Microstrip Slot Antenna for Wireless LAN Application

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Abstract

Wireless Local Area Network (WLAN) becomes more popular due to its capability to carry high speed signal and low cost. In this system, antenna is important for establishing effective communication between places at different location. Microstrip Slot Antenna has been design and develop based on IEEE 802.11b/g standard in the frequency range of 2.4 GHz – 2.4835 GHz for WLAN system applications. This paper describes the design of Microstrip Slot Antenna for WLAN application operating at frequency 2.4 GHz. A coaxial feed has been considered for this antenna. Measurement and simulation of return loss and radiation pattern have been presented. Microwave office was introduced as software to simulate and analyze the design of the antenna. Measurement and simulation result have been compared. The result showed, the resonant frequency is shifted forward. The amount of shifted was 6.6 %. Then, the antenna has been redesign based on the shifted frequency in order to achieve the desired frequency for WLAN application. The bandwidth up to 4.82 % has been achieved with cross isolation for both plane > 10dB. The HPBW for E plane is 70^o and H plane is 85^o.

I. INTRODUCTION

Wireless network devices operate within specified frequency ranges. The use of radio frequency bands is subjected to regulation by national governments. The Federal Communications Commission (FCC) requires licenses for the use of some segments of the broadcast spectrum, including those used by radio broadcasters and cellphone operators.

Wi-Fi networks must operate in one of two unlicensed areas of the spectrum frequency of 2.4-2.4853 GHz band and 5.15

- 5.825 GHz. These frequencies are among those set aside for Industrial, Scientific, and Medical (ISM) uses and UNII (Unlicensed National Information Infrastructure) bands defined by the ITU.

Although no license required in the 2.4 GHz and 5 GHz frequency bands, the FCC does impose some regulations on equipment. These rules ensure that wireless transmissions do not use excess bandwidth and that devices do not interfere with other users of the band by too-powerful broadcasting signal [1]. Different versions of wireless LAN standards exist in the 2.4 GHz and 5 GHz bands. Fig. 1 illustrates a simplified structure of wireless LAN system. A wireless terminal accesses servers distributed in LAN and internet via nearby access point (AP).

Today's wireless LAN standards include: ETSI-BRAN HiperLAN/2 (5 GHz), IEEE802.11a (5 GHz) and IEEE802.11b (2.4 GHz), and ARIB high-speed wireless access network (HisWAN) and CSMA (5 GHz), etc [2]. 5 GHz wireless LAN standard are more or less identical with OFDM modulation, 20 MHz channel spacing, data rates up to 54 Mbps, while IEEE802.11b uses Direct Sequence Spread Spectrum Techniques (DSSS) and provides 11 Mbps data rate in the 2.4 GHz band. Two types of multiple access techniques are adopted in WLANs. They are CSMA/CA using distributed control and TDMA TDD/ DSA adopting the central control.

In this paper a new micostrip antenna has been design using slotted line antenna to replace the existing antenna used for the access point.

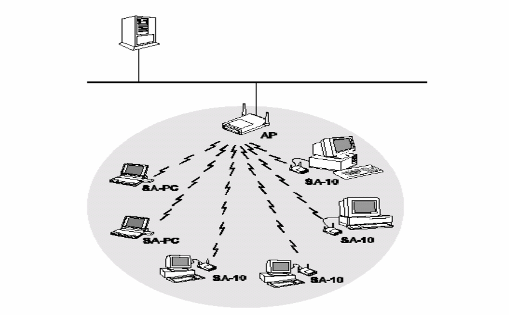


Fig. 1 : Indoor WLAN configurations

II. DESIGN CONSIDERATION OF MICROSTRIP SLOT ANTENNA

The basic geometry for this antenna is a slotted square-patch antenna as shown in Fig. 2. Two pair's narrow slots, with dimensions L_{sa}, L_{sb} and w, are etched on the patch close to and parallel to the radiating edges. The location of the slots with respect to the patch is defined by the quantities d_1 and d_2 which are small with respect to the dimensions *L* and *W* of the patch. Two pair of orthogonal slots on a square patch has been applied as the design. The antenna has been fed with a probe feed. As mention before, the half wave length concept has been used to determine the length of slots. Patch width has a minor effect on the resonant frequency and radiation pattern of the antenna. The slot length inside the square patch determines the resonant frequency.

The equation to calculate the length of slot inside the square patch as below:

The equation to calculate a wavelength on free space:

$$\lambda_o = \frac{c}{f_r} \qquad (1)$$

where,

λo = wavelength on free space
c = light velocity
f_r = resonant frequency

The equation to calculate a wavelength in the slot:

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_r}} \qquad (2)$$

where,

λg = wavelength in the slot
ε_r = Dielectric constant

To obtain an optimum length for the radiating slot, the equation below has been used,

$$L = \frac{\lambda_g}{2} \qquad (3)$$

where,

L= length dimension of a slot

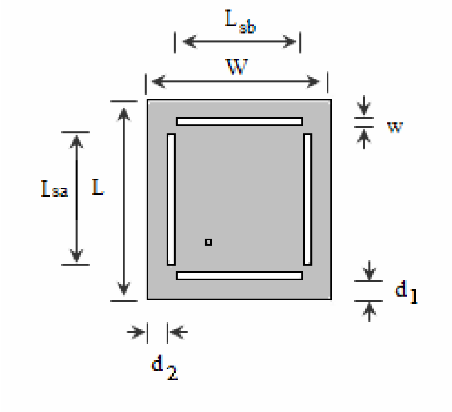


Fig. 2 : The geometry of the microstrip slot antenna

Microstrip slot antenna has been feed with a coaxial probe as a design. This is because a probe-fed patch has several key advantages. First, the fed network, where phase shifters and filters may be located, is isolated from the radiating element via a ground plane. This feature allows independent optimization of each layer. Second, of all the excitation methods, probe feed is probably the most efficient because the feed mechanism is in direct contact with the antenna and most of the feed network is isolated from the patch, minimizing spurious radiation. The high efficiency of this printed antenna has seen a renaissance of the probe-fed-styled patch, despite the added complexity of developing a connection.

Probe-fed microstrip patches have similar issued to edge-fed patches; namely, their bandwidth is somewhat small and these printed antennas are somewhat difficult to accurately analyze. The probe used to couple power to the patch can generate somewhat high cross-polarized fields if electrically thick substrates are used. Also because this antenna is no longer a single-layered geometry, a result of the location of the feed network, it is more complicated to manufacture.

After selecting the patch dimensions L and W for a given substrate, the next task is to determine the feed point (x_o, y_o) so as to obtain a good impedance matching between the generator impedance and the input impedance of the patch element. If the feed is located at $x_o = x_f$ and $0 \le y_f \le W$, the input resistance at resonance for the dominant TM_{10} mode can be express as

$$R_{in} = R_r \cos^2 (\pi x_f / L) \qquad R_r \ge R_{in} \qquad (4)$$

where

x_f is the insert distance from the radiating edge
R_r is the radiation resistance at resonance where the patch is fed at a radiating edge.

The insert distance x_f is selected such that R_{in} is equal to the feed line impedance, usually taken to be 50 Ω. Kara has suggested an expression for x_f that does not need to calculation of radiation resistance [2]. It is approximately given by

$$x_f = \frac{L}{2\sqrt{\varepsilon_{re}(L)}} \tag{5}$$

where

$\varepsilon_{re}(L)$ is define by

$$\varepsilon_{re}(L) = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} F(L/h) \tag{6}$$

where,

$$F(L/h) = \begin{cases} (1 + 12h/L)^{-1/2} + 0.04(1 - L/h)^2 \\ (1 + 12h/L)^{-1/2} \end{cases} \tag{7}$$

III SIMULATION AND MEASUREMENT RESULT

The simulated slot length are 29.62 mm, 31.82 mm and 39.92 mm for L_{sa} and 30.64 mm, 32.84 mm and 33.94 mm for L_{sb} respectively. Slot lengths have a direct effect on the resonant frequency. It is observed that the longer the slot length, the lower the resonant frequency. The bandwidth achieved in the simulation is more than 100 MHz and enough to cover the range of WLAN application.

Table 1 shows a list of parameters for input impedance optimization. The simulation results have been used as a guide line to design the microstrip slot antenna.

TABLE 1 : INPUT IMPEDANCE OPTIMIZATION

No	Measurement parameters	Fixed parameters
1	Slot length, where $L_{sa} \neq L_{sb}$ Lsa = 29.62 mm, 31.82 mm, 32.92 mm Lsb = 30.64 mm, 32.84 mm, 33.94 mm	W = L = 48.125 mm W = 1.85 mm d_1 = 4.48 mm d_2 = 5.45 mm
2	Slot length, where $L_{sa} = L_{sb}$ L_{sa} = 29.62 mm, 31.82 mm, 32.92 mm	W = L = 48.125 mm W = 1.85 mm d_1 = 4.48 mm d_2 = 5.45 mm
3	Slot location, where $d_1 \neq d_2$ d_1 = 3.45 mm, 4.45 mm, 5.45 mm d_2 = 4.45 mm, 5.45 mm, 6.45 mm	W = L = 48.125 mm W = 1.85 mm L_{sa} = 31.82 mm L_{sb} = 32.84 mm
4	Slot location, where $d_1 = d_2$ d_1 = 3.45 mm, 4.45 mm, 5.45 mm	W = L = 48.125 mm W = 1.85 mm L_{sa} = 31.82 mm L_{sb} = 32.84 mm

The antenna is simulated for the best return loss at 2.25 GHz. It is found out that the best return loss is achieved when the coaxial probe is fed from under the patch at an x-position of 14.22 mm, and y-position of 11.52 mm. Thus after optimization for the best return loss and S_{11} matching, the final dimensions are as follow:

i. Patch Width (W) = 50.22 mm
ii. Relative dielectric constant (ε_r) = 4.7
iii. Patch length (L) = 50.22 mm
iv. Slot width (w) = 1.85 mm
v. Slot length (L_{sa}) = 35.1 mm
vi. Slot length (L_{sb}) = 34.22 mm
vii. Slot location (d_1) = 3.69 mm
viii. Slot location (d_2) = 4.92 mm

The testing and measurement results for the microstrip slot antenna are collected and plotted on graphs in data-processing software such as Microsoft Excel. Return loss measurement was done using Scalar network analyzer Marconi Instruments. The radiation pattern was obtained by transmitting the signal at 2.4 GHz and measured using network analyzer in the anechoic chamber..

Return Loss

The measured microstrip slot antenna before the shifted frequency considered, generates a return loss of -24.64 dB and -23.27 dB at resonant frequency of 2.59 GHz and 2.65 GHz respectively. The return loss produced is higher than those the simulations for the first resonant frequency. The second resonant frequency produced lower return loss compared to the simulation. The simulation result produced a return loss of -18.5 dB and -26.57 dB. The bandwidth produced is 4.83 %, which is slightly lower than the simulated bandwidth of 4.97 %.

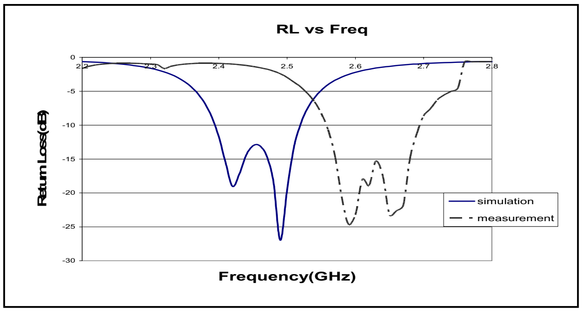


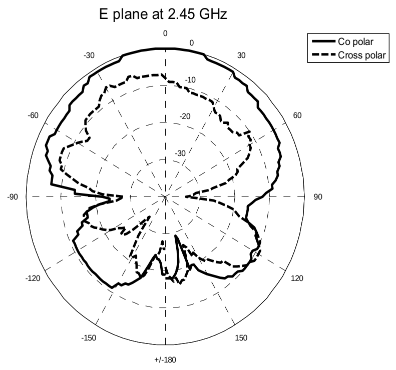
Fig. 3 : The measurement and simulation result for return loss after them shifted frequency considered

As can be clearly seen from the graph in Fig. 3 which shows the measured return loss after the shifted frequency has been considered. The bandwidth of this antenna is 2.37 GHz up to 2.49 GHz and the percentage of bandwidth is 4.82 %. The measured bandwidth is wide enough to cover the Wireless Local Area Network 802.11 b/g frequency, since WLAN requires antennas to be operational between 2.4 GHz and 2.485 GHz. The return loss that generated from measurement is -28.2 dB and -25.84 dB at resonant frequency 2.41 GHz and 2.44 GHz respectively.

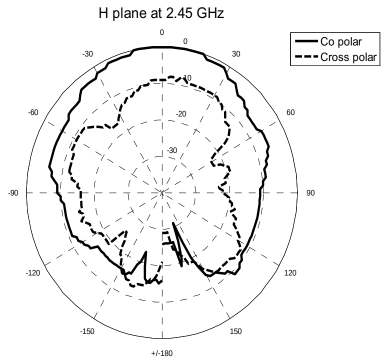
Radiation Pattern

The microstrip slot antenna radiation's patterns are shown in Figure 4 (a) for E plane and (b) for H plane. This antenna has been designed after the consideration of shifted frequency . The E plane maximum co polarization plot has a maximum power of -39 dBm while the maximum power cross polarized field has a value of -45 dBm. The maximum cross polar isolation produced by the E plane is 6 dB. The E plane HPBW generated by the antenna is 94º.

The co polarization maximum power is at a higher value of -39 dBm while the maximum power cross polarized field has a value of -47 dBm. The cross polar isolation for H plane is 8 dB. The measurement also shows a smaller HPBW compared to the one generate by E plane. H plane produced a HPBW about 76º. This result is shown in figure 4(b).



(a) E plane radiation pattern



(b)H plane radiation pattern

Fig. 4 : Measurement radiation pattern at 2.4 GHz

IV CONCLUSION

Microstrip antenna is suitable for WLAN application due to its easiness of manufacturing in mass volume and its geometry structure Low cost solution for antenna design became critical and is required since both market and technologies are so far ready for mass production. The characteristic of microstrip antenna such as low cost and low profile will be providing high market in application. There are various techniques to enhance the bandwidth of microstrip antenna. In this project, the slotted patches technique has been used to improve the bandwidth of the microstrip antenna. The microstrip slot antenna (MSA) has been designed to operate at 2.4 GHz frequency. The project has been carried out on simulation and fabrication basis. The antenna was designed and measured and is proven operable, with sufficient amount of return loss and bandwidth. The microstrip slot antenna resonates at 2.41 GHz and gives a good return loss, which is -28.2 dB. This is a good value because only 0.15 % power is reflected and 99.85 % power is transmitted. The bandwidth of this microstrip antenna is also good, which is 4.82 % and enough to cover the range of WLAN frequency which is 2.4 GHz up to 2.4835 GHz or 3.42 %. From the propagation measuerement it shows that this antenna reception is comparable to the existing monopole antenna.

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