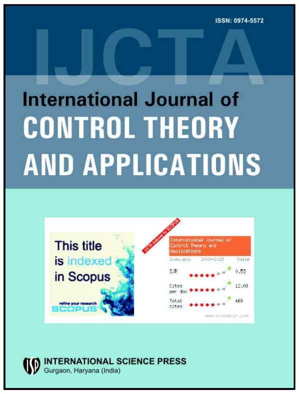

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Design of S-Shape Microstrip Radiator for Wireless Secured Communication

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Abstract: The role of antenna in wireless communication is very important. *Wireless security* is the prevention of unauthorized access or damage to computers using *wireless* networks. The most common types of *wireless security* are Wired Equivalent Privacy (WEP) and Wi-Fi Protected Access (WPA). So, a perfect design of antenna can show its performance. In this paper, a dual band design with inset feed for S- shape patch antenna is proposed that can work in Wi- Max/ S- band and C- band satellite application. The rectangular patch is used for S- shape by inserting the wide slots at the opposite faces of non radiating edges. FR4- epoxy material is used for the substrate whose thickness is of about 17 % of operating wavelength. By changing the electrical features of the rectangular patch with appropriate perturbation the performance of antenna show its performance for the above said applications. From the perturbation S- shape patch radiator and the bandwidth is improved which single is feed dual band. The simulation result proves a better impedance matching over the wide bandwidth as well as the better bandwidth performance than that of simple rectangular patch antenna and suitable for Wi- Max application as well as S- band and C- band application. The bandwidth for proposed antenna is of 140.6 MHz from 3.2971 GHz to 3.4377 GHz, 131.5 MHz from 4.3621 GHz to 4.2306 GHz (simulated) which is 1.8 to 2.5 times that of the corresponding un-slotted rectangular patch radiator. The results are shown for return loss, bandwidth and radiation pattern.

Keywords: Microstrip antenna, Wi-Max, multi band antenna, dual band antenna, broadband antenna.

1. INTRODUCTION

Antenna as because an important component in modern wireless communication that requires the study, analysis, modification and enhancement of performance of the antenna. As, there are many applications of antenna in the field of microwave engineering, navigation radar, biomedical engineering, satellite, telemetry and wireless communication, the requirement will be different. Based on these requirements the antenna is to be designed. Many cases the bandwidth has been enhanced by researchers, by changing the substrate, by using the slits and comparing the impedance bandwidth along with feed compatibility [1-5].

For a microstrip patch antenna bandwidth enhancement can be obtained, when foam substrate or a thick air is used. It has been shown that, an impedance bandwidth greater than can easily be achieved by embedding a pair of wide slits in the rectangular patch; with a probe feed [6]. In [7] K.F. Lee showed that a rectangular patch with U- slot by using coaxially fed can attain over 30% impedance bandwidth with good radiation characteristics. In this paper, design of S-shape patch is implemented and simulated results are presented with discussion. The experimental results include return loss, bandwidth and radiation pattern. Also S – shape patch antenna of dual frequency behavior is presented and investigated. Simulation results are obtained using HFSS. The simulated results confirm the dual band characteristics of the proposed antenna. Enhancement of bandwidth has been demonstrated in rectangular patch [8] or circular patch [9] by cutting U- slot. By introducing U-slot in the patch, two adjacent resonant modes near the fundamental resonant frequency with similar radiation characteristics of the simple patch radiator without the slot can be excited, which significantly enhances the antenna bandwidth. Also, due to introduction of slot in patch, the input impedance inductive reactance component is large for thick substrate associated with probe feed found to be reduced, makes the easier impedance matching. In [10], the demonstration was done by using a set of two right angle slots and using U- shaped slot with better impedance matching, the two resonant modes of $TM_{\delta 0}$, TM_{10} can be excited at the frequency which is very nearer to each other. The possible condition makes an improved bandwidth which is created by these two resonant modes for the rectangular patch. In [11] broadband triangular U- slotted patch antenna has been developed by using a coaxial feed and thick substrate due to capacitive reactance introduced by slot can be remunerated by the large inductive reactance which facilitates the impedance matching of the present broadband design. Apart from it in this paper, we have approached for a new shape as S-shape by the help of slits within the patch.

2. ANTENNA DESIGN

As the basis for the design procedure of S- shape patch for Wi-Max/ S-band and C- band satellite applications has been employed. The selection of irregularly shaped radiators in deigning integrated antennas provides broad-band or multi frequency operation [13]. When using S-shape patch in fact multiple resonances can be introduced in the antenna operation and in principle, they can be frequently placed along the frequency axis through a proper selection of the geometrical parameters. Since a single feed line is usually able to excite no more than two resonant frequencies, the subsequent design procedure will be based on the excitation of two resonant modes, exactly spaced in the frequency axis so that a broad band performance can be obtained.

2.1. Design Methodology

Microstrip antennas consist of thin metallic patch of thickness $t << \lambda_0$ etched on a substrate whose height is $0.0003\ \lambda_0 \leq h \leq \lambda_0$ in this case, wavelength in air is denoted by λ_0 and is placed on a ground plane. The patch length is in $\frac{\lambda_0}{3} < L < \frac{\lambda_0}{2}$ and due to the variation of operating frequency as in [14-15]. From the above condition the value of operating wavelength lies in between 2L and 3L. So based on that the general formula for the relation between resonant frequency and operating wavelength derived is:

$$f = \frac{c}{kL} \tag{1}$$

Where k varies from 2, 2.1………, 3.

2.2. Design Procedure

The antenna bandwidth is determined by the thickness, substrate dielectric constant and antenna geometry. To expose matter of bandwidth and to give a benchmark in terms of bandwidth and space in simple planar structures a rectangular patch has first been sized. The antenna dimensions can be derived from analytical expressions [15-16].

(a) Patch Width:

$$W = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

(b) Effective Dielectric Constant:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}}$$

(c) The change in length due to fringing effects:

$$\Delta L = 0.412h \frac{\left(\in_{reff} + 0.3\right)\left(\frac{W_{patch}}{h} + 0.264\right)}{\left(\in_{reff} - 0.258\right)\left(\frac{W_{patch}}{h} + 0.8\right)}$$

(d) Patch length:

$$L = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} - 2\Delta L$$

Where h = Substrate thickness, f_0 = Resonant frequency, ε_r dielectric constant

The factors for controlling bandwidth are increasing width of antenna. To obtain an appropriate result with a simple shape patch radiator, it is very difficult. That is why we propose an S-shape patch to widen the antenna bandwidth while keeping reasonable dimensions. This geometry changes the surface current density distribution generating multiple resonances.

The main purpose of designing S – shape patch antenna at 3.35 GHz, 4.25 GHz, and 4.3 GHz is to improve bandwidth and directivity for the Wi-Max / S- band & C-band Satellite application. The patch antenna's width is

Table 1
Design Specification of Patch Antenna

Parameter	*Value*
Substrate	FR4- epoxy
Center frequency (f_r)	2.32 GHz, 3.62 GHz
Substrate height (h)	1.6 mm
Loss tangent	0.02
Dielectric const.	4.4
Patch width (W_{patch})	38.04 mm
Patch Length (L_{patch})	29.44 mm
Feed width (w_0)	1.8 mm
y_0	5 mm
x_0	0.6 mm

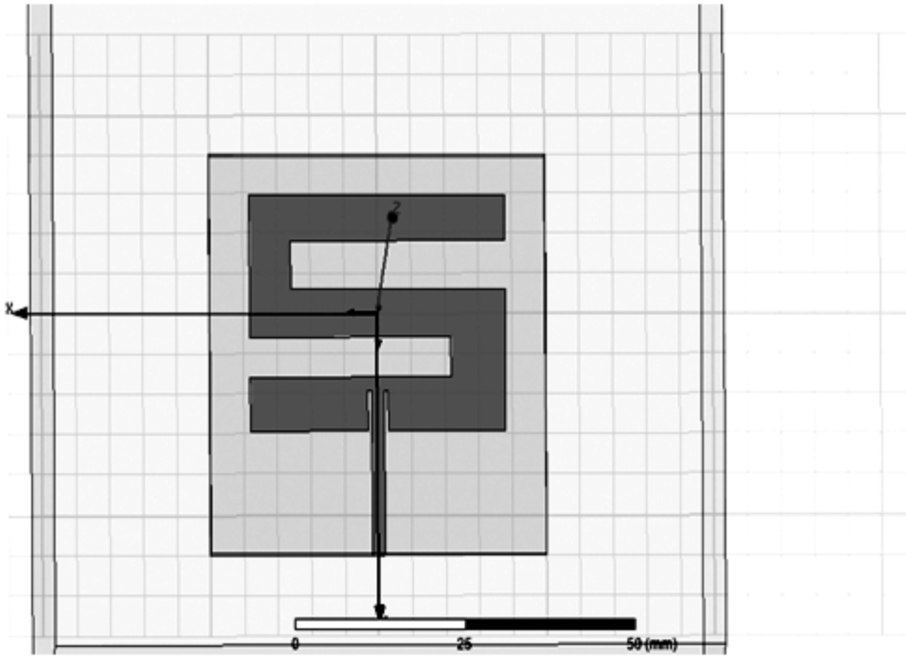


Figure 1: S - Shape patch antenna

usually chosen to be larger than the patch length to get higher bandwidth. Lower dielectric constant is used to design patch antenna. Because in lower dielectric constant substrate, surface wave losses are more severe and dielectric and conductor losses are less severe. The specifications for the rectangular patch radiator are given in Table 1.

2.3. S-shape Patch Antenna Design

The rectangular patch whose resonances are controlled by width and length dimensions have been taken to be designed to work in the Wi-Max/ S-band and C- band satellite application frequency range does not fulfill the bandwidth requirements as displayed in Fig. 5 (a). The Fig. 1 shows the perturbation of original shape for bandwidth impedance improvement of the antenna. Fig 1 and Fig. 2 show the geometry and configuration of the intended S-shape patch antenna, in which the design features are its width, length, transmission line length and width. The patch is fed by 50 Ω inset feed over a wide bandwidth for good excitation of the intended antenna. The two wide slots are of lengths L_1 and L_7 and of width L_2 and L_6 are placed at the opposite face of non radiating edge of patch which is approximately equal to the length of patch. The two slits of separation w_2 are placed symmetrically with respect to the center line of the radiating element (x axis and y axis). So, for the wide slits there are three parameters ($L_7 = L_1$, $L_6 = L_2$ and w_2) used here. Table 2 shows the specifications for the intended S- shape patch antenna.

Table 2
Design specification of S- shape patch antenna

Parameter	*Value*
L_1	30 mm
L_2	5 mm
L_6	6 mm
L_7	32 mm

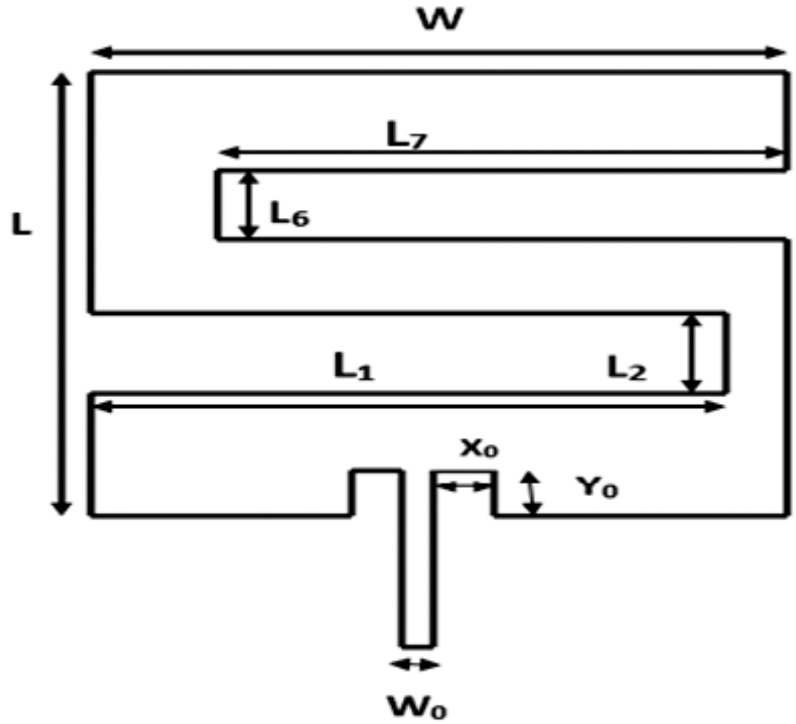


Figure 2: Patch configuration of S- shape patch antenna

3. EXPERIMENTAL RESULTS

The proposed antenna is to be used for Wi-Max / Satellite application. The simulation is simulated using Ansoft High Frequency System Simulator (HFSS). The S- shape patch antenna is to operate in the range of frequency from 96.1 MHz from 3.3759 to 3.2798 GHz, 120.4 MHz from 4.3 to 4.1796 GHz (simulated) A substrate having low dielectric constant is used for good efficiency, larger bandwidth and radiation. The objective is to get an improve bandwidth from the conventional patch. The S-shape patch antenna is designed for the operating frequency of 3.35 GHz, 4.25 GHz (simulated).

Both the calculated value of S- shape patch comes out to be 3.35 GHz, 4.25 GHz and 4.3 GHz with the antenna dimensions as given in Table 1, 2 and 3 and matches well with the observed value (equation(7)).

$$f_1 = \frac{c}{3L} \, and \, f_2 = \frac{c}{2.3L}$$

Fig. 3 shows the simulated return loss plot of rectangular patch and S- shape patch. Here return loss at 3.35 GHz is -22.011 db, at 4.25 GHz is -20.248 db (simulated) for S- shape patch.

Bandwidth % of rectangular patch antenna: 3.75% at 2.32 GHz and 2.48 % at 3.62 GHz.

Bandwidth % of S-shape patch antenna: 2.86 % at 3.35 GHz, 2.83% at 4.25 GHz (simulated).

For wide bandwidth and good impedance matching, the slit lengths L_1 and L_7 symmetrical to width of patch is found to be about 0.78 to 0.84W. Again, the two slits are symmetrical and parallel to width of patch. The width of the slots (6 mm) is of about the depth of inset feed (y_0) of the transmission line about 5 mm. The space between outer edges of the two slits L6+L_2+6 mm is about 0.57L. Again the two slits are cut from the top and buttom edge of the width 6 mm, because the antenna width is determined by the center frequency, substrate dielectric constant (ε_r) which is related by the mathematical equation

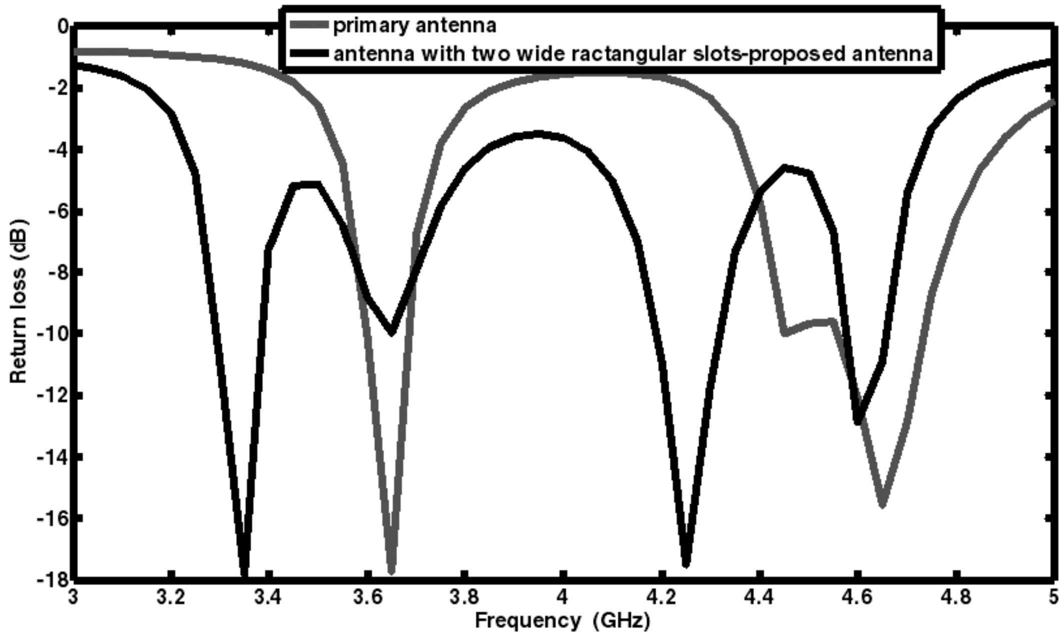


Figure 3: Simulated Return loss plot of S-shape patch Vs Rectangular patch

$$\text{dist} = 15.77\% \text{ of } W = 15.77\% \text{ of } \frac{c}{2f_c}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

From the feed point position the first slit is of 18 mm which is calculated from the relation:

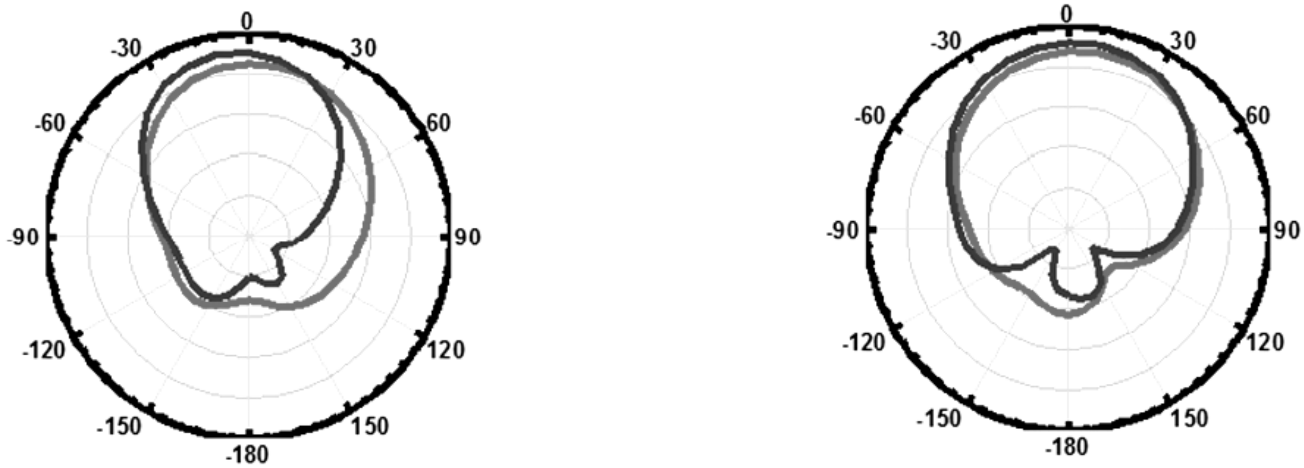
$$L - (\text{dist.} + L_6)$$

The I- shaped slot situated at the centre of the patch is 14 mm distance away from the feed position which is 47.5 % of L. The S-shape patch antenna resonate at two frequencies bands at 3.35 GHz, 4.25 GHz (simulated). The Fig. 5 shows two resonant frequencies which leads to a dual band bandwidth comparison to conventional rectangular patch antenna. These resonant frequencies are related to L_1, L_2 and L_6, L_7 and the dimensions are associated by the fact that the single excitation point must have impedance matching (50Ω) with the two resonant frequencies. This characteristic is different and better to that obtained for the wide slitted patch antenna which resonates at single resonant frequency [6]. It is observed that the bandwidth is wider as compared to conventional rectangular patch antenna with a center frequency of 2.32 GHz, 3.62 GHz.

In [10], the demonstration was done by using a set of two right angle slots and using U- shaped slot with good impedance matching, the two resonant modes of $TM_{\delta 0}$, TM_{10} can be excited at the frequency which is very nearer to each other. In that work the bandwidth was found only 53 MHz which is single band.

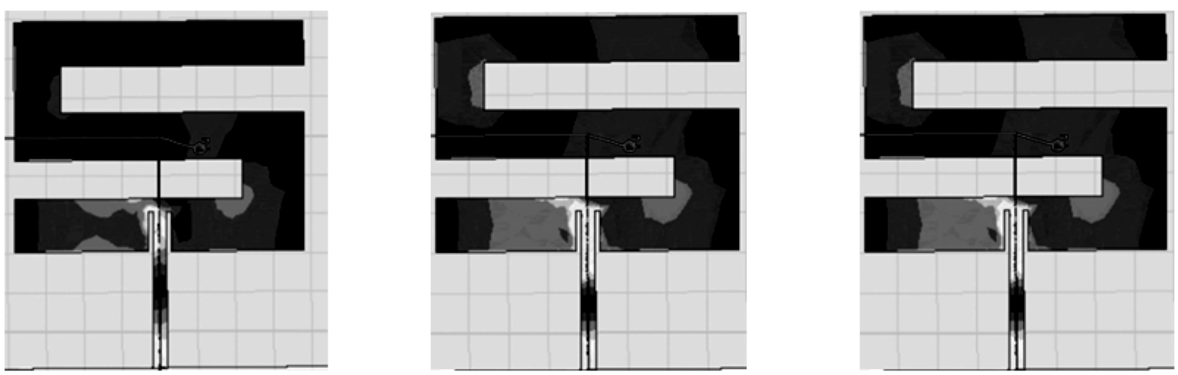
The antenna is to operate in the range of frequency from 140.6 MHz from 3.2971 GHz to 3.4377 GHz at 3.35 GHz, 131.5 MHz from 4.2306 GHz to 4.3621 GHz at 4.3 GHz (simulated) Its bandwidth is of 140.6 MHz from 3.2971 GHz to 3.4377 GHz, 131.5 MHz from 4.3621 GHz to 4.2306 GHz (simulated) which can be 1.8 to 2.5 times that of the corresponding un slotted rectangular patch radiator.

The S-shape patch antenna resonate at two frequencies bands at 3.35 GHz, 4.25 GHz (simulated) .The Fig .5 shows two resonant frequencies which leads to a dual band bandwidth comparison to conventional rectangular patch radiator. The simulated radiation pattern at different frequencies is stated in Fig. 4. The radiation pattern is large and better compared to radiation pattern obtained for the rectangular patch antenna, due to thick substrate (about 0.17 λ_0.



(a) **(b)**

Figure 4. Radiation pattern of S- shape patch antenna at (a) 3.05 GHz (b) 4.25 GHz, red for rectangular patch and black for S- shape patch



(a) **(b)** **(c)**

Figure 5: Simulated surface current density distribution on S- shape radiator at (a) 3.35 GHz (b) 3.05 GHz (c) 4.25 GHz

By using HFSS, the elevated radiating element's surface current distribution of the intended radiator is deliberated and resultant is shown in Fig. 5.

Results for three typical frequencies at 3.35 GHz, 3.05 GHz and 4.25 GHz are displayed. Here it is shown that the resultant resonant frequencies have same surface current distribution on the radiating element.

4. CONCLUSION

The S-shape patch antenna is proposed for multi frequency operations. The antenna shall be suitable for Wi-Max/ S- band & C- band satellite application. The S- shape patch antenna at 3.35 GHz, 4.25 GHz and 4.3 GHz for Wi-Max/ S- band & C- band satellite application was designed. The proposed S-shape patch antenna performs better than the rectangular patch antenna in terms of bandwidth which is the improved version.

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