<th>Parameter</th>
<th>Value (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lₛ</td>
<td>20</td>
<td>D</td>
<td>5</td>
</tr>
<tr>
<td>Wₛ</td>
<td>20</td>
<td>W</td>
<td>6</td>
</tr>
<tr>
<td>L₁</td>
<td>8</td>
<td>H</td>
<td>4</td>
</tr>
<tr>
<td>L₂</td>
<td>12</td>
<td>g</td>
<td>1</td>
</tr>
<tr>
<td>r₁</td>
<td>2</td>
<td>c</td>
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</tr>
<tr>
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<td>3</td>
<td>d</td>
<td>1</td>
</tr>
<tr>
<td>r₃</td>
<td>4</td>
<td>r₄</td>
<td>5</td>
</tr>
</tbody>
</table>

A. Proposed Antenna Design

The proposed antenna is similar to conventional antenna design. In the proposed antenna design split ring resonator is loaded on conventional PIFA for the bandwidth enhancement. In the proposed design two case of slot on SRR are compared. Double ring with single slot on each ring design is used for proposed work. Effect of slot position variation is targeted for proposed work. Rings are concentric and centred at the position -1mm × -1mm from the centre point of the antenna. The dimension of ring is shown in table 1. The proposed antenna structure is shown in Figure 4.

### TABLE 2

<table>
<thead>
<tr>
<th>Antenna design</th>
<th>conventional PIFA</th>
<th>slot same side</th>
<th>slot opposite side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ring structure</td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
<td><img src="image7" alt="Image" /></td>
</tr>
<tr>
<td>Resonant Frequency</td>
<td>5 GHz</td>
<td>5 and 6.33 GHz</td>
<td>4.8 and 6.33 GHz</td>
</tr>
<tr>
<td>Band width</td>
<td>1.7GHz</td>
<td>1.83GHz</td>
<td>1.41GHz</td>
</tr>
<tr>
<td>Gain (dB)</td>
<td>5.3157</td>
<td>5.8</td>
<td>5.794</td>
</tr>
<tr>
<td>Return loss (dB)</td>
<td>-24.5</td>
<td>-35.41</td>
<td>-33.45</td>
</tr>
<tr>
<td>VSWR</td>
<td>1.1438</td>
<td>1.0345</td>
<td>1.1195</td>
</tr>
</tbody>
</table>

III. RESULTS AND DISCUSSIONS

Conventional and the proposed structure of planar inverted F antenna are simulated with the help of high frequency Structure simulator. Antenna parameters such as bandwidth, gain, return loss and VSWR are used for the comparison of the antenna designs structure mentioned in Table 2

Figure 5 shows the comparison of antenna parameter such as return loss, bandwidth and resonant frequency of conventional and proposed antenna for both cases. Antenna with slots same side has more bandwidth compared to conventional and opposite side slot antenna design.

Figure 6 shows the comparison of gain vs. frequency for conventional and proposed designs. Antenna design in which slots are in same side has slight more gain than other design. For gain requirement this design can be used.
FIGURE 5
RETURN LOSS PLOTS OF CONVENTIONAL AND PROPOSED DESIGN

FIGURE 6
GAIN VS. FREQUENCY PLOTS OF CONVENTIONAL AND PROPOSED DESIGN

Figure 7 shows the VSWR plot of conventional and proposed designs at the resonating frequency of 5Hz. Antenna with slots on opposite side has lowest VSWR.

IV. CONCLUSION

In this paper, a compact antenna is designed for Wi-Fi (5.15-5.825 GHz) applications. Split ring resonator is loaded on the planar inverted F antenna with slot position variations. The proposed antenna has bandwidth of GHz in case of same side slots and gain of 5.8 dB in case of opposite side slots. For high bandwidth requirement antenna with same side slot is used. In case where high gain is needed, antenna with same side slots can be used.

V. REFERENCES


