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Design of a Compact PIFA for WLAN Wi-Fiwireless Applications

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Abstract:- With recent advancements in electronics communication technologies more and more compact and powerful electronics devices are coming up with wireless communication capabilities, Not only computers or mobile now even vehicles are equipped with wireless communication capabilities, this advancement create need for new antennas to be developed to fit the new device and service requirements. In this paper a study of Planar Inverted F Antenna is presented. PIFA is most commonly used antenna especially in mobile communication because of its simplicity and low cost, though it suffers bandwidth limitations, some methods used for improvement in bandwidth and reduction in antenna volume are also discussed here. A compact PIFA is also proposed for WLAN Wi-Fi applications. The simulation results for RL is shown and effect of antenna dimension on simulation results has also been discussed.

Index Terms:- Bandwidth, PIFA, Return loss, VSWR.

I. INTRODUCTION

PIFA is basically a "grounded" patch antenna - λ/4 patch length instead of the conventional λ/2, It consists of a ground plane, a top plate element, a feed wire feeding the resonating top plate, and a DC-shorting plate that is connecting the ground and the top plate at one end of the resonating patch. PIFA has many advantages as compared with other antennas commonly used in Mobile communication, PIFA is easy to fabricate , low manufacturing cost and relatively simple structure. Also PIFA has reduced backward radiation towards the user's head , minimizing the electromagnetic wave power absorption (SAR) [1]. Also PIFA has moderate to high gain in both vertical and horizontal polarization states, which makes it quite suitable for the wireless communication service where the antenna orientations are not fixed and the environment is active, i.e. signal reflections are possible from all corners of the vicinity. In this case where environment is reflective major parameter of concern is total field that is the sum of the horizontal and vertical polarization field [1]. However small bandwidth is major concern with PIFA, careful design with respect to ground and radiation element dimensions and position of feed is needed to achieve workable bandwidth in wireless communication spectrum range.

With Mobile and Wireless devices becoming compact in size, the antenna size should also be maintain so as to be used in new small size devices, not only radiation element dimensions but the distance of active element from ground i.e. height of element with respect to ground is major concern when sizing the antenna. In this work compact PIFA design for Wi-Fi 2-2.4GHz frequency range applications is presented. IDS Antenna Design Framework EMS CAD tool is used for designing and MoM full wave simulation of the PIFA.
In next sections describes the structure of a simple PIFA and discusses the various performance parameters. Successive sections describes design of compact PIFA for Wi-Fi applications. Simulation results obtained with respect to change in dimensions and feed position are discussed . Finally, the conclusions are detailed in last section.

II. PLANAR INVERTED F ANTENNA (PIFA)

The PIFA comprises of a ground plane, on top ground plane is the radiation plate element, a feed wire attached between the ground and the radiation element, use of coaxial feed wire gives freedom to move around length of radiation plate to locate the max. impedance matching, a shorting plate of suitable height is used to connect radiating plate and ground plane. Figure 1 shows a simple PIFA configuration where ground plane is circle , in mobile application ground is generally taken as rectangle of suitable dimension. The antenna is fed at the lower base of the feed wire i.e. at a point where the wire connects to the ground plane. The simple architecture make PIFA quite suitable for wireless systems where the antenna cost and dimensions are quite limited. Since the top radiating plate must only be printed on board the manufacturing becomes simple and cost effective. The use of feed wire and shorting plate allows good impedance match to be achieved with top plate that is generally less than λ/4 long. The resulting PIFA ismore compact than a conventional half-wavelengthprobe-fed patch antenna [2].

The design parameters for this antenna length, width, and height of the top radiating plate, the width and location of shorting plate and the location of the feed wire. Coax is used as feed wire the wire extend from top radiating to the bottom of ground plane at specific location where max matching is achieved. Use of shorting plate is good method to reduce the antenna size , but it limits the bandwidth. Various modification and design technique has been suggested to obtain a tradeoff between size and bandwidth of PIFA. Figure 1 shows a simple PIFA dimensions are top plate L= 25mm, W=19.4mm, H=3.2mm, ground plane is circle of diameter= 32mm, the feed is coax wire 0.2mm thick and feed position is at 5mm from the top and shorting plate junction.

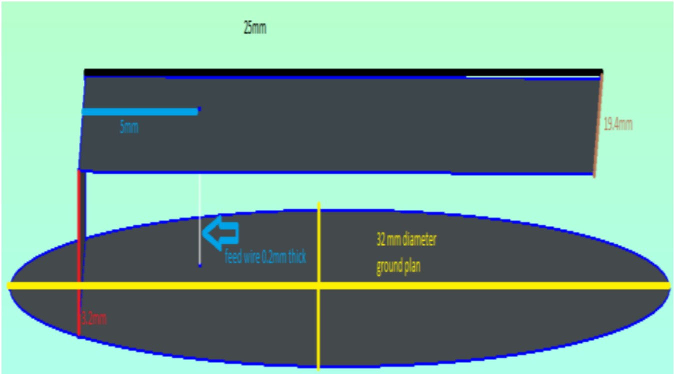

Figure 1: Simple PIFA

The main relationship among various parameters of the PIFA which influence performance are as follows:

$$Bandwidth = \frac{f_u - f_l}{f_r} \propto \frac{1}{Q}$$

$$Q = \frac{\sqrt{L}}{R\sqrt{C}}, \quad Q \propto 1/S$$

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 common method to increase the bandwidth is to raise the height of the shorting plate i.e. increase the antenna volume, but with mobile devices becoming slim and compact antenna volume on device is limited. Another quite well known method is by varying the size of the ground plane, By varying the size of ground plane bandwidth can be adjusted, in practice reducing the size of the ground plane can increase the antenna bandwidth. Also by creating several slits at the ground plane edges can reduce the Q factor hence increase bandwidth. Other bandwidth enhancement design methods used are using dual resonance by additional patch i.e. adding a capacitive load [3], loading a dielectric material with high permittivity [4].

With Bandwidth another important parameter for PIFA design is its dimensions, The resonate frequency of PIFA is related to the PIFA dimensions as:

$L+W1-W_2=\lambda_g/4$

Where L and W1 are length and width of top plate and W2 is width of the shorting plate, λ_g is guided wavelength which is given as $\lambda_g=\lambda_o/\sqrt{\varepsilon_r}$. Here ε_r is the relative permittivity of the substrate and λ_o is the wavelength in free space.

Now there are some special cases first case is if the width of top plate and shorting plate are equal i.e. $W_1 = W_2$ the relationship reduced to:

$L=\lambda_g/4$

The second case is if shorting plate has width equal to zero, i.e. $W_2=0$, in other words shorting plate is actually a shorting pin. In this case the relationship changes to :

$L+W_1=\lambda_g/4$

From the above equations it is obvious that antenna dimensions changes the resonate frequency, also with limited space for antenna in slim mobile devices it is rather more important to optimize the antenna dimensions for particular resonate frequency.

The most common method of reducing PIFA size is simply the use of shorting plate [5]. Other well-known method is capacitive loading of the antenna structure [3] , the capacitive load can be produced by simply adding plate between top patch and ground to create a parallel plate capacitor. However this method compromise the bandwidth and good matching. Another technique which is quite widely used is using slots on the top patch to increase the electrical length of the antenna [6], i.e. to increase the current travel path . Usually to get a highly optimized antenna dimension and bandwidth a combination of two techniques are used to create PIFA example a PIFA structure that employs slots and capacitive loading in order to reduce the antenna size but still maintain the required operating bandwidth. Another important parameter when dimensioning the antenna is width of the shorting plate, as from the equations with decrease in width od shorting plate the resonate frequency also decreases, so optimization of shorting plate width is necessary to achieve a good antenna performance with limited size.

Impedance matching is another very important parameter for any antenna, Max matching means max power transfer or low return loss. With PIFA a good advantage is that the matching of antenna is achieved by positioning of the single feed with in the shaped top plate, This single feed position adjustment along the top plate for impedance matching avoids the need of extra lumped elements for matching network and therefore avoid losses due to these extra elements.

III. DESIGN OF A COMPACT PIFA FOR WLAN WIRELESS APPLICATIONS

This section discusses design of a compact PIFA with suitable bandwidth for wireless application at Wi Fi renage. The bandwidth is defined as the frequency band in which VSWR is less that 2:1 which corresponds to -10 dB return loss i.e. the level at which 10% of the incident power is reflected back to source.

The PIFA design parameters are Top radiating plate Length : 28mm, Width = 19.4 mm, ground plane is circle with diameter 32mm, height (distance between ground and patch) = 6mm, Feed is vertical coaxial wire feed with wire diameter =0.2mm and Feed position at a distance of 5mm form patch edge. Air as dielectric, Figure 2 shows the PIFA for Wi-Fi applications and Figure 3 shows the MoM simulation results for the antenna.

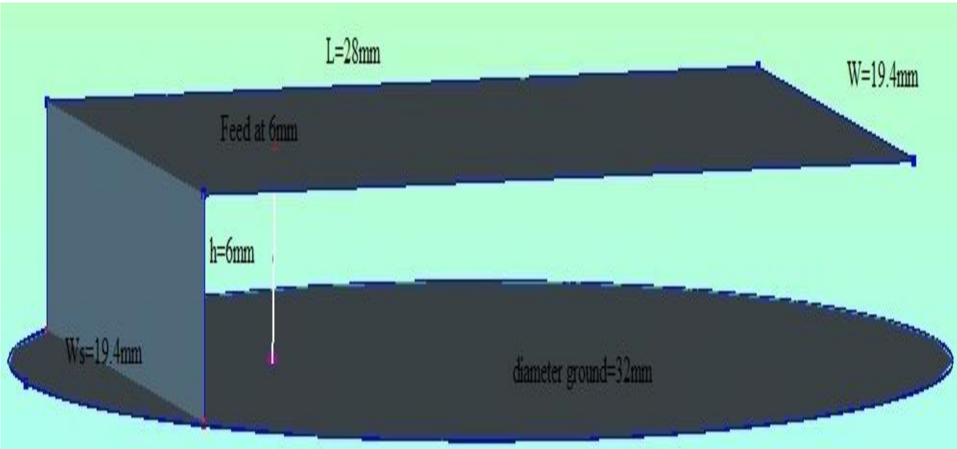

Figure2: compact PIFA for Wi-Fi applications

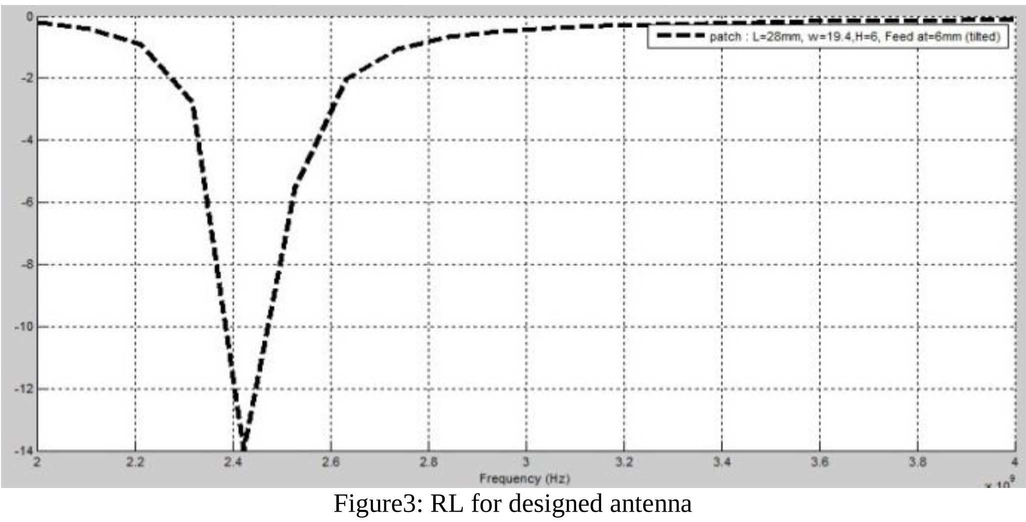

Figure3: RL for designed antenna

The designed antenna resonate at around 2.4 Ghz for target RL of -10 dB, but Since antenna is targeted to resonate between 2-2.4Ghz frequency i.e. WLAN Wi-Fi range, optimization of antenna parameters/dimensions are done to achieve the required target . Figure 4 shows re designed PIFA with Longer and wider top plate length 30 mm and width 20mm and distance between ground and top plate now increased to 10mm, figure 5 shows the MoM simulation result for RL of re designed antenna, Simulations results also shows the change in RL, resonate frequency and Bandwidth with respect to the change feed position and feed wire thickness as we know the coxial feed gives us freedom to move freely on radiating patch and select the position which gives the maximum matching, so we different feed position was tested to get the best possible result.

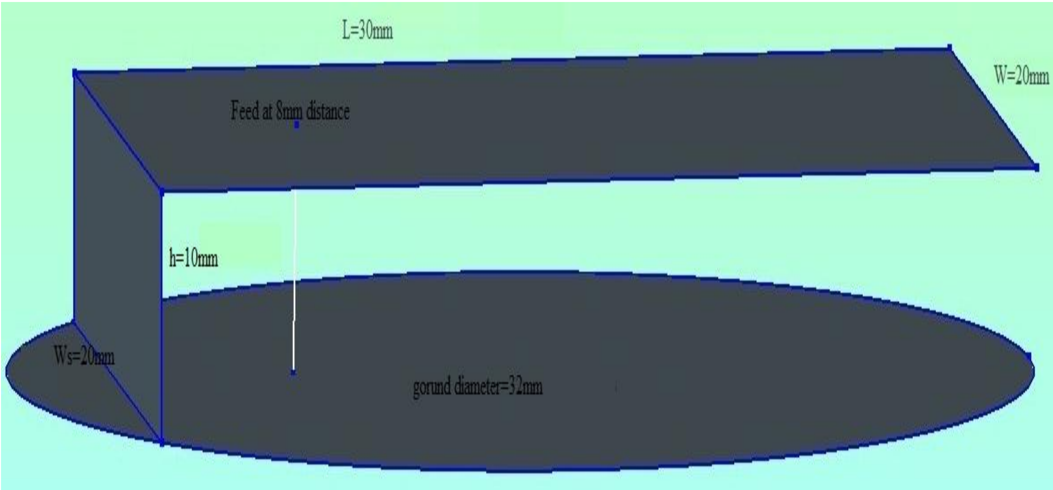

Figure4: re designed PIFA for Wi-Fi applications

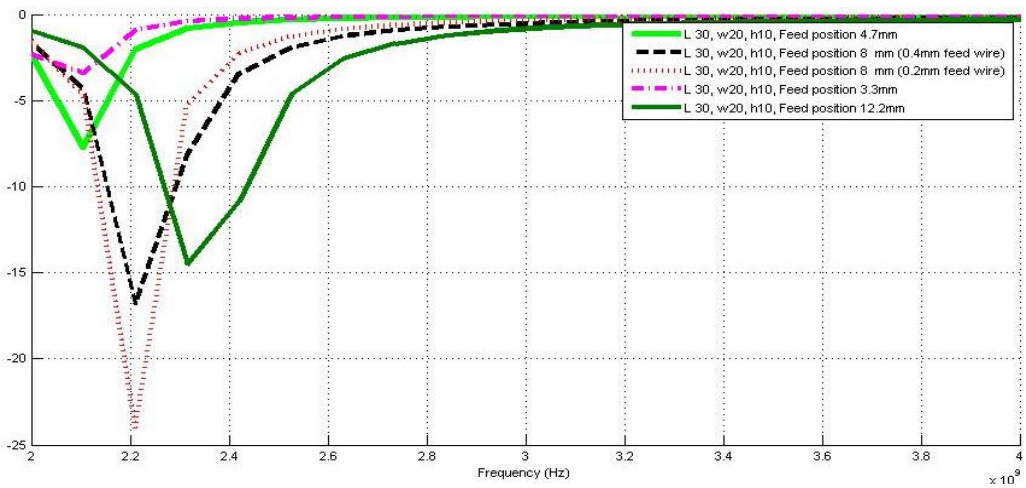

Figure5: RL for re designed antenna

In figure 4 the Length of the top plate is extended to 30mm and height with respect to ground extended to 10mm and width shorting plate is equal to width of the top plate 20mm. The effect of changed dimensions, change in feed position and feed wire radius on resonance frequency, RL and Bandwidth are shown in simulation results figure5. From the simulation graph figure5 we see the change in resonance frequency, the new re designed PIFA resonate between 2.2-2.4Ghz unlike previous PIFA resonating at around 2.4-2.5 Ghz also Bandwidth enhancement is achieved by optimizing the dimensions (L,W,h). Results also show the shift in matching with respect to shift in feed position, for feed position near to patch edge green solid curve feed position at 4.7mm along the length and dashed pink curve for feed at 3.3 mm the resonance occur at around 2.1 GHz but RL is worst very high for feed at 4.7mm RL is -7 dB for feed at 3.3mm very high RL around – 3dB. By shifting the feed away now at 12.2mm distance dark green curve we shift the center frequency to around 2.3 GHz with RL of around -15dB and with an Enhance bandwidth. Seeing the above results with feed at 3-4mm distance and 12mm distance , now again changing the feed to a distance of 8mm , the centre frequency is shifted slightly towards 2.2 GHz also we see the effect of feed wire radius on performance of antenna , The first case red dashed curve for feed wire with radius 0.2mm at distance of 8mm shows a good low RL of around -24 dB and resonate at 2.2 GHz, The second black dashed curve for thick feed wire radius 0.4mm also resonate at 2.2

GHz but the RL performance goes down , the RL in this case is -16 dB. So we see that feed position in this case not only change the RL but also shifts the centre frequency, The feed wire thickness does not shift the centre frequency but it alter the RL performance of antenna.Figure 6, 7, 8 Shows The VSWR, input impedance Zin and Active current distribution for re designed PIFA Figure4.

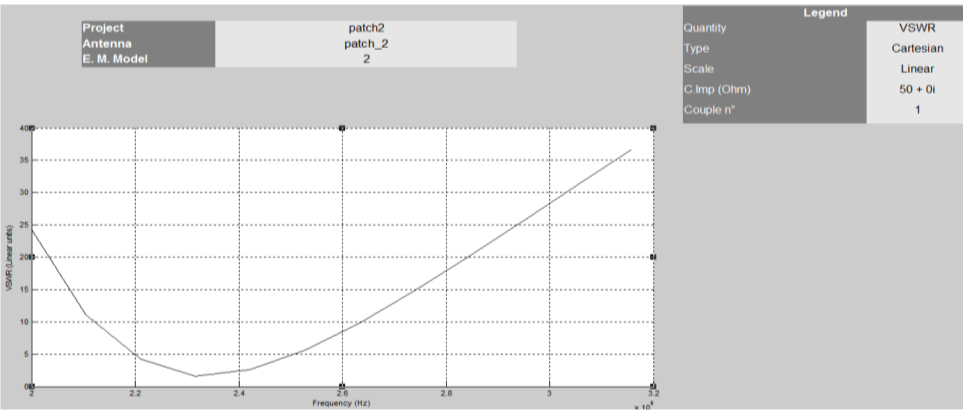

Figure6: VSWR re designed PIFA

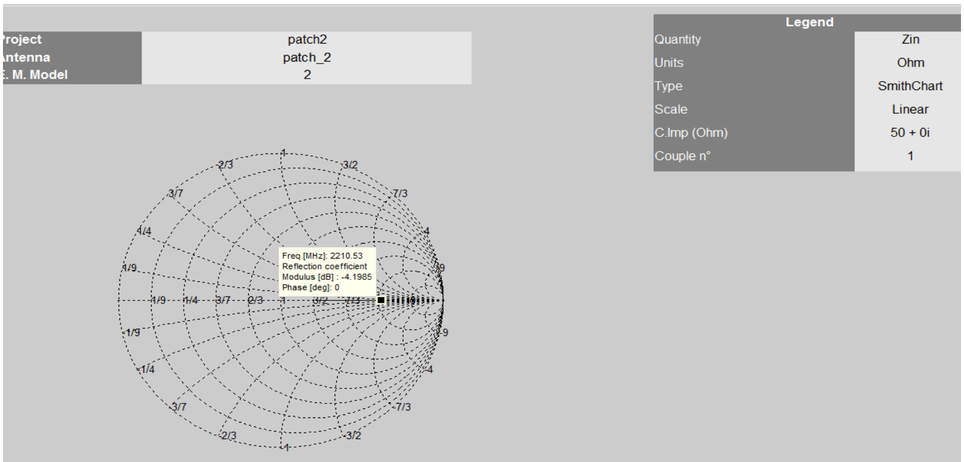

Figure7: Zin re designed PIFA for Wi-Fi applications

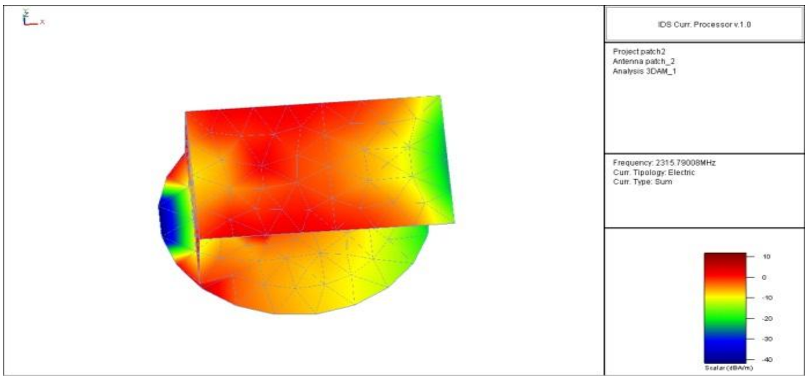

Figure8: current distribution re designed PIFA

IV. CONCLUSION

The design of a compact PIFA for WLAN Wi-Fi applications have been presented and proposed. A theoretical study of PIFA has been discussed, Methods to increase bandwidth and reduce antenna volume has also been discussed and effect of PIFA parameter change on performance has been shown and discussed. The main purpose of the design is to have a compact PIFA with adequate bandwidth. Simulations results for designed PIFA have shown good results with respect to RL, VSWR, and Bandwidth.

The design can be used for further optimization of antenna parameter like making slots on top plate to design compact PIFA for multiband applications.

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