Compact planar Multi-band Antenna for GPS, DCS, 2.4/5.8 GHz WLAN applications

A compact single feed multi-band planar antenna configuration suitable for GPS, DCS, 2.4/5.8GHz WLAN applications is developed. The antenna of dimensions 38mm x 3mm x 1.6mm offers good radiation and reflection characteristics in the above frequency bands. The antenna has a simple geometry and can be easily fed using a 50Ω coaxial probe. The wide 2:1 VSWR bandwidths at the three resonant bands along with moderate gain and radiation characteristics make the proposed antenna an ideal choice for multi-band wireless communication gadgets.
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A.1 Introduction

The rapid progress in personal and computer communication technologies demand integration of more than one communication systems into a single compact module. To comply with the above requirement compact high performance multi-band planar antennas with good radiation characteristics are needed. A planar single feed dual L antenna of dimensions 30.5mm x 21.5mm x 13mm operating in GPS and PCS bands is proposed in [1]. The dual band antenna for the ISM band (2.4/5.8GHz) using a backed microstrip line proposed in [2] has an overall dimension of 30 x 20 mm² on FR4 substrate and offers a maximum gain of 4dBi. Dual frequency antenna configuration proposed in [3] uses triple stacked microstrip patch antennas with a slot in the middle patch, to achieve triple band operation.

This work presents a compact single feed planar antenna with three wide 2:1 VSWR operating bands around 1.8GHz, 2.4GHz and 5.8GHz respectively, covering four useful frequency bands namely GPS (1575.4MHz), DCS (1800MHz), 2.4GHz (2400-2485MHz) and 5.8GHz (5725-5825MHz) WLAN.

A.2 Antenna design

Geometry of the proposed antenna is shown in Fig. A.1. It is etched on FR4 substrate of relative permittivity, εr = 4.7 and thickness h = 1.6mm. The antenna has two arms of lengths l_1 = 38mm, l_2 = 33mm and widths w_1 = w_2 = 1mm placed symmetrically on either side of a middle element of length l_3 = 17mm and width w_3 = 1mm. The feed point of the antenna is optimized to be at the middle of edge AB.
Good impedance matching is achieved by embedding a reflector of dimensions $I_r = 40\text{mm}$ and $W = 25\text{mm}$ on the bottom side of the substrate at an offset $d = 0.5\text{mm}$ from the edge $AB$ as shown in the figure.

![Diagram of the antenna with dimensions and labels](image)

Fig. A.1 Geometry of the proposed antenna (a) Top view (b) Side view

$L = 40 \text{ mm}, l_1 = 38 \text{ mm}, l_2 = 33 \text{ mm}, l_3 = 17 \text{ mm}, W = 25 \text{ mm}, w_1 = w_2 = w_3 = 1 \text{ mm}, h = 1.6 \text{ mm}, d = 0.5 \text{ mm}
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From the experimental and simulation results, it is understood that the lower resonance can be tuned by varying the length $l_1$ of arm 1. Resonance in the 2.4GHz band is influenced by the length $l_1 + l_2 - 2 l_3$. When length $l_3$ of the middle element is increased, the second resonance shifts upwards whereas, it gets lowered when the length $l_2$ is increased. Dimensions of the reflector affect both the resonance frequency and impedance matching in the 5.8GHz band. Another antenna with $l_1 = 79.4\text{mm}, l_2 = 77.48\text{mm}$ and $l_3 = 60.54\text{mm}$, exhibits resonance at 940MHz, 1.85GHz and 5.2GHz respectively suitable for GSM/DCS/5.2GHz WLAN applications.

A.3 Results and Discussion

The measured return loss characteristic of the proposed antenna is shown in Fig. A.2.

![Return loss characteristics of the antenna](image)

Three resonant bands are observed at frequencies 1.75 GHz, 2.45GHz and 5.76GHz with 2:1 VSWR bandwidths of 23%, 5% and 4.5% respectively. The lower
resonant band with 406MHz (1466-1872) bandwidth is wide enough to cover the GPS/DCS bands. The higher resonant bands with 124MHz (2372-2496) and 260MHz (5630-5890) bandwidths cover the 2.4GHz and 5.8GHz WLAN bands respectively.

The normalized E-plane and H-plane radiation patterns measured at the centre frequencies of the respective bands are shown in Fig. A3. The patterns are observed to be nearly omni directional in the H-plane, with a cross polar level better than -15dB in the bore-sight direction. The antenna exhibits similar radiation characteristics in all the desired bands.

The measured antenna gain against frequency is presented in Fig. A4. The antenna offers a peak gain of 7.38dBi in the GPS band. The maximum gain observed in the DCS, 2.4GHz WLAN, 5.8GHz WLAN bands are 3.73dBi, 4.22dBi and 4.65dBi respectively.

The radiation performance of the antenna in all the above bands is summarized in Table. It is observed that all bands except the 5.8GHz band are linearly polarized along Y direction. The 5.8GHz band is orthogonal to the other bands.
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Fig. A.3: Radiation Patterns at the centre frequency of the desired bands
3.a GPS band 3.b. DCS band 3.c. 2.4GHz WLAN band 3.d. 5.8GHz WLAN band
Fig. A.4. Gain of the antenna in the desired bands

<table>
<thead>
<tr>
<th>Band (GHz) and application</th>
<th>Gain (dBi) max/ min</th>
<th>Polarisation</th>
<th>Cross-polar level (dB)</th>
<th>Radiation pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.46–1.87 GPS DCS</td>
<td>7.38/5.45</td>
<td>Linear along y direction</td>
<td>-23</td>
<td>Omni-directional</td>
</tr>
<tr>
<td>2.37–2.49 2.4 GHz WLAN</td>
<td>4.22/1.31</td>
<td>Linear along y direction</td>
<td>-25</td>
<td>Omni-directional</td>
</tr>
<tr>
<td>5.63–5.89 5.8 GHz WLAN</td>
<td>4.65/3.12</td>
<td>Linear along x direction</td>
<td>-19</td>
<td>Omni-directional</td>
</tr>
</tbody>
</table>

Development and Analysis of a Compact Dual-band Coplanar Antenna
A.4 References


A compact microstrip antenna integrated with an amplifier having an area reduction of 70%, compared to the standard circular microstrip patch antenna, is presented in this section. The antenna also provides an enhanced gain of 10 dB more than its passive counter part. The measured 2:1 VSWR band width is 4% at 790 MHz, which is 2.5 times larger than that of the passive microstrip antenna.
B.1 Introduction

There is a growing tendency for portable equipment to be made smaller and smaller as the demand for personal communication rapidly increases, and the development of very compact handheld units has become urgent. Various compact microstrip antenna designs have been reported in the literature to overcome the size problem of the conventional microstrip patch antenna, such as embedding slots in microstrip patch and shorting pins placed between radiating element and the ground plane [1, 2].

For most compact antennas, the gain and radiation efficiency is much lower than the conventional microstrip antenna. In this work, area reduction is achieved by the patch geometry [3], which is obtained by modifying standard rectangular and circular microstrip patches, and gain is enhanced by integrating an amplifier to it.

The active integrated antenna has become a growing area of research in recent years, as microwave-integrated circuits and monolithic microwave-integrated circuit (MMIC) technology have become more mature, thus allowing for high-level integration. Active integrated antennas also have strong potential for commercial applications in wireless communications and radar. An amplifier-type active integrated antenna integrates a two-port active device to a passive antenna element at its input or output port.
The implementation of an amplifier in a passive antenna structure increases the antenna gain and bandwidth, and improves the noise performance. Such an active slotted equilateral-triangular microstrip antenna with an amplifier circuit has already been illustrated in [4]. In this work, a compact microstrip receiving antenna with enhanced gain and wide-impedance bandwidth is presented.

B.2 Active Antenna Design

Fig. B.1 shows the top view of the proposed amplifier-integrated microstrip antenna.

The antenna geometry is based on a rectangular geometry with its resonating edges replaced by two circular arcs of radii \( r_1 = r_2 = 6 \) cm on two sides. The antenna and the amplifier circuit are etched on a substrate of thickness \( h = 0.148 \) cm and relative permittivity 3.95, as shown in figure.
The antenna output is coupled to the input port of the amplifier using 50 ohm microstrip feed line. Signal transmission can also be carried out using the same circuit by connecting the amplifier output to antenna input. The schematic diagram of the amplifier circuit is shown in Figure B.2. The transistor used is an NEC 2SC3357, with input impedance of $51 + j0.3084$ ohm and output impedance of $91.67 + j43.56$ ohm at 800 MHz. The amplifier is biased for class A operation. The input and output of the transistor are conjugate matched to the source and load impedance, respectively, using microstrip short-circuited stubs and impedance transformers [5].

Fig. B.2. Schematic diagram of the BJT amplifier.
A high impedance microstrip line is used as load impedance at the collector of the transistor. $R_1$ and $R_2$ are potential divider bias resistors and $RE$ is the emitter resistor. $C_1$ and $C_2$ are input and output coupling capacitors and $CE$ provides emitter bypass capacitance.

**B.3 Results and discussion**

The active receiving microstrip antenna is fabricated and the impedance bandwidth, relative gain, and radiation patterns are measured using an HP 8510C vector network analyzer. Fig. B.3 shows the return-loss curve of the active receiving antenna. Relative gain of the active antenna compared to the passive element is also plotted in the figure. It is observed that the proposed antenna has an impedance bandwidth of 4% and a gain enhancement of 10 dB, compared to that of the passive counter part. $E$ and $H$ plane radiation patterns of the antenna at 790 MHz are shown in Fig. B.4. The patterns are broad as in the case of standard rectangular microstrip patch and cross-polarization levels are better than 20 dB.

The overall size of the antenna including the amplifier circuit is 36 cm$^2$, whereas the size of a circular microstrip antenna operating at this frequency is 121 cm$^2$. Thus, the size of the new antenna is only 30% of the circular microstrip antenna.
Fig. B.3. Return loss and gain curves of the passive and active antenna

Fig. B.4. Radiation patterns of the active antenna at 790 MHz
(a) $E$ plane; (b) $H$ plane
B.4 References


