Techniques to Improve Bandwidth of Rectangular Planar Monopole Antenna

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Abstract- This paper gives information about construction of planar rectangular monopole antenna on Printed Circuit Board (PCB). Behaviour of such planar antenna is same as the rectangular patch antenna with finite ground plane which lies in same plane of given PCB. The designed antenna is a broadband antenna as its ratio bandwidth falls under broadband category. In comparison with monopole antenna broadband planar monopole antenna has more advantages in terms of their cost, ease of fabrication and bandwidth. Modern wireless system demands for larger bandwidth to carry huge amount of data at a time through medium so as to increase the data rate. We have designed a printed rectangular monopole antenna for wireless application at 2.4 GHz such that it can be used for commercial frequency such as Bluetooth, Wi-max, HSPDA, and Wi-Fi. Parameters of presented antenna are same as monopole antenna but with improve bandwidth.

Keywords—feed length, planar monopole antenna, printed circuit board (PCB), radiation pattern, S11, VSWR

I. INTRODUCTION

Wireless application demands use of single broadband antenna which covers a broad range of frequencies and high data rate of communication as like sensing and imaging, position and tracking and radar system. Solution for such requirement is the use of cost effective planar rectangular monopole antenna. These antennas are very popular because of their broad impedance bandwidth, linearly polarized unidirectional radiation pattern and are very cost effective to construct. Structure of this type of antenna is planar i.e. copper metal element of PCB can be used instead of conventional wire element of monopole antenna

Conventionally microstrip antennas are designed in small size with different forms. Basically, due to higher value of quality factor Q i.e. up to 100 causes narrow bandwidth[5], it has been found from research results that microstrip antenna can have very wide field of frequency bands [1][2][8][9]. In their study, printed circuit board is built by rectangular patch and ground of antenna. Mobile communication system employs the most popular antenna that is monopole antenna and its family it is possible to match impedance of 50Ω for monopole antennas as they are unbalanced. This eliminates the need for a balun, which may have a limited bandwidth (BW) [5].

Among the family of all monopole antennas the simplest member is the quarter wave monopole antenna above a prefect ground plane. The radius of the cylindrical stub decides impedance BW for quarter wave monopole antenna and it increases with increased radius. This is true up to a point where the stepped radius from the feed probe to the cylindrical element becomes abrupt.

II. ANTENNA DESIGN

The geometrical configuration of the proposed printed broadband antenna is shown in Fig. 1 and in Fig. 2. The antenna with substrate length 60 mm and width 80 mm is constructed on Glass Epoxy material with thickness of 1.59 mm and dielectric constant \( \varepsilon_r = 4.3 \). The microstrip probe feed line having 3 mm width is used to excite the proposed antenna. The basic antenna structure is a rectangular patch of 30 mm × 40 mm. The gap between the patch and ground plane i.e. feed length is 1 mm initially. The dimension of the ground plane is 60 mm × 22 mm. The dimensions of antenna were estimated using formulation given for planar disc monopole antenna the lower frequency for VSWR = 2 are given as [7]

\[
\frac{2\pi r L}{W x L} = \frac{r}{W/2\pi}
\]

which gives

\[
r = \frac{W}{2\pi}
\]

The input impedance of a \( \lambda/4 \) monopole antenna is half of that of the \( \lambda/2 \) dipole antenna. Thus, the input impedance of an infinitesimally thin monopole antenna is 36.5 + j 21.25 Ω, which is inductive. The real input impedance is obtained when a slightly smaller length of the monopole is used as given by [7]

\[
L = \frac{0.244}{\lambda F}
\]

where

\[F = (L/\lambda) / (1+L/r) = L/(L+r),\]

so that the wavelength \( \lambda \) is obtained as

\[
\lambda = (L + r)/0.24
\]

Therefore, the lower frequency \( f_L \) is given by

\[
f_L = \frac{c}{\lambda} = (30 \times 0.24) / (L + r) = 7.2/(L + r) \text{ GHz}
\]

where \( L \) = length of the monopole in cm, \( r \) = effective radius of an equivalent cylindrical monopole antenna in cm and \( p \) = length of the feed line in cm.
III. Specification Required

The three essential parameters for the design of a rectangular Micro-strip Patch Antenna are as follow:

i) **Frequency of operation** ($f_o$): The resonant frequency of the antenna must be selected appropriately. The ISM Band frequency ranges from 2.4 - 2.4835 GHz. Hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for my design is 2.45 GHz.

ii) **Selection of dimensions of for desired frequency**: Once frequency of operation of antenna is known one can decide the dimensions of planar antenna by knowing the relationship between $f_o$, W and L of planar antenna.

iii) **Dielectric constant of the substrate** ($\varepsilon_r$): The dielectric material selected for my design is Silicon which has a dielectric constant of 3.4. A substrate with a high dielectric constant as been selected since it reduces the dimensions of the antenna.

iv) **Height of dielectric substrate** ($h$): For the microstrip patch antenna to be used in ISM Band Application, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.54 mm.

IV. Design Steps

**Step 1: Software simulation**

i. Define basic parameters for simulation such as the dielectric constant of different layers, the units and layout dimensions, and metal types among other parameters.

ii. To draw the antenna layout.

iii. Select the feed location and type of feed.

iv. The next step is to run the simulation. However, before that, let us first mesh the structure; this mesh is used in the Method of Moment (MoM) calculation.

v. Observe the result for various parameters such as radiation pattern, current distribution, gain vs frequency plot, resonance frequency and bandwidth.

vi. Vary the feed length ($p$) of a given design from $p=0.5$ mm to 30 mm to observe the bandwidth variation.

After getting optimum value of feed length, by putting this value of feed length constant vary the dimensions of ground plane and observe the variation in bandwidth.

**Step 2: Hardware Implementation**

i. Implement the designed antenna on dielectric substrate over finite ground plane.

ii. Attach the feed port to the antenna.

iii. Observe the result for above designed parameters that are mentioned in software simulation.

**Step 3: Comparison of Result**

Both software simulation and hardware result will be observed and tabulated.
On the basis of software and hardware results obtained; comparative study of the results with other methods, antenna studied in literature survey and then conclusion will be deduced.

Table No.1 shows variation of bandwidth with change in feed length (\(p\)) and Table No. 2 shows variation of bandwidth with change in size of ground plane.

This shows that band width of given rectangular monopole design is maximum that is 4.24 GHz for feed length of 1 mm and ground plane is equal to 22 mm.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Feed Length ((p) in mm)</th>
<th>Lower Cutoff Frequency ((f_l) in GHz)</th>
<th>Bandwidth in GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>1.84</td>
<td>0.4</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1.75</td>
<td>2.90</td>
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<td>3</td>
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<tr>
<td>4</td>
<td>3</td>
<td>1.60</td>
<td>1.704</td>
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<tr>
<td>5</td>
<td>4</td>
<td>1.51</td>
<td>1.674</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Feed Length ((p) in mm)</th>
<th>Lower Cutoff Frequency ((f_l) in GHz)</th>
<th>Bandwidth in GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1.98</td>
<td>0.771</td>
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<tr>
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<td>10</td>
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<tr>
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<td>5</td>
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<td>1.74</td>
<td>4.24</td>
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<td>1.68</td>
<td>1.41</td>
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<tr>
<td>7</td>
<td>30</td>
<td>1.498</td>
<td>1.632</td>
</tr>
</tbody>
</table>

V. CONCLUSION

In this paper, we have investigated printed monopole antenna, etched on ground plane for Broadband applications and multi-band applications. Bandwidth of the designed antenna is dependent on feed length and size of ground plane. Printed monopole antennas are less fragile, planar and can be integrated with the integrated circuits unlike monopole antennas which have non-planar or protruded structures above the ground plane. Printed monopole antennas are studied first for such application. Then monopole antennas for high gain and high bandwidth are studied. It has been concluded that the printed monopole antennas are one of the versatile candidates for ISM band applications as well as it can be used for various Wireless Applications such as Wi-Max with a very large bandwidth of 4.245 GHz.
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REFERENCES