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DESIGN OF A CIRCULARLY POLARIZED MICROSTRIP ANTENNA FOR WLAN

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Abstract—The design and performance of a circularly polarized microstrip patch antenna, for the application in Wireless Local Area Network (WLAN), are reported here. The antenna is a proximity coupled microstrip patch antenna where the radiating patch is loaded by a V-slot. This miniaturized microstrip antenna has wide bandwidth in the frequency band of WLAN and exhibits circularly polarized far field with very good axial ratio bandwidth. The simulated results using IE3D software are verified by measurement.

1. INTRODUCTION

The need for wireless broadband communications has increased rapidly in recent years demanding quality of service, security, handover, and increased throughput for the Wireless Local Area Networks (WLANs). The main aim of future wireless communication is high speed networking services for multimedia communication. The most important high data rate wireless broadband networking systems for future wireless communications are High Performance Local Area Network type 1 (HIPERLAN/1) and High Performance Local Area Network type 2 (HIPERLAN/2) which use the frequency bands 5.150 GHz–5.350 GHz and 5.470 GHz–5.725 GHz respectively with omni-directional antennas [1]. But for short distance indoor LAN communication, directive antenna can be used. HIPERLAN/2 has a very high transmission rate up to 54 Mbit/s. The modern wireless communication systems require the antennas for different systems and standards with characteristics like compact, broadband, multiple resonant frequencies and moderate gain. Because of many attractive features, microstrip patch antennas have received considerable attention for wireless communication applications [2–12]. In [2] a patch antenna was developed for HIPERLAN to operate at higher order mode and at the frequency band of 5 GHz, 6.1% bandwidth and 4.2 dB gain were achieved. The design of dual frequency shorted stacked patch antenna [3] and shorted E-shaped patch antenna [4] are also developed for the application in wireless communication. Dual frequency antennas for wireless LAN also developed [6, 7]. Current research works also include miniaturized multiband short circuited microstrip antennas [9–11] and wideband proximity coupled microstrip antennas [12–18]. Single layer microstrip antennas have very narrow bandwidth, but using multi-layered configurations like proximity coupled microstrip antennas or aperture coupled microstrip antennas, higher bandwidth can be achieved [12–18]. Design and development of compact printed antennas for wireless communications are also reported [19–28]. A thin wideband microstrip patch using two parallel slots is designed for WLAN [19]. In [20] a triple band omnidirectional antenna, consisting of three pairs of back-to-back printed dipoles, for the operation at 2.4 GHz, 5.2 GHz and 5.8 GHz bands, is described. Design of efficient patch antennas for the applications in wireless communication are reported in [21, 22]. The loop structure and two-layered meander strips are used to design small size and broadband antenna for mobile terminals [23]. Important related work also reported by various authors [24–28] where broadband miniaturized printed antennas are developed.

The input impedance of a proximity coupled microstrip antenna is a sensitive function of length and width of the microstrip feed line. Since radiation pattern of a microstrip antenna has wide beamwidth in one hemisphere, two back-to-back microstrip antennas in the same module can be used to produce nearly omni-directional radiation pattern required for WLAN applications. Two back-to-back proposed microstrip antennas may be placed vertically to produce far fields with wide beamwidths in two directions. There will be distinct nulls in two opposite directions, bur this is not a major concern for indoor WLAN communication. The HIPERLAN/2 is principally used for indoor wireless local area network and for indoor signal propagation due to multiple reflections from walls and other human made constructions, signal changes its direction and hence signals from other directions except null directions will be received by the receiving antenna. Investigations on slot loaded single layer microstrip antennas are reported but research work on slot loaded proximity coupled microstrip antennas are insufficient [5, 16, 17].

In this paper, the investigations on a proximity coupled microstrip antennas are reported where the square radiating patch was loaded by cutting a V-shaped slot on the patch. Then from this V-shaped slot loaded square radiating patch, small isosceles right angle triangular sections are removed from the diagonally opposite corners to produce orthogonal modes for the generation of circular polarization and this technique is used to design circularly polarized single layer patch antenna [17]. Then this truncated V-shaped slot loaded square radiating patch is proximity coupled by a microstrip line. The simulated impedance bandwidth, gain, and axial ratio bandwidth are compared with measured results. Results show that the proposed circularly polarized microstrip patch antenna has very small size, wide bandwidth, moderate gain and very good axial ratio bandwidth, required for the communication using HIPERLAN/2.

2. DESCRIPTION OF ANTENNA STRUCTURE AND PRINCIPLES OF DESIGN

In proximity coupled microstrip antenna, the radiating patch, fabricated on a dielectric substrate, is excited by a microstrip line on another substrate, fed by a co-axial SMA connector, as shown in Fig. 1. The coupling between the patch and the microstrip feed line is capacitive in nature and being two-layer configuration, effectively the patch is placed on the double layer, resulting larger bandwidth.

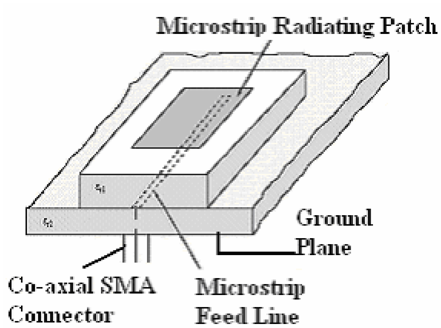

Figure 1. Proximity coupled microstrip antenna.

The dielectric constants and height of the substrates, used for microstrip patch and microstrip line may be different. Compact microstrip antennas can be designed by embedding suitable slots on the radiating patch. The loading can be varied by varying the length and width of the slot. Slots can be of different shapes and some slots or combination of two slots on the patch can produce dual frequencies [16, 17]. The geometry of V-slot loaded proximity coupled microstrip antennas with dimensions of the patch and the dimensions of the V-slot are shown in Fig. 2 and Fig. 3 respectively.

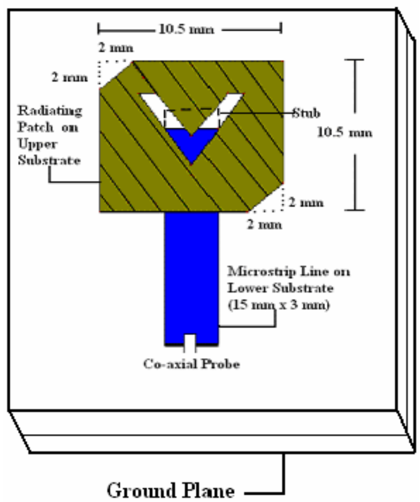

Figure 2. Geometry of the proximity coupled V-slot loaded microstrip antenna.

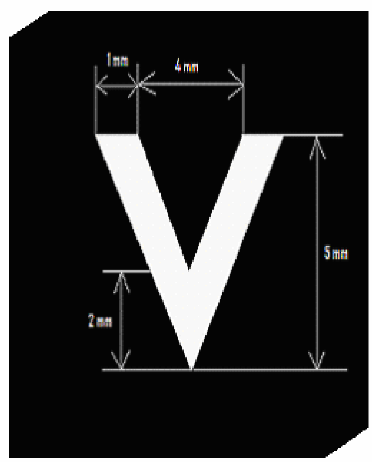

Figure 3. The dimensions of the V Slot on the microstrip patch.

In simulation and measurement, it is found that for linearly polarized proximity coupled microstrip patch antenna in the 5 GHz WLAN band, the impedance bandwidth is greater for V-slot loaded patch than U-slot loaded and rectangular-slot loaded patches. For that reason, for circularly polarized patch design, V-slot loaded patch is considered here. Both the microstrip patch and the microstrip feed line were fabricated on Glass Epoxy substrate with dielectric constant of 4.36, substrate height of 1.57 mm. and loss tangent of 0.001. The microstrip feed line was placed below the centre of the V-slot which is located at the centre of the radiating patch and far from the edges of the radiating patch, so that the slot does not affect the radiation pattern of the antenna. The length of the microstrip feed line which appears beyond the centre of the patch, is stub length (Fig. 2). For proximity coupled microstrip antenna, this stub length is important for impedance matching. The bandwidth for HIPERLAN/2 communication is 255 MHz.

3. SIMULATED AND MEASURED RESULTS

For antenna design, IE3D simulation software is used, which is a full wave electromagnetic simulation software for the microwave and millimeter wave integrated circuits. The primary formulation of the IE3D software is an integral equation obtained through the use of Green's function. The basic form of the equation to be solved by the Method of Moment is $f(g) = h$. Where '$f(g)$' is a known linear operator, of an unknown function 'g', and 'h' is the source or excitation function. The aim is to find 'g', when 'f' and 'h' are known. This unknown function 'g' can be expanded as a linear combination of 'n' terms consisting of 'n' number of unknown constants 'a_n' and 'n' number of known functions 'g_n'. The known functions 'g_n' are called basis functions or expansion functions. Since microstrip antenna structure is of mixed dielectric type, in IE3D simulation, these unknowns are obtained by using Green's function in the electric field integral equation formulation, which satisfies boundary conditions at the microstrip patch metallization. The resulting integral equations are discretized into a set of linear equations to yield a matrix equation. The current distribution on the metal patch can be obtained from the solution of this matrix equation and then the required quantities are determined from this current distribution. The simulation using IE3D, takes into account the effect of co-axial SMA connector, by which the antenna was fed.

A large number of V-slot loaded proximity coupled microstrip antennas with different dimensions were simulated and the best impedance matching and best 3-dB axial ratio bandwidth at 5.6 GHz were obtained when the stub length was 5 mm and with the truncation of 2 mm × 2 mm at two opposite corners of the patch. The length of the square patch was 10.5 mm and the dimensions of the microstrip line were 15 mm × 3 mm. The simulated results for the performances of proposed microstrip antenna with the variation of length of the stub line are shown in Fig. 4, where the length of the square patch was 10.5 mm and truncation of 2 mm × 2 mm at two opposite corners of the patch. The maximum 10 dB return loss bandwidth and the 3 dB axial ratio bandwidth were obtained when stub length was 5 mm. Stub length is zero when the feed line is just below the centre of the patch.

The simulated results for the performances of proposed microstrip antenna with the variation of truncated corner dimension are tabulated in Table 1.

Though the simulated 3 dB axial ratio bandwidths were achieved for other truncation dimensions, as shown in Table 1, but the lowest values of axial ratio are high (not less than 2.4 dB) and for corner

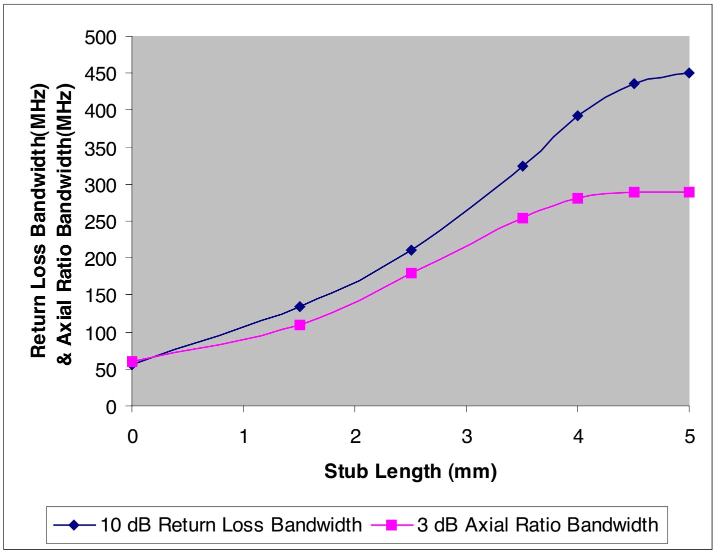

Figure 4. Variation of return loss bandwidth and the axial ratio bandwidth with stub length dimension.

Table 1. Simulated results for the performances of proposed microstrip antenna with the variation of truncated corner dimension.

Square V-slot loaded proximity coupled microstrip antenna with patch dimension of 10.5 mm and truncated in both the corners with microstrip line dimension of 15 mm × 3 mm and stub length of 5 mm.		
Truncation dimension	-10dB return loss bandwidth (MHz)	3dB axial ratio bandwidth (MHz)
1.0 mm × 1.0 mm	415	100
1.5 mm × 1.5 mm	425	165
2.0 mm × 2.0 mm	450	290
2.5 mm × 2.5 mm	430	210
3.0 mm × 3.0 mm	420	90

truncation of 2.0 mm × 2.0 mm lowest value of axial ratio was 0.45 dB. There was no appreciable change in 10 dB return loss bandwidth due to change in truncation dimension, as shown in Table 1 and small change in resonance frequency was observed.

The proposed proximity coupled microstrip antenna, as shown in Fig. 2, was simulated and the simulated input reflection coefficient is compared with measured result (measured using Vector Network Analyzer, PNA N5230A, Agilent Technologies) in Fig. 5.

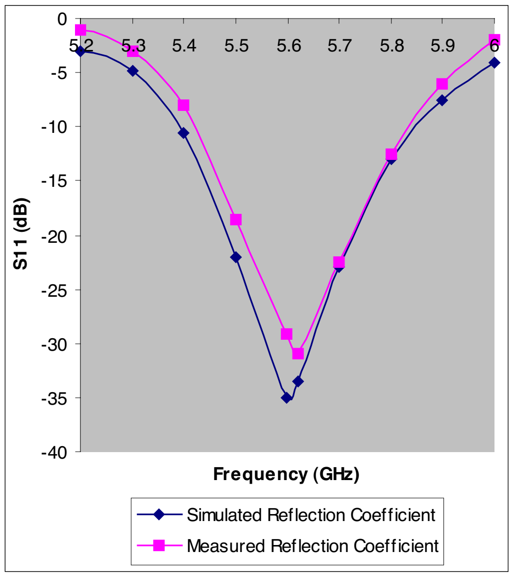

Figure 5. Simulated and measured reflection coefficients of the antenna.

The simulated and measured resonance frequencies were 5.6 GHz and 5.62 GHz respectively. The simulated and measured −10 dB return loss bandwidths were 450 MHz and 410 MHz respectively, covering the frequency range of HIPERLAN/2 which is 5.470 GHz–5.725 GHz. The antenna exhibits circularly polarized broadside radiation patterns.

In Fig. 6, the simulated and measured radiation patterns, on two principal planes, are compared.

Simulation, using IE3D (version 10.2) assumes infinite ground plane whereas in fabricated antenna prototype, the ground plane was 25 mm × 25 mm. The ripples in the measured radiation patterns in Fig. 6, are due to the diffraction effect from the edges of the small ground plane. The gain of the antenna was measured over the frequency range of HIPERLAN/2, using two identical proximity coupled microstrip antennas and measuring radiated power of the antenna, axial ratio was determined. For gain measurement, two identical antennas were designed to use as transmitting and receiving

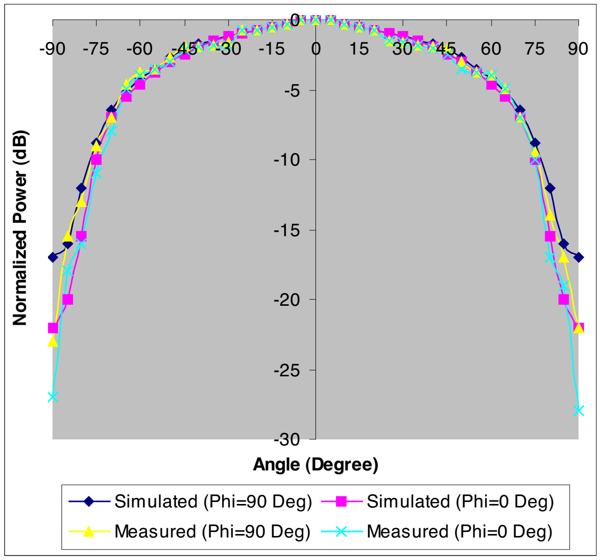

Figure 6. Simulated and measured radiation patterns of the antenna.

antennas and transmission coefficient (S_{21}) was measured. The two antennas were separated by a distance 'r' which must be more than the minimum distance to receive far field. One antenna was connected to the port 1 of the network analyzer and other antenna was connected to the port 2 of the network analyzer.

The transmitted power (P_t) and the received power (P_r) can be related to the transmission coefficient S_{21} by the expression

$$P_r/Pt = |S_{21}|^2$$

Then Friis transmission formula can be re-written as

$$|S_{21}|^2 = \left(G_r^2\lambda^2\right)/(4\pi r)^2$$

where gain of transmitted antenna (G_t) and received antenna (G_r) are same and λ is the wavelength corresponding to the frequency of measurement. That is, the gain of the receiving antenna is

$$G_r = (4\pi r/\lambda)|S_{21}|$$

The comparison of measured gain and axial ratio with simulated gain and axial ratio are shown in Fig. 7.

The minimum simulated gain over the frequency range of HIPERLAN/2 is 4.8 dBi with a maximum value of 5.1 dBi at the

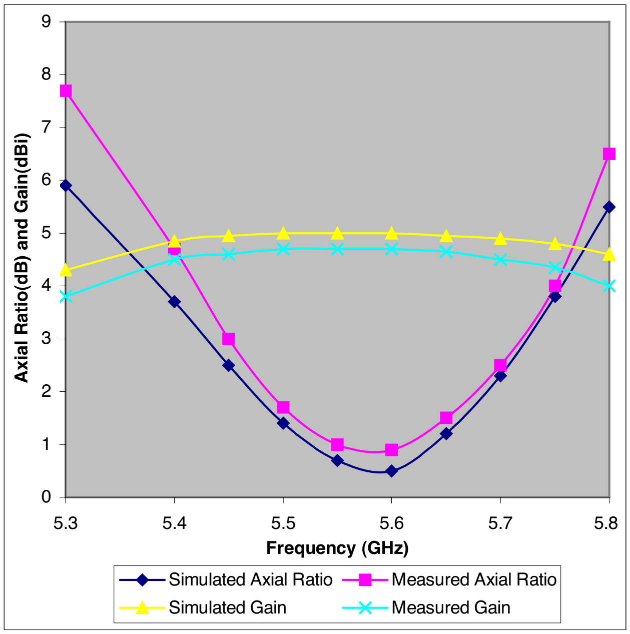

Figure 7. The comparison of simulated and measured axial ratio and gain of the proximity coupled V-slot loaded microstrip patch antenna.

frequency of 5.6 GHz. The simulated 3-dB axial ratio bandwidth is 290 MHz and measured 3-dB axial ratio bandwidth is 275 MHz. The small differences between simulated and experimental results, in all the cases, were due to the fact that multi-layered fabrication was not used for the design of the antenna module. The patch was designed on one substrate and microstrip line was designed on another substrate and then these two were pasted by a thin gum.

4. CONCLUSION

The principles of design of a circularly polarized microstrip antenna for the application in WLAN are described. The variation of performances of the antenna with the change of stub length dimension and corner truncation dimension are also reported here which are important information for proper design of the antenna. The simulated and experimental results on proposed circularly polarized proximity coupled microstrip antenna show that impedance bandwidth and axial ratio bandwidth of the antenna is very good at 5 GHz WLAN band and may be used for HIPERLAN/2.

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