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MULTIBAND PATCH ANTENNA FOR WIRELESS COMMUNICATION SYSTEM

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ABSTRACT

This paper presents the design of a low-profile, reconfigurable, tunable multiband patch antenna. The antenna design is fabricated on FR4 substrate with dielectric constant ε_r *4.4. The proposed antenna design can be used for different types of wireless applications such as Wi-Fi, Wi-max, Bluetooth within a microwave S and C frequency bands in electromagnetic spectrum. Now-a-days, various antennas are preferred and frame for different wireless applications. This enlarges the complexity and size of the device. The proposed work deals with the design of an antenna which can be used for various wireless applications. Thus, band selection in communication systems can be conveniently served by only single antenna. This will make an overall antenna a compact one. The following Parameters that shall be considered in this work for performance analysis are Return Loss, Gain, VSWR and Directivity.*

Key Words: Directivity, Gain, Return Loss, VSWR

I. INTRODUCTION

Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated. Nowadays broadband compact antennas are highly preferred for mobile terminals as they occupy limited space and can interface with various communication standards [1]. By cutting U-slot in rectangular patch antenna on thick and low dielectric substrate, a broad bandwidth is obtained [2]. Modern mobile handsets are miniature in size and support different wireless application. Due to the device convergence trend in antenna structure, very limited space is available for the antenna structure and they are required to operate at multiple-frequency bands in order to provide the enhanced multifunctional performances [3]. V.-A. Nguyen et. al. demonstrates antenna design with a volume of $20 \times 13 \times 4 mm^3$ mounted on FR-4 substrate with ground plane $80 \times 45mm^2$ and it covers following frequency bands DCS (1710–1880 MHz), PCS (1850–1990 MHz), UMTS (1920–2170 MHz), WiBro (2300–2400 MHz), WLAN (5.2 GHz), and partial C-band (3–4.2 GHz) [3]. H. F. Abutarboush*et al.* demonstrates appreciable *C* slotted antenna design using single feed used for narrowband applications in a range of 5 to 7 GHz with the size of 50×50×1.57 mm^3 [4]. Peak gains of the antenna at different frequencies are between 3 to5 dBi [4]. H. F. Abutarboush*et al.* have designed compact printed antenna with a dimensions of 50×50 mm^2. It provides frequency bands of 0.92, 1.73, 1.98, 2.4, and 2.9 GHz with simulated gains -1.0, 1.6, 1.2, 1.05, 2.2 dBi, respectively [5].

Design of broadband antenna for different wireless standards is a difficult task and to cover large frequency range tunable and reconfigurable multiband antennas can be preferred. This paper presents the design of compact multiband microstrip patch antenna for wireless applications. It provides frequency bands in *S* and *C* band of electromagnetic spectrum. It includes different wireless applications for the wireless devices such as Mobile phones, WLAN, Bluetooth, Wi-Fi, WiMax**.** This paper is a further study of antenna design methodology, with changing the length of patch and die-electric constant and its effect on frequency tuning and reconfiguration comparatively higher gain and directivity.

II. PROPOSED ANTENNA DESIGN

This paper proposed the design of multiband microstrip patch antenna which covers both S (2-4 GHz) and C (4-8 GHz) band in electromagnetic spectrum. Antenna includes main radiator and four sub-patches placed on FR-4 substrate with relative permittivity 4.4 and height of a substrate h =1.57. Total volume of the antenna design is 50×50×1.57 mm^3. It provides frequency bands like 1.73, 2, 2.4, 2.97, 3.91 to 4.3, 5, 5.56, 6.8, 7.7 GHz. Software used for antenna design & its simulation is Agilent Advanced Design System (ADS) 2011.05. It reinforces Momentum as well as FEM (finite element method) mode of simulation. Geometry of patch antenna is as shown in Fig.1 and Fig.2 shows structure implemented in ADS software. Dimensions of all patches are as shown in Table I.

III. SIMULATION AND EXPERIMENTAL RESULTS

The S11 represents how much power is reflected from the antenna, and hence is known as the **reflection coefficient** (sometimes written as gamma: Γ or **return loss**). If S11=0 dB, then all the power is reflected from the antenna and nothing is radiated. If S11=-10 dB, this implies that if 3 dB of power is delivered to the antenna, -7 dB is the reflected power [6]. The remainder of the power was "accepted by" or delivered to the antenna. This accepted power is either radiated or absorbed as losses within the antenna. Since antennas are typically designed to be low loss, ideally the majority of the power delivered to the antenna is radiated. Return loss should be as low as possible for transmission of maximum power. Return loss (s11) should be less than -10 dB [7]. Fig.3 shows the simulation results of proposed design. Antenna design consists of array of patches, having different frequency bands, 1.73, 2, 2.4, 2.97, 3.91 to 4.3, 5, 5.56, 6.8, 7.7 GHz with return loss ≤10 dB. It gives the bands which are used for wireless applications such as Wimax, Wi-Fi, Bluetooth, and WLAN.

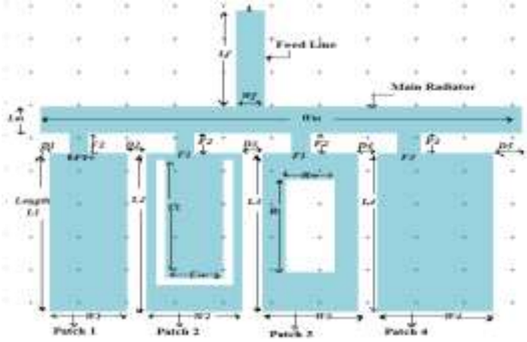


Fig.1 Structure Of Patch Antenna.

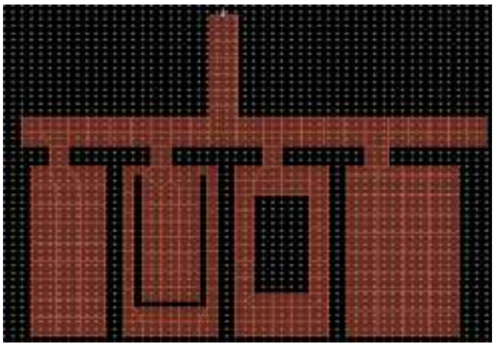


Fig.2 Structure Implemented In ADS Software.

Table I: Dimensions of All Patches.

L1	*L2*	*L3*	*L4*	*Lf*	*W1*	*W2*	*W3*	*W4*	*Wf*
24	24	24	24	14.6	8	10	10	12	3
Lm	*Wm*	*F1*	*F2*	*F3*	*F4*	*D1*	*D2*	*D3*	D4
50	4	2	3	2.5	3	1	2	2	2
D5	*Ul*	*Uw*	*Rl*	*Rw*	*H*				
3	19	6	14	5	1.57				

After implementation the measured results of an antenna design shown in Fig.3. It is observed that the antenna exhibits ≤10 dB reflection coefficients over multiband frequency bands such as 1.74 GHz, 2 GHz, 2.45 GHz, 3.58 GHz, 4 GHz, 5.1 GHz, 5.52 GHz, 6.5 GHz, and 7.08 GHz.

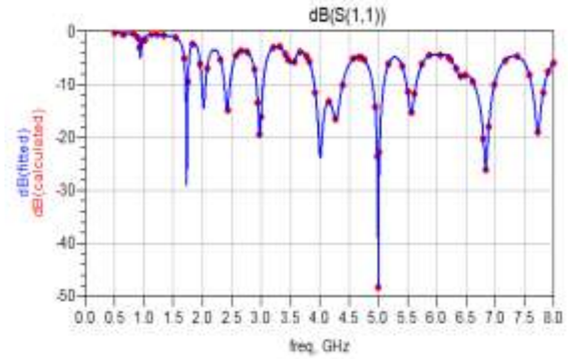


Fig.3 Simulation Result of Fig.1

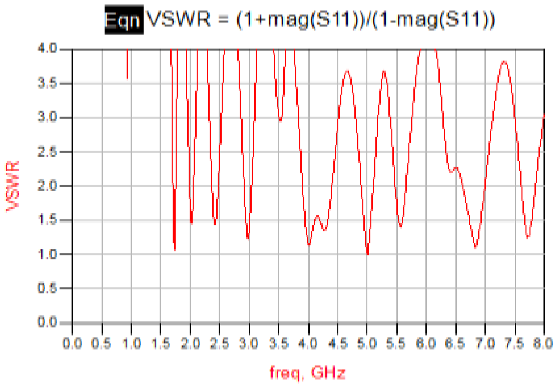
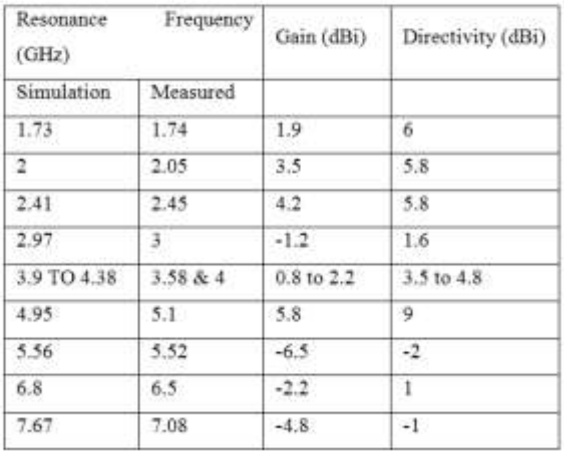


Fig.4 VSWR Plot of Fig.1.

Table II shows simulated gain and directivity with corresponding resonance frequency using Advanced Design System (ADS) software. As rectangular width of a slot size is decreased, area of a patch in antenna design is increased hence directivity also increases. Fig.5 shows VSWR plot of multiband antenna design. For all resonance frequencies, VSWR is less than 2 which is desirable.

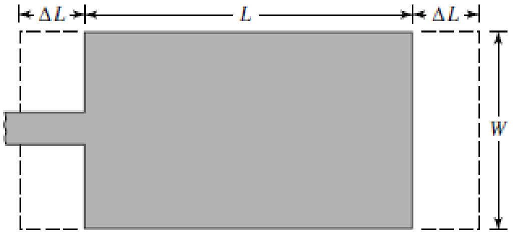
Table II: Simulated Gain and Directivity With Corresponding Resonance Frequency



Resonance Frequency (GHz)		Gain (dBi)	Directivity (dBi)
Simulation	Measured		
1.73	1.74	1.9	6
2	2.05	3.5	5.8
2.41	2.45	4.2	5.8
2.97	3	-1.2	1.6
3.9 TO 4.38	3.58 & 4	0.8 to 2.2	3.5 to 4.8
4.95	5.1	5.8	9
5.56	5.52	-6.5	-2
6.8	6.5	-2.2	1
7.67	7.08	-4.8	-1

IV. SIMULATION RESULT WITH VARYING LENGTH AND CHANGING DIELECTRIC CONSTANT (3.4)

The resonant length of the patch, however, is not exactly equal to the physical length due to the fringing effect. The fringing effect makes the effective electrical length of the patch longer than its physical length, $L_{eff}>L$ [8].



(a) Top view

(b) Side view

Fig.5 Physical and Effective Lengths of Rectangular Microstrip Patch.

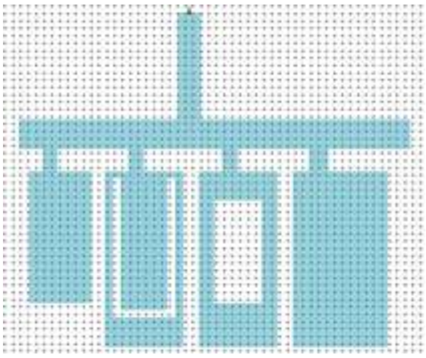
$$\Delta L = 0.412 \times h \times \left(\frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258}\right) \times \frac{\left(\frac{W}{h} + 0.264\right)}{\left(\frac{W}{h} + 0.8\right)} \qquad (1)$$

Since the length of the patch has been extended by ΔLon each side, the effective length of the patch is [9].

$$L = L_{eff} - 2 \times \Delta L \qquad (2)$$

For an efficient radiator, a practical width that leads to good radiation efficiencies is

$$W = \frac{c}{2 \times f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (3)$$



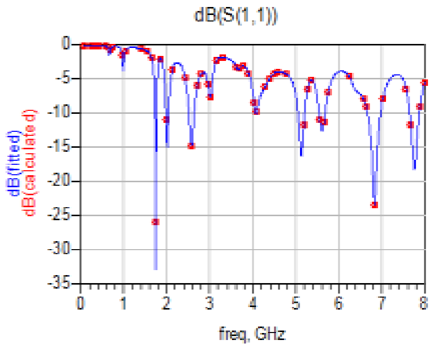
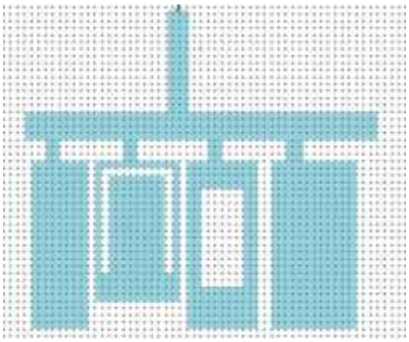


Fig.6 Varying Length (18 Mm) of First Patch. Fig.7 Simulation Result (18 Mm) of First Patch.



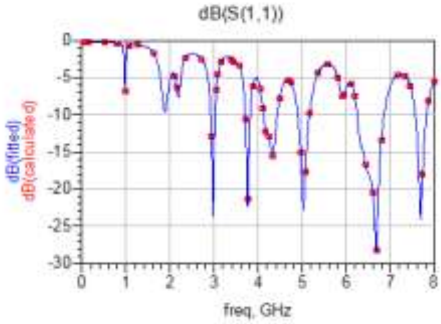
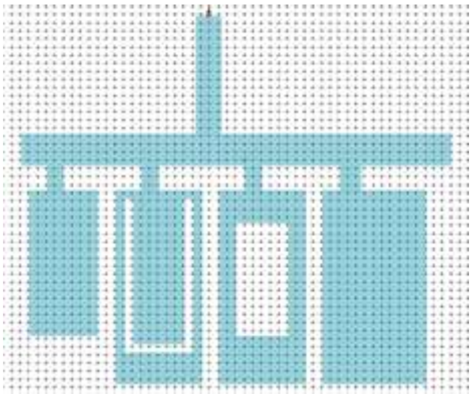


Fig.8 Varying Length (18 Mm) of Second Patch. Fig.9 Simulation Result (18 Mm) of Second tch.



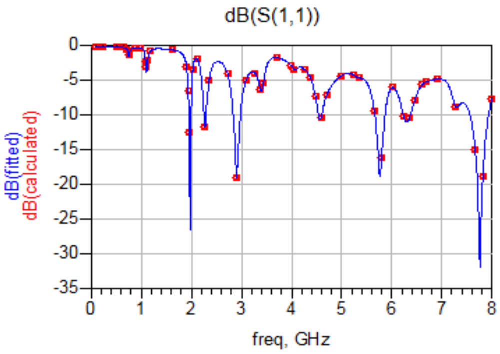
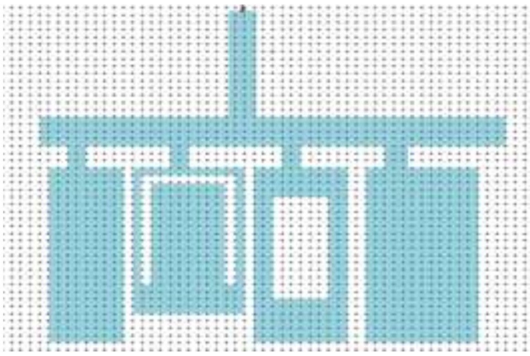


Fig.10 Varying dielectric constant (3.4) of first patch. Fig.11 Simulation result (3.4) of first patch.



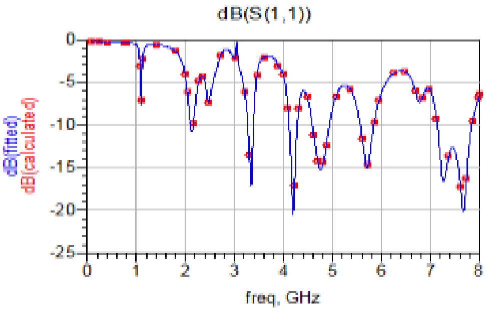


Fig.12 Varying dielectric constant (3.4) of second patch. Fig.13 Simulation result (3.4) of second patch.

Table III: frequency with varying length and dielectric constant of patch 1.

Frequency (GHz)	Frequency (GHz) By varying length of patcl	By varying dielectric constant(3.4)
1.73	1.8	-
2	2	2
2.41	2.6	2.3
2.97	-	2.8 to 3
3.9 to 4.38	4	-
4.95	5 to 5.2	4.6
5.56	5.6	5.8
6.8	6.8 to 7	6.3
7.67	7.8	7.4 to 8

Table IV: frequency with varying length and dielectric constant of patch 2.

Frequency (GHz)	Frequency (GHz) By varying length of patc	By varying diel ectric constant(3.4)
1.73	1.8	-
2	-	2.2
2.41	-	2.4
2.97	3	3.3
3.9 to 4.38	3.7	4.2
4.95	4.2 to 4.6	4.6 to 5
5.56	-	5.6 to 5.9
6.8	6.2 to 6.8	-
7.67	7.6 to 7.8	7.2 to 7.9

FR-4 glass epoxy is a popular and versatile high-pressure thermoset plastic laminate grade with good strength to weight ratios. With near zero water absorption, FR-4 is most commonly used as an electrical insulator possessing considerable mechanical strength [10]. The material is known to retain its high mechanical values and electrical insulating qualities in both dry and humid conditions. These attributes, along with good fabrication characteristics, lend utility to this grade for a wide variety of electrical and mechanical applications.

Tunability can be achieved by varying length of the patch. We have considered two cases. First case is variation in length of patch 1 and 2, and second case is variation in Dielectric constant of patch 1 and 2. By varying length of patch 1 and patch 2 from 24 mm to 18 mm, depending upon the current distribution frequencies which are depend upon patch 1 and 2 has been shifted and the results are shown in Fig.7, Fig.9. Similarly by changing dielectric constant of patch 1 and patch 2 from 4.4 to 3.4, the new frequencies obtained are shown in Fig.11, Fig. 13.

Using first case that is variation in length of patch 1 and 2 in multiband patch antenna provides variation in lower frequencies and using second case that is variation in dielectric constant of patch 1 and 2 in multiband patch antenna provides variation in higher frequencies. Similarly we can vary the length and dielectric constant of patch 3 and patch 4 also and by using PIN diode patches can be switch on and off to achieve tunability and reconfigurability which is desirable for wireless application.

IV. APPLICATIONS

Modified (varying length & dielectric constant) structures provide bands of frequencies for Wimax IEEE 802.16 (2.3-2.4GHz), Wi-Fi IEEE 802.11 (2.4-2.48GHz), UMTS (1.9-2.17GHz), WLAN, Bluetooth IEEE 802.15 (2.4-2.48 GHz), GPS (1.57 GHz), PCS (1.85-1.99 GHz), DCS (1.71-1.88GHz) applications. It covers both S-band and C-band of electromagnetic spectrum.

V. CONCLUSION

The compact, tunable & reconfigurable multiband patch antenna is proposed which provides different frequencies of S (2-4 GHz) and C (4-8 GHz) band with minimum return loss. By variation in length of patch 1 and 2 in multiband patch antenna provides variation in frequencies and by variation in dielectric constant of patch 1 and 2 in multiband patch antenna provides tuning in frequencies which makes antenna tunable. It can be designed using PIN diode to make patches on and off selectively. The proposed antenna dimensions are 50 mm x 50 mm and provide bands for Wimax, Wi-Fi, WLAN, and Bluetooth applications. Such applications can be served by using proposed single antenna which reduces complexity and cost as well.

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