Multiband Patch Antenna for Wireless Devices

Manjiri Gogate
Electronics and Telecommunication
SLRTCE, Mira Road
manjiri_3980@rediffmail.com

Aditya Desai
Electronics and Telecommunication
SLRTCE, Mira Road
aditya_d15@yahoo.com

Madhuri Bhujbal
Electronics and Telecommunication
SLRTCE, Mira Road
bhujbalmadhuri@yahoo.com

Abstract — In this paper, a novel microstrip antenna is designed, fabricated and experimentally verified for operation in various bands like GPS, WI MAX and WLAN bands. This microstrip patch antenna is based on a DSP antenna design with U-shaped slots and resonant strip to achieve the wideband operation required to meet the specifications. The effect of variation of dimensions and locations of the U- slots and resonant stripe are studied thoroughly to get an appropriate design. It can sever most of wireless communication applications that operate between 1 GHz to 12GHz and require wide band characteristics. The antenna is planner and will be printed on both the sides of FR4 substrate which adds compactness to it, so as to easily embed it in any portable appliances.

Keywords—*Microstrip antennas; Wi MAX; mobile antennas; WLAN; GSM; Bluetooth; wideband antennas***.**

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I. INTRODUCTION

The rapid increase in communication standards has led to greater demands for antennas with low size, low cost of fabrication and ease of integration with various feeding network [1]. Numerous applications were developed after designing of multiband antennas with desired slots which makes antenna conformal with arrays, reduces the size of the antenna to avoid the usage of two or more antennas for multiband responses. Practical requirements in wireless communication systems are to decrease the size of current antenna while providing acceptable performance over the frequency bands [2] and [3].

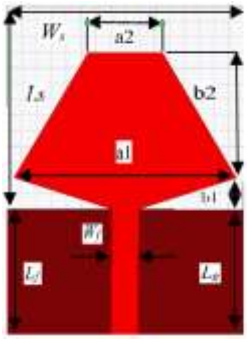


Fig. 1. Base DSP antenna

Multiband printed monopole antennas can be designed in two ways which are reported here [4]. One way is to design a small-size antenna to cover the highest frequency band and then add an extra resonant element to the main body to incorporate lower frequency bands. The second way is to first design a patch antenna to cover the desired lower frequency band which increases the size of the antenna. Then to create the multi-band behavior, notches are introduced into the antenna. In this paper a U-shaped resonant element is added to integrate the lower frequency band with the base UWB monopole antenna.

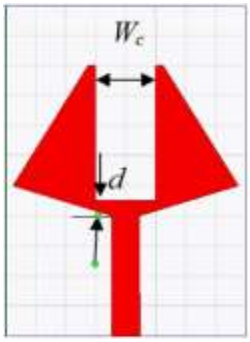


Fig. 2. DSP antenna with notched.

In this communication, an antenna that covers UWB frequency band is considered as base antenna to create a multiband antenna [5]. DSP patch antenna fits this requirement the best. Multiband behavior is achieved by inserting a notched region and adding a quarter-wavelength strips in the center part of the base antenna. The novelty of this method is that Resonant strip is applied to notch region of the base antenna without affecting the response in UWB band of the antenna and get a wide lower band at about 1 GHz, this is because the resonant strip can be directly connected to the main base radiating patch, hence making the antenna easy to design and fabricate [6] -[9]. The antenna covers WWAN, WLAN, Wi MAX operation, and some of the band in GSM and for Bluetooth operation. The size of the proposed multi-band antenna remains same as the base antenna substrate even after adding the notches and resonant strip [10]. Details of which are presented here, and a prototype of the proposed design has been constructed and studied experimentally. The effects of some parameters on the performance are analyzed and discussed with the simulation results. The simulation is carried out via the HFSS software package [11].

II. ANTENNA DESIGN

The structure shown in Fig. 1 is used as the base for the proposed multi-band antenna, operating over UWB frequency band [3]. The base antenna which covers UWB range can be referred to as the DSP antenna. The antenna has a dimension of 16 x 22 x 1 mm which can be fabricated on an FR4 substrate with dielectric constant of 4.4 and a loss tangent of 0.02. The width of microstrip fed line W_f is kept 1.86 mm to achieve 50 ohm characteristic impedance, and is connected to the base antenna via a length of line L_f. A rectangular ground plane is placed on the back side of the substrate with the width W_s and length L_g.

In designing the multi-band antenna, the base DSP antenna is considered to cover the UWB range [4]. As shown in Fig. 1, there are four parameters a1, a2, b1 and b2 that could affect the performance of the UWB antenna. To obtain a compact size antenna that covers the entire UWB range, parametric studies for these four parameters are carried out and it is clear that the DSP antenna of Fig. 1 should be broader along the lower side (towards ground plane) to improve the reflection coefficient characteristic over the desired band. Furthermore, the value of b1 and b2 changes the lower cutoff frequency of the DSP antenna.

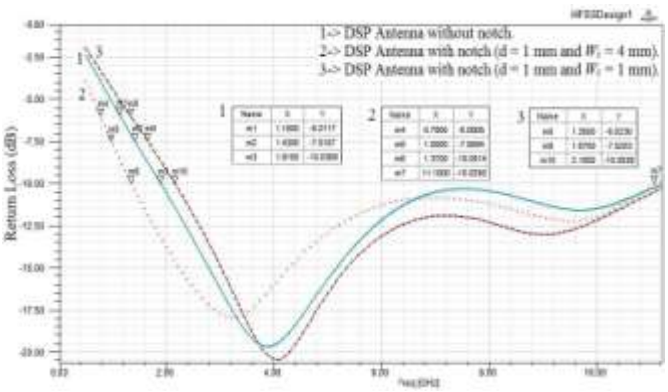


Fig. 3. Simulated reflection coefficient of the DSP antenna before and after inserting notched region for various widths of the cut out section W_c. (a1 = 14 mm, a2 = 5 mm, b1 = 2 mm, b2 = 8 mm, L_f = 8mm and Lg = 8 mm).

An appropriate value of a1 can improve the return loss at higher frequencies and provide wider impedance matching over the entire UWB range. The current distribution over this DSP antenna is mostly concentrated over the outside edges of the patch with negligible current in the center region. Thus, a rectangular section along the axis of the DSP antenna can be removed as shown in Fig. 2, without affecting the overall antenna impedance and radiation characteristics leading to the UWB antenna. This adjustment also ensures the asymmetrical design of the antenna. Results of Fig. 3 shows that the parameter of the notch does not have a significant effect on the reflection coefficient [1]. But it is large enough so that when a rectangular section is removed, as shown in Fig. 2, several resonant strips can be placed within the notched region to design a multi-band antenna.

Fig. 3 shows the reflection coefficient of the base DSP antenna and two different sizes of notched region. It is seen that narrow notched region has almost no effect on the reflection coefficient results [5]. Also, increasing the notch size has no effect on cutoff frequency of the base DSP antenna patch. Center feed method is used to design small size multiband antennas as it is desired to have other frequency bands at specific wireless communication frequencies below the UWB.

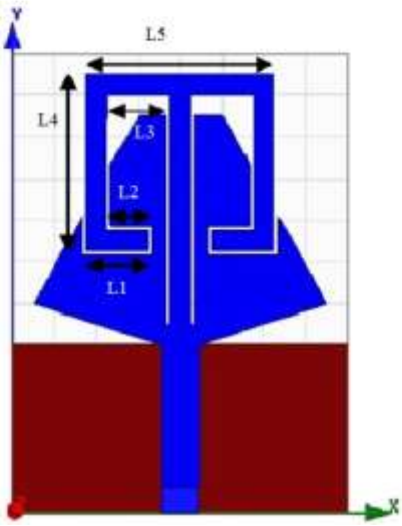


Fig. 4. Base antenna with resonant strip inside notch

To reduce the effect of ground plane and cabling loss at low frequency a notched region is introduced in a UWB base antenna. After the creation of the notched region, the resonant length of the created path is λ/2. As shown in the previous section, one can insert a notched region into the base patch antenna without affecting the characteristics of the antenna. To obtain multi-band behavior, additional resonant strips can be placed in the notched region. These strips are efficiently excited, if placed along the direction of the current flow and near the main Microstrip feed line. This technique of creating a multi-band antenna can be referred to as the center feed method.

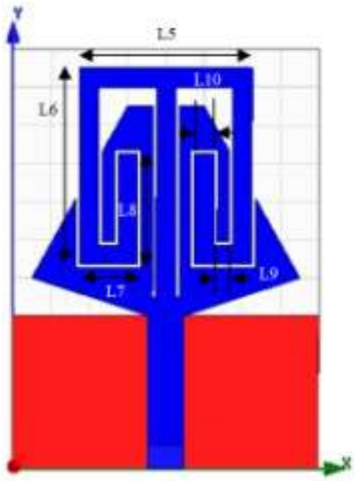


Fig. 5. Designed Multi-band DSP antenna configuration.

Fig. 4 and Fig. 5 shows a Multi-band antenna structure using this center feed method. By using the center feed method, a segment of the added strips can be placed within the notched region of the base patch while the remaining sections are brought back towards the patch. Even though strips are added to the base antenna, the overall substrate dimension has not changed, leading to small-size multi-band antenna.

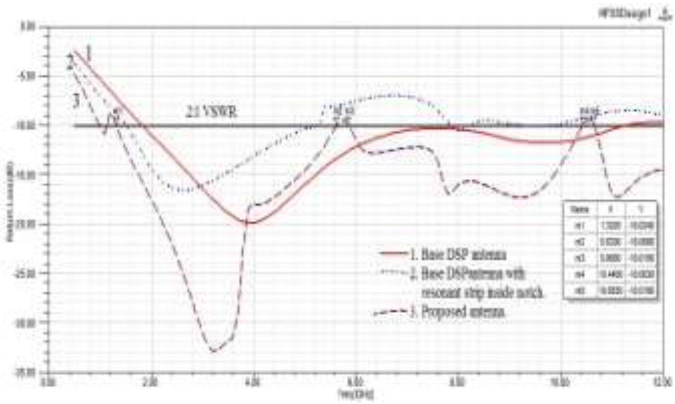


Fig. 6. Comparison of Reflection coefficient of antenna shown in fig. 1, fig. 4, and fig. 5.

In this section, the design of a multi-band antenna is presented. The structures of the proposed antennas are shown in Fig. 4 and Fig. 5 and lengths of various stripes are summarized in table 1 for optimum result. In all these structures, the width of the slot lines, between the added strips and the base patch, is set at 0.2 mm and has negligible effect on the antenna performance. Fig. 6 shows the reflection coefficient of an antenna shown in Fig. 4 and Fig. 5.

TABLE I
Length of Various strips shown in Fig. 5

Strip	Length (mm)	Strip	Length (mm)
L1	3 MM	L6	10.3 MM
L2	2 MM	L7	3 MM
L3	3 MM	L8	5.8 MM
L4	8.4 MM	L9	1 MM
L5	9 MM	L10	1 MM

The results shown in Fig. 6 are suitable for WLAN/UWB applications. To obtain resonant frequencies between 1 GHz and 2.4 GHz (i.e. to integrate GPS, GSM or WLAN with UWB antenna) for the multiband structure, the length of the strips are to be set accordingly for the lower frequency band. Also, the dimension of the DSP antenna is kept fixed for the UWB range. As the operation frequency of the antenna increases, the guided wavelength of the structure decreases, resulting in the feed line length being several times that of the wavelengths.

Fig. 7. Final fabricated antenna.

The dimensions of the various added strips are adjusted to create a GSM/WLAN/UWB antenna. It is seen that the multi-band antenna has suitable reflection coefficient below 10 dB over the UWB range with VSWR < 2 which is considered as a standard in the communication industry. Fig. 7 shows the fabricated antenna of the proposed design to verify the value obtained in simulation.

III. Experimental Results and discussions

The HFSS full-wave simulation software has been used to obtain the simulation data. A fabricated prototype for the proposed triple-band antenna was constructed and implemented. The measurement was performed by using a vector network analyser (Rohde and Schwarz and model: - ZVB 8). The studies are developed through optimizing the parameters step by step.

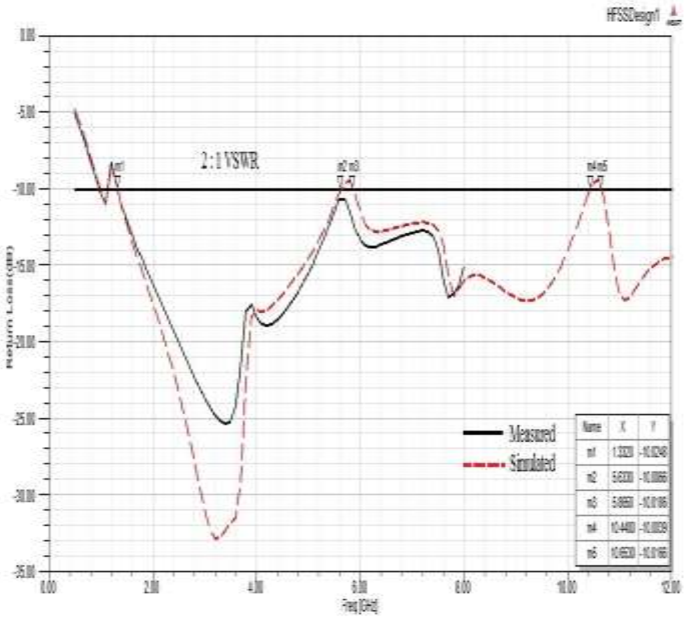
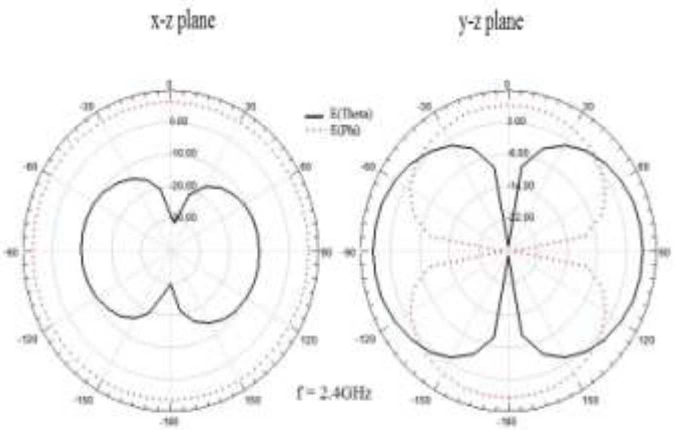
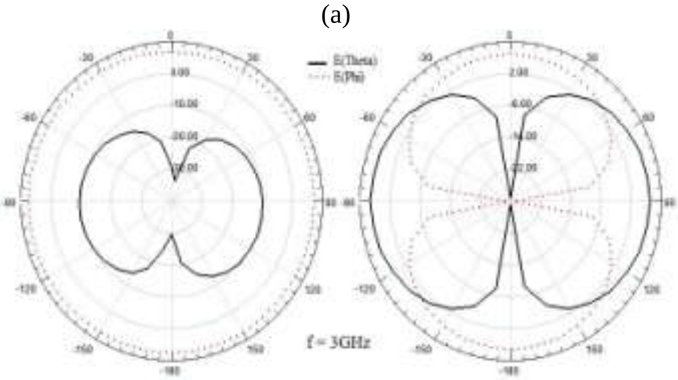


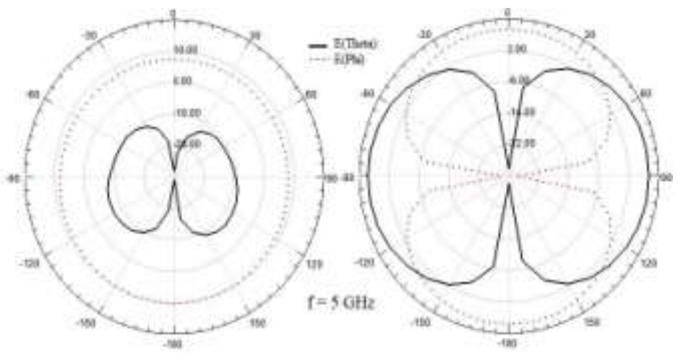
Fig. 8. Comparison of measured and simulated return loss of designed and fabricated antenna.



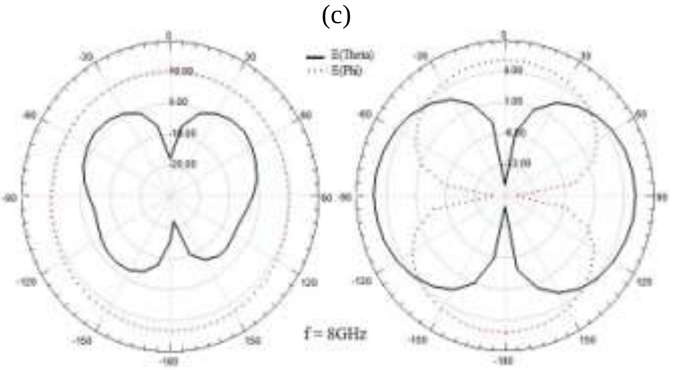
(a)



(b)



(c)

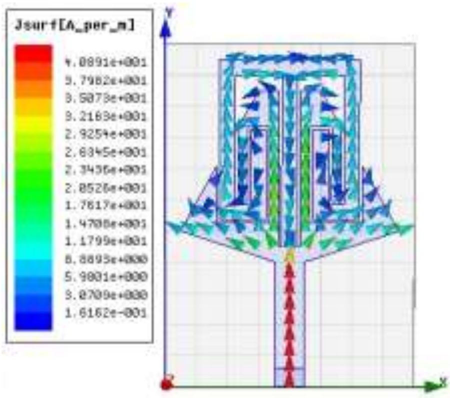


(d)

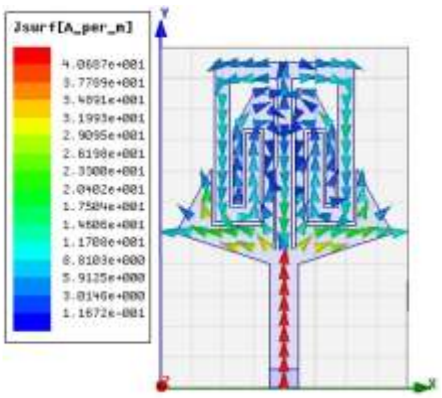
Fig. 9. Radiation pattern of the multi-band antenna at various frequencies (a) 2.4GHz, (b) 3GHz, (c) 5GHz and (d) 8GHz.

Fig. 8 displays the simulated and measured return loss over the entire considered frequency band with VSWR < 2, the bandwidth of the desired lower and upper bands are observed, respectively. Fig. 8 describes the simulated and experimental return loss against the frequency of the proposed antenna, which are in good agreement with each other.

The radiation patterns of the base DSP, multi-band antennas are investigated. It is seen that the multi-band antennas provide omnidirectional radiation patterns in the H-plane (x-z plane) and stable patterns in the form of figure-eight in the E-plane (y-z plane). These results are similar to those of ordinary dipole antennas. Also, the measured and simulated E - plane radiation patterns of the proposed multi-band antenna in Fig. 5, at the desired frequencies of 2.4, 3, 5 and 8 GHz are shown in Fig. 9. It is seen that the proposed antenna has stable radiation pattern characteristics over the band frequencies.



(a)



(b)

Fig. 10. Current distribution of the antenna at (a) 2.4 GHz and (b) 5 GHz

The radiation patterns are not normalized to make it easy to read the value of both components. The current distribution on the proposed antenna at 2.4 GHz and 5 GHz are shown in Fig. 10 (a) and (b), respectively. The base patch of the antenna at 2.4 GHz has negligible current, while on the added strip maximum current is seen at the beginning and minimum current at the end of the strip, which, according to, confirms that the length of the strip is about a quarter-wavelength. Fig. 10 (b) shows that at a frequency of 5 GHz the base patch has appreciable current while the current on the added strip runs in opposite directions leading to negligible effect on radiation. It means that the added strips and the main body of the antenna

ISSN: 2321-8169
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do not have much effect on each other. As the operation frequency of the antenna increases, the guided wavelength of the structure decreases, resulting in the feed line length being several times that of the wavelengths.

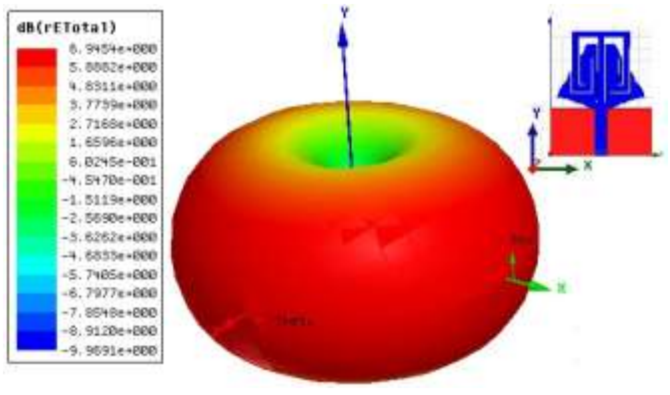

Fig. 11. Simulated 3D Radiation Pattern of the proposed antenna.

The three-dimensional (3-D) total-power radiation patterns are plotted in Fig. 11. The full 3-D pattern (the plane where the display ground is located) for six representative frequencies are shown. At lower frequencies (1300 and 1700 MHz in the bands), near-omnidirectional radiation is observed. While at higher frequencies (2400, 3000, 5000 and 8000 MHz in the bands), more variations are seen in the radiation patterns. This behavior is similar to that observed for the internal WWAN handset antennas. From the results shown in Fig. 6 and Fig. 8, it is seen that bands for LTE/2300/2500, UMTS, GSM/1800/1900/ UMTS, and UWB (3.1-10.6 GHz) are supported.

IV. CONCLUSION

A novel compact multiband monopole diamond shaped Microstrip patch antenna for handheld devices has been proposed. The technique of using a Parallel resonant strip in the slot, which normally does not increase the antenna size, has been shown to be promising in greatly enhancing the bandwidth of the antenna. Experimental and Simulated results demonstrate that the center frequency can be tuned by varying the size of the slots and strip. The proposed antennas deign show omnidirectional radiation patterns over entire frequency bands. The antenna is fabricated on both sides of FR4 substrate of size 22 X 16 mm and support frequency bands for GPS, GSM, Wi MAX, WLAN and the UWB. The proposed design is a desirable candidate for stationary terminals of various indoor wireless communication networks.

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