Study of Planar Inverted-F Antenna (PIFA) for Mobile Devices

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Abstract

Now-a-days more and more radios are being integrated into a single wireless platform to allow maximum connectivity. In this paper a theoretical study of Planar Inverted F Antenna is presented. PIFA as a low profile antenna is widely used in several application areas due to several advantages. Research and experiments done on PIFA structures are discussed and categorized. Some methods that can be used to improve efficiency, bandwidth & reduce volume of an antenna are also discussed which includes effect of dielectric substrate, dimensions of the antenna etc.

Keywords PIFA, Low Profile, Substrate, Volume, Efficiency

Introduction

In last three decades PIFA antenna structure has emerged as one of the most promising candidate in the category of low profile antennas used in handheld devices. Wide range of applications uses PIFA as their basic antenna. For a system to perform optimally, the antennas must have simple construction, high radiation efficiency, small volume, low-loss impedance matching. In IEEE literature PIFA was first appeared in the year 1987[1] . Vast range of applications uses PIFA as their basic antenna covering wide frequency band of GSM 850, 900, DCS 1800, PCS 1900, WLAN, Wi-Bro, Bluetooth, UMTS, 4G LTE. The research works are primarily focused in the following areas:

- Technology improvement for multi band operations, broadbanding and reduction in size
- Mathematical formulation and analysis of characteristic parameters using experimental, analytical and numerical methods
- PIFA as an array element
- Electromagnetic interaction of PIFA with human head & body.

There are many advantages of PIFA making its widespread use in devices that is, easy fabrication, simple structure, small volume, low manufacturing cost. PIFA structure is easy to hide in the casing of the mobile handset as compared to monopole, rod & helix antennas. Also, PIFA has reduced backward radiation towards user's head and body which further minimizes SAR and improves performance[1].

They can resonate at much smaller antenna size and by cutting slots in radiating patch, resonance can be modified. Proper shape of the patch and positions of feeding and shorting pins results in multiband operation.PIFA size can be reduced by shortening the antenna dimensions. However, by using this approach the impedance at the antenna terminals is affected which makes the radiation resistance reactive as well. By applying capacitive top loading this can be compensated. This loading results in resonance length reduction from λ/4 to less than λ/8 but this is achieved at the expense of good matching and bandwidth. By adding a plate (parallel to the ground) producec a parallel plate capacitor to be used as capacitive load [6].The Inverted F antenna has transformed the horizontal element from a wire to a plate resulting in the so called Planar Inverted-F Antenna (PIFA). It has a self-resonating structure with purely resistive load impedance at the frequency of operation. PIFA is an antenna which is not only small in size but also has wide bandwidth and high efficiency. Variation of length, distance and location of the feed and shorting point, height of the radiator etc. affects the electrical performance of these antenna structures[2]. Typical configuration of PIFA is shown in fig. 1. The antenna is fed through feeding pin which connects to the ground plane through the dielectric substrate. The shorting pin and shorting plate allows good impedance matching achieved with the patch above ground plane of size less than λ/4. Resulting PIFA structure is of compact size than conventional λ/2 patch antennas

The major drawback of PIFA is its narrow bandwidth; therefore it is important and necessary to widen the bandwidth for using it in mobile phones and other handheld devices. The evolution of the handset antenna structures from a monopole to the PIFA shows that the essential component of a mobile handset antenna is the "wire". The patches, slots, and stubs are only used to compensate for the mismatch and improve the radiation characteristics. Next Section explains basic structure of PIFA and various methods to improve its bandwidth and efficiency.

Planar Inverted F Antenna

The Inverted F antenna has transformed the horizontal element from a wire to a plate resulting in the so called Planar Inverted-F Antenna (PIFA). It has a self-resonating structure with purely resistive load impedance at the frequency of operation. PIFA is an antenna which is not only small in size but also has wide bandwidth and high efficiency. Variation of length, distance and location of the feed and shorting point, height of the radiator etc. affects the electrical performance of these antenna structures[2]. Typical configuration of PIFA is shown in fig. 1. The antenna is fed through feeding pin which connects to the ground plane through the dielectric substrate. The shorting pin and shorting plate allows good impedance matching achieved with the patch above ground plane of size less than λ/4. Resulting PIFA structure is of compact size than conventional λ/2 patch antennas.

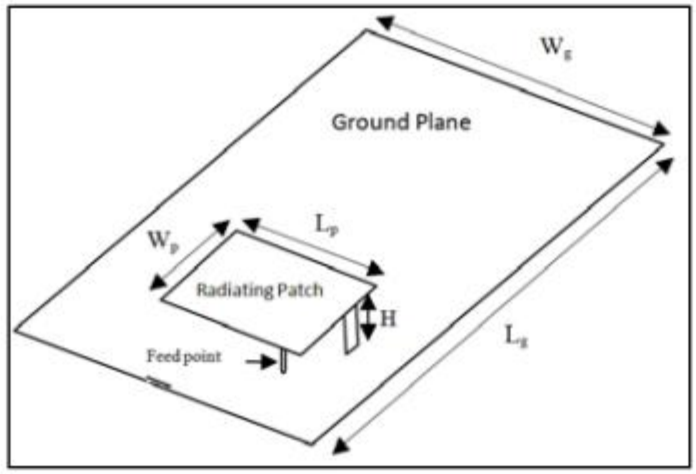

Fig. 1: Basic PIFA Structure

Above equation means that the sum of the width and length of the top plate should be λ/4. This approximation is very rough and does not cover all the parameters that significantly affects the resonant frequency of the antenna. As width of the shorting plate also affects resonant frequency of the antenna. So by reducing the width of shorting plate results in lowering the resonant frequency and vice versa

The design variables for the antenna are the length, width, and height of the patch, the width and location of shorting plate, and feed point location. A coaxial cable with a centre conductor that extends beyond the end of the outer conductor is the feed wire for PIFA. The outer layer of conductor is soldered to the ground plane at the selected feed point. The shorting plate of usual PIFA is a useful method for reducing the antenna dimensions, but results in narrow impedance bandwidth. Several modifications have beensuggested to obtain a trade off between size, bandwidth and other properties of a PIFA

A. Techniques to Increase the Bandwidth for the PIFA

The most frequently used method to broaden the bandwidth is to raise the height of the shorting plane i.e increase the volume. Size of the ground plane affects Bandwidth very much. The bandwidth of a PIFA can be improved by modifying the size of the ground plane i.e. reducing the ground plane can broaden the bandwidth of the antenna system. Several slits at the ground plane edges can be inserted to lower the Q factor of the structure which results in increase of 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 [3], loading dielectric with high permittivity [4], attaching chip resistor that is increasing loss term [5]

B. PIFA Dimensions

PIFA size can be reduced by shortening the antenna dimensions. However, by using this approach the impedance at the antenna terminals is affected which makes the radiation resistance reactive as well. By applying capacitive top loading this can be compensated. This loading results in resonance length reduction from λ/4 to less than λ/8 but this is achieved at the expense of good matching and bandwidth. By adding a plate (parallel to the ground) producec a parallel plate capacitor to be used as capacitive load [6].

C. Resonant Frequency

To approximate the resonant frequency of PIFA following relation is used [7]: $Lp + Wp = \lambda /4$ (3) when, $Ws/Lp=1$ then $Lp + H = \lambda /4$ when, $Ws=0$ then $Lp + Wp + H = \lambda /4$ Where Lp and Wp are length and width of patch, Ws is width of shorting plate H is height of shorting plate By creating an open slot the frequency gets reduced [8]. This is because currents are flowing at the edges of the created slot, therefore the frequency and antenna dimensions gets reduced significantly due to a capacitive loaded slot. Similarly by making slots in the patch, two or more frequency band operation can be achieved. Modifying the width of the patch also affects the selection of the resonant frequency. The width of the shorting plate of the PIFA acts as governing factor for its resonant frequency. Resonant frequency decreases with the decrease in plate width, Ws [9]. PIFA's are made of just quarter wavelength whereas micro-strip antennas are conventionally made of half wavelength dimensions, By analyzing bandwidth and resonant frequency, characteristics of the antenna can be easily improved by determining the site for feed point [10], at which reflection coefficient is to be minimum.The Inverted F antenna has transformed the horizontal element from a wire to a plate resulting in the so called Planar Inverted-F Antenna (PIFA). It has a self-resonating structure with purely resistive load impedance at the frequency of operation. PIFA is an antenna which is not only small in size but also has wide bandwidth and high efficiency. Variation of length, distance and location of the feed and shorting point, height of the radiator etc. affects the electrical performance of these antenna structures[2]. Typical configuration of PIFA is shown in fig. 1. The antenna is fed through feeding pin which connects to the ground plane through the dielectric substrate. The shorting pin and shorting plate allows good impedance matching achieved with the patch above ground plane of size less than λ/4. Resulting PIFA structure is of compact size than conventional λ/2 patch antennas

D. Effects of Substrate Parameters

The quality factor Q is defined as: Q = Energy Stored / Power Lost (4) Impedance bandwidth of PIFA is inversely proportional to Q factor. Substrates with high dielectric constant (εr) tends to store energy more than radiating it. Lossy capacitor model of PIFA with high dielectric constant leads to high value of Q and consequently narrowing the bandwidth [9]. 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. Thus, the decrease of εr and increase in height can be used to widen the impedance bandwidth of PIFA.

E. Efficiency

The efficiency of PIFA is reduced by all losses suffered by its structure in its environment, including: mismatch losses, ohmic losses, external parasitic resonances, edge power losses, transmission losses etc. The Inverted F antenna has transformed the horizontal element from a wire to a plate resulting in the so called Planar Inverted-F Antenna (PIFA). It has a self-resonating structure with purely resistive load impedance at the frequency of operation. PIFA is an antenna which is not only small in size but also has wide bandwidth and high efficiency. Variation of length, distance and location of the feed and shorting point, height of the radiator etc. affects the electrical performance of these antenna structures[2]. Typical configuration of PIFA is shown in fig. 1. The antenna is fed through feeding pin which connects to the ground plane through the dielectric substrate. The shorting pin and shorting plate allows good impedance matching achieved with the patch above ground plane of size less than λ/4. Resulting PIFA structure is of compact size than conventional λ/2 patch antennas

Conclusion

From above discussion we can conclude that PIFA structures are mostly used antennas suitable for mobile devices and are good for being used as multiband antennas also. Limitations of PIFA can be mitigated by applying several techniques to improve its bandwidth characteristics, efficiency, gain& reduce dimensions etc.

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