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Designs of Controllable Dual Band Planar Monopole Patch Antennas

K.S. Alimgeer[1], Nihala Khalid[1], S. A. Khan[1], S. A. Malik[1]
and R. M. Hashmi[2]

[1]*Comsats Institute of Information technology /Electrical Engineering,*
Islamabad, Pakistan
[2]*Graduate Student/ Department of Electronics and Information,*
Politecnico di Milano, Milan Italy
khurram_saleem,nihalakhalid,shahidk,smailk@comsats.edu.pk,
raheel.hashmi@mail.polimi.it

Abstract

The designs of dual band microstrip patch antennas because of their multi-functionality are becoming popular. Satellite mobile and fixed communication for Space Research, Met. Satellite, Radiolocation, Meteorological aids, aeronautical Radio navigation data and analysis has got lot of attentions in the recent years. Achieving selected multiband operation requires precise bandwidth and mutually exclusive resonating bands. Several designs with a bit modification in the basic design are proposed by placement of appropriate slots to achieve multi-band functionality in this paper. Proposed design deals with the four slot patch antenna that can control dual band operation in the range of 1.5 GHz - 2.5 GHz and 6 GHz - 10 GHz. Stable radiation patterns for the whole frequency range and for all the applications are achieved. Wide band impedance matching is achieved through slot dimension variations near feed line. Mathematical model for the resonant frequency as a function of dimensions of the slots is also proposed in the paper.

Keywords: *dual band microstrip patch antennas, slot patch antenna, dual band*

1. Introduction

In the past few years' extensive work has been done on the microstrip antenna through the little modifications as Mobile communication systems has gained unplugged popularity. Especially, satellite mobile and fixed communication has increased due to their huge demands and applications. Due to antenna's Multiband characteristic their demand has been greater than ever for dual or multi communication applications. For this purpose, techniques have been developed that afflicts impedance matching and improving bandwidth of the antennas. Several techniques have been proposed and implemented for improving the impendence bandwidth and multiband characteristics. Some of the techniques to improve bandwidth, impedance matching, gain and multiband characteristics are like diamond shape slot [1], inverted L-shaped feed line [2], fractal patch [3], microstrip patch antenna array [4], stacked patch [5] and different shaped slots [6]

Multi-band characteristics can be achieved through feed operation and introducing slots in the radiating patch area. The dimensions of the slots, both lengths and width are used for tuning the resonating bands [7]. The trends observed while slot varying the dimensions, discussed in this paper.

The idea proposed in this paper is to introduce two slots near the feed line and two at the corners of the patch to provide more radiating edges. Introducing the two slots near feed line facilitate to have dual-band behavior [8]. Variation in the dimension, both length and width, tunes the higher and lower resonating bands, while observing the band shifting trends discussed herein.

Section I describes the introduction. In Section II, the geometrical structure of antenna model is discussed. Section III describes the trends of dimensional variation of slots, while keeping their placement on the patch as fixed. Section IV demonstrates the compliance of measured results with the simulated ones, whereas Section V concludes the paper.

2. Proposed Geometry

The proposed idea of the patch is a small square of dimension 15 x 20 mm^2 fed by a transmission line. Figure 1 shows the proposed design with the vertical type slots on the radiating surface. Two symmetric slots are place at two edges of the patch area and two symmetric slots are placed near the transmission line [4]. Each slot has dimension of 2 x 14 mm^2 while varying the length L_s from 2 mm to 14 mm with the step size of 1 mm for the S2 and S3 keeping the other dimension as constant. Similarly, varying the width W_i from 1 mm to 6 mm with the step size of 1mm keeping the other dimensions constant, for S1 and S4. The results are observed for all the possible dimensions of S1, S4 and S2, S3. Table I contains the specifications of the patch.

Table 1. Specifications Adopted For The Simulated Inverter

Parameter	Size (mm)
L_p	15
W_p	20
L_f	10
d	2
L_g x W_g	5 x 30
W_o x L_o	2 x 14
W_i x L_i	Variable
S2 ,S3	Variable
S1, S4	Fixed

It is observed that the inserted slots have more concentration of current especially around the transmission line as shown in Figure 2. It is also observed that due to constructive and destructive interference, central point of transmission line exhibits a null in current distribution. Current distribution on the patch can be modified using placement of the slots at appropriate positions [3].

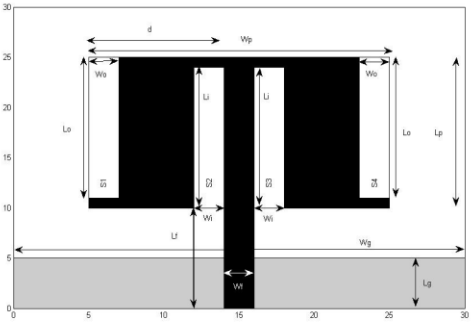

Figure 1. Proposed Design of Antenna

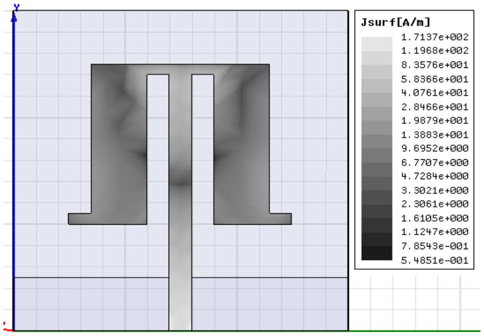

Figure 2. Current Distribution of Proposed Design of Antenna

3. The Trends of Dimensional Variations of Slots

3.1 Trends Observed by Width of Outer Slot

Similarly varying the width W_o of the outer slots at a fixed length of 14 mm and keeping dimension of the S2 and S3 as constant. Variations are performed at the regular interval of 1mm from 1 mm to 6 mm where initially these slots were dimensioned at 1 x 2 mm^2. It is found through simulations that there are slight variations in their band width and return loss. Some of the selected return loss dB against frequency GHz of outer slot variations is shown in Figure 3 and simulated plots in Figure 4.

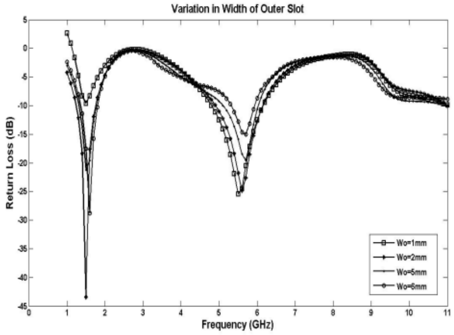

Figure 3. Effects of variation in the width of outer slots S1 and S4 while observing variation in width from 1 mm to 6 mm keeping other dimensions as constant

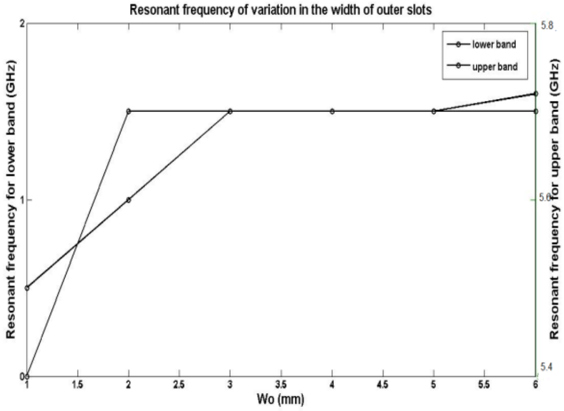

Figure 4. Simulated plots of resonant frequency of variation in the width of outer slots S1 and S4 while observing variation in width from 1 mm to 6 mm keeping other dimensions constant

3.2 Trends Observed by Outer Slot Length Variations

In this section, it is observed the variation in the length L_o of the S1 and S4 slots have effects on resonating frequency with width and dimensions of other slots as constants. The variation has been observed at the regular interval of 1 mm starting from 2 mm to 14 mm where initially these slots are dimensioned as 2 x 2 mm^2. Experimental results exhibits that there is no significant difference except for a little drift in the resonant frequency for the lower band. This observation leads to keep length as fixed at 14 mm. Some of the selected return loss dB against frequency GHz of outer slot variations is shown in Figure 5 and simulated plots in Figure 6.

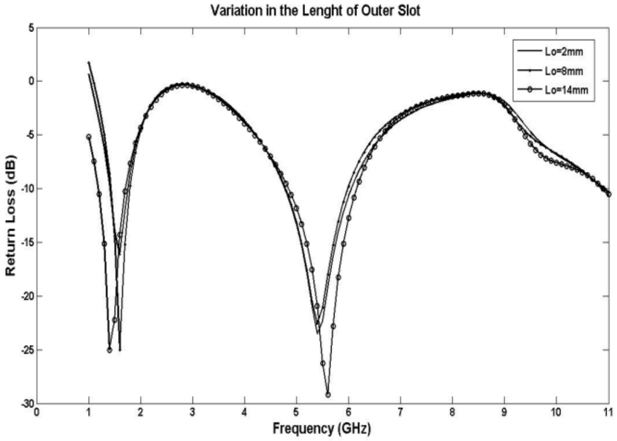

Figure 5. Effects of variation in the length of outer slots S1 and S4 while observing variation in length from 2 mm to 14 mm keeping other dimensions constant

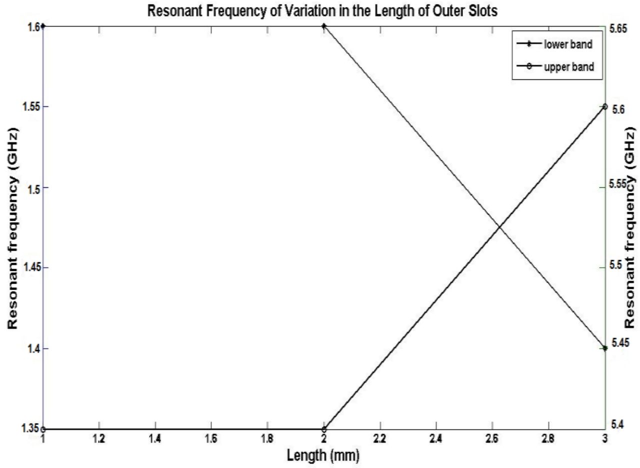

Figure 6. Simulated plots of resonant frequency of variation in the length of outer slots S1 and S4 while observing variation in length from 2 mm to 14 mm keeping other dimensions constant

3.3 Trends Observed by Width Variation in Inner Slot

In this section, variations in width W_i of S2 and S3 has been observed at the regular interval of 1mm from 1 mm to 6 mm where initially these slots were dimensioned at 2 x 2 mm^2. Figure 7 shows that there is little shift in the upper band while keeping the lower band as fixed. Some of the selected return loss dB against frequency GHz for outer slot width variations is shown in Figure 7 and simulated plots in Figure 8.

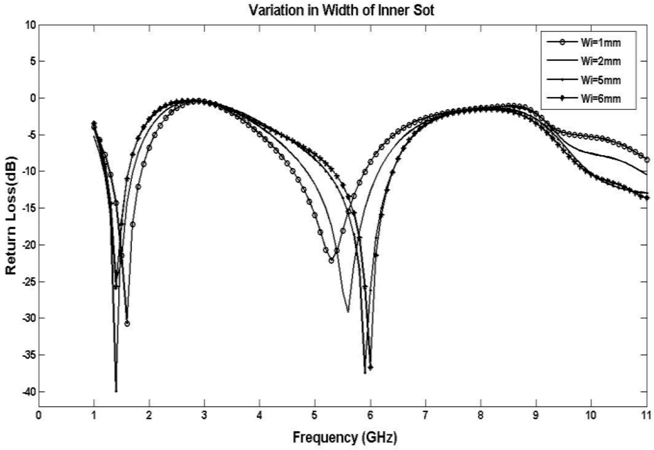

Figure 7. Effects of variation in width of the inner slots S2 and S3 while observing variation in width from 1 mm to 6 mm keeping other dimensions constant

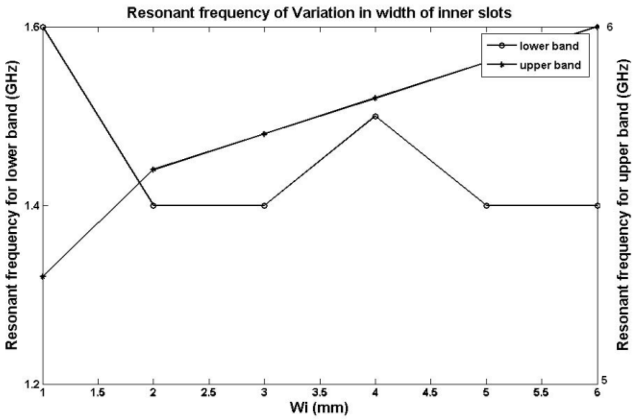

Figure 8. Simulated plots of resonant frequency of variation in the width of inner slots S2 and S3 while observing variation in width from 1 mm to 6 mm keeping other dimensions constant

3.4 Trends Observed by Length Variation in Inner Slot

A fixed dimension of 2 x 14 mm^2 is selected for S1 and S4 as variation in dimensions for these slots have minute effects on return loss as described in previous section. In this section, observations of resonant frequencies with the variation in slot length L_i of S2 and S3 slots near transmission line on the surface of the patch are taken. Initially these slots were placed near transmission line and dimensioned as 2 mm while their length L_i is varied from 2 mm to 14 mm with the step size of 1 mm keeping the constant width W_i. Three important trends have been observed with the variations in the length i.e. firstly, bands shifting towards the lower frequency without an increment in the patch size. This is very important result as the frequency of operation is usually considered as function of length of patch; Secondly, new bands are commencing in the high frequency range and showing multiband behaviour as the length of S2 and S3 slots near the transmission line increased; thirdly bands are becoming narrower. The advantage can be taken out from narrow bandwidth is to achieve specific band according to the standard [4] and had less interference in other bands operating in that particular range. Figure 9 shows the results which are observed for all the possible variations in length of S2 and S3 slots, results are observed and bracketed in the range of 1 GHz - 11 GHz. Some of the selected return loss dB against frequency GHz of inner slot variations is shown in Figure 9 and fitted plots in Figure 10.

The simulation results are then used to formulate a mathematical expression using method of least square error [9, 10].The modelled and simulated results are shown in Figure 11. The modelled results can be formulated in mathematical relation as described in 1.

$$f\left(x\right)=\frac{a\times c}{2L\sqrt{\varepsilon_r}}+b \qquad (1)$$

where f is the resonant frequency in GHz, L is the length of the inner slot, a and b are the constants and found through method of least square errors a =3.5743e-7 and b =3.944.

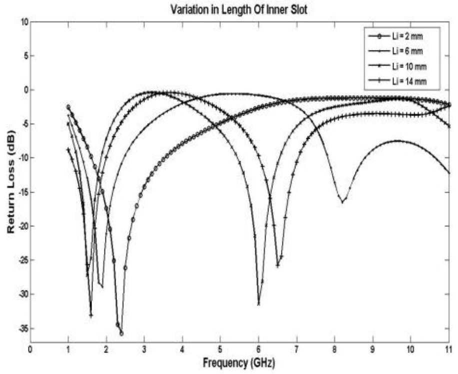

Figure 9. Effects of variation in the length of the inner slots S2 and S3 while observing variation in length from 2 mm to 14 mm keeping other dimensions as constant

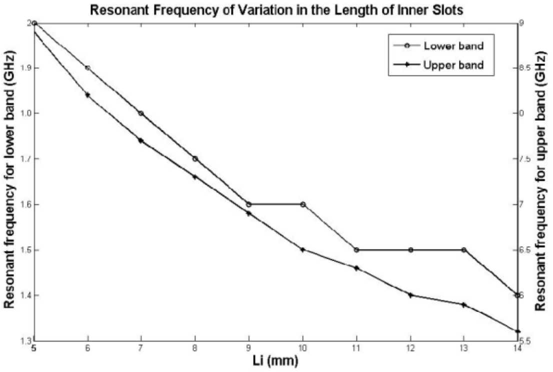

Figure 10. Fitted plots of resonant frequency of variation in the length of inner slots S2 and S3 showing observation from5 mm to 14 mm while observing variation in width from 2 mm to 14 mm keeping other dimensions constant

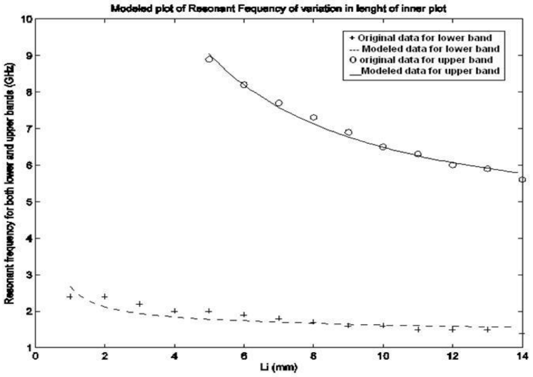

Figure 11. Modelled and simulated plot for variation in length of the inner slots S2 and S3 while observing variation in length from 1 mm to 14 mm keeping other dimensions constant

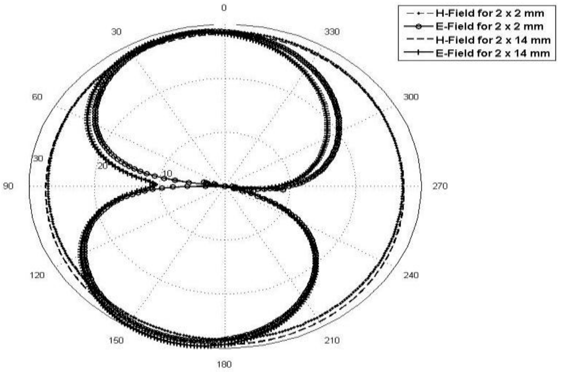

Figure 12. Simulated radiation pattern of the antenna for length of inner slots S2 and S3 of dimension 2 x 14 mm^2

3.5 Simulated vs. Fabricated Results of Final Design

The prototype is verified for acquiescence using Agilent PNA-X series Network Analyzer Model-N5242A. Figure 13 shows the Fabricated vs. Simulated Result of final design. The dimension for final design is selected to be 2 x 14 mm$^{2.}$ It is observed that the close harmony between simulated and fabricated results for return loss and VSWR. The fabricated prototype has patch size of 15 x 15 mm, etched over 30 x 30 mm ground plane.

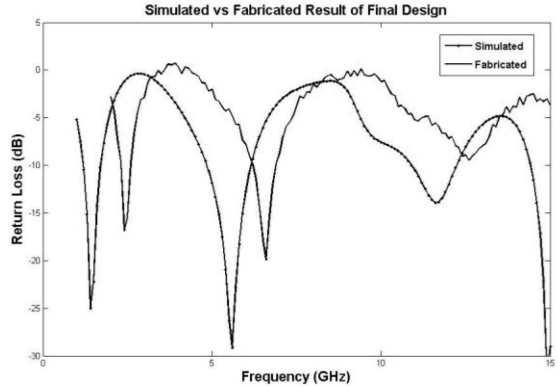

Figure 13. Simulated vs. Fabricated result of Final design of the antenna

4. Conclusion

Analysis can be utilized to design four slot patch antenna having dual band operation in the range of 1.5 GHz-2.5 GHz and 6 GHz-10 GHz and have controllable resonant frequency for both upper and lower bands. It is observed that the length of inner slots near transmission line is major factor to control the resonant frequency. Stable radiation patterns for the whole frequency range and for all the applications are achieved. Wide band impedance matching is achieved through slot dimension variations near feed line. Mathematical model for the resonant frequency as a function of dimensions of the slots is also presented.

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Authors

Khurram Saleem Alimgeer

K. S. Alimgeer did his Bachelors degree in IT in 2002 and completed his MS in Telecommunications (Gold Medal) in 2006. He has been with Dept. of Electrical Engineering, Comsats Institute of Information Technology (CIIT) since 2003. He is active researcher and supervising extensive research work at Bachelors and Masters Level. Currently, he is Assistant Professor at CIIT and is also working as doctoral researcher. He has published research papers in the field of Wireless Communications, Image Processing & Antenna Design.

Nihala Khalid

Nihala Khalid did his Bachelor's degree in Telecommunication engineering in 2010. She has been with Dept. of Electrical Engineering, Comsats Institute of Information Technology (CIIT) since 2011.

Dr. Shahid Ahmed Khan

Professor, Electrical Engineering, CIIT Islamabad, Pakistan. Professor/Dean Faculty of Engineering Research Publications: 40-papers published in International journals/conferences Research Area: RF Communications

Dr. Shahzad A. Malik

Chairman Faculty of Engineering Research Publications: 40-papers published in International journals/conferences Research Area: Networks and Communications.

Raheel Maqsood hashmi

Raheel Maqsood hashmi did his Bachelor’s degree in Telecommunication engineering in 2009 and his MS in Telecommunications in 2011 from 5Graduate Student/ Department of Electronics and Information, Politecnico di Milano, Milan Italy.