Multiband Microstrip Antenna with Multiple Rectangular Slots

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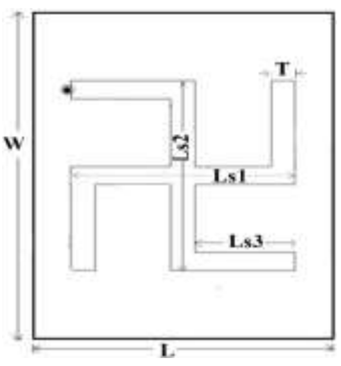
ABSTRACT
A compact multiband antenna with multiple narrow slits is studied. The reported antenna yields a multi-band response in the range of 5 – 8 GHz. But the effect of the multiple narrow slits on the lower order modes of the antenna is not mentioned. Hence, a parametric study of various slot dimensions is carried out and the effect of increasing slot length on the lower order modes is studied. Further, the equivalent dimensions of the same structure for operation at 900 MHz are calculated and the simulated and measured results for the same are presented.

Keywords
Microstrip antenna, multi-band response, multiple rectangular slots

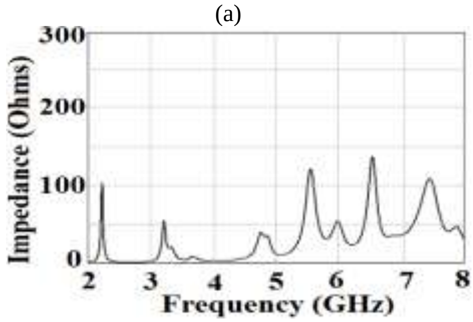
1. INTRODUCTION
Microstrip Antennas (MSA) have the advantages of being lightweight and having a low-profile planar structure [1]. They can also be made compact for use in mobile communication. Many modern day wireless mobile communication applications require the antenna to be compact and also operate over multiple frequency bands. To design multi-band MSAs various techniques like use of stacked patches [2 - 4], fractal antennas [5], use of shorting posts [6, 7], slots in the ground plane [8], etc. A multi-band response can also be obtained by cutting multiple rectangular slots as reported in [9].

In this paper, a multiband microstrip antenna with multiple rectangular slots is analyzed. First the structure reported in [9] is analyzed. The reported structure consists of a plus-shaped slot with rectangular slots perpendicular to each of the arms. The configuration yields a dual band response in the range of 5 GHz to 7 GHz and a wideband response in the range of 7 GHz to 8 GHz. In [9], results only in the range of 5 GHz to 8 GHz are mentioned. The analysis for the lower order modes of the structure have not been conducted. Hence a comprehensive parametric study of varying slot lengths is conducted. The current distributions at all frequencies for different slot lengths are studied and the identified modes are tabulated. The resonance curve and return loss plots for varying slot lengths have been presented. Further, the same structure is redesigned to operate at 900 MHz using resonance frequency formulations for RMSA [1]. The simulated and measured results for this structure are presented and it is observed that they are in good agreement with each other. All these antennas have been initially analyzed and optimized using IE3D software [12] on glass epoxy substrate ($\varepsilon r = 4.3$, $h = 1.6$ mm, $\tan \delta = 0.02$) followed by experimental verifications. The impedance measurements were carried out using R & S vector network analyzer whereas the pattern and gain were measured using R & S RF source and spectrum analyzer in minimum reflection surroundings.

2. MULTIBAND MICROSTRIP ANTENNA WITH MULTIPLE RECTANGULAR SLOTS
Fig 1 shows the geometry of the configuration reported in [9]. The length of the patch, L=26mm and width,W =37.5mm and the dimensions of the slots are LS_1=19.5 mm, LS_2=21.5 mm,LS_3=8.7mm.The return loss and resonance frequency plots that are reported, have been simulated and measured only from 5.5 GHz to 8 GHz. A study of the lower order modes of the configuration has not been presented. Fig 2 shows the resonance frequency plot ranging from 2 GHz to 8 GHz. It is observed that the fundamental TM10 mode of the patch is obtained at 2.198 GHz.



(a)



(b)

Fig 1: (a) Geometry and (b) resonance frequency plot of the reported configuration.

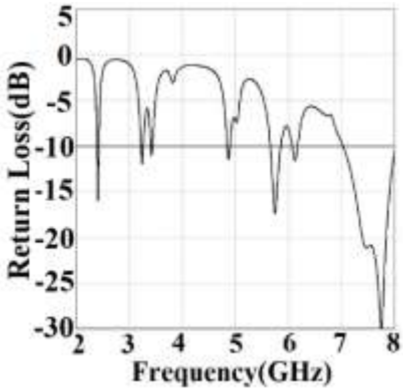
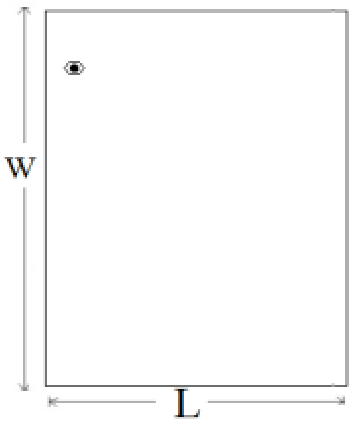
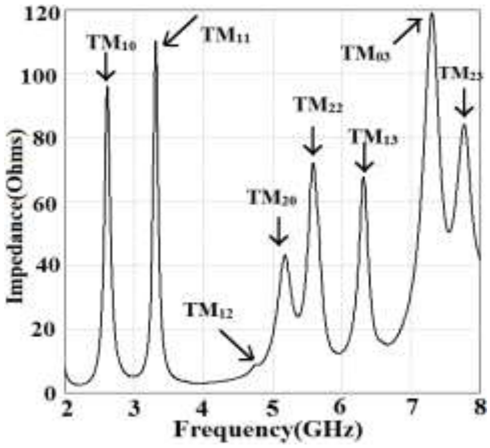


Fig 2: Return loss plot of the reported configuration.

In order to analyze the effect of cutting narrow slits within the patch, a parametric study of various lengths of the slits is carried out. First, a rectangular patch of the same dimensions with no slots is simulated. Fig 2 shows the resonance frequency plot for the RMSA. The current distributions at each frequency is studied and the mode of distribution is noted as shown in the figure. It is observed that the patch resonates at 2.198 GHz at its fundamental TM_{10} mode.



(a)



(b)

Fig 3: (a) Geometry and (b) resonance frequency plot of the RMSA without slot

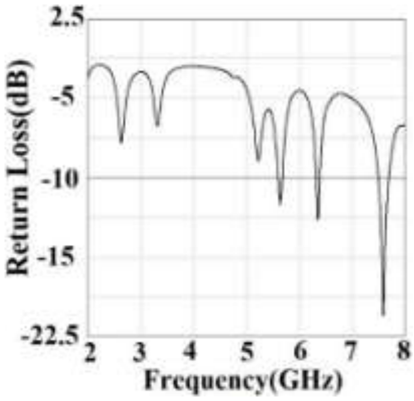
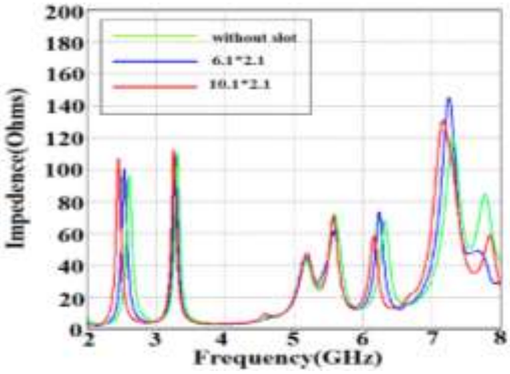
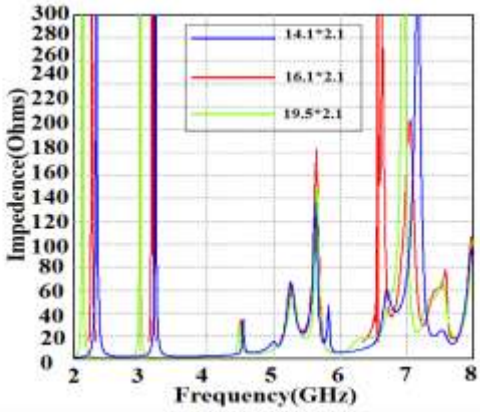


Fig 4: Return loss plot RMSA without slot

Then, a plus-shaped slot is cut at the center of the patch and the lengths of all the arms are increased and the effect of increasing length on the lower order modes of the patch is studied. Fig 5 (a) and (b)show the resonance frequency plots for varying slot lengths. The slot length is varied from 0 mm to 19.5 mm and optimum results are obtained for a slot length of 19.5 mm.



(a)



(b)

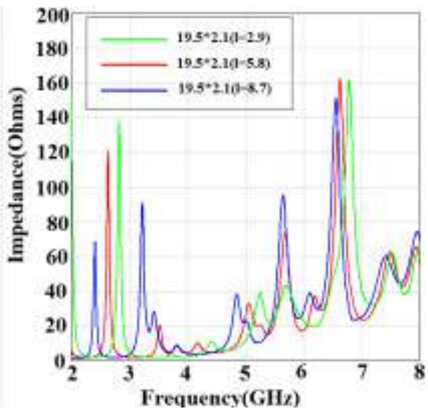
Fig 5: Resonance frequency plots for slot lengths varying from (a) L=0 and (b) L=19.5mm

It can be observed from the graphs that as the length of the slots is increased, there is a slight decrease in impedance which results in better impedance matching. Also, the lower order modes shift to lower frequencies with increasing slot lengths. The current distribution for all frequencies at different slot lengths is studied and the modes are identified and tabulated in table 1.

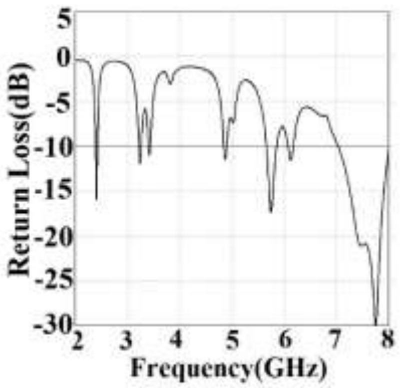
Table 1:TM Modes for various slot dimensions

Modes	6.1*2.1	10.1*2.1	14.1*2.1	16.1*2.1	19.5*2.1
10	2.543	2.612	2.458	2.252	2.108
11	3.285	3.2	3.27	3.14	2.96
12	4.649	4.748	4.49	4.472	4.436
20	5.172	5.18	5.164	5.216	5.24
21	5.556	5.66	5.6	5.612	5.576
23	7.703	7.722	7.741	6.994	6.848
13	6.624	6.32	7.176	---	---
03	---	----	----	7.388	7.388
14	---	----	----	7.88	7.88

Further, rectangular slots that are perpendicular to the existing slots are cut at each end of the slots. On doing so, we obtain the original configuration reported in [8]. The resonance curves for varying lengths of these additional slots is shown in Fig 6. The slot lengths are varied from 2.9 mm to 8.7 mm. It is observed that the lower order modes shift to even lower frequencies and the impedance decreases further.



(a)

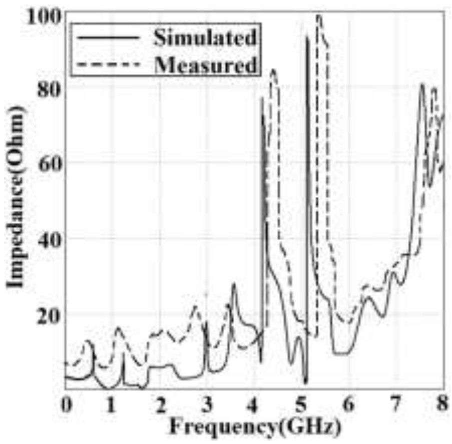


(b)

Fig6(a):Resonance frequency plot for varying slot length $Ls_3$and(b)Return loss plot for optimized configuration

From the parametric study of varying slot lengths and the analysis of current distributions conducted above it can be inferred that the second order TM_{23} and TM_{23}modes are responsible for the dual band response obtained in the range of 5 GHz to 7 GHz and the third order $TM_{13}$and TM_{03} are responsible for the wideband response obtained in the range of 7 GHz to 8 GHz. The same structure is then redesigned to operate at its fundamental TM_{10} mode at 900 MHz. The dimensions are calculated using the resonance frequency formulations for RMSA [1]. Thedimensions of the patch are length L=26mm and width =37.5mm and the slot dimensions areL_{S1}=19.5 mm, L_{S2} =21.5 mm, LS3=8.7mm. The fabricated prototype of the antenna is shown in Fig 7(a). The simulated and measured resonance frequency and return loss plots are given in Fig 7(b) and (c)respectively.

(a)



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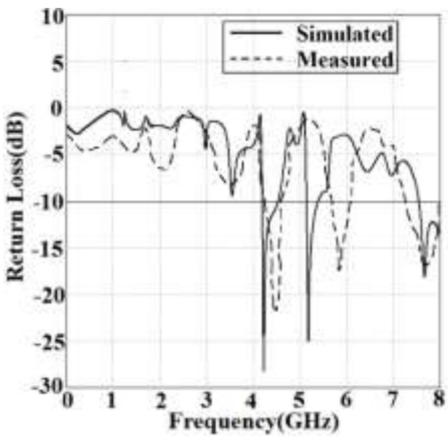

(c)

Fig 7 (a):Geometryof and (b)Return loss plot ofand (c) Resonance curve of fabricated prototype

3. CONCLUSION

A compact multiband antenna with multiple narrow slits is studied. In the reported paper, the results only in the range of 5 – 8 GHz and not for lower frequencies. Hence in order to study the lower order modes for this configuration, a parametric study of varying slot lengths is presented. It is observed that optimum results are obtained for slot lengths of 0 mm and 19.5mm. The current distribution for all frequencies for different slot lengths is also studied. With an increase in slot lengths, the lower order modes shift to lower frequencies. Also, it can be concluded that the dual and wideband response is obtained due to the TM_{21}, TM_{23} and TM 03, modes respectively. Further, the equivalent dimensions of the same structure for operation at 900 MHz are calculated and the simulated and measured results for the same are presented. The future scope of the proposed antenna lies in further detailed analysis of a dual band dual polarized structure. Also the effect of the addition of a stub to the proposed configuration will be studied.

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