Single Patch E-Shaped Compact Microstrip Antenna

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Abstract: *Micro strip antennas have been the subject of some inventive work in recent years, and are currently one of the most dynamic fields in antenna theory. A single wideband, E-shaped, compact microstrip antenna is presented in this article in order to be employed for high speed WLANs operating in the C band range. Employing only a single patch, a high impedance bandwidth is achieved. The simulated impedance bandwidth (VSWR<1.75) is 30%, and the momentum bandwidth is about 28.5%. The structure of the antenna consists of a perfect conductor on the top of a substrate (RT_DURROID_5880) with a dielectric constant of about 2.2 and a height of 20 mile, which is backed with a perfect conductor ground plane. The impacts of different parameter of antenna are also studied in this article.*

Index Terms: *E-shaped antenna, ADS2009, RT_Duroid 5880, microstrip*

I. INTRODUCTION

In applications of aerospace, satellite and missile which requires small size, easy installation and low cost, antennas with low knob are used like microstrip antennas. Current commercial applications such as mobile communications and wireless telecommunications are taken into account. The printed-circuit antennas use technology simply because they are considered to be made simple and cheap. While installing on the stiff surface, they will have good durability. Appropriate forms can also change diffusion fashion. Microstrip antenna has diversity at the resonant frequency, polarization, pattern and impedance requirements.

The main disadvantages of microstrip antenna can be low efficiency, low throughput, narrow bandwidth and low frequency range. However, it is desirable to use it in some low bandwidth applications. Of course, increasing the thickness of the substrate can expand the bandwidth efficiency. However, this increases the surface waves that is an undesirable factor, because waves can be absorbed in the environment. Surface waves move on the surface layer, scattered in the surface curvature and discontinuities (cuts dielectric surface) and reduce antenna patterns and polarization characteristics.

When bandwidth is large, surface waves can be eliminated using the holes.

Microstrip antennas have reached a stage that can accommodate many other types of antennas for their low power applications.

However, a serious limitation of microstrip antenna is its narrow bandwidth. To strengthen and increase the bandwidth of microstrip antennas, many techniques have been developed. In this paper, by using some of the techniques of traditional microstrip antenna, bandwidth has been increased. The design of triangular patch antennas has been simulated in different frequency cohort. In this paper, using IE3D software, voltage standing wave ratio, end-use, axial ratio, radiation pattern of the designed antenna will be assessed. This paper deals with a single probe feed.

Of the proposed antenna, the impedance bandwidth of 37 percent was achieved.

The increasing use of wireless devices has necessitated the need for larger bandwidths.

Hence, the bit rate should be higher or in different standards that are applied in different frequency bands.

Ultra-broadband systems (UWB) as a system with a special focus has been considered because this system can realize the bit rate of up to several hundred Mbps. But the main problem is to design an appropriate antenna system.

Microstrip patch antennas are broadly used due to several advantages they have [1], [5-8], namely the light weight, low volume, low fabrication cost, and their capability of dual and triple frequency operations. Yet, microstrip antennas suffer from some disadvantages too. Narrow bandwidth is a serious one of them and different techniques are used to overcome this limitation, including increasing the thickness of the dielectric substrate, decreasing the dielectric constant [1] and using parasitic patches [2]. These techniques, in turn, have some limitations too, namely the excitation of surface waves and the increase in the antenna size. In wireless local area networks, the antenna employed is in PCMCIA format for which a small size, low volume antenna is requisite. A rectangular patch with a U slot [3] embedded in it will give a broadband antenna, and a single E-shaped patch of 15 mm height provides a bandwidth up to 30%. [11] provided mathematical analysis of microstrip as below:

The electric field radiated from a micro strip antenna provides a boundary between two different dielectrics: air and the substrate material. Due to the slight distortion of the field at the boundary, the patch may appear longer in an electrical sense.

Therefore, we have an effective patch length. There is also an effective relative permittivity when analyzing micro strip antenna. The effective relative permittivity can be defined using the following formula [11]:

E-plane pattern

$$E_\phi = \frac{kV_0 w}{2\pi r} e^{-jkr} \left[\sin\theta \left(\frac{\sin\left(\frac{kw}{2}\cos\theta\right)}{\frac{kw}{2}\cos\theta} \right) \right] \quad (1)$$

H-plane pattern

$$H_{\theta} = E_{\phi} / \eta \quad (2)$$

Characteristic impedance of microstrip line feed for w/h ≤ 1

$$Z_0 = \frac{60}{\sqrt{\varepsilon_{reff}}} \ln\left[\frac{8h}{w} + \frac{w}{4h}\right] \quad (3)$$

for w/h ≥1

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{reff}}\left[\frac{w}{h} + 1.393 + .667\ln\left(\frac{w}{h} + 1.44\right)\right]} \quad (4)$$

Beam widths E-plane

$$\theta_E \cong 2\cos^{-1}\sqrt{\frac{7.03\lambda 0^2}{4\left(3Le^2 + h^2\right)\pi^2}} \quad (5)$$

H-plane

$$\theta_H \cong 2\cos^{-1}\sqrt{\frac{1}{2 + kw}} \quad (6)$$

Compared to other methods, transmission line method is the easiest one, which represents the rectangular micro strip antenna as an array of two radiating slots, separated by a low impedance transmission line of certain length.
We can see the fringing at the edges that increases the effective length.

$$\varepsilon_{reff} = \frac{\left(\varepsilon_r - 1\right)}{2} + \frac{\left(\varepsilon_r + 1\right)}{2}\left(1 + 10\frac{h}{w}\right)^{-1/2} \quad (7)$$

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (8)$$

II. E-SHAPED MICROSTRIP PATCH ANTENNA

By incorporating two parallel slots into the rectangular microstrip patch antenna, it becomes an E-shaped microstrip patch antenna, which is simpler in construction. The geometry of this antenna is presented in Figure1.

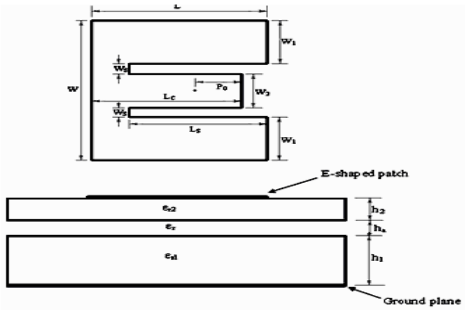

Figure 1. Geometry of the E-shaped microstrip patch antenna

The E-shaped microstrip patch antenna has the width of W_1, two outer patch strips of the length of L and the width of W, one central patch strip of the length of L_c and the width of W_2, and also, two slots of the length of L_s and the width of W_s are introduced symmetrically, regarding the probe position. Employing a coaxial probe, the patch is fed at position P_0, and two dielectric substrate materials are employed to fabricate the antenna element. An air gap of 1mm is let between the two substrates. The upper substrate is selected to be with high dielectric constant for compact size, and the lower substrate is foam dielectric material in order to provide ground plane. An air gap is let since the thickness of the foam material is fixed, and it helps in optimizing the wide bandwidth.

III. DESIGN OF SINGLE PATCH E-SHAPED MICROSTRIP ANTENNA

We designed the rectangular microstrip patch antenna first, and then incorporated the two parallel slots into the patch. The parameters in designing rectangular microstrip antenna are the followings:

A. Frequency of operation (f0)

The high-speed computer wireless local area networks function at two frequency bands of (5.15 - 5.35 GHz and 5.725 - 5.850 GHZ). The resonant frequency selected for the rectangular patch is the centre frequency of the upper band (5.8 GHZ), and with the introduction of the two slots, the E-shaped microstrip antenna covers the lower band.

B. Selection of the substrates

Two substrates are used in fabricating antenna. Upper foam Substrate **(**RT_DURROID_5880) is of the dielectric constant of ε_{r1} =2.2 and the thickness of h1= 20mm. We have let an air gap of 1.0mm between the two substrates. The foam substrate and the air gap are employed for large band width. Lower substrate is of the dielectric constant of ε_{r2} = 9.6 and the thickness of h2=30 mm.

The microstrip antennas are employed with WLAN adaptor cards in the PCMCIA (also known as PC) format, which have the standard thickness of 5 mm. Therefore, we have limited the total height (4.9624 mm) of the antenna to be less than 5 mm. For designing the microstrip antenna, the advanced Design System (ADS2009) was employed. The dimensions of the optimized antenna element are provided in Table 1.

IV. PARAMETRIC ANALYSIS

The following section deals with the effects of various parameters. By increasing LS, the whole VSWR curve shifts towards lower frequencies. The change is higher in resonant frequency of higher mode, since the relative change in current path length for higher mode is greater than the lower mode current path, as shown in Figure 2. The width WS has a significant effect on the matching to the input port, while it marginally affects the resonant frequencies of the two modes, as presented in Figure 3.

TABLE I. DIMENSION OF OPTIMIZED ANTENNA PARAMETERS

Frequency	5-6 GHz
W	18 mm
L	12 mm
W_1	5.5mm
L_C	8.5mm
W_2	5 mm

L_S	8.5mm
W_S	1mm
P_0	2.5mm

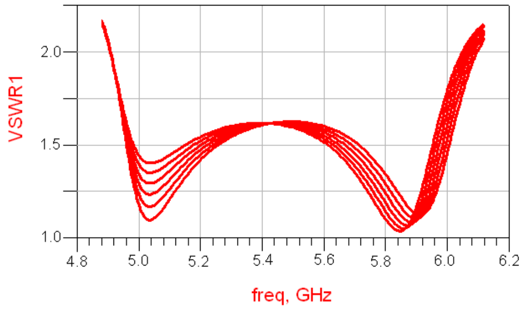

Figure 2. Effect of slot length (LS)

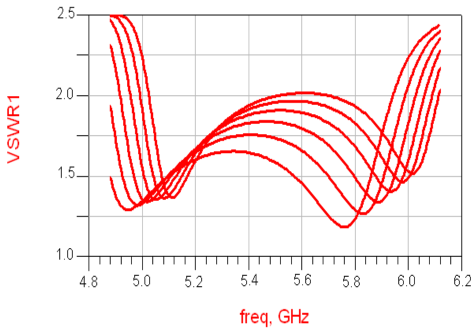

Figure 3. Effect of slot width (WS)

The slot position PS employed for optimizing the matching of both modes is presented in Figure 4.

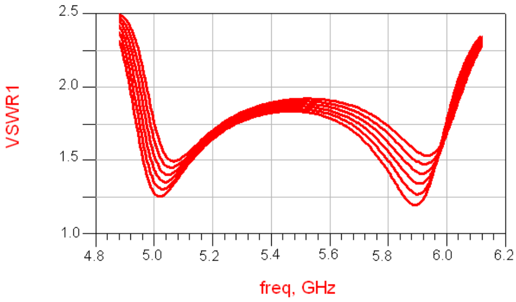

Figure 4. Effect of slot position (PS)

The resonant frequency of the higher mode decreases as L_c increases, while there is no significant change in resonant frequency of the lower mode, as shown in Figure 5.

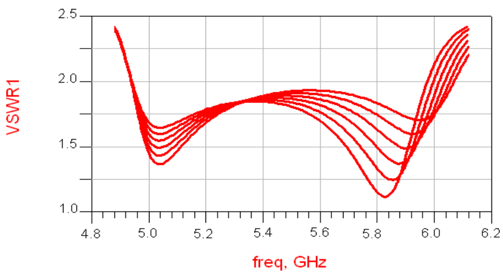

Figure 5. Effect of central patch strip length (LC)

V. RESULTS

The simulated 2:1 VSWR bandwidth is 30 % covering the (4.82 – 6.43 GHz) frequency band and the momentum 2:1 VSWR bandwidth is 28.8 % covering (4.91 – 6.4 GHz) frequency band, which are presented in Fig. 7. The shift in the frequency band is because of the decrease in the height of the upper substrate with high dielectric constant in the fabrication process. Decreasing the height of upper dielectric substrate is about 0.5 mm, which leads to this shift of frequency band. The radiation pattern was measured in anechoic chamber. Also, there were back lobes in the measured radiation patterns because of the finite size of ground plane. Figure 6 represents Microstrip layout of this antenna.

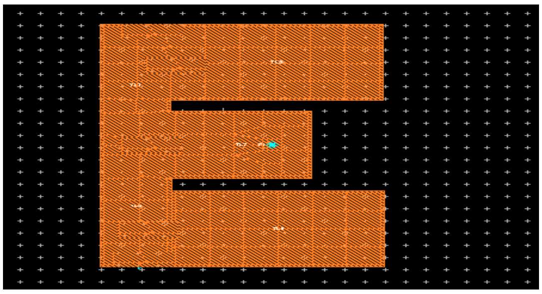

Figure 6. Microstrip Layout of the E-shaped antenna

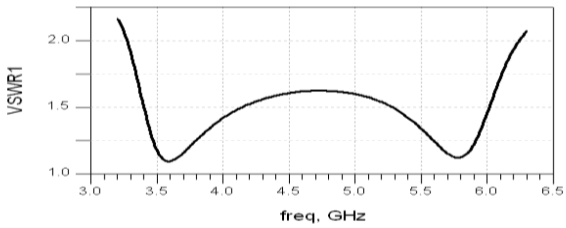

Figure 7. simulated impedance (VSWR < 1.75) bandwidth of wideband E-shaped microstrip patch antenna.

VI. CONCLUSIONS

Regarding the simulated and the measured results, it can be concluded that the E-shaped patch antenna geometry provides wide bandwidth with single patch. The momentum result matches simulated bandwidths. Besides, the antenna shows a good front to back radiation (FBR) ratio. The effect of various parameters of E-shaped patch antenna have been studied without changing the permittivity and the height of the substrates.

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