PIFA – Planar Inverted F Antenna

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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. 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. 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.

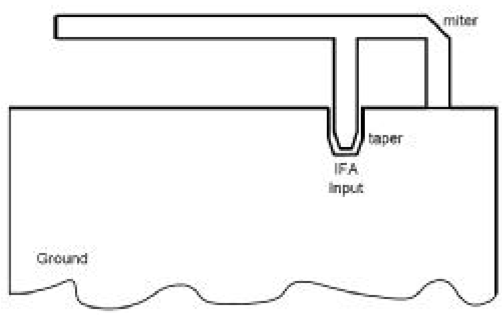
♦ The antenna/ground combination will behave as an asymmetric dipole, the differences in current distribution on the two-dipole arms being responsible for some distortion of the radiation pattern.

♦ In general, the required PCB ground plane length is roughly one quarter (λ/4) of the operating wavelength.

♦ If the ground plane is much longer than λ/4, the radiation patterns will become increasingly multi-lobed.

♦ On the other hand, if the ground plane is significantly smaller than λ/4, then tuning becomes increasingly difficult and the overall performance degrades.

♦ The optimum location of the IFA in order to achieve an omni-directional far-field pattern and 50Ω impedance matching was found to be close to the edge of the Printed Circuit Board.



♦ The miter is used to avoid a right angle microstrip bend, which results in a poor current flow on the stub.

♦ The taper is needed in order to compensate the abrupt step transition encountered between the microstrip line feed and the antenna.

The omni-directional behavior of the IFA with gain values that ensure adequate performance for typical indoor environments taking into account the standard values of the output power and receiver sensitivity of short range radio devices.

The polarization of the antenna is rather elliptical than linear since the axial ratio rarely reaches 20 dB.

Thus, the antenna has the ability to receive both vertically and horizontally polarized electromagnetic waves, which can be proven beneficial in indoor environments where depolarization is a dominant phenomenon and the choice of the best polarization difficult.

Although, currently, many wireless systems are vertically polarized, it has been predicted that using horizontal antennas at both the receiver and the transmitter results in 10dB more power in the median as compared to the power received using vertical antennas at both ends of the link.

♦ The IFA bandwidth increases with its thickness.
♦ The input impedance of IFA can be arranged to have an appropriate value to match the load impedance without using any additional circuits.

Planar Inverted F Antenna - PIFA

PIFA can be considered as a kind of linear Inverted F antenna (IFA) with the wire radiator element replaced by a plate to expand the bandwidth.

- One advantage of PIFA is that can be hiding into the housing of the mobile when comparable to whip/rod/helix antennas.
- Second advantage of PIFA is having reduced backward radiation toward the user's head, minimizing the electromagnetic wave power absorption (SAR) and enhance antenna performance.
- Third advantage is that PIFA it exhibits moderate to high gain in both vertical and horizontal states of polarization. This feature is very useful in certain wireless communications where the antenna orientation is not fixed and the reflections are present from the different corners of the environment. In those cases, the important parameter to be considered is the total field that is the vector sum of horizontal and vertical states of polarization.

Narrow bandwidth characteristic of PIFA is one of the limitations for its commercial application for wireless mobile.
The shorting post near the feed probe point of usual PIFA types is good method for reducing the antenna size, but this results into the narrow impedance bandwidth.

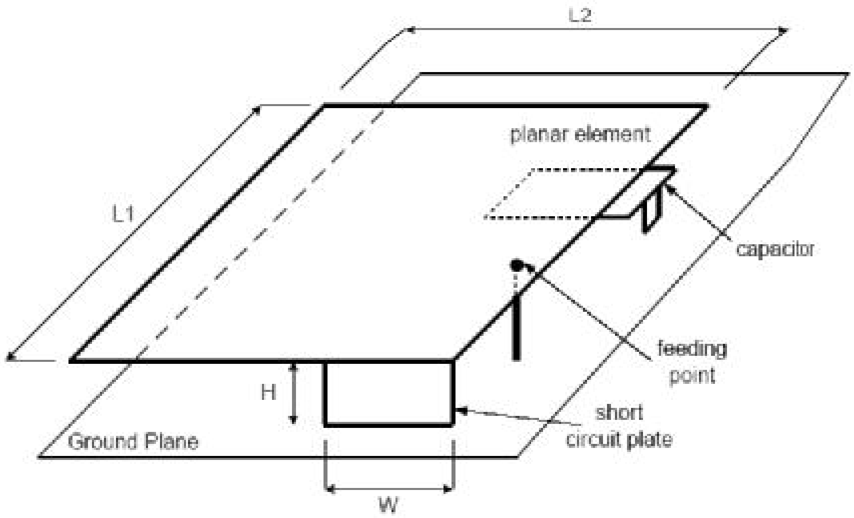
Techniques to increase the Bandwidth for PIFA:

♦ 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 broadened the bandwidth of the antenna system. To reduce the quality factor of the structure (and to increase the bandwidth), can be inserted several slits at the ground plane edges.
♦ Use of thick air substrate to lower the Q and increase the bandwidth.
♦ Using parasitic resonators with resonant lengths close to main resonant frequency.
♦ Adjusting the location and the spacing between two shorting posts.
♦ Excitation of multiple modes designed to be close together or far apart depending on requirements
♦ Using Stacked elements it will increase the Bandwidth.

PIFA dimensions

One method of reducing PIFA size is simply by shortening the antenna. However, this approach affects the impedance at the antenna terminals such that the radiation resistance becomes reactive as well. This can be compensated with capacitive top loading. In practice, the missing antenna height is replaced with an equivalent circuit, which improves the impedance match and the efficiency.

The capacitive loading reduces the resonance length from $\lambda/4$ to less than $\lambda/8$ at the expense of bandwidth and good matching. The capacitive load can be produced by adding a plate (parallel to the ground) to produce a parallel plate capacitor.



Resonant Frequency

♦ The resonant frequency of PIFA can be approximate with:

$L1 + L2 = \lambda/4$
when W/L1=1 then $L1 + H = \lambda/4$
when W=0 then $L1 + L2 + H = \lambda/4$

♦ 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.

♦ Analyzing the resonant frequency and the bandwidth characteristics of the antenna can be easily done by determining the site of the feed point, which the minimum reflection coefficient is to be obtained.

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 designing a PIFA is to don't use any extra lumped components for matching network, and thus avoid any losses due to that.

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.

Electric Field Distribution

The dominant component of the electric field Ez 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 Ex and Ey there is pointy part, which corresponds to the feed source. Means that the electric line of force is directed from feed source to the ground plane.

Then, when the width of the short-circuit plate is narrower than the planar element, the electric field Ex and Ey start generating at all open-circuit edges of the planar element.

These fringing fields are the radiating sources in PIFA.

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 on 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 vary for different widths of short-circuit plates. The maximum current distribution is close to the short pin and decrease 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 bandgap 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, which would discuss above.

Effects of Substrates Parameters

♦ Impedance bandwidth of PIFA is inversely proportional to the quality factor Q that is defined for a resonator:

Q = Energy Stored / Power Lost

♦ Substrates with high dielectric constant (Er) tend to store energy more than radiate it.
This is equivalent by modeling the PIFA as a lossy capacitor with high Er, thus leading to high Q value and obviously reducing the bandwidth. Similarly when the substrate thickness is increased the inverse proportionality of thickness to the capacitance decreases the energy stored in the PIFA and the Q factor also.

In summary, the increase in height and decrease of Er can be used to increase the bandwidth of the PIFA.

Efficiency

The efficiency of PIFA in its environment is reduced by all losses suffered by it, including: ohmic losses, mismatch losses, feedline transmission losses, edge power losses, external parasitic resonances, etc.

References:

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2. Microwave Engineering - Pozar
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5. RF Design Magazine, 1996 – 2003

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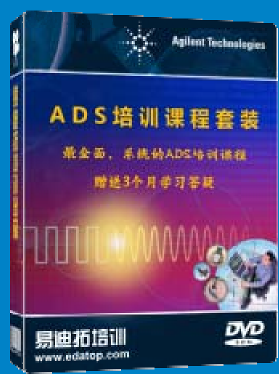

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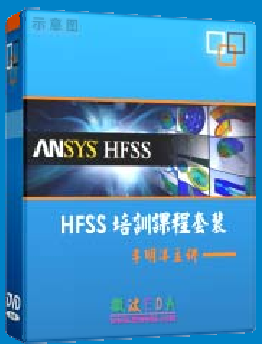

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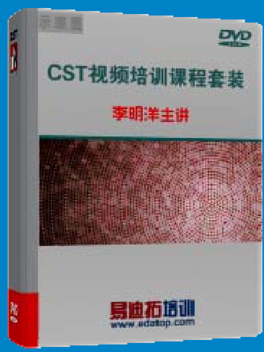

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