Design and Simulational Characterization of Slotted Aperture Planar Inverted-F Antenna

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ABSTRACT
A novel slotted aperture shorting plate planar Inverted-F antenna is designed to operate at 2.6 GHz and its simulational characterization is presented in this paper. The proposed antenna is compact in size of 24X22X1.4 mm with good radiation characteristics. The commercial electromagnetic simulator HFSS is used to carry out the simulation works and the simulation results of return loss less than -10dB at resonating frequency and VSWR<2 and gain more than 5dB are showing the applicability of this antenna in the mobile communication applications.

Keywords: Simulational Characterization, Planar Inverted-F Antenna, Return Loss, VSWR.

1. INTRODUCTION
With the rapid development of mobile communications and miniaturization of mobile phones, requirements for small and low profile antennas are constantly growing. For optimum system performance, the antennas must have high radiation efficiency, small volume, isotropic radiation characteristics, simple and low-loss impedance matching to the receive and transmit paths, and simple mechanical construction [1-2]. The major types of configurations of low-profile antennas with enhanced bandwidth performance include planar inverted F Antennas, Radiation-Coupled Dual L Antenna and Diode-Tunable PIFA.

The Inverted F Antenna (IFA) typically consists of a rectangular planar element located above a ground plane, a short circuiting plate or pin, and a feeding mechanism for the planar element. The Inverted F antenna is a variant of the monopole where the top section has been folded down so as to be parallel with the ground plane. This is done to reduce the height of the antenna, while maintaining a resonant trace length [3]. This parallel section introduces capacitance to the input impedance of the antenna, which is compensated by implementing a short-circuit stub. The stub’s end is connected to the ground plane through a via.

The ground plane of the antenna plays a significant role in its operation. Excitation of currents in the printed IFA causes excitation of currents in the ground plane [4-5]. The resulting electromagnetic field is formed by the interaction of the IFA and an image of itself below the ground plane. Its behavior as a perfect energy reflector is consistent only when the ground plane is infinite or very much larger in its dimensions than the monopole itself. In practice the metallic layers are of comparable dimensions to the monopole and act as the other part of the dipole.

The design variables for this antenna are the height, width, and length of the top plate, the width and location of shorting plate, and the location of the feed wire [6]. A semi-rigid coax with a centre conductor that extends beyond the end of the outer conductor is used to form the PIFA feed wire. The outer conductor of the coax is soldered to the edge of a small hole drilled in the ground plane at the specified feed point. The shorting post of usual PIFA types is a good method for reducing the antenna size, but results in narrow impedance bandwidth [7]. Several modifications have been suggested to obtain a tradeoff between size, bandwidth and other properties of a PIFA.

1.1 Techniques to increase the Bandwidth for the PIFA
The main relationships among various parameters having influence on bandwidth are follows;
Bandwidth = (Fu – Fl)/Fr \(\approx 1/Q\)

\[ Q = \sqrt{L / R} \sqrt{C} \]

\[ Q \approx 1/S \]

where, \(fu\) and \(fl\) are upper and lower frequency of bandwidth, \(fr\) is resonant frequency, \(Q\) is quality factor, \(R\) is loss component of antenna, \(L\) is inductive component of antenna, \(C\) is capacitive component of antenna, \(S\) is volume of antenna. The most frequently used method to broaden the bandwidth is to raise the height of the shorting plane i.e increase the volume. Bandwidth is affected very much by the size of the ground plane. By varying the size of the ground plane, the bandwidth of a PIFA can be adjusted. For example, reducing the ground plane can effectively broaden the bandwidth of the antenna system. Several slits at the ground plane edges can be inserted to reduce the quality factor of the structure (and to increase the bandwidth). Bandwidth enhancement of a PIFA can also be achieved by several efficient approaches, namely using dual resonance by additional patch that is adding capacitive load, loading dielectric with high permittivity attaching chip resistor that is increasing loss term.

The resonant frequency of PIFA can be approximated with:

\[ L_1 + L_2 = \lambda /4 \]

When \(W/L_1=1\) then \(L_1 + H = \lambda /4\)

When \(W=0\) then \(L_1 + L_2 + H = \lambda /4\)

The introduction of an open slot reduces the frequency. This is due to the fact that there are currents flowing at the edge of the shaped slot, therefore a capacitive loaded slot reduces the frequency and thus the antenna dimensions drastically. The same principle of making slots in the planar element can be applied for dual frequency operation as well. Changes in the width of the planar element can also affect the determination of the resonant frequency. The width of the short circuit plate of the PIFA plays a very important role in governing its resonant frequency. Resonant frequency decreases with the decrease in short circuit plate width, \(W\). Unlike micro-strip antennas that are conventionally made of half wavelength dimensions, PIFA’s are made of just quarter wavelength [8]. Analyzing the resonant frequency and the bandwidth characteristics of the antenna can be easily done by determining the site of the feed point, at which the minimum reflection coefficient is to be obtained.

RESULTS AND DISCUSSION

2.1 Impedance Matching

The impedance matching of the PIFA is obtained by positioning of the single feed and the shorting pin within the shaped slot, and by optimizing the space between feed and shorting pins. The main idea behind designing a PIFA is to avoid using any extra lumped components for matching network, and thus avoid any losses due to that. Figure 2 shows the return loss curve and input impedance smith chart curve. A return loss of more than -12dB and the bandwidth of 0.84% is attained from the current model.

![Figure 2 Return loss Vs Frequency and Input Impedance Smith Chart](image)

2.2 Radiation Pattern

The radiation pattern of the PIFA is the relative distribution of radiated power as a function of direction in space. In the usual case the radiation pattern is determined in the far-field region and is represented as a function of directional coordinates. Radiation properties include power flux density, field strength, phase, and polarization. Figure 3 shows the radiation pattern of the proposed antenna.

2.3 Electric Field Distribution

The dominant component of the electric field \(E_z\) is equal to zero at the short-circuit plate while the intensity of this field at the opposite edge of the planar element is significantly large. For fields \(E_x\) and \(E_y\), there is pointing part, which corresponds to the feed source. This means that the electric lines of force are directed from feed source to the ground plane. When the width of the short circuit plate is narrower than the planar element, the
electric fields $E_x$ and $E_y$ start generating at all open circuit edges of the planar element. These fringing fields are the radiating sources in PIFA. Figure 4 shows the E-Field and H-Field of the current antenna.

![Figure 3 Radiation Pattern in Phi and Theta Directions](image)

![Figure 4 E-Field and H-Field Distributions](image)

![Figure 5 Current Distribution](image)

2.4 Current Distribution
PIFA has very large current flows on the undersurface of the planar element and the ground plane compared to the field on the upper surface of the element. Due to this behavior PIFA is one of the best candidate when is talking about the influence of the external objects that affect the antenna characteristics (e.g. mobile operator’s hand/head). PIFA surface current distribution varies for different widths of short-circuit plates. The maximum current distribution is close to the short pin and decreases away from it. The ground surface waves can produce spurious radiations or couple energy at discontinuities, leading to distortions in the main pattern, or unwanted loss of power. The surface wave effects can be controlled by the use of photonic band gap structures or simply by choosing air as the dielectric. This solves the limitation of poor efficiency as well along with certain degree of bandwidth enhancement.

CONCLUSION
This paper has focused on the development of low profile integrated antennas with enhanced bandwidth performance. The proposed antenna is giving moderate gain with low loss at resonating frequency. The featured slots have several advantages over other candidate antenna elements. From the results, these antennas are potential low profile candidates for wireless communications systems. The PIFA can be designed for up to about 8.4% bandwidth by using other advanced techniques.
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REFERENCES

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