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Design of Microstrip Antenna for WLAN

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Abstract: This study presents theoretical investigation and simulation of Input Impedance behavior of nearly square single fed aperture coupled microstrip patch antenna that can satisfy the narrowband WLAN applications with 2.4 GHz band with 80 MHZ bandwidth. For maximum coupling the patch should be centered over the slot, moving the patch relative to the slot in the H-plane direction has little effect, while moving the patch relative to the slot in the E-plane (resonant) direction will decrease the coupling level, also for maximum coupling, the feed line should be positioned at right angles to the center of the slot. Skewing the feed line from the slot will reduce the coupling, as will positioning the feed line towards the edge of the slot. Position of the feed line in different places relative to patch also was presented.

Key words: Microstrip antenna, WLAN, input impedance

INTRODUCTION

Mathematical modeling of the basic microstrip radiator was initially carried out by the application of transmission-line analogies to simple rectangular patch fed at the center of radiating wall. The radiation pattern of a circular patch was analyzed and measurements reported by Carver[1]. The first mathematical analyze of a wide variety of microstrip patch shapes was published in 1977 by Bahl and Bhartia[2], which he used the modal-expansion technique to analyze to rectangular, circular, semicircular and triangular patch shapes.

High speed, broadband and high capacity in or outdoor wireless local area networks (WLAN) are becoming more and more predominant today, its interesting to become familiar with some of the aspects of wireless design that must be faced and overcome. The advantages of microstrip antennas have made them a perfect candidate for use in the wireless local area network (WLAN) applications. Though bound by certain disadvantages, microstrip patch antennas can be tailored so they can be used in the new high-speed broadband WLAN systems and other applications, e.g. PCS, Bluetooth, RFID, etc.

Foundations for microstrip design: A microstrip patch antenna is a radiating patch on one side of a dielectric substrate, which has a ground plane on the underside[3]. The EM waves fringe off the top patch into the substrate, reflecting off the ground plane and radiates out into the air. Radiation occurs mostly due to the fringing field between the patch and ground (Fig. 1).

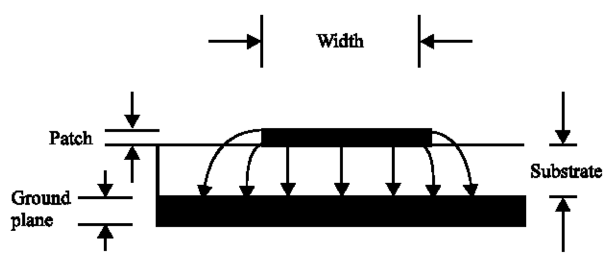

Fig. 1: Operations of microstrip patch

The radiation efficiency of the patch antenna depends largely on the permittivity (ϵ_r) of the dielectric. Ideally, a thick dielectric, low ϵ_r and low insertion loss is preferred for broadband purposes and increased efficiency. The advantages of microstrip antenna that they are low-cost, conformable, lightweight and low profile, while both linear and circular polarization easily achieved. These attributes are desirable when considering antennas for WLAN systems. Disadvantages of microstrip antenna include such as a narrow bandwidth, a low gain (~6 dB) and polarization purity is hard to achieve[3].

Polarization types: Usually the polarization of the wave radiated by the antenna in a particular direction. This is usually dependant on the feeding technique. When the direction is not specified, it is in the direction of maximum radiation[4]. Two most widely polarizations (linear and circular) are shown in Fig. 2 and 3.

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Linear polarization: A slot antenna is the counter part and the simplest form of a linearly polarized antenna. On a slot antenna the E field is orientated perpendicular to its length dimension. The usual microstrip patches are just different variations of the slot antenna and all radiate due to linear polarization. Figure 2 illustrates the operations of a linearly polarized wave radiating perpendicular to the patch plane.

Circular polarization: Circular polarization (CP) is usually a result of orthogonally fed signal input. When two signals of equal amplitude have 90° phases, the resulting wave is circularly polarized. Circular polarization can result; left hand circularly polarized (LHCP) where the wave with anticlockwise, or right hand circularly polarized (RHCP) wave with clockwise rotation. The main advantage of CP is that regardless of receiver orientation, it will always able receiving a component of the signal. This is due to the resulting wave having an angular variation.

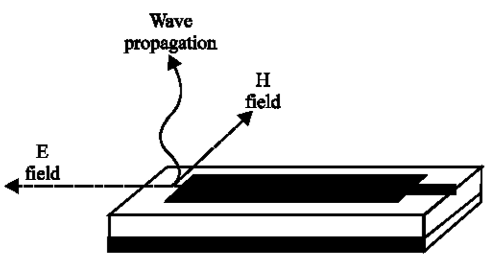

Fig. 2: Microstrip antenna patch with linear polarization wave

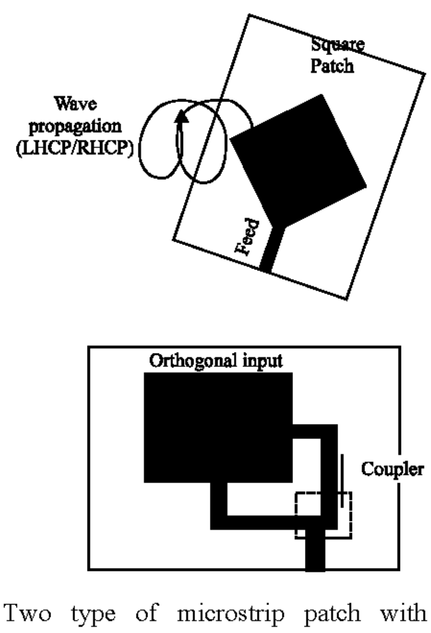

Fig. 3: Two type of microstrip patch with circular polarization wave

Bandwidth: The bandwidth of the patch is defined as the frequency range over which it is matched with that feed line within specified limits[5]. In other words, the frequency range over which the antenna will perform satisfactorily. This means the channels have larger usable frequency range and thus results in increased transmission. The bandwidth of an antenna is usually defined by the acceptable standing wave ratio (SWR) value over the concerned frequency range.

$$BW = \frac{SWR - 1}{Q\sqrt{SWR}} \quad (1)$$

Where, Q is a qualify factor.

The Fig. 4 shows a typical narrow and broadband phenomenon in terms of frequency band usage.

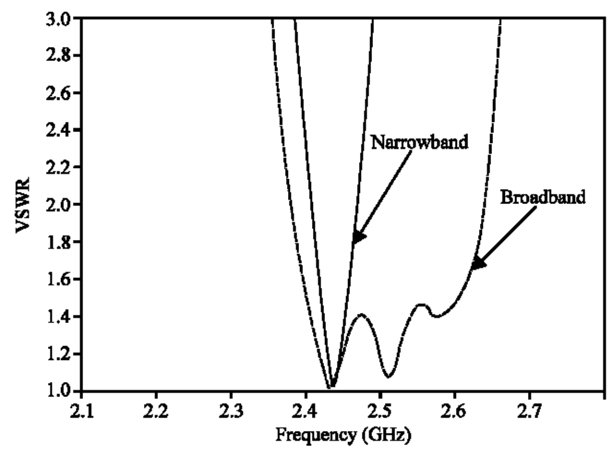

Fig. 4: Narrowband and broadband for microstrip antenna

Feeding techniques: Feeding technique influences the input impedance and polarization characteristics of the antenna. There are three most common structures that are used to feed planar printed antennas. These are coaxial probe feeds, microstrip line feeds and aperture coupled feeds.

For aperture-coupled a feed, which is used in this study the microstrip feed line, is etched on the bottom of the feed substrate.

Aperture coupled microstrip antennas: In an aperture-coupled feed, which is another type of electro magnetically coupled (EMC) feed; the RF energy from the feed line is coupled to the radiating element through a common aperture in the form of a rectangular slot. This type of feed was first proposed by Pozar[6]. The aperture coupled feeding mechanism is shown in Fig. 5.

Figure 5 shows the geometry of the basic aperture coupled patch antenna that is designed in this work and

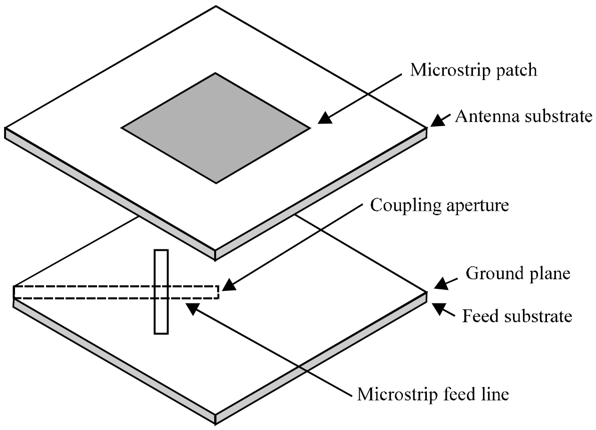

Fig. 5: Geometry of the aperture coupled microstrip antenna with corner feeding for circular polarization

considered in simulation parameters. The radiating microstrip patch element is etched on the top of the antenna substrate and the microstrip feed line here is etched of the corner of bottom of the feed substrate. Rectangular slot 45° is also used the nearly square ground plane.

Designs and simulation procedure: The aim of this design is to provide a good performance in input impedance resonant frequency matching and perfect circular polarization for WLAN requirements, The design parameters; considered here are as follows:

Substrate thickness: Substrate thickness should be chosen as large as possible to maximize bandwidth and efficiency, but not so large as to risk surface-wave excitation. For maximum operating frequency f_u the substrate thickness (h)[7] should satisfy:

$$h \leq \frac{0.3\ c}{2\pi f_u \sqrt{\varepsilon_r}} \tag{2}$$

Where, ε_r is the relative dielectric constant obtained using resonant line method[6] and c is the light speed.

Antenna patch dimensions: The patch length is determined by condition for resonance. This occurs when the input impedance is purely real[8]. For nearly square geometry the length (l) must slightly greater than the width (w), to obtain an initial value of l:

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_r}} \tag{3}$$

f_r = 2.45 GHz. Using equation (3) we can calculate the effective relative permittivity (ε_{eff}) as follows:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{w}\right)^{-0.5} \tag{4}$$

To calculate patch width the following equation used.

$$w = \frac{c}{2 f_r}\left(\frac{\varepsilon_r + 1}{2}\right)^{-0.5} \tag{5}$$

For improved value of l we can find the fringe factor dl.

$$dL = 0.412h\,\frac{(\varepsilon_{eff} + 0.3)\ (w/h + 0.264)}{(\varepsilon_{eff} - 0.258)\ (w/h + 0.8)} \tag{6}$$

The foregoing procedure may be repeated with a result that improves l.

Excitation: Figure 5 shows that it is possible to excite the two modes (TM_{10}, TM_{01}) using one feed by introducing a small perturbation in the patch and it radiates Right-Hand Circular Polarization (RHCP). For (LHCP) feed is placed on other diagonal[9]. In this simulation different location for the feeder were used.

RESULTS AND DISCUSSION

Analytical results are obtained using equations 1-6 with the help of FORTRAN simulation software and compared with[10] for verification.

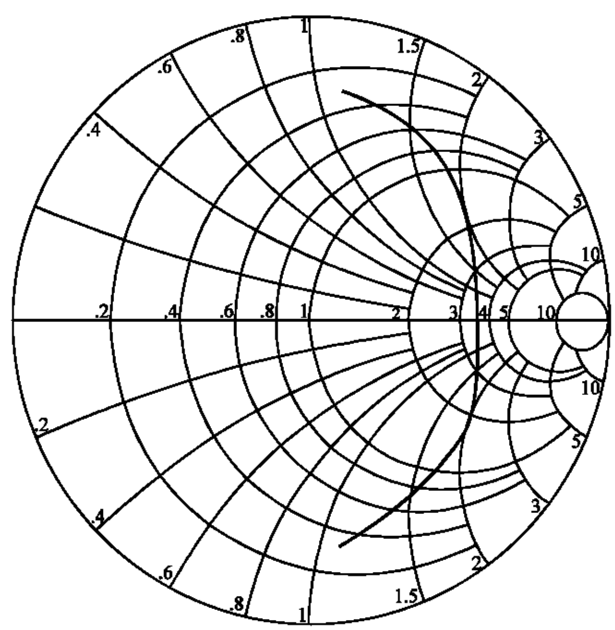

Fig. 6: Input impedance for microstrip rectangular patch

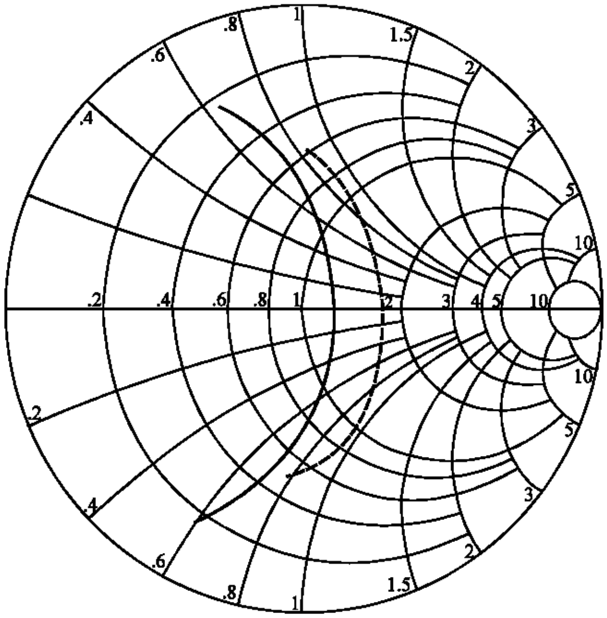

Fig. 7: Trade-off insetting feed point with input impedance (A) $y_0 = 0.079\lambda_0$ (solid line) (B) $y_0 = 0.026\lambda_0$ (Dot line)

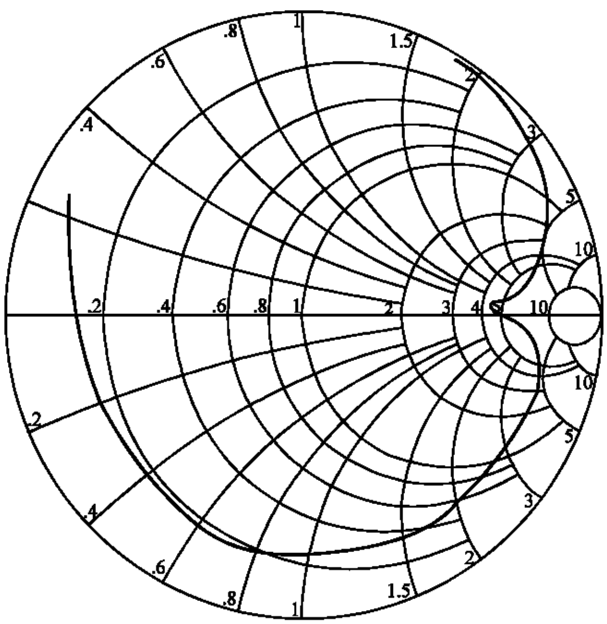

Fig. 8: The input impedance for corner fed microstrip patch

Smith chart shown in Fig. 6, show the input impedance for microstrip rectangular patch with these following parameters and BW which it calculates from equation (1) as a relative bandwidth as shown in the Table 1, which it same as appeared in Brown[10].

Table 1: The parameters of microstrip antenna rectangular patch

Dimension			Excitation					
w	l	h	y_0	x_0	ε_r	f_r	SWR	BW
$0.495\lambda_0$	$0.330\lambda_0$	$0.0064\lambda_0$	0	$0.013\lambda_0$	2.2	1.57 GHz	3.6	16%

Table 2: The parameters of microstrip antenna rectangular patch

	Excitation			
	y_0	x_0	SWR	BW
Solid line	$0.079\lambda_0$	$0.013\lambda_0$	2.0	8%
Dots line	$0.026\lambda_0$	$0.013\lambda_0$	2.6	12%

Table 3: The parameters of center feed microstrip antenna rectangular patch

Dimension			Excitation					
w	l	h	y_0	x_0	ε_r	f_r	SWR	BW
$0.224\lambda_0$	$0.217\lambda_0$	$0.0083\lambda_0$	0	0	2.62	2.42 GHz	4.5	18.7%

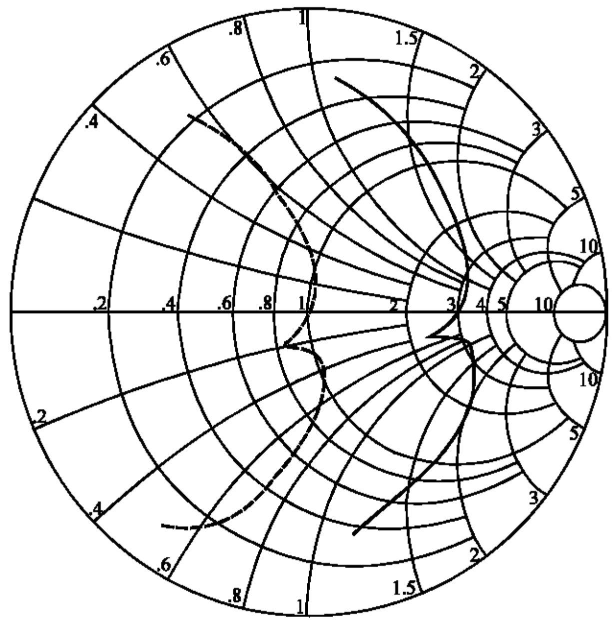

Fig. 9: The input impedance for LHCP microstrip antenna nearly square patch
(a) $x_0 = 0.11\lambda_0$, $y_0 = 0.11\lambda_0$ (dot line)
(b) $x_0 = 0.068\lambda_0$, $y_0 = 0.068\lambda_0$ (solid line)

Also Fig. 7 shows the input impedance with increased feed points at y_0= $0.079\lambda_0$ and y_0= $0.026\lambda_0$ has been studied. All other parameters same as in Fig. 6 and Table 2 describes these.

For a simple circular polarization for single feed microstrip antenna with an aperture coupled has been demonstrated. Properly adjusting the length of the patch and using inset feed line can easily obtain the right-hand or left-hand. Smith chart shown in Fig. 8 the input impedance for microstrip rectangular patch corner feed with these following parameters and BW, as shown in the Table 3.

As shown in Table 3 the microstrip antenna corner feed give center frequency 2.425 GHz, which it is approximately equal to unlicensed ISM WLAN IEEE802.11b or Wi-Fi band. But with narrower bandwidth than it, with carefully select dielectric constant better bandwidth can be obtained.

Figure 9 shows the variation of the feed line positions to give optimum state circular polarization for two modes (TM_{10}, TM_{10}) for equal amplitude and 90°phase differences, but with cost pay for the antenna bandwidth.

CONCLUSION

Theoretical investigations have been conducted to evaluate nearly square single polarized WLAN applications. The accuracy of the theoretical model assessed by a comparison with pervious working and the agreements were very good. Further optimization and improvement is required to ensured correct circular polarization and wider bandwidth, also more rigorous model can be used. Also antenna array[11] can be investigated to improve the performance.

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