



BANDWIDTH ENHANCEMENT OF PIFA ANTENNAS FOR WIRELESS APPLICATIONS BY GROUND PLANE OPTIMIZATION

S. Sharavanapavan*, W. M. S. M. Wickramasinghe and D. R. M. T. N. Bandara
Department of Electrotechnology, Wayamba University of Sri Lanka, Sri Lanka

Planar Inverted-F Antennas (PIFAs) are widely used in wireless applications because of their simple design, low profile, light weight, low cost, relatively low specific absorption rate (SAR), and good performance. However, they suffer from narrow bandwidth, which affects their performance in modern wireless applications. This research focuses on enhancing the bandwidth performance of PIFA antennas through ground plane optimization. The objective of the optimization was to maximize the bandwidth ($S_{11} \leq -6$ dB) at 900 MHz, by modifying the geometry and dimensions of the ground plane. A basic PIFA antenna with dimensions of 100 mm x 40 mm x 1.6 mm was designed and simulated on an FR4 substrate (relative permittivity (ϵ_r) of 4.4 and loss tangent of 0.02) at 900 MHz, using High-Frequency Structure Simulator (HFSS) software. Then, as a bandwidth enhancement technique, slots were introduced on the ground plane. Initially, a single slot was created, and the position of the slot and its dimensions were optimized using parametric optimization. It was observed that the slot's position significantly affected the performance of bandwidth, with the highest bandwidth improvement achieved when a 30 mm x 5 mm horizontal slot was placed under the radiating patch. The bandwidth ($S_{11} \leq -6$ dB) increased to 23.3% with a single slot, compared to 17.7% without any slot. Subsequently, a second slot with the same dimensions as the first was introduced, and its position was optimized through parametric optimization. The bandwidth was further improved up to 24.4% after inserting the second slot. The results confirm that ground plane optimization techniques, such as inserting slots, enhance the bandwidth of PIFAs.

Keywords: PIFAs, bandwidth enhancement, ground plane optimization

**Corresponding Author: spsharan1999@gmail.com*



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S. Sharavanapavan^{}, W.M.S.M. Wickramasinghe and D.R.M.T.N. Bandara*
Department of Electrotechnology, Wayamba University of Sri Lanka, Sri Lanka

INTRODUCTION

The antenna is the most important part in wireless applications. Antennas transform the electrical signal into radio waves and vice versa (Khan et al., 2016). Due to its compact size, planar inverted-F Antennas (PIFAs) are most suitable to be employed in wireless equipment (Puri et al., 2014). PIFA is a promising antenna for future technology due to the adjustability of its structure. The drawbacks of PIFA include narrow bandwidth, making it more expensive for multi-band or wideband operations. This research focuses on enhancing the bandwidth of PIFA by optimizing the ground plane via slots.

There are several bandwidth enhancement techniques reported in the literature, such as, optimizing the widths of the feed plate and shorting plate (Halaoui et al., 2014), adding an inverted L- L-shaped and rectangular parasitic element (Halaoui et al., 2014), optimizing the radiating plate (Halaoui et al., 2014), and adjusting the height of the radiating plate (Halaoui et al., 2014). Ground plane optimization through the insertion of slots offers a cost-effective and simple method to expand bandwidth without increasing the antenna's physical size.

METHODOLOGY

The basic PIFA antenna was designed to resonate at 900 MHz using High Frequency Structure Simulator (HFSS) software. The ground plane dimensions were 100 mm x 40mm x 1.6 mm. The substrate is FR4, which has a relative permittivity (ϵ_r) of 4.4, and a loss tangent of 0.02. The ground plane and the radiating patch were optimized through parametric optimization to achieve the resonant frequency at 900 MHz. The $S_{11} \leq -6$ dB bandwidth of the optimized design was 17.7%. Then, as a bandwidth enhancement technique, a single slot was introduced on the ground plane. The position and the dimensions of the slot were optimized using parametric optimization. The bandwidth of the PIFA with the slotted ground plane was improved significantly, up to 23.3 %. In order to improve the bandwidth further, a second slot was introduced on the ground plane while keeping the position and dimensions of the first slot fixed. The position and dimensions of the second slot were also optimized using parametric optimization. The addition of the second slot further enhanced the bandwidth up to 24.4%.

RESULTS AND DISCUSSION

Basic Optimized Design

The result of the parametric optimization and the optimized design of the basic PIFA, configured to resonate at 900 MHz, are shown in Figure 1 (a) and (b), respectively.

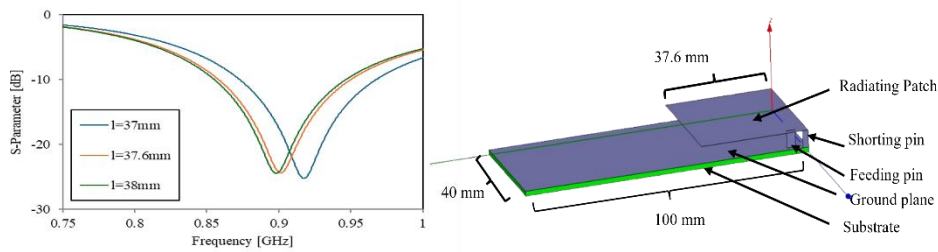


Figure 1: (a) Parametric optimization of patch length (b) Basic optimized PIFA design

Figure 2(a) illustrates the surface current distribution. It shows a strong concentration of current near the shorting pin and an intermediate concentration beneath the radiating patch. As per the results shown in Figure 2(b), the $S_{11} \leq -6$ dB bandwidth is 17.7 %.

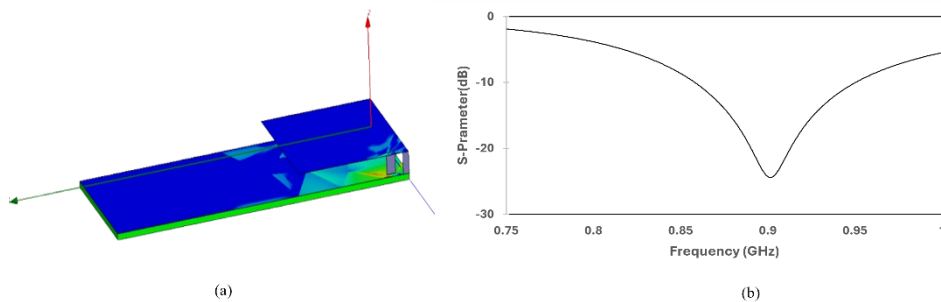


Figure 2: (a) Simulated surface current distribution (b) S_{11} plot of the basic PIFA

Single Slot Optimized Design

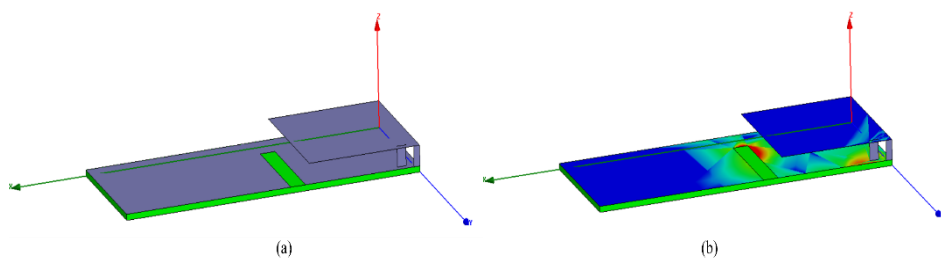


Figure 16: (a) Optimised PIFA with a single slot (b) surface current distribution

Figure 3(a) shows the optimized design after inserting a slot on the ground plane. The introduction of a slot on the ground plane effectively increases the electrical length of PIFAs. The surface current distribution is shown in Figure 3(b).

The slot's position is the most critical parameter for bandwidth enhancement. Once the position is optimized, increasing the length further enhances the bandwidth

performance. The impact of the slot's width on bandwidth enhancement is minimal compared to its position and length.

The optimized design for the single slot improved the $S_{11} \leq -6$ dB bandwidth to 23.3%. This represents a 5.6% enhancement compared to the basic optimized design. According to Figure 3(b), there is a strong current path concentrated around the single slot area.

Double Slot Optimized Design

The optimized design with double slots and the surface current distribution are shown in Figures 4(a) and (b), respectively.

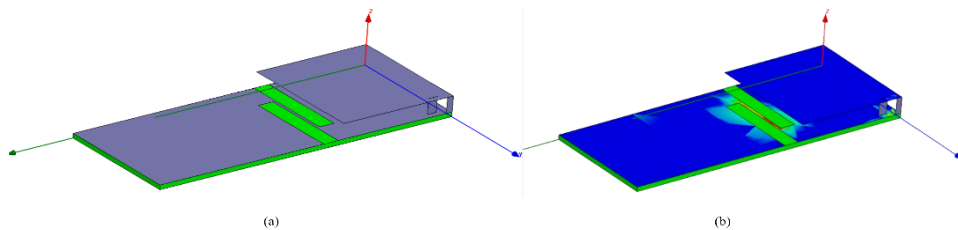
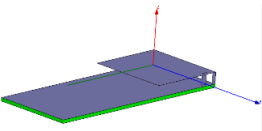
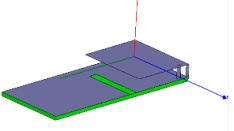
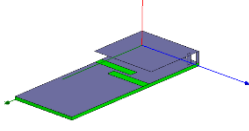


Figure 17: (a) Optimized PIFA with double slots (b) surface current distribution

The double slot design achieved a 24.4% bandwidth improvement, which is about 37.9% better than the antenna without slots. According to Figure 4(b), there is a strong current path concentrated between two slots.

Table 1 compares the performance of the optimized PIFA designs. Accordingly, the slotted ground planes have demonstrated greater bandwidth than planar ground planes.

Table 1: Bandwidth comparison of optimized PIFA designs.

	Design 1	Design 2	Design 3
Optimized Design			
Bandwidth at 900 MHz	17.7 %	23.3 %	24.4 %
Bandwidth improvement compared to Design 1	-	31.6. %	37.9%



CONCLUSIONS

Slotted ground planes have significantly enhanced the bandwidth of PIFA antennas without increasing their physical size. By adding slots to the ground plane, the effective electrical length of the PIFA antenna is increased. After analyzing the results following the insertion of a single slot, its position was found to have the most significant impact on enhancing bandwidth. The length of the slot also contributes to the bandwidth enhancement, but the slot width has less effect. The bandwidth increased to 23.3% with a single slot, compared to 17.7% without any slot, and the double slot design achieved 24.4%. In future work, the possibility of enhancing the bandwidth by adding different shapes of slots on the ground plane will be investigated.

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