Compact Wideband Microstrip Antenna for Universal 5GHz WLAN Applications

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Abstract: A microstrip-fed compact antenna with omnidirectional radiation patterns in the azimuth plane is proposed. It provides an impedance bandwidth of 41% (from 4.5 to 6.82GHz) below 10dB and below 14dB it attains 37.3% (from 4.62 to 6.74 GHz), so that it easily covers the required universal 5GHz bandwidths for wireless local area network applications (WLAN) The proposed antenna is composed of a square spiral patch and a partial ground plane with a small rectangular stub. It occupies an area of only 14 × 15mm when printed on an FR4 substrate with a thickness of 1.6mm.

Key words: Wideband Antenna, low cost, compact microstrip antenna, WLAN.

INTRODUCTION

With the tremendous development of mobile wireless communication, systems such as notebook computers, PDAs, digital notepad and so on demand broadband connectivity with greater transmission and receive speeds through wireless local network (WLAN). The IEEE 802.11b and 802.11g standards utilize the 2.4-GHz ISM band. The frequency band is license-free; hence the WLAN equipment will suffer interference from microwave ovens, cordless phone, Bluetooth devices and other appliances that use this same band. However the other frequency spectrum allowed for WLAN (5GHz band) have wider band with less disturbance from other services. But this standard is different from country to country.

The American IEEE and European ETSI organizations have characterized their respective standards for the 5GHz band: IEEE802.11a (Draft supplement to standard, 1999) and HIPERLAN/2 (ETSI, 1999). The IEEE 802.11a standard defines three frequency bands that can be used. A first band extends from 5.15 to 5.25GHz, the second from 5.25 to 5.35GHz and the third from 5.725 to 5.825GHz. HIPERLAN/2 specifies two bands: from 5.15 to 5.35GHz and from 5.470 to 5.725GHz.

In order to response the universal application of WLAN in portable devices with less interference consequently the design of antenna become more acute and critical which is required to have some special properties namely small size, broadband and omnidirectional radiation. In this regard printed microstrip antennas are the best candidate, due to their low profile and cost. Even though their significant advantages this microstrip antennas undergoes the constrict bandwidth. For this reason the antenna design with microstrip structure necessitates careful measures to be taken to achieve broadband characteristics.

Broadband microstrip antennas with single feed have been proposed in various configurations for WLAN applications. Even though the antenna reported in (Mahatthanajatuphat, C., 2009) is capable to satisfy the whole 5GHz band with E-shaped antennas, these are pretty difficult to fabricate. Wide bandwidths are achieved by antennas presented in the literature; some of them have inadequate coverage in the 5 GHz band (Augustin, G., 2006; Cormos, D., 2003; Leong, K.M.K.H., 2001; Mahatthanajatuphat, C., 2009). However, all these antennas are either relatively of big size (Ge, Y., 2005; Leong, K.M.K.H., Y. Qian, T. Itoh, 2001; Raj, R.K., 2006; Gao, Y., 2006; Mahatthanajatuphat, C., 2009) or use a big ground plane (Augustin, G., 2006; Cormos, D., 2003; Ma, H., Q.X. Chu and Q. Zhang, 2008; Ang, B.K. and B.K. Chung, 2007) to achieve a broad bandwidth – so in fact not compact in practice.

In this letter a compact wideband antenna is projected for the 5GHz universal WLAN applications. The antenna covers 47% impedance bandwidth below the 10 dB return loss with dipole like omnidirectional stable radiation patterns.

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Antenna Geometry & Design:

The antenna geometry is depicted in Figure 1 (a, b & c). For easy fabrication and to take the advantages of the PCB technique, the antenna is built on a FR4 substrate with relative permittivity of $\varepsilon_r = 4.4$, loss tangent of 0.02 and thickness of $h = 1.6\text{mm}$. The total area of the antenna is $14\times15\text{ mm}$. The antenna is composed of a square spiral and a finite ground plane with an elongated rectangular stub. The antenna is fed at the corner of the spiral patch by a $50\Omega$ SMA connector. The optimized antenna parameters in $\text{mm}$ are: $L_1 = 14$, $L_2 = 13$, $L_3 = 11.5$, $L_4 = 12.5$, $L_5 = 9.5$, $L_6 = 10.5$, $L_7 = 7$, $L_8 = 7.5$, $W_1 = 1$, $W_2 = 1.5$, $W_3 = 15$, $L_9 = 5.5$, $W_s = 1$, $L_s = 4.5$.

Fig. 1: Schematic diagram of the antenna a) top view, b) side view, c) bottom view
The initial geometry of the proposed microstrip antenna was first designed using a square regular spiral. The inductance and capacitance introduced by the antenna was approximated by using equation 1 & 2. Equation (1) (Samavati, H., 1998) is used for calculating the capacitance of the parallel plate capacitor where $A$ is the area of the plate and $D$ is the distance between two parallel plates. $\varepsilon_r$ is the permittivity of free space and $\varepsilon_r$ is the relative permittivity of the dielectric substrate. Equation (2) is a modified Wheeler (MW) expression (Mohan, S.S., 1999.), where $\mu_o$ is the free space permeability, $n$ is the number of turns, $d_{out}$ is the outer diameter, $d_{in}$ is the inner diameter, $d_{avg}$ is the average diameter, and $\rho$ is the fill ratio, equal to $(d_{out} - d_{in})/(d_{out} + d_{in})$. $k_1$ and $k_2$ in (2) are constants given by 2.34 and 2.75 for square spiral layout.

$$C = \frac{\varepsilon_r \varepsilon_o A}{D}$$  \hspace{1cm} (1)

$$L = k_1 \mu_o \frac{n^2 D_{avg}}{1+k_2 \rho}$$  \hspace{1cm} (2)

The antenna was then optimized to find the geometry by using commercially available full-wave, method-of-moment based electromagnetic simulator Zeland IE3D version 12.0. The inductance coupling imposed by the spiral is the main dominating factor in obtaining wide bandwidth. The ground plane is applied partially to compensate the effect of the capacitance introduced by the ground plane with the spiral patch. Furthermore the elongated stub helps to maintain the current distribution of the ground plane to achieve wide bandwidth. From the input impedance curve of the proposed antenna, pictured in Figure 2, it is evident that it has a good impedance matching. The real part of the input impedance is around 50\,\Omega in the operating frequency. On the other hand the imaginary part is mainly inductive over the operating band. This is due to the effect of the inductive coupling of the spiral.

![Fig. 2: Input Impedance of the designed antenna](image)

The simulated current distribution in IE3D is figured in Figure 3. In Figure 3 (a) the transverse variation of the surface current distribution shows the resonant path is approximately one guided wavelength ($L_1 + W_1 + L_2 + W_2 + L_3 + 2W_1 + L_3 - W_1 + W_2 + L_4$ where $\lambda_{g1}$ is the guided wavelength at $f = 5.2\,\text{GHz}$). It is obvious from Figure 3 (b) that at $f = 5.8\,\text{GHz}$ the resonant path $L_1 + W_1 + L_2 + 2W_1 + L_3 - W_1 + W_2 + L_4$ corresponds to $\lambda_{g2}$ where $\lambda_{g2}$ is the guided wavelength at $f = 5.8\,\text{GHz}$. Nevertheless in the ground plane the current distribution is more intensive in Figure 3 (a), while at $f = 5.8\,\text{GHz}$ there are more current null on the ground. The inductive spiral patch is thus excited by the resonance path of inner side of the compact microstrip antenna.
RESULTS AND DISCUSSION

The return loss of the antenna is exhibited in Figure 4. From the curve it is apparent that the antenna achieved -10dB return loss bandwidth of 2.32GHz, ranging from 4.5 to 6.82GHz, or about 41% with respect to the centre frequency at 5.66GHz. However below 14dB return loss (or VSWR less than 1.5) the antenna demonstrates a 2.12GHz bandwidth from 4.62 to 6.74GHz, which is equivalent to 37.3% centered at 5.68GHz. Obviously, the antenna provides sufficient bandwidth for the whole 5 GHz band WLAN standards.

Fig. 4: Return Loss of the proposed antenna
Figure 5 illustrates the maximum antenna gain over the whole operating bands. With the maximum gain of 1.42dBi the antenna exhibits the gain >0.7dBi over the required frequencies. It is evident that the antenna gain is mainly deteriorated by the compact size of the radiating element. Moreover the gain of the proposed antenna also depends on the loss tangent of the substrate used to fabricate the antenna. From Figure 6 it can be easily understood that using low loss substrates the proposed design can attain higher gain.

![Fig. 5: Gain of the proposed antenna](image1)

![Fig. 6: Effect of different FR4 substrates with various loss tangents](image2)

Figure 7 shows the radiation pattern of E-plane (x-z plane) and H-plane (y-z plane) of the designed antenna. It is clearly seen that the antenna shows a dipole like omnidirectional radiation pattern with maximum gain of 1.05dBi at $f = 5.2$GHz and of 1.34dBi at $f = 5.8$GHz. Almost symmetrical radiation pattern with no back lobe radiation has been observed. One of the significant advantages of symmetrical radiation pattern as seen from Figure 7, is that the maximum power direction is always at the broadside direction and does not shift to different directions at different frequencies.

**Conclusion:**

A single-layered wideband microstrip antenna design is proposed in this paper. It exhibits a bandwidth of 41% (4.5 to 6.82GHz, centered at 5.66GHz) below 10dB return loss, while below 14dB return loss the impedance bandwidth is 37% (4.62 - 6.74GHz, centered at 5.68GHz). Moreover it exhibits a stable dipole like
omnidirectional radiation pattern over the whole operating band. The antenna is compact in shape of $14 \times 15$ mm which is projected for the integration in any portable device for the universal 5GHz WLAN applications.

Fig. 7: Radiation Pattern of the proposed antenna at a) 5.2GHz & b) 5.8GHz

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