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ORIGINAL ARTICLE

# MODELLING & SIMULATION OF DIFFERENT ANTENNAS USED FOR MULTIBAND APPLICATION

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## ABSTRACT

Antennas have lot of attraction in the field of Wireless communication. Due to the requirements, and improvements in technologies, devices become smaller in size as the antennas are needed to be small and light-weighted due to the requirements new applications. here four antennas are designed which are Dipole, patch, PIFA and slot which are smaller in size and which can also be used as multiband application in wireless communication .

This paper presents design and comparative analysis of four antennas Dipole, Patch, PIFA and Slot that can be used for multiband operation which is important need for Wireless communication. These four antennas are designedby High frequency structure simulator (HFSS) software. All these four antennas are implemented using RT DUROID dielectric substrate which has $\epsilon_r$ = 2.2 and h = 1.575mm and made to resonates at 2.5 GHzfrequency. The obtained results for the various antennas allow knowing which antenna is best for multiband operation. Comparison is based in terms of return loss, bandwidth, Radiation efficiency and size.

## 1. INTRODUCTION

In area of communication system popularity of Wireless technology has increased and Antenna is one of the fundamental part of these system. To study communication system without understanding the design and fabrication of antenna is incomplete. Because antennas are dependent on frequency, they are designed to operate for certain frequency bands. There are several frequency bands used in wireless communication such as GSM 900/1800/1900 bands, Universal Mobile Telecommunication Systems (UMTS) and UMTS 3G expansion bands and Wi-Fi (Wireless Fidelity)/Wireless Local Area Networks (WLAN) bands. One antenna cannot operate at these all frequency band of Wireless communication. One way to use multiple different antennas for covering these bands separately but it is limited by cost and volume constraints of applicationso it is necessary to establishment of multiband antennas to cover all these frequency bands of communication. A multiband antenna can be defined as the antenna operating at distinct frequency bands, but not at the intermediate frequencies between bands. Mainly these four antenna Dipole antenna, Patch antenna, Planner Inverted F antenna and Slot antenna among the various available antennas can be used for multiband operation in which Dipole antenna is external antenna while Patch, PIFA and slot antenna are Internal antenna.

## 2. THEORY

### 2.1. Microstrip Patch Antenna

A micro strip antenna consists of conducting patch on a ground plane separated by dielectric substrate that is radiating patch on one side of a dielectric substrate and ground plane at other side .The patch is generally made of conducting material such as copper or gold and can be of any possible shape like rectangular, circular. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. The antenna can be excited by a coaxial cable feed, a micro strip feed, aperture coupled feed or proximity coupled feed. Excitation to the patch generates negative charges at the feed point and positive charges of the other part of the patch. This difference in charge creates electric fields in the antenna radiation of the patch antenna occurs. Micro strip antennas are become popular for use in wireless communication due to their light weight, low cost, miniature in size and conformability. Calculation for find out some important parameters regarding Patch antenna design is given below,

**Calculation of the Width**

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}}$$

**Calculation of Effective dielectric constant ($\varepsilon_{reff}$):**

$\varepsilon_{reff} = (\varepsilon_r + 1)/2 + (\varepsilon_r - 1)/2[1+12h/W]^{-1/2}$

**Calculation of the length extension ($\Delta L$):**

$\Delta L = 0.412h(\varepsilon_{reff} + 0.3)(W/h + 0.264)/((\varepsilon_{reff} - 0.258)(W/h + 0.8))$

**Calculation of the Effective length ($L_{eff}$):**

$L_{eff} = c/(2f_r\sqrt{(\varepsilon_{reff}}) = \lambda/2$

**Calculation of actual length of patch ( $L$ ):**

$L = L_{eff} - 2\ \Delta L$

**Find Feed Position**

$$G_1 = \frac{1}{90}\left\{\frac{W}{\lambda}\right\}^2$$

$R_{in} = \frac{1}{2G_1}$

$R = R_{in}\,COS^2\left(\frac{\pi}{L}Y_0\right)$ // In PIFA instead of L we consider $L_2$

Feed Position = $\frac{Y_0}{2}$

### 2.2. Planar inverted F antenna(PIFA)

Invert F antenna is a one type of the monopole antenna in which top section of the wire monopole has been folded down for reduce the antenna height. Wire invert F antenna, which is considered as a transmission line with an open end, have a very narrow relative bandwidth. The bandwidth can be significantly increased by replacing the invert F antenna horizontal element by a planar conduction patch, namely, a planarinvert F antenna (PIFA). PIFA reduces the size of patch from half –wavelength antenna to quarter- wavelength antenna by using ground point on patch.

The PIFAs are most widely used internal antenna in mobile phones due to its relatively small size andmany other advantages like simple structure,ease of fabrication, capable of multifrequencies operations, low profile planar configuration, low cost, less prone to breakage.PIFA has signal characteristics of dual polarization that is important requirement for mobile transceivers as mobile transceivers can receive signal in any orientation. The major drawback of PIFAis its narrow bandwidth that limits its application. It is necessary to find method for enhance the bandwidth of PIFA antenna for using in mobile phones and other applications.In cell phone minimum radiation should be towards the user's head while in opposite direction radiated power is maximum and this can be achieved by PIFA.

**Calculation of the Width**

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}}$$

**Calculation of Effective dielectric constant ($\varepsilon_{reff}$)**

$$\varepsilon_{reff} = (\varepsilon_r + 1)/2 + (\varepsilon_r - 1)/2[1+12h/W]^{-1/2}$$

**Calculation of L2**

$$L1+L2-W+H=\lambda/4$$

$$L1+L2-W+H= c/(4f_r\sqrt{(\varepsilon_{reff})}$$

**Find Feed Position**

$$\boldsymbol{G_1 = \frac{1}{90}\left\{\frac{W}{\lambda}\right\}^2}$$

$R_{in} = \frac{1}{2G_1}$

$R = R_{in}\,COS^2\left(\frac{\pi}{L_2}Y_0\right)$

Where $R = 50\Omega$

Feed Position = $\frac{Y_0}{2}$

### 2.3. Slot Antenna

Slot antennas are used in frequency range between 300 MHz to 24 GHz. A slot antenna consists of metal plate with slot cut out; the slot radiates electromagnetic waves and has omnidirectional radiation patterns similar as linear wire antenna. Instead of line antennas slot antennas are widely used at microwave frequencies when great control of radiation pattern is required. Main advantages of slot antenna are its size, robustness, simplicity in design and convenient adaptation to mass production using PC board technology. Compared to microstrip antennas, stot antennas have lower radiation loss and wider bandwidth. Calculation for find out length, width of slot, feed offset and microstrip offset is given below,

**Length of slot =** $\frac{\lambda}{2}$

**Width of slot = 0.02λ**

**Measure VSWR for 2.5 GHZ**

**Calculation of Reflection Coefficient**

$$\rho = \frac{S-1}{S+1}$$

**Calculation of $Z_L$**

$$\rho = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$$Z_{L}= Z_0 \left(\frac{1+\rho}{1-\rho}\right)$$

**Calculation of Microstrip Offset**

$$l = \frac{\lambda}{2\pi}\tan^{-1}\left(\sqrt{\frac{Z_L}{Z_0}}\right)$$

Microstrip Offset = l + Slot Width/2

**Calculation of Feed Offset**

$$l' = \frac{\lambda}{2\pi}\tan^{-1}\left(\frac{\sqrt{Z_L}\sqrt{Z_0}}{Z_L - Z_0}\right)$$

### 2.4. Dipole Antenna

As the name suggests the dipole antenna is consists of two terminals or "poles" into which radio frequency current flows. It can be made of two metal conductors with small space between them. It can be considered as simple wire with center fed element. The excitation is applied at the center between them. It is fully described by four parameters frequency, wavelength, length of dipole and feeding gap. For half wave dipole two quarter wavelength elements placed back to back for a total length of λ/2.On element of a length λ/4 , standing wave yields the greatest voltage differential, as one end of the element is at a node while the other is at an antinode of the wave. The larger the differential voltage, the greater the current between the elements. Calculation for find out the length of dipole is given below,

**Calculation of G**

Rin (dipole) = $24.7G^{2.5}$ $(\lambda/4 \leq l < \lambda/2)$

Where Rin=50Ω

**Calculation of dipole Length**

G = βl/2 for dipole

G = 2πl/2λ

## 3. ANTENNA DESIGN

All these four antennas are designed at 2.5GHz with the structure, as shown in Figure (1), (2), (3), (4). These antennas are designed on RT DUROID, the substrate with thickness (t) of 1.575mm and dielectric constant ∈r of 2.2.

### 3.1. Design Patch Antenna

The geometry and detailed dimensions of the proposed antenna is depicted in fig. 1 and tab. 1.Lg, Wg are length and width of the ground plane respectively. Lp, Wp are length andwidth of the radiating patch respectively. Lf is length of the feed.

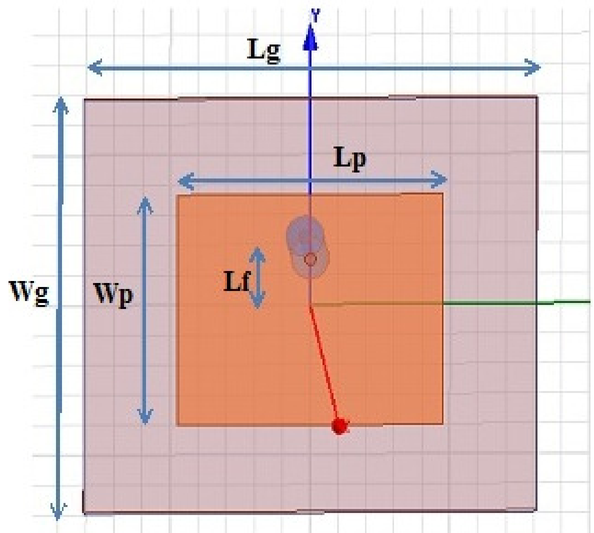


**Figure 1: Design structure of Patch on HFSS tool**

| Parameter | Value(cm) |
|---|---|
| Lg | 8.1 |
| Wg | 6.9 |
| Lp | 4.74 |
| Wp | 3.97 |
| Lf | 0.77 |

**Table 1**

### 3.2. Design Planar Inverted F Antenna

The geometry and detailed dimensions of the proposed antenna is depicted in fig. 2 and tab. 2. Here Lg, Wg are length and width of the ground plane respectively. Lp, Wp are length and width of the radiating patch respectively. Lf is length of the feed. W, h are width and height of the shorting platerespectively.

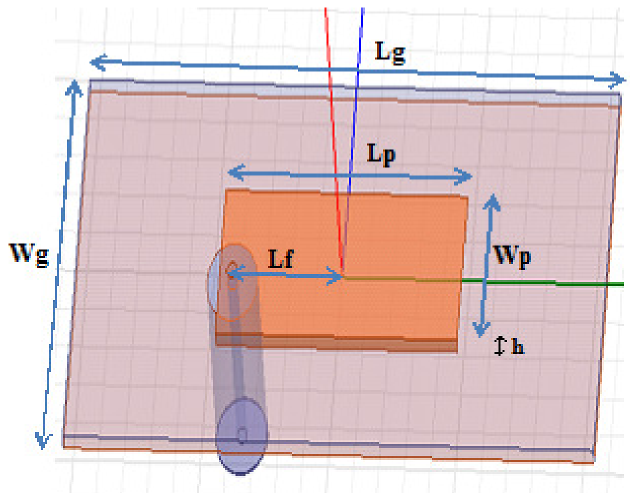


**Figure 2: Design structure of PIFA on HFSS tool**

| Parameter | Value(cm) |
|---|---|
| Lg | 10.4 |
| Wg | 8.7 |
| Lp | 4.74 |
| Wp | 1.88 |
| Lf | 2.14 |
| W | 4.74 |
| H | 1.575 |

**Table 2**

### 3.3. Design Slot Antenna

The geometry and detailed dimensions of the proposed antenna is depicted in fig. 3 and tab. 3. Here Ls, Ws are length and width of the ground plane respectively. L1, W1 are length and width of the Slot respectively. W2 is width of microstrip. *l* is microstrip offset and *l'* is feed offset.

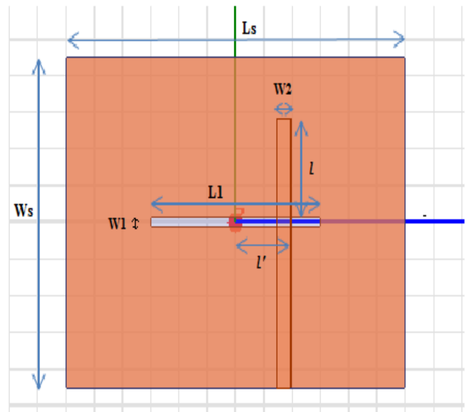


**Figure 3: Design structure of Slot on HFSS tool**

| Parameter | Value(cm) |
|---|---|
| Ls | 12 |
| Ws | 9 |
| Slot length(L1) | 6 |
| Slot width(W1) | 0.25 |
| Microstrip offset(*l*) | 2.7 |
| Microstrip Width(W2) | 0.49 |
| Feed offset(*l'*) | 1.7 |

**Table 3**

### 3.4. Design Dipole Antenna

Fig shows and the structure designed on HFSS software of the half wave dipole antenna. The following dimensions and parameter are used for design of proposed antenna.Here Ls, Ws are length and width of the substrate respectively. L, W are the length and width of Dipole respectively.

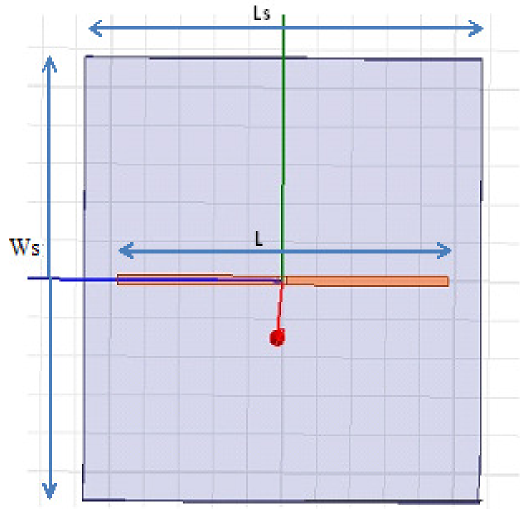


**Figure 4: Design structure of Dipole on HFSS tool**

| Parameter | Value(cm) |
|---|---|
| Dipole length(L) | 4.64 |
| Width(W) | 0.12 |
| Port-gap | 0.12 |
| Ls | 5.76 |
| Ws | 5.76 |

**Table 4**

## 4. SIMULATION RESULTS

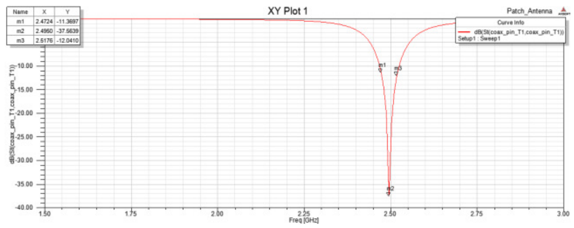


**Figure 5: Simulated Return loss curve of Patch antenna**

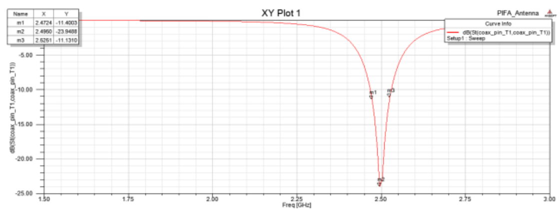


**Figure 6: Simulated Return loss curve of PIFA antenna**

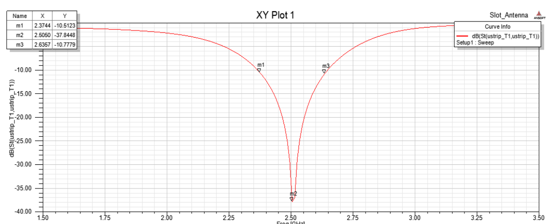


**Figure 7: Simulated Return loss curve of Slot antenna**

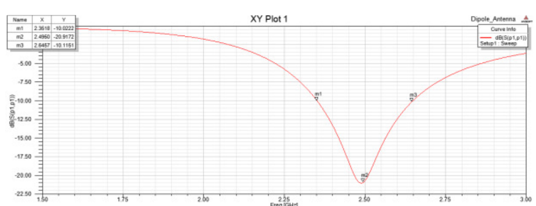


**Figure 8: Simulated Return loss curve of Dipole antenna**

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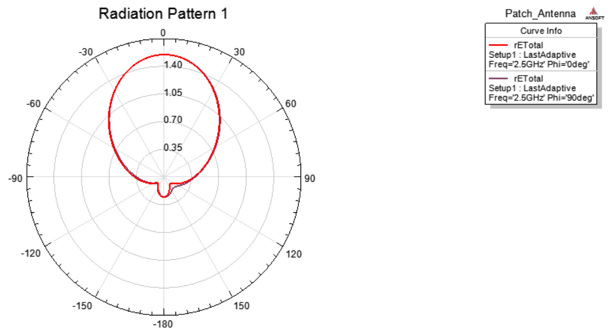


**Figure 9: Radiation Pattern of Patch antenna**

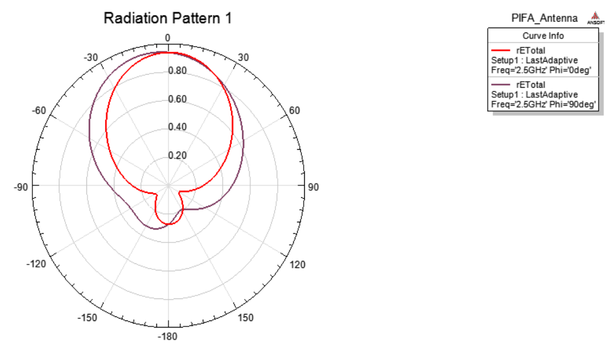


**Figure 10: Radiation Pattern of PIFA antenna**

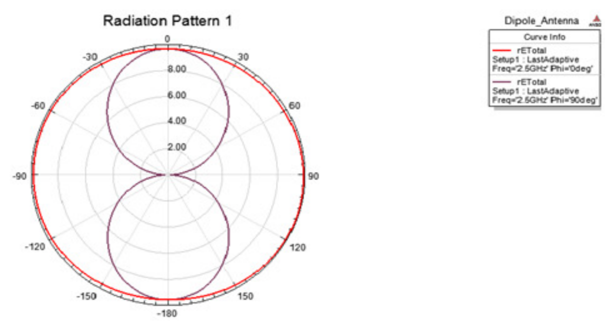


**Figure 11: Radiation Pattern of Slot antenna**

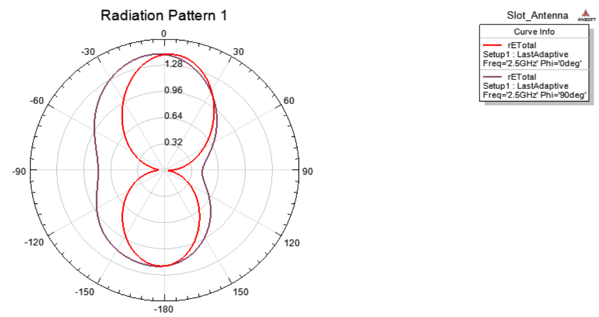


**Figure 12: Radiation Pattern of Dipole antenna**

**Comparative Analysis Result**

| PARAMETERS | DIPOLE | PATCH | PIFA | SLOT |
|---|---|---|---|---|
| **Return Loss** | -20.9db | -37.56db | -23.94db | -37.85db |
| **Bandwidth** | 290Mhz | 40Mhz | 50Mhz | 260Mhz |
| **Size** | 5.76 x 5.76cm | 8.1 x 6.9cm | 10.4 x 4.7cm | 9 x 12cm |
| **Type** | External Antenna | Internal Antenna | Internal Antenna | Internal Antenna |
| **Peak Directivity** | 1.6381 | 4.1506 | 2.0854 | 3.2355 |
| **Peak Gain** | 1.6565 | 4.0409 | 2.036 | 3.3595 |
| **Radiation efficiency** | 098 | 0.9735 | 0.9763 | 0.985 |
| **Front to Back Ratio** | 1.0155 | 38.002 | 14.276 | 1.5217 |

## 5. CONCLUSION

MostlyDipole, Patch, PIFA and Slot antennas are used for multiband operation in wireless communication. Here these four antennas are designed with same substrate and simulated on same frequency.

From comparative results of these four antennas, return loss of Slot antenna is -37.85db which is better than Dipole, Patch and PIFA as well as bandwidth of Slot antenna isabout 260MHz which isoptimum than remaining three.

The radiation efficiency of Slot antenna is also better than Dipole, Patch and PIFA and main advantage of Slot antenna compare to other three antennas is size can be further reduce by using different shapes of slot in order to make compact multiband antenna for wireless communication.

## 6. REFERENCES

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