International Journal of Scientific and Research Publications, Volume 3, Issue 11, November 2013
ISSN 2250-3153

Analysis of S-shape Microstrip Patch Antenna for Bluetooth application

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***Abstract*-** In this paper, S-shape microstrip patch antenna is investigated for wideband operation using circuit theory concept based on modal expansion cavity model. It is found that the antenna resonates at 2.62 GHz. The bandwidth of the S-shape microstrip patch antenna 21.62 % (theoretical) and 20.49% (simulated). The theoretical results are compared with IE3D simulation as well as reported experimental results and they are in close agreement.

***Index Terms*-** Microstrip Patch Antenna (MSA), Notch, Wireless, Bluetooth.

I. INTRODUCTION

The rapid development of wireless communication urges the need of wide and dualband antennas. Microstrip patch antennas (MSA) have found wide spread application in wireless communication industry due to their various advantages such as low cost ease fabrication, linearly and circularly polarization. Due to these advantages, many researchers worked on MSA; firstly, it was reported by Deschamp [1] while first experimental MSA was reported by Howell [2], and till now rapid development have been reported in the field of MSA. Further several designs of microstrip patch antennas are reported in this field, Deshmukh and Ray reported Analysis of Broadband Psi (Ψ)-Shaped Microstrip Antennas[3], Simulated and measured results for a S-shaped monopole patch antenna on a BiNbO4 layer[4], A compact microstrip slot antenna with novel E-shaped coupling aperture[5], Analysis of an H-shape cross slotted aperture-coupled microstrip patch antenna[6], FDTD analysis of a compact, H-shaped microstrip patch antenna[7], H-shaped microstrip patch antenna using L-probe fed for wideband applications[8], Design of an H-shape cross slotted aperture-coupled microstrip patch antenna[9], A tri-band H- Shaped microstrip patch antenna for DCS and WLAN applications[10], stacked H shaped microstrip patch antenna[11], experimental study of microstip patch antenna with an L-shaped probe[12], Compact and Broadband Microstrip Stacked Patch Antenna With Circular Polarization for 2.45-GHz Mobile RFID Reader[13]. Above reported papers lack theoretical analysis for S-shape notch loaded MSA and they have not compared theoretical and simulated results, these papers also lack equivalent circuits.

In this paper, the theoretical results of S-shape notch loaded MSA are compared with theoretical and simulated results. Details of the antennas design, theoretical, and simulated results are also presented and discussed.

II. ANTENNA DESIGN AND ITS EQUIVALENT CIRCUIT

The geometry of proposed S-shape microstrip patch antenna is shown in Fig. 1. The proposed antenna is loaded with two notches. The design specification of antenna is given in the Table 1. The microstrip patch is considered as a parallel combination of resistance (R_1), inductance (L_1) and capacitance (C_1) as shown in Fig. 2(a). The values of R_1, L_1, and C_1 can be calculated as:

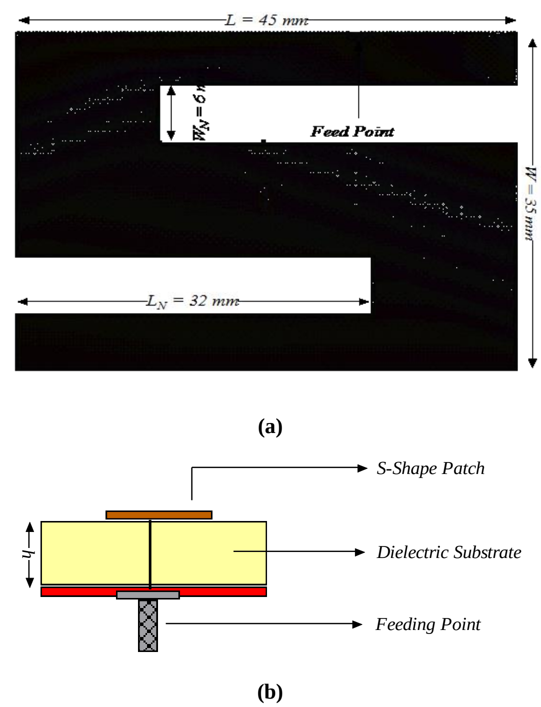


Figure 1. S-Shape notch loaded patch antenna (a) Top view (b) Side View

Table 1: Design specifications for different configuration of S shape MSA

Length of the rectangular patch (L)	45.00 mm
Width of the rectangular patch (W)	35.00 mm
Substrate Thickness (h)	10.50 mm
Length of the notch (L_N)	32.00 mm
Width of the notch (W_N)	06.00 mm
Dielectric constant of the material (ε_r)	1.07
Feed point location(x_o,y_o)	(8,17)

ISSN 2250-3153

$$R_1 = \frac{Q_T}{\omega C_1} \tag{1}$$

$$L_1 = \frac{1}{\omega^2 C_1} \tag{2}$$

$$C_1 = \frac{\varepsilon_0 \varepsilon_e LW}{2h} \cos^{-2}\left(\frac{\pi y_0}{L}\right) \tag{3}$$

where *L*, *W* is the length and width of the rectangular patch respectively. y_0 = feed point location, *h*= thickness of the substrate material.

$$Q_T = \frac{c\sqrt{\varepsilon_e}}{4fh} \tag{5}$$

where *c*= velocity of light, *f*=the design frequency, ε_e is effective permittivity of the medium which is given by [14]

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10h}{W}\right)^{-\frac{1}{2}} \tag{6}$$

where ε_r is relative permittivity of the substrate material.

Therefore, the impedance of the rectangular patch can be calculated from Fig. 2(a) as

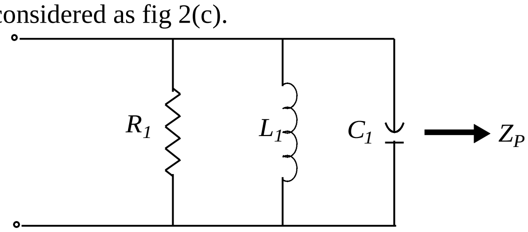
$$Z_P = \frac{1}{\left(\frac{1}{R_1} + \frac{1}{j\omega L_1} + j\omega C_1\right)} \tag{7}$$

In this rectangular patch two notches $(L_n \times W_n)$ are loaded, which cause the flow of two currents in the patch, one is the normal patch current which causes the antenna to resonate at the design of frequency of the initial patch; however, the other current flows around the notch resulting into second resonance frequency. Discontinues due to notch incorporated in the patch are considered in terms of an additional series inductance (ΔL) and series capacitance (ΔC) that modify the equivalent circuit of the RMSA as shown in Fig. 2(b), in which ΔL and ΔC can be calculated as [15]-[16]

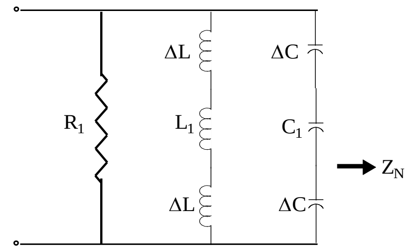
$$L_2 = L_1 + 2\Delta L \tag{8}$$

$$C_2 = \frac{C_1 \Delta C^2}{\Delta C^2 + 2C_1 \Delta C} \tag{9}$$

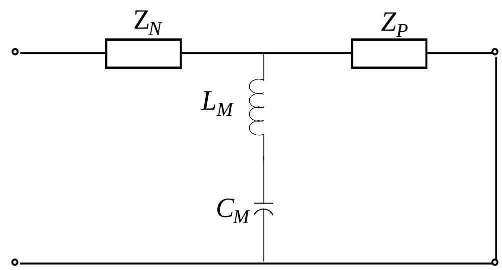
The value of the R_1 after cutting the notch is calculated by [17]. It may be noted that the two resonant circuits, rectangular patch and notch loaded patch are coupled through mutual inductance (L_M) and mutual capacitance (C_M). Thus the notch loaded patch can be considered as fig 2(c).



(a)



(b)



(c)

Figure 2. (a) Equivalent circuit of patch
(b) Equivalent circuit of notch
(c) Equivalent circuit of coupled S-Shape notch loaded patch antenna

The total input impedance of the S-shape notch loaded patch

$$Z_T = Z_N + \frac{Z_M Z_P}{Z_M + Z_P} \tag{10}$$

III. RESULTS AND DISCUSSION

Figure 3(a) shows the comparison between theoretical and simulated results for S-shape antenna and they are found in close agreement. Figure 3(b) shows the variation of reflection coefficient with frequency for different length (L_n) of S-shape antenna. On increasing the length of notch from 32 to 40 mm lower and higher resonance frequencies shift towards lower side.
Figure 3(c) shows the variation of reflection coefficient with frequency for different width of notch. On increasing the width from 6 to 8 mm, wideband is obtained and frequencies are shifted to lower resonance side, while for the notch width 7 mm to 7.5 mm lower and higher resonance frequencies having no significant change.

Figure 3(d) shows the variation of reflection coefficient with frequency for different height (*h*) of the substrate of S shape antenna. On increasing the height (*h*) of the substrate from 10.5 to 13.5 mm lower frequencies shifted towards lower side and higher resonance frequencies shifted towards higher side. Figure 3(e) shows the gain plot with frequency. The maximum gain of the antenna is obtained at center frequency 2.62 GHz is 8.1 dBi and 8.2 dBi theoretical and simulated values respectively. Which are found in close agreement with each other. Figure 3(f) shows the efficiency plot with frequency, it is found that theoretical and simulated maximum efficiency is 91.75 and 92.04 % respectively, which is obtained at center frequency 2.62 GHz.

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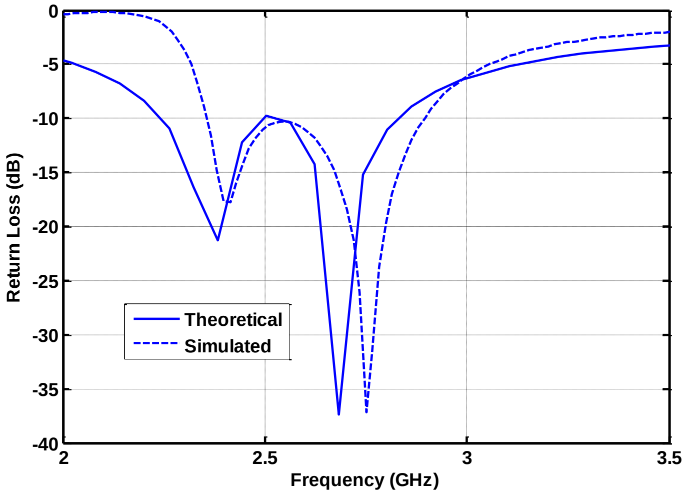

Fig. 3(a) Comparative plot of theoretical and simulated results for antenna

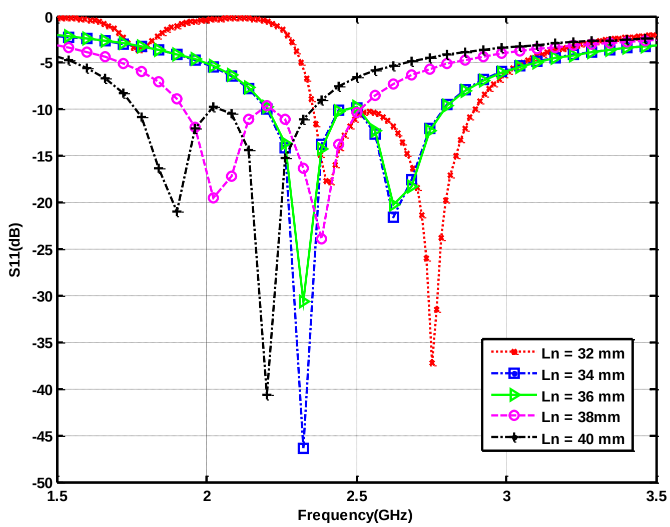

Fig. 3(b) Variation of reflection coefficient with frequency for different length of notch (*Ln*)

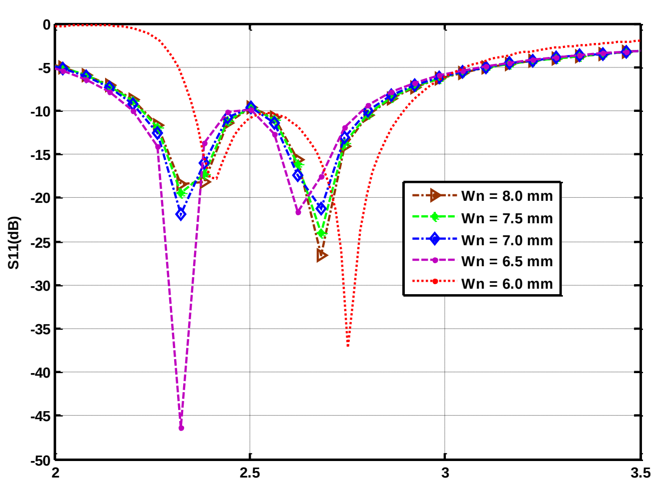

Fig. 3(c) Variation of reflection coefficient with frequency for different width of notch (Wn)

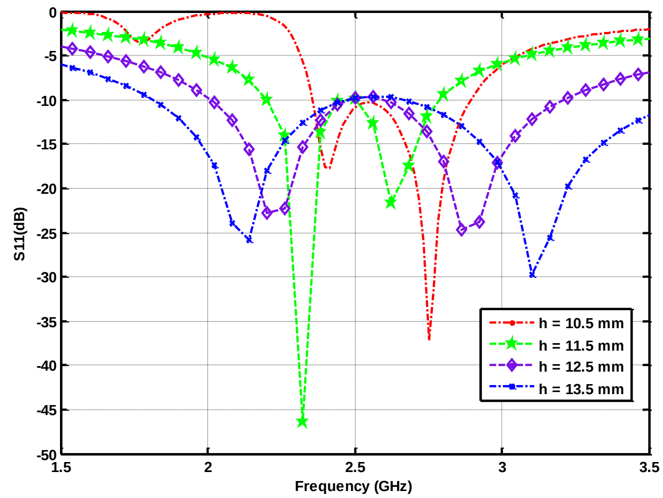

Fig. 3(d) Variation of reflection coefficient with frequency for different height of the substrate (*h*)

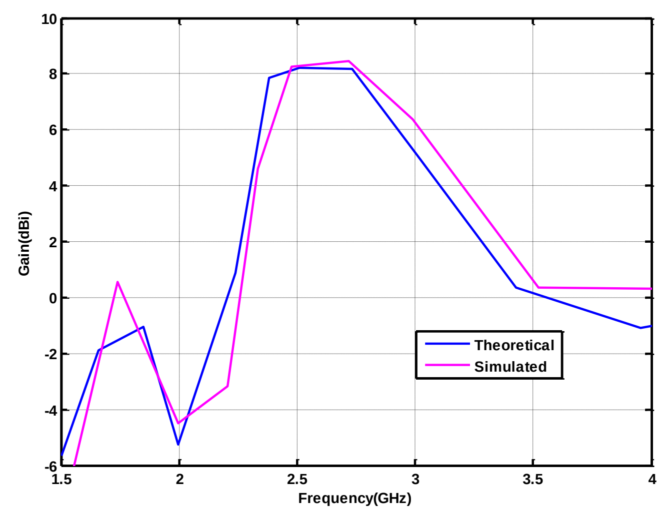

Fig. 3(e) Comparative plot of gain with frequency

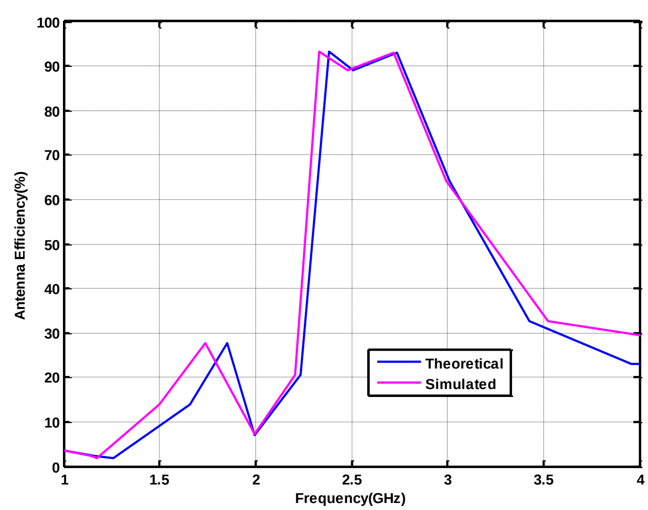

Fig. 3(f) Comparative plot of antenna efficiency vs frequency

IV. CONCLUSION

An analysis of S-shape MSA has been carried out. The S-shape MSA parameters depend on length of notch, width of the notch and height of the substrate. The theoretical and simulated results are in close agreement of S-shape MSA which has center frequency at 2.62 GHz and suitable for broadband operation with sufficient bandwidth and moderate gain, this antenna can be utilized in various wireless communication systems.

ACKNOWLEDGMENT

The author is very grateful to Maulana Azad National Fellowship, University Grant Commission, New Delhi for providing me financial assistance through senior research fellowship.

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