Planar Monopole Ultrawideband Antenna with Reduced Ground Plane Dependence

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Abstract: A technique to reduce ground plane effect on a printed wideband antenna is presented. The antenna consists of a ground plane, and a wing-shaped monopole with an attached strip. The strip is attached to introduce a slight disturbance in the return loss of the antenna. Here, a slight peak in the form of a notch is introduced in the return loss at a specific frequency depending on the length of the attached strip. At this frequency, the antenna has reduced ground plane effect. The proposed antenna is etched on 11 × 15 mm² FR4 substrate and covers an operating frequency from 5 – 15 GHz (VSWR < 2.5) with a stable gain and good radiation properties. Experimental results show good antenna performance.

Key words: Return loss, ultrawideband, wing-shaped monopole antenna, ground plane effect.

1. Introduction

Ultrawideband (UWB) systems have gained enormous amount of attention due to its wide operating bandwidth. UWB systems have enormous advantages in performance such as high speed data rate, low power spectral density and omnidirectional radiation patterns. Other beneficial physical features include low cost, low profile and ease of fabrication. Among the numerous wideband antenna types available, the printed monopole wideband antennas [1]-[6] has gained a lot of recognition due to its flat structure, its small size and its ease of integration with other microwave circuit components. However the ground plane effect is a major issue in planar monopole antennas. Essentially, the ground plane and radiator of the antenna form an unbalanced system where the electric current is distributed on both the ground plane and the radiator. This means that the performance of the antenna in terms of operating frequency, impedance bandwidth, and radiation properties are affected by the shape and size of the ground plane [7], [8]. This brings about design complexities and deployment difficulties.

A few designs have being proposed to reduce ground plane effect. In [9], a method of cutting slots was introduced on the ground plane to confine the electric currents around the slots on the ground plane and reduce the effects on other parts of the ground plane. This method is complicated and the relatively large slots on the ground plane affect the radiation pattern. In [10], a notch was made on the radiator of a UWB antenna to concentrate most of the current on the radiator to reduce the currents on the ground plane. This solution isn't a general solution, and may affect the radiation pattern. In [11], leakage blocking slots were used to partially avoid currents on the ground plane from floating back to the RF cable which in turn reduces the effects of the ground plane. This technique slightly reduces leakage from the ground plane to the RF cable but doesn't mitigate or reduce the ground plane electric currents. There is a lack of methods to effectively reduce the ground plane effect. All these methods stated above are not independent or general and are quite difficult to implement.

In this paper, a technique has been proposed to reduce the ground plane effect of a planar monopole wideband antenna. Here, a quarter wavelength strip has been attached to the monopole to introduce a disturbance in a form of a slight notch in the impedance bandwidth. At this notch frequency, majority of the currents will be present on the strip on the monopole and therefore reduce the currents present on the ground plane. This means the antenna will be greatly sensitive at the radiator and almost insensitive to the ground plane at this frequency, therefore greatly suppressing ground plane effect. This technique, compared to the others, is easy to implement and easy to tune. Section 2 discusses the antenna design including the parametric study. Section 3 will explain the results and discussion and Section 4 will discuss the conclusion.

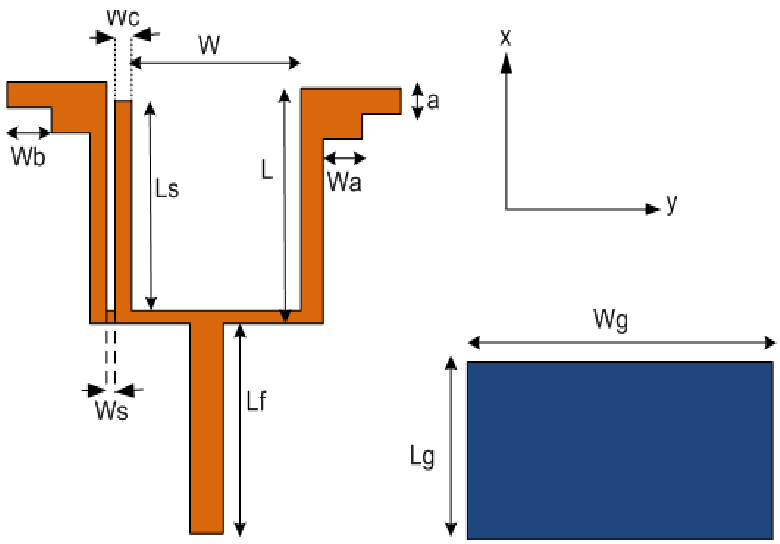


Fig. 1. Dimensions of proposed antenna.

2. Antenna Characteristics

2.1. Antenna Geometry

The proposed antenna is shown in Fig. 1. It is printed on an FR4 substrate of thickness 1mm and relative permittivity 4.4. The width of the feed line is 2 mm. The basic antenna consists of a wing-shaped radiating patch, a microstrip feed line and a rectangular ground plane printed on the other side of the substrate. The wing-shape [3] is used to improve the impedance bandwidth. The proposed antenna is fed by a 50-Ω SMA connector. The final dimensions of the antenna are given as follows; L_f = 8.5 mm, W = 4.9 mm, L_s = 5.8 mm, L = 6.5 mm, W_s = 0.13 mm, W_c = 0.4 mm, W_b = 1 mm, W_a = 1 mm, a = 1 mm, W_g = 11 mm, L_g = 7.5 mm. The antenna is printed on the *xoy* axis as shown. In this design, a very small antenna is used. The small ground plane size of the antenna is chosen since it is guaranteed to increase ground plane effect of the antenna. This can be noticed in discrepancy between simulated and measured return loss results at low frequency. However, by introducing the proposed technique at a certain frequency, the ground plane dependence is suppressed at that frequency, and the simulated and measured results agree very well at that frequency. This will be noted in the later sections.

2.2. Parametric Study

Knowledge of different parameters is essential since it provides insight into the different characteristics of the antenna. Mainly, the different lengths and widths are taking into consideration when parametric analysis is done since they represent the capacitive and inductive characteristics of the antenna. The height of the strip is responsible for the inductive change since a change in height will cause a change in current flow on the strip. The different gaps and widths between the strips also cause capacitive changes. The effect of the strip length Ls is exhibited in Fig. 2.

It can be noted from Fig. 2 that the length of the strip has great effect at the notch frequency. As the length increases, the notch frequency moves to lower frequency. The intensity of the notch also decreases with increased length. The notch frequency is related to the strip length in the formula given below.

$$L_s \approx \frac{C}{4 f_{notch}\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

Using this formula, Ls can be obtained for the desired frequency. However, this formula provides us with starting values where the value can be optimized to achieve the desired final value.

Fig. 3 shows the effect of Wc on the return loss. It can be noted that the notched frequency is barely affected with changes in Wc. Hence we can say that the notch isn't very dependent on the width of the strip.

Fig. 4 shows the changes in return loss with changes in Ws. It can be noted that as Ws increases, the intensity of the notch increases as well. However the frequency points remain the same. Hence we can safely say that the Ws can be used to increase or lower the notch intensity

The current distribution of the proposed antenna is shown in Fig. 5. It can be shown that the current is unevenly distributed at the notch frequency. Here, majority of the current is distributed on the radiator between the strip and the left side of the radiator. This means that at this frequency, the antenna is sensitive to this portion on the radiator and not the ground plane or otherwise. Therefore at this frequency, the antenna isn't sensitive to the ground plane and the ground plane effect of the antenna is greatly reduced. The current distribution of the antenna without the notch is shown for comparison. It is noticed that, at 7.5 and 10 GHz for the antenna without strip, the majority of the currents are equally distributed on the arms of the radiator, the feedline and on the ground plane closer to the feedline, and also around the edges closer to the monopole. This means the ground plane and monopole both contribute immensely as radiators.

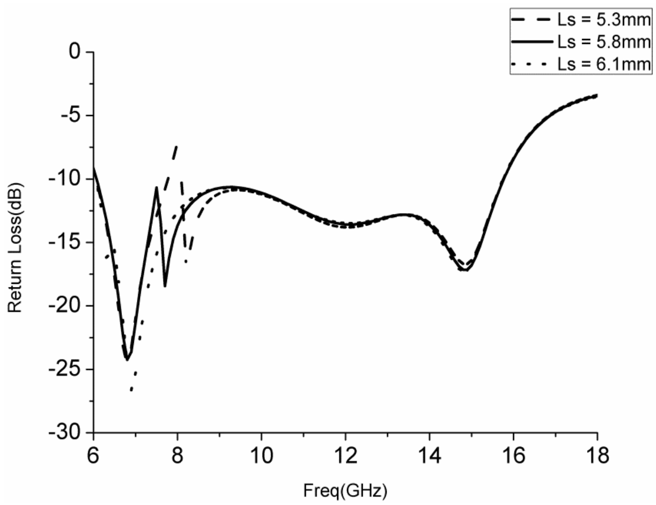


Fig. 2. Simulated reflection coefficients for different Ls values.

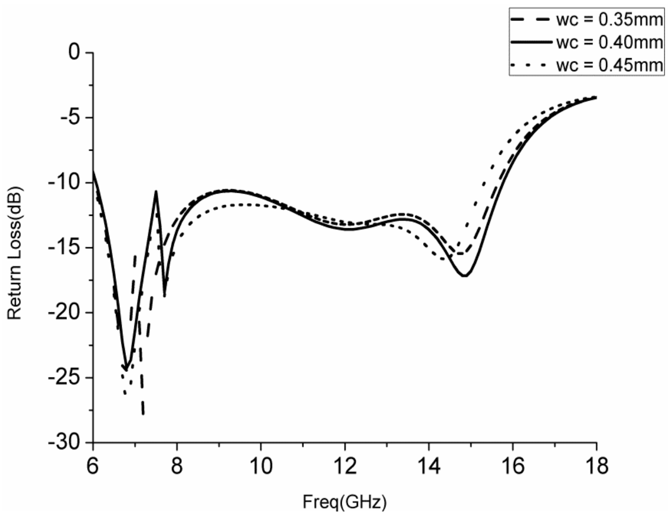


Fig. 3. Simulated reflection coefficients for different wc values.

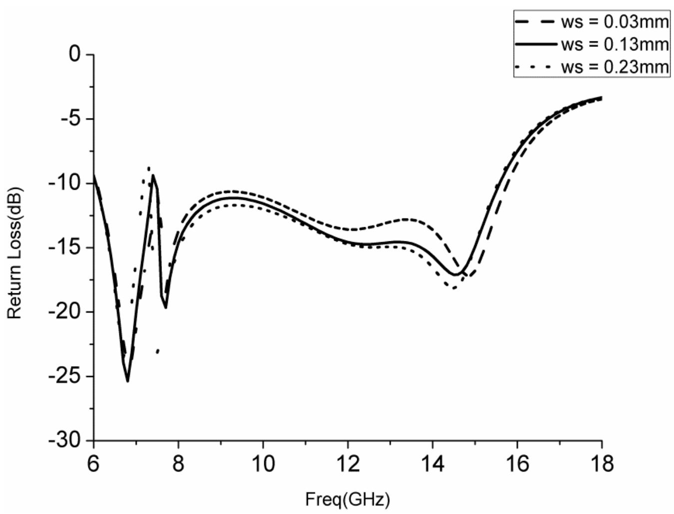


Fig. 4. Simulated reflection coefficients for different ws values.

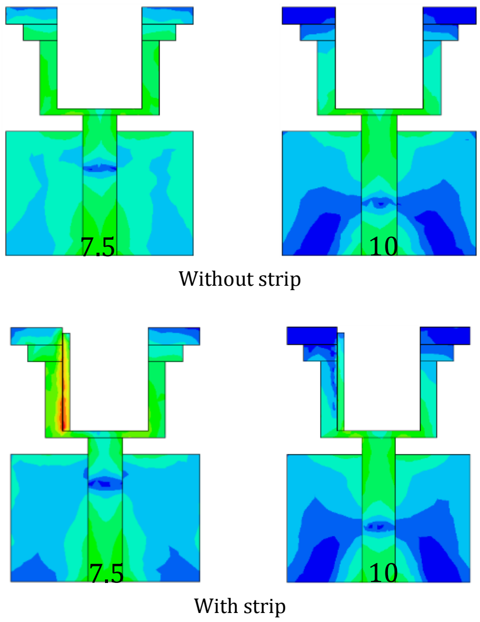


Fig. 5. Current distribution of the antenna with and without strips at different frequencies (7.5 GHz and 10 GHz).

3. Results and Discussion

The proposed antenna is fabricated and measured by using an Agilent E8363B performance network analyzer (PNA) and SATIMO antenna measurement system. The photograph of the fabricated prototype of the proposed antenna is shown in Fig. 6. Fig. 7 shows the measured and simulated reflection coefficient of the proposed antenna. It provides a wide bandwidth (VSWR < 2.5) covering 5 -15 GHz. It was earlier explained that, the size of the antenna and ground plane were chosen to be small in order to make sure that the antenna was ground plane dependent. This can be noticed at the low frequency. Discrepancies exist between the simulated and measured results at low frequency. This is due to the fact that, at that low frequency, when the SMA is attached to the antenna, the currents of the ground plane couple or leak to the SMA connector as well. Therefore the ground plane together with the attached SMA connector looks like a bigger ground plane than during simulation without the SMA. Therefore with a 'bigger' ground plane size, the lower frequency is noticed to improve in the measured results. At 7.5GHz however, where the notch was introduced, it can be noticed from Fig. 7 that the simulated and measured return loss agree perfectly well showing that the presence of the RF cable doesn't affect the antenna performance. Hence we can say with conviction that the antenna is ground plane independent at this frequency.

Fig. 6. Photograph of the fabricated prototype of the proposed antenna.

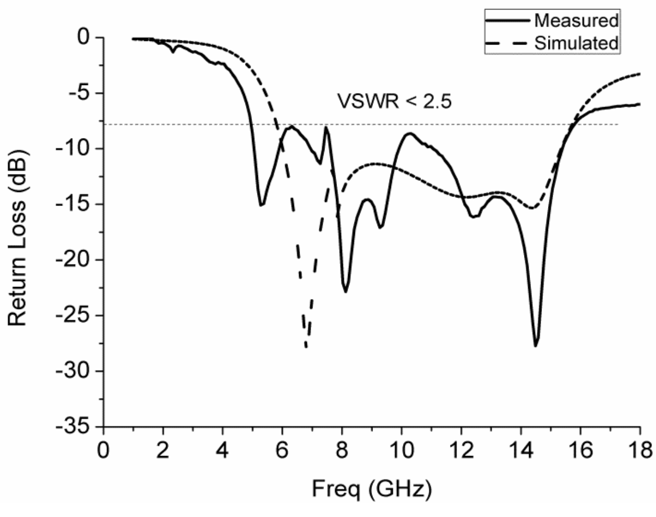


Fig. 7. Measured reflection coefficient of the proposed antenna.

The measured peak gain is shown in Fig. 8. The constant peak gain is achieved except at about 9 GHz where a slightly sharp decrease in gain is noticed. The radiation patterns of the proposed antenna are noticed in Fig. 9. The antenna is printed on the *xoy* axis, hence the *E*-plane is (*xoy, θ = -90*) and *H*-plane is (*yoz, ϕ = 90*). The E-plane radiation patterns exhibit a monopole-like radiation with nulls appearing at the centre and the H-plane radiation patterns exhibit an omnidirectional radiation pattern. The simulated and measured radiations agree well.

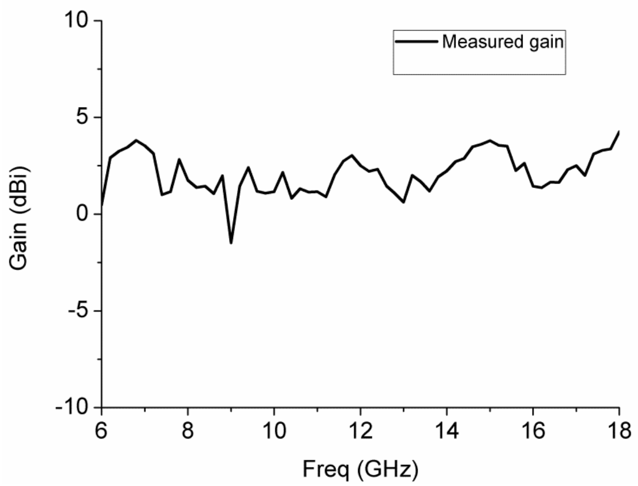
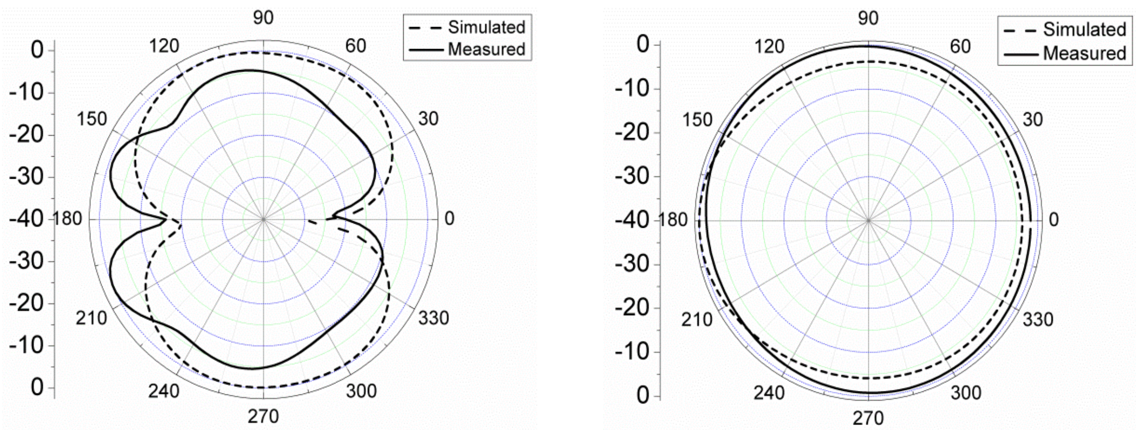
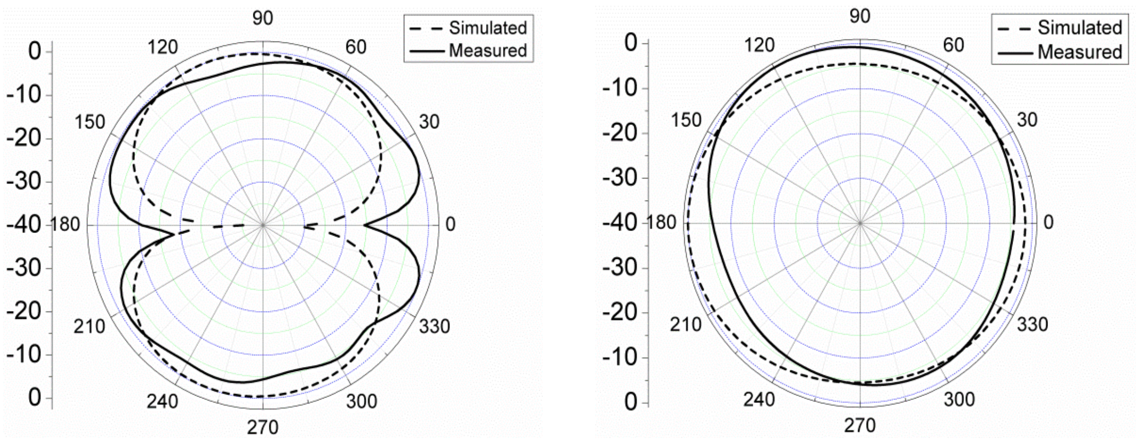


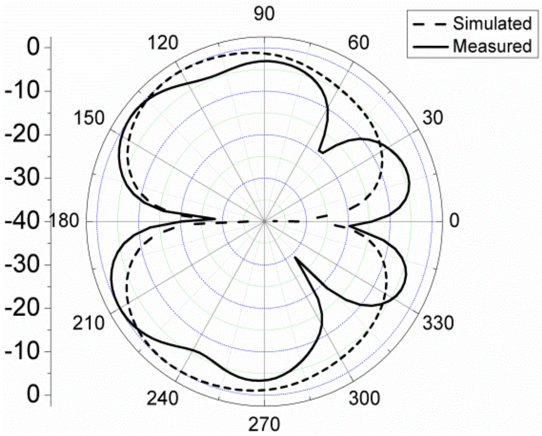
Fig. 8. Measured peak gain of the proposed antenna.

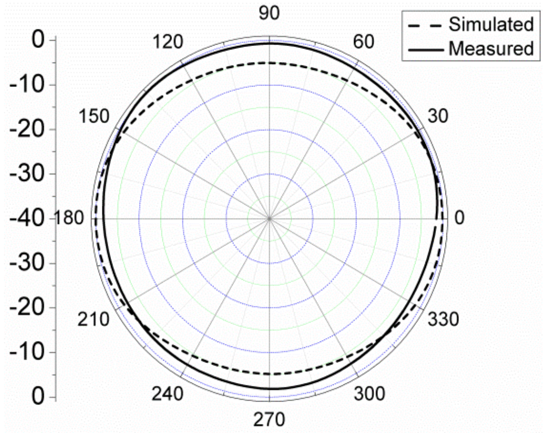


(a) 7 GHz



(b) 10 GHz





(c) 12 GHz

Fig. 9. Measured radiation patterns of the proposed antenna at different frequencies. (left) E-plane and (right) H-plane.

4. Conclusion

A printed planar monopole UWB antenna with suppressed ground plane effect has been presented. In this design, a strip is attached to the hollow center of the radiator to create a slight notch at a certain frequency in the impedance bandwidth. The notch is chosen to be minimal, so that at this frequency, the antenna is works as an efficient radiator. However at the notch frequency, majority of the current is present at monopole and minimal current is present at the ground plane. The antenna is therefore sensitive to the radiator at this frequency and not the ground plane. This property is important in most practical situations when the antenna is integrated with other circuit components like in mobile antenna applications. This technique is very flexible and allows for easy tuning of the notch to any frequency desired. The proposed antenna exhibits good radiation properties and a fairly stable gain.

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