Design of Wideband Printed Monopole Antenna using Modified Ground Plane for ISM Band Applications

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Abstract— This paper presents a printed rectangular monopole antenna (PRMA) design for wideband applications. It also presents a comparative study to show the effects of bandwidth increment using ground plane truncation technique. The proposed antenna exhibits a wide bandwidth of 4.73 GHz ranging from 2.02 GHz to 6.75 GHz which is suitable for ISM, WLAN applications as well as radar communication.

Key words: Ground Plane, Truncation, Wideband, Printed Rectangular Monopole Antenna

I. INTRODUCTION

The ever increasing demands of compact antenna solutions for wideband applications in recent years has drawn lots of attraction with technological boost in wireless communications. From past decade or so, the field of microstrip antennas has attracted many researchers for their numerous advantages [1]. The major concern is to design a single antenna which can accommodate various wideband applications [2]. Printed monopole antennas have proved their suitability for large bandwidth applications owing to no. of advantages like high degree of compactness, conformality, low cost, ease of fabrication etc [2],[3]. Various geometries of printed monopoles have been investigated earlier for their performance which exhibits different impedance characteristics [4],[5]. Bandwidth enhancement in printed monopoles can be achieved by optimizing various design parameters like microstrip line feed, patch dimensions, feedpoint position etc [2]. In [2], multifeed arrangement is investigated for the same purpose. One of the recent techniques for rectangular monopoles includes modification of radiating patch for improved impedance matching by truncating bottom contour of radiating patch [1]. ISM (Industrial, Scientific, Medical) band which occupies 2.4 GHz (2.4 to 2.4835 GHz operated by IEEE 802.11b/g) and 5 GHz (5.15 to 5.35 and 5.725 to 5.825 GHz operated by IEEE 802.11a) refers to a group of unlicensed radio bands that are globally reserved for the purpose of industrial, scientific, medical applications [6]. To count a few, these bands are used for RF devices like RF welding machines, industrial heaters and microwave ovens etc. The 2.4 GHz ISM band is used for low power Bluetooth and Wi-Fi applications whereas 5 GHz band is used by HiperLAN technology [7].

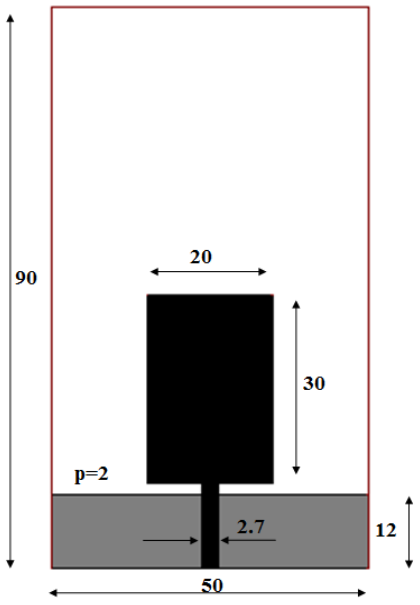

Fig. 1: Simple PRMA

This paper presents the performance of simple PRMA suitable for ISM band which exhibits an impedance bandwidth of 3.91 GHz (from 2.16 GHz to 6.08 GHz) having VSWR ≤ 2. Further bandwidth enhancement in the same design is proposed and investigated by truncating the ground plane dimensions exhibiting an improved bandwidth of 4.73 GHz (from 2.02 GHz to 6.75 GHz) having VSWR ≤ 2.

II. ANTENNA DESIGNS

Wide bandwidth is generally characterized by its edge frequencies. Hence, instead of considering resonant frequency, the lower band edge frequency is considered which influences the dimensions of the radiating patch. The lower band edge frequency f_L can be thus obtained by using the formulation described in [2],

$$f_L = 7.2/\{(L + p) + 0.159W\}kGHz \quad (1)$$

Where all the dimensions are considered in centimetres. correction factor k is taken as 1.15 for glass epoxy FR-4 substrate.

Sr. No.	Parameters	Values
1	Length of Substrate, L_s	90 mm
2	Width of Substrate, W_s	50 mm
3	Length of Radiator, L_p	30 mm
4	Width of Radiator, W_p	20 mm
5	Length of ground plane, L_g	12 mm
6	Width of ground plane , W_g	50 mm
7	Feedgap, p	2 mm
8	Width of Feed line, W_f	2.7 mm

Table 1: Optimized parameters of simple prma

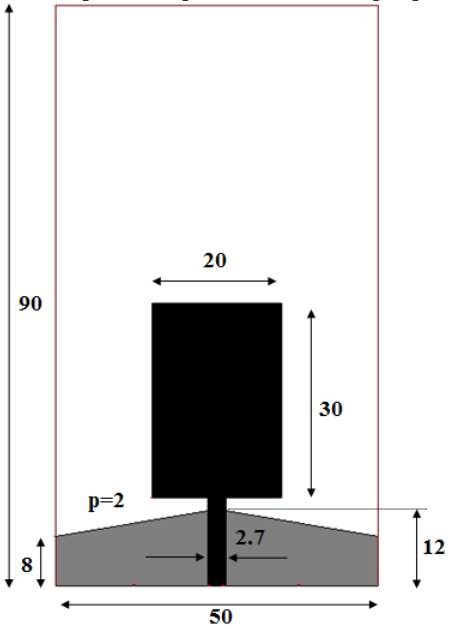

Fig. 2: PRMA with truncated ground plane length

The substrate material considered for the respective design is FR-4 material having dielectric constant ε_r = 4.3, thickness h = 1.59 mm and loss tangent tanδ = 0.01 which offers high reliability, low losses and most importantly its low manufacturing cost [1].

The optimized parameters of conventional PRMA as shown in Fig.1 are tabularized in table 1. Various parameters of this design like feedpoint position, feedline width, ground plane length etc were systematically optimized for achieving the wide bandwidth response. The width of patch excites higher order modes whereas the length of patch significantly affects the lower band edge frequency. To enhance the bandwidth of this design further, the ground plane length truncation is proposed and investigated as shown in Fig.2. This truncation allows improved bandwidth response due to modified abrupt geometry of ground plane into gradually tapered manner. Maintaining all the parameters constant, the ground plane length is truncated from its vertex position in both the directions symmetrically. Symmetrical truncation is much better as compared to asymmetrical case due to its good radiation characteristics especially in azimuthal radiation plane. By optimizing the flaring or truncation angles the upper band edge frequency can be controlled in an efficiently as required.

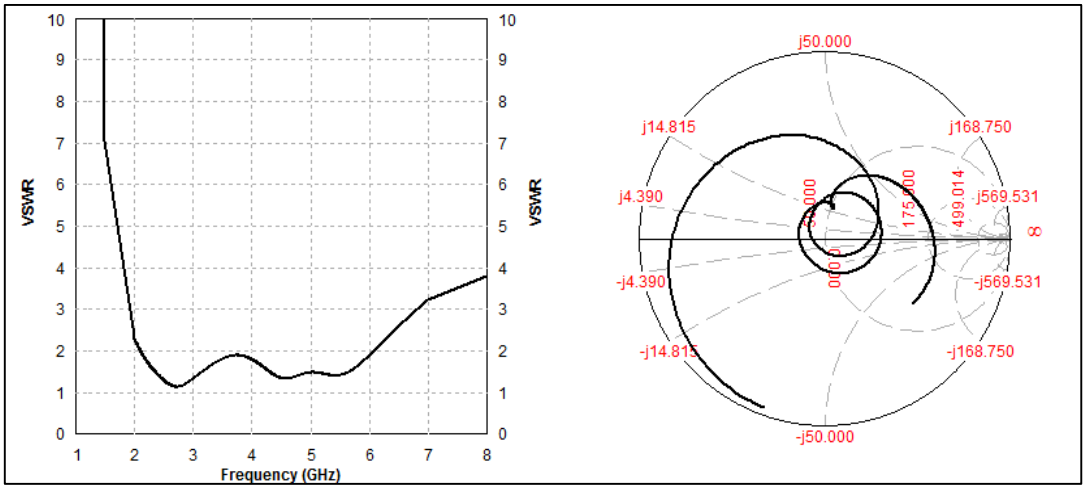

Fig. 3: (a) VSWR plot; and (b) Impedance plot for simple PRMA

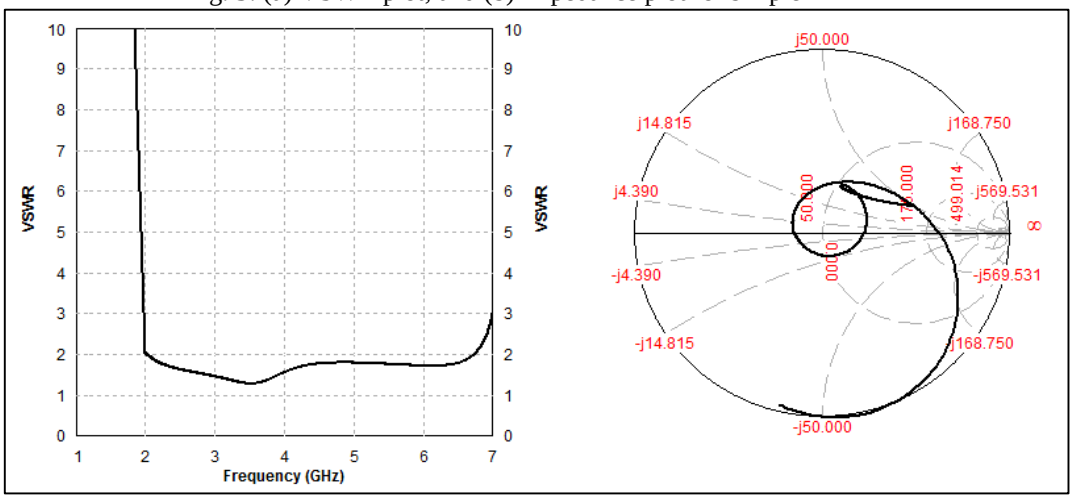

Fig. 4: (a) VSWR plot; and (b) Impedance plot for PRMA with truncated ground plane length

III. RESULTS & DISCUSSIONS

The simulated bandwidth for simple design is investigated as 3.91 GHz having VSWR ≤ 2 (from 2.16 GHz to 6.08 GHz) which caters the ISM and WLAN operating bands as specified earlier. Fig.3(a) and (b) shows the VSWR and impedance plots for the simple PRMA design respectively. For monopole antennas, the impedance characteristics are strongly depended on the balance between ground plane, feedpoint and radiating patch geometry. The backing ground plane selected for the proposed design is partial instead of finite one as it reduces the inductive effect of antenna impedance. This provides better impedance matching for wide bandwidth performance [8].

To further enhance the bandwidth of simple PRMA, ground plane length has been truncated symmetrically as shown in Fig. Fig. 4 (a) and (b). The bandwidth recorded for this design is 4.73 GHz having VSWR ≤ 2 (from 2.02 GHz to 6.75 GHz). By employing this technique, the impedance variations among various modes excited in the patch decreases and it brings the higher order modes together for improved bandwidth exhibition. The truncation helps in smoothing out the sharp and abrupt edges of rectangular shaped ground plane and provides a better transition between the radiating patch and ground plane [1]. The tapered ends of truncated ground pane allow smooth travelling paths for the electric current vectors as compared to simple PRMA case. This improves the impedance and radiation characteristics in much better and controlled way.

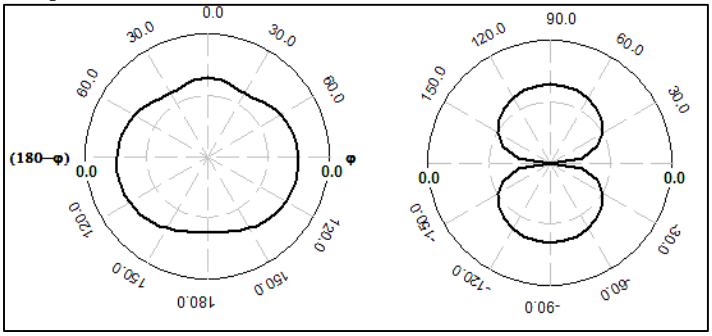

Fig. 5: Radiation patterns at 3 GHz (a) Azimuthal; and corresponding (b) Elevation for simple PRMA

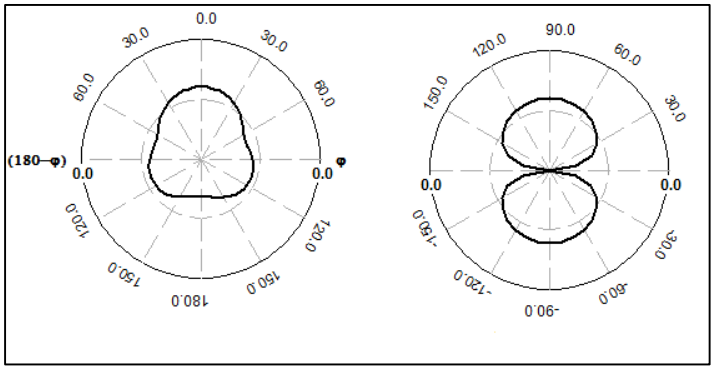

Fig. 6: Radiation patterns at 3 GHz (a) Azimuthal; and corresponding (b) Elevation for PRMA with truncated ground plane length

The electric current distribution as shown in Fig.7 and Fig.8 on the surface of radiator and ground plane is unevenly distributed and changes with change in operating frequencies [1],[8]. Hence the impedance and radiation characteristics of monopoles are strongly depended on current distribution. The ground plane radiations especially at higher frequencies are unavoidable. It tends to oppose the forward travelling current vectors at some portions thereby affecting the corresponding mode. The ground plane geometry is strongly controls the performance parameters of printed monopoles and hence need to be modified for achieving required response [8].

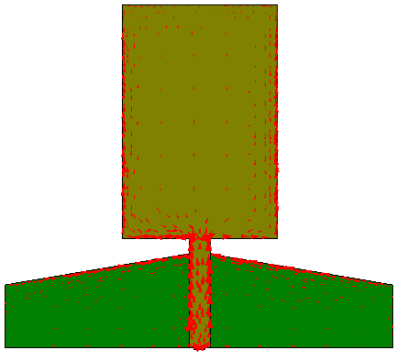

Fig. 7: Vector current distribution at 2 GHz for PRMA with truncated ground plane length

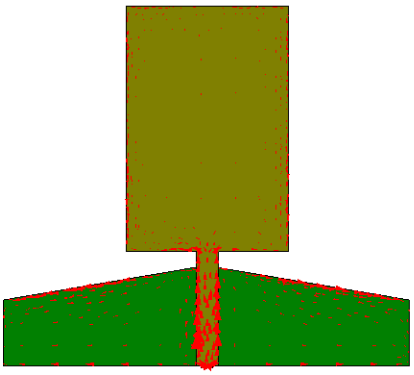

Fig. 8: Vector current distribution at 5 GHz for PRMA with truncated ground plane length

The current distribution at 5 GHz for PRMA with truncated ground plane length shows the effects of ground plane radiations as compared to that at 2 GHz. It can be seen that the radiations from ground plane are much more significant and spurious at higher frequencies [8]. Hence for the given set of optimized design parameters the impedance mismatching becomes significant above 7 GHz.

IV. CONCLUSION

Bandwidth enhancement in printed monopole antenna is achieved by modifying the ground plane geometry as proposed in the design. The ground plane has better control over the impedance and radiation characteristics of antenna. Truncation of ground plane at optimized values leads to change in input impedance of antenna thereby improving the impedance characteristics. The percentage bandwidth obtained by simple PRMA is 95.01% as compared to improved percentage bandwidth of 107.86% by modifying ground plane. The proposed antenna can be used for unlicensed ISM and WLAN applications.

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