Multiband Stepped Impedance Resonator (SIR) Based Antenna for Future Wireless Applications

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***Abstract*—A novel multiband stepped impedance resonator (SIR) based microstrip antenna is presented in this paper. The presented antenna is explicitly designed to overcome the multi-standard requirements of future wireless communication systems. The antenna contains six radiating patches, occupies a volume of 85x50x1.574mm. The antenna contains three short-circuited dual band SIR radiating patches. The SIR radiating patches are optimized to operate at the specified frequency bands of 0.9GHz, 1.2GHz, 1.5GHz, 2.5GHz, 2.75GHz, and 3.65 GHz. The SIR radiating patches are fed using a single coaxial feeding technique which shows a good matching of 50 Ohm. In stepped impedance technique; of three resonators one of the radiating patches is short circuited with a ground. The simulated results of reflection coefficient, impedance matching, and peak gains show stable responses and are acceptable. Antenna is designed using FR-4 as a substrate whereas; CST studio and MATLAB are utilized as simulation tool. The proposed antenna verifies to be a suitable candidate for small mobile devices and other multi-standard wireless communication devices.**

Keywords—Multiband antenna, microstrip antenna, stepped impedance resonators, coaxial feed.

I. INTRODUCTION

The multi standard requirements of the modern wireless communication system necessitate RF systems capable of operating at multi-frequency bands. As antenna plays an important role in wireless communication, with an increase in high data rate and compact telecommunication devices. Many electronic devices and telecommunication devices operate on different frequencies to perform multiple operations, therefore one antenna that has multiband characteristic is certainly more efficient as compared to having many antennas for each frequency band. As the demand of smart communication devices is increasing similarly the demand of multiband antennas is also increasing. Micro strip patch antenna is of great interest for researcher because it is a suitable candidate to fulfill the demands of modern era [1]. Micro strip patch antennas are widely used for wireless communication because of its limitless features like planar structure, light weight, low profile and can be easily integrated in smart communication devices [2]. Almost all of the significant wireless applications range starts from 0.9 GHz to 5.5 GHz which includes the GSM (0.88-0.96), GPS (1.56-1.59 GHz), DCS (1.71-1.88 GHz), Personal communication system (1.85-1.99 GHz), UMTS (1.92- 2.17 GHz) and IEEE 802.11 b/g (2.4-2.48 GHz) [1-4]. Researchers have investigated different techniques and methods to accomplish multiband characteristics and compact size antenna some of the techniques includes changing the radiating structure of antenna and adding additional layers [3] [4]. On the other hand, some techniques involve adding gaps which increase the size of radiators. Other methods include U-slot array, multiple layers to achieve multiple bands of different frequencies. This becomes difficult to manufacture and integrate in the device [5]. Micro strip monopoles antennas designed [2] and [3] to achieve multiple bands but the important parameter like gain was not achieved compared to the other micro strip patch antennas which are acceptable. Different multiband antennas are designed using stacked structure [6].

The proposed antenna operates at different frequency band L band, S band and WiMAX. The operating frequency for L band (1-2) GHz, S band (2-4) GHz and WiMAX ranges from (2.5-2.69) GHz [7]. In this paper, a simple procedure to design multiband composite antenna geometries based on stepped impedance is applied and micro strip antenna is designed using FR-4 as a dielectric material. The modeled microstrip antenna contains six rectangular shaped radiating patches and occupies a volume of 85x50x1.574mm, which includes substrate and ground plane. CST Microwave Studio® is user friendly as compared to other simulators, the antenna was modeled in it [8]. Simulated results analysis verifies that the proposed antenna feasible appropriate candidate for handheld communication devices and other multi-standard wireless communication devices.

Moving on, the paper comprises of three different sections. The design and development of the propose antenna is discussed in Section II. Further on, section III entails the

performance of the antenna and section IV derives up the conclusions.

II. Antenna Design and Developments

Micro strip antenna is mainly a radiating structure. Therefore, its dimensions must be approximately $\lambda_g/2$, where λg is the guided wavelength. The substrate properties such as dielectric constant and its height play an important role in the performance of the micro strip patch antenna [1]-[3]. The proposed antenna comprises of Hexa-radiating elements, which are rectangular in shape and are placed on FR-4 dielectric material which has a permittivity of 4.3 while thickness of the substrate is 1.574µm. Different features like easy availability, convenient to fabricate, remain stable in different environments and low permittivity which enhance the bandwidth as well as efficiency indicates to select FR-4 as a substrate [3][11]. For printed circuit boards fr-4 is the most popular and suitable substrate. It consists of glass fibers embedded in an epoxy resin [10].

The antenna radiating patches have different length and width and its radiating portion covers a T-shape, overall designed antenna covers 85x50x1.574mm including ground and the substrate. The geometrical shape of the designed antenna is illustrated in fig 1 whereas the dimensions are explained in the provided table. The radiating patches are rectangular in shape each patch has different length and width, 1st radiating patch has a length of 24.9mm and width of 4mm whereas patch 2nd is connected to the top of the patch one its length is 17.4mm and it has a width of 0.45mm. This section is responsible for operating at 0.9 and 1.5 GHz. Radiating element 3rd has a length of 27.8mm and its width is 4.88mm whereas patch 4th relates to 3rd radiating element its length is 15.50mm and width of 1.1mm. This section radiates at 1.2 and 2.75 GHz. Similarly, 5th patch has length of 19.25mm and width of 3.4mm which is connected to 6th radiating element; it has length of 12.26mm and width of 0.11mm. This section radiates at 2.5 and 3.65 GHz. Designed antenna is feed using a coaxial feed which is placed at the 1st radiating element and its show a perfect matching of 50 ohms. Radiating element is short-circuited with a ground for Stepped impedance, this was performed by placing a thin copper attachment in the 1st patch which is passing through the substrate and is connected to the ground. This proposed multiband antenna was designed and simulated using CST Microwave Studio®. [8]

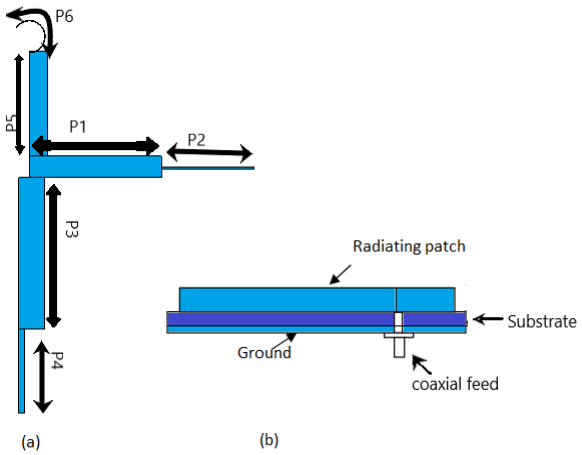

Fig 1 (a)Geomatric front view (b) Side view of the proposed antenna

III. Antenna Results and Discussion

some of the important parameters like reflection coefficient, impedance matching, and current distribution are considered for the evaluation of designed multiband micro strip patch antenna.

A. *Current distribution*

It is evident from the fig 2 that majority of the current is coming from the coaxial feeding point to the various sections and travelling wave pattern is observed in the proposed antenna. All the radiating plates contribution is satisfactory.

B. *Radiation pattern*

The 3D-radiation pattern of the antenna exhibits that antenna coverage is excellent and radiations covering all the surrounded angles. The angular width of the antenna at 0.9 GHz and 1.2 GHz is 95° whereas the antenna gain at 1.2GHz was also calculated 3.73 dBi. E-plane and H-plane radiation pattern at 0.9 GHz is illustrated in fig 3. The direction of main lobe at 1.2 GHz is 5.0° show in fig 4. Antenna gain at 1.5 GHz slightly increases 4.57 dBi whereas angular width is 91.0° shown in fig 5, the direction of the main lobe is at 7.0° with a side lobe and minimal value of -7.1 db. The results illustrate that antenna has good radiation coverage in E-plane and H-plane. The antenna radiation gain has some nulls in certain direction which in common in high frequency range. Antenna gain at 2.51 GHz is 5.21 dBi, whereas the direction of main lobe is 36.0° and angular width of 59.1° at this frequency antenna has minimal side lobe -2.6 dB illustrated in fig 6. Antenna performance at 2.75 GHz is shown in the fig 7, it can be analyzed that antenna has good radiation coverage and antenna gain is 5.38 dBi, whereas it offers a 3 dB angular width of 65.7°. Similarly, antenna performance at 3.65 GHz is depicted in fig 8; it offers an excellent coverage in all the surrounded angles. The gain of the antenna is slightly improved, and it offers a high gain which is 6.49 dBi as compared to the other frequencies. The direction of the main lobe is 54.0° and offers a 3dB-angular width of 59.6° The performance of the antenna specially its radiation pattern and antenna gain at different frequencies is sufficient to make it suitable for the small mobile devices and other electronic devices used for communication.

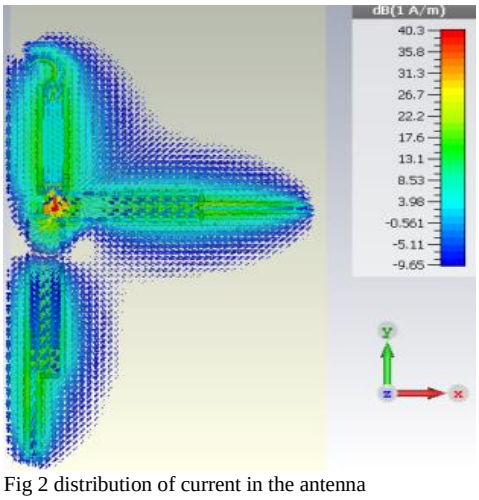

Fig 2 distribution of current in the antenna

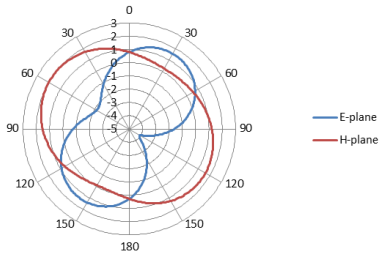

Fig 3 E Ø=0 and H Ø=90 plane at 0.9 GHz

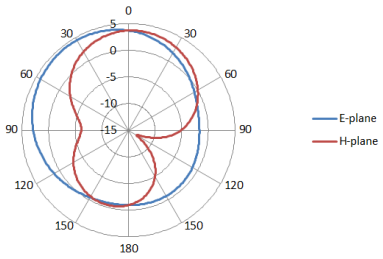

Fig 4 E Ø=0 and H Ø=90 plane at 1.2 GHz

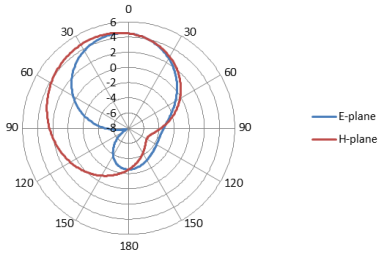

Fig 5 E Ø=0 and H Ø=90 plane at 1.5 GHz

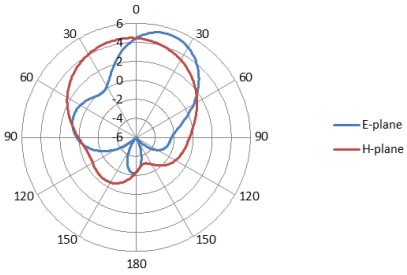

Fig 6 E Ø=0 and H Ø=90 plane at 2.5 GHz

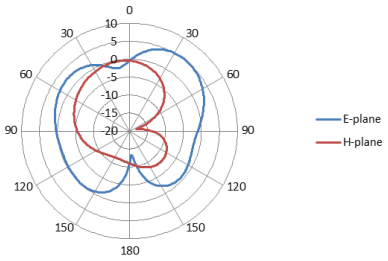

Fig 7 E Ø=0 and H Ø=90 plane at 2.75 GHz

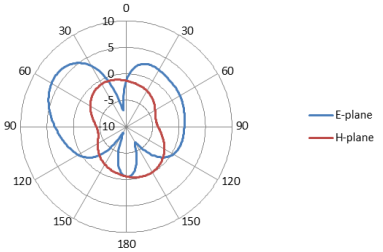

Fig 8 E Ø=0 and H Ø=90 plane at 3.65 GHz

C. Reflection coefficient

Fig 9 exhibits the simulated results which verify the reflection coefficient of the antenna. The return loss lesser than -10 dB verify that different frequencies have been achieved and antenna have achieved multiband characteristics. The first three frequency bands 0.9 GHz, 1.2 GHz and 1.5 GHz are below -10dB, whereas the 4th and 5th frequency bands 2.5 GHz and 2.75 GHz are meeting the commercial acceptable standards of -6 dB. The 6th frequency band 3.65 GHz is below -10dB. These bands fall in between some useful frequency bands like personal communication system, wireless LAN, ISM and WiMAX.

D. Impedance matching

The proposed antenna was feed using a coaxial feeding technique to make it suitable for smart communication devices. The reference impedance is shown in the fig 10. It can be observed from the depicted fig that antenna is perfectly matched at 50 ohms. The power to the radiation patches is transmitted with minimum loss.

IV. CONCLUSION

In conclusion a micro strip patch antenna was designed, as the demand of high data rate and compact smart devices are rapidly increasing so it was necessary to design an antenna with a capability of radiating at different frequencies. In this paper a micro strip patch antenna is designed because of their advance features like light weight, low cost, planar structure and can be simply fabricated. The designed antenna contains radiating elements and a stepped impedance technique was utilized to manage the frequency bands. Fr-4 is employed as a dielectric material and designed antenna occupies a size of 85x50x1.574mm. Simulated results have shown multiband performance is achieved, antenna was feed by coaxial feeding technique which confirm a perfect matching of 50 ohms. The designed antenna is suitable for small mobile devices and other multi-standard wireless communication devices.

TABLE I. ANTENNA DIMENSIONS

Antenna elements	***Parameters***	***Dimensions***
Patch1 (P1)	Length	24.9mm
	Width	4mm
Patch 2 (P2)	Length	17.4mm
	Width	0.45mm
Patch 3 (P3)	Length	27.8mm
	Width	4.88mm
Patch 4 (P4)	Length	15.50mm
	Width	1.1mm
Patch 5 (P5)	Length	19.25mm
	Width	3.4mm
Patch 6 (P6)	Length	12.26mm
	Width	0.11mm
Ground (g)	Length	85mm
	Width	50mm
Substrate	Length	85mm
	Width	50mm

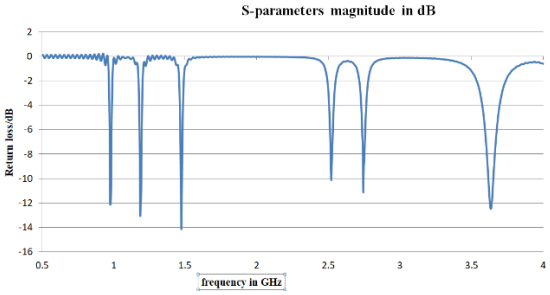

Fig 9 reflection coefficient response

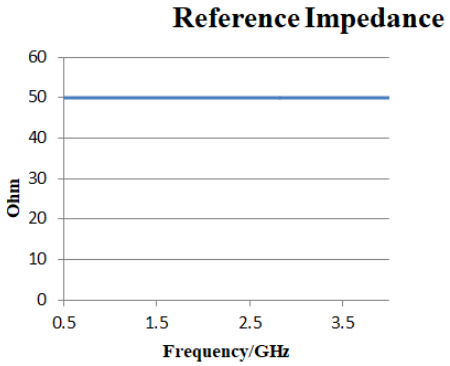

Fig 10 impedance matching of the proposed antenna

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