A Performance Assessment of a Slotted Reconfigured Microstrip Patch Antenna for Multi-Wireless Applications

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Abstract - A Dual Frequency reconfigurable antenna is presented in this paper. Achieving Reconfigurability in the resonant frequency of microstrip patch antenna by introducing slots and structure alteration has been proposed. The proposed designs of rectangular microstrip patch antennas are resonating at 5 and 2.1 GHz(reconfigured) respectively. Modeling of reconfigurable antenna to achieve max size reduction by introducing partial ground concept and patch structure alteration has been used. Modelling of reconfigurable antenna for multiband operation is the one of the major challenges and the solution for this challenge is by introducing the slots over the patch of the antenna. To achieve wider bandwidth for wireless applications changing the structure patch and partial ground plane concept is proposed. Reconfigured antennas are well known for their characteristics like lightweight, low profile, and compact enough to be employed in smart wearable technology as well as portable electronics (such as, watches, smartphones, iPads, PDAs, and laptops), A Finite Element Method (FEM) and numerical Finite Integration Technique (FIT) are used in CST Microwave studio to estimate the antenna scattering and far-field characteristics.

Keywords - Frequency reconfigurable antenna, FIT, FEM

I. INTRODUCTION

A modern communication device (such as a smart phone, IPAD, PDA, or laptop) is required to handle multiple services, hence an antenna that can broadcast and receive at several frequency bands is need of the hour. Global System for Mobile Communication (GSM at 1.712.17GHz), Universal Mobile Telecommunications System (UMTS 1.92-2.17GHz), Personal Communication System (PCS at 1.85-1.99 GHz), Bluetooth (at 2.4-2.48GHz), Wireless Fidelity (Wi-Fi at 2.4 GHz), and certain other specific wireless applications require a specific frequency standard for operation [1-4]. Researches focus on constructing effective frequency reconfigurable planar antennas (FRPA's) because of these attractive characteristics (size, cost, and numerous frequency bands). [2-4]. The major work in the field of microstrip antenna design is to have multi band operation with reduced size and maintaining considerable gain, VSWR and return loss in the operating frequency range for various wireless applications. Planar antennas are the best choice because of their low profile, lower incidence in size, light weight, and ease of system integration, which make them more suitable for accommodating various wireless technologies in a single antenna hardware [5-8]. The majority of dual band antennas are linearly polarized for the dual band operation. Such a category of multiband antennas is classified as frequency reconfigurable antennas (FRA's).

The capacity to operate just in the desired range of frequency while rejecting adjacent ones is provided by a frequency reconfigurable antenna. This minimizes interference, increasing signal to noise ratio (SNR) and channel capacity as a result [9]. As the communication spectrum shifts, a multiband antenna, which concurrently covers many bands, is needed to separate the RF signals. By adjusting the length of the resonating parts [10] and slots [8] in this article, frequency reconfigurability can be achieved. The presented Microstrip antenna runs at 2.3 GHz and is appropriate for WiMax at IEEE 802.16 standard, wireless body area networks, and telemedicine applications.

Fig 1 summarizes the most popular and extensively employed methods to accomplish reconfigurability.

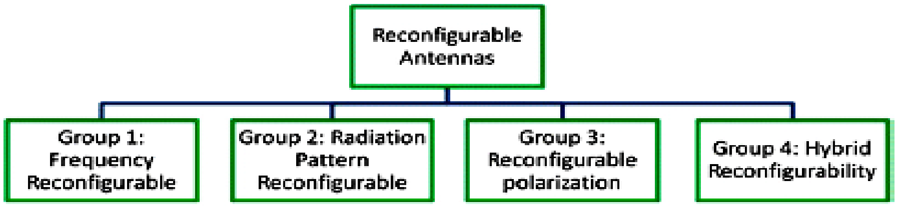

Fig 1. Various Techniques Adopted to Achieve Reconfigurable Antennas

II. ANTENNA STRUCTURE AND DESIGN PROCEDURE

In order to feed the antenna, a quarter-wavelength transmission line with characteristic impedance Z_1 is used to link the microstrip antenna to a transmission line with characteristic impedance Z_0. The objective is to match the transmission line's input impedance (Z_{in}) (Z_0). When examining at the input impedance from the start of the quarter-wavelength line, if the antenna impedance is ZA, then

$$Z_{in} = Z_0 = \frac{Z_1^2}{Z_A} \tag{1}$$

By choosing Z_1, you may change the input impedance Z_{in} such that it equals Z_0 and the antenna is impedance balanced. By adjusting the quarter-wavelength strip's width, the parameter Z_1 may be changed. The characteristic impedance (Z0) for that portion of line decreases with increasing strip width.

As depicted in Fig.2, the antenna is composed of three different layers shown patch, substrate, and ground. The measurements are all done in millimeters. on FR-4 lossy dielectric sheet, the suggested antenna is embedded. The edges of the patch behave like open-circuit boundary condition.

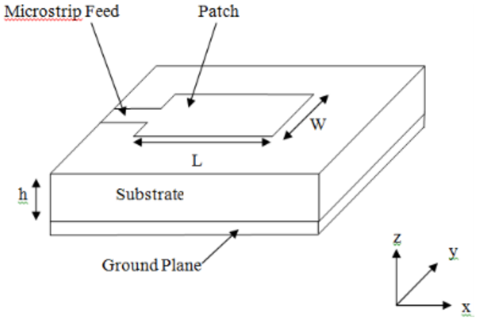

Fig 2. Structure of a Microstrip Patch Antenna

Given below is the fundamental formula for calculating the length and breadth of patch antennas. Each end of the patch's dimensions has a distance of ΔL appended to them along its length.

$$\Delta L = 0.412h\frac{(e_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(e_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \tag{2}$$

The effective length of the patch Leff:

$$L_{reff} = L + 2\Delta L \tag{3}$$

For a given resonance frequency f_0, the effective length is given by

$$L_{reff} = \frac{c}{2f_0\sqrt{e_{reff}}} \tag{4}$$

$$f_o = \frac{c}{2\sqrt{e_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}} \quad (5)$$

Where m and n are modes along L and W respectively.

$$W = \frac{c}{2f_0\sqrt{\frac{(e_r+1)}{2}}} \quad (6)$$

$$L = \frac{c_0}{2f_r\sqrt{e_{reff}}} \quad (7)$$

Dielectric constant (r=4.3) and substrate height (h = 1.6mm) are two fundamental characteristics of the antenna since FR-4 lossy is employed as the substrate. And fr=5GHz, the resonance frequency.

Microstrip Patch Antenna Design Resonating at 5 GHz.

The antenna design is depicted in the Fig.3 as being made up of a patch printed on a dielectric substrate and a ground plane for producing a single resonance frequency of 5GHz.

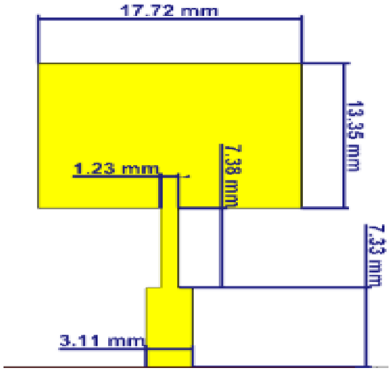

Fig 3. Schematic representation of proposed Microstrip patch antenna with single resonance frequency of 5GHz. The dimensions of microstrip patch antenna resonating at 5 GHz is listed in the Table. I

Table 1. Dimension of microstrip patch antenna radiating at 5GHz frequency

Parameters	**Dimensions in (mm)**
Ground	35.7792X27.0216
Substrate	35.7792X27.0216
Patch	17.8896X13.5108
Substrate Height	1.6
Width of quarter wave transformer line (WT)	1.2714
Length of quarter wave transformer line (LT)	7.4589
Width of feed line (WF)	3.1693
Length of feed line (LF)	7.4106

The dimensions of antenna are to be calculated using the design equations. Using these values in CST tool the proposed design in Fig.4 is obtained and further by reconfiguring the patch antenna by varying the size of ground and the feed line, a shift in the band can be observed and the band will be shifted to 2.1GHz.

The size of the patch antenna operating at 2.1 GHz operating frequency is much larger compared to that of 5GHz. The dimensions required designing 2.1GHz antenna is shown in Fig.4.

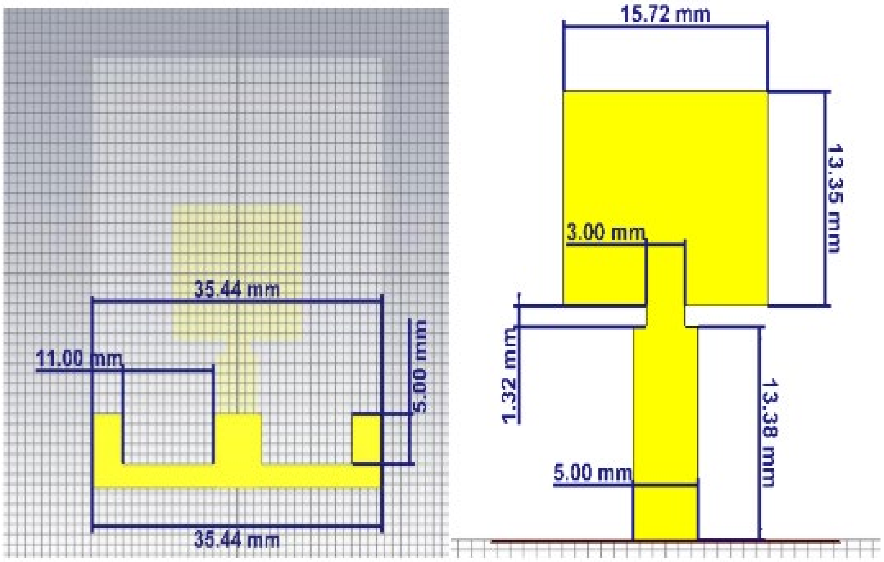

Fig 4. Schematic representations of Microstrip patch antenna with single resonance frequency of 2.1 GHz obtain by reconfiguring the basic 5GHz antenna.

The fig.5 is a reconfigured 5GHz patch antenna, where the ground is modified by adding two slots in it, and further by varying the patch length and width, the shift in the frequency is observed. By adding slots in the reconfigured 5 GHz patch antenna multiple bands can be achieved and further by varying the dimensions of ground, patch, feed line and thickness of the substrate the desired results were obtained. The Fig.5 represents the slotted microstrip patch antenna operating at multiple frequencies.

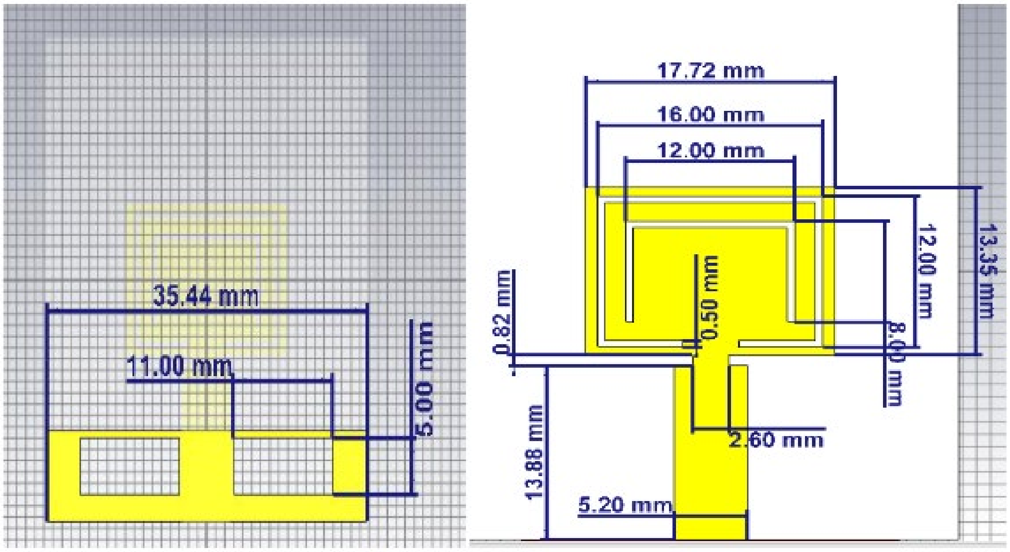

Fig 5. Schematic representations of the Slotted Microstrip patch antenna

The reconfigured slotted microstrip patch antennas operate at three different center frequencies with an acceptable return loss, VSWR and radiation patterns.

III. SIMULATIONS AND RESULTS

Result Analysis of Microstrip Patch Antenna Radiating At 5ghz

Return Loss versus Frequency graph

Fig.6 Results shows that the antenna attained a return loss of -23.4336 dB, which is less than -10 dB in the impedance bandwidth of around 24 MHz, at the resonant frequency of 5 GHz (4.8228 GHz- 5.0628GHz)

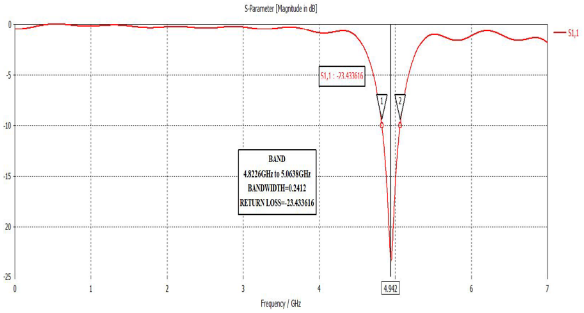

Fig 6. Return Loss and Bandwidth for 5GHz frequency

VSWR versus Frequency graph

Fig.7 demonstrates that the proposed antenna achieves the lowest VSWR at 5 GHz. Over the entire bandwidth, it is noted that the VSWR value is 1.1444, which is less than 2.

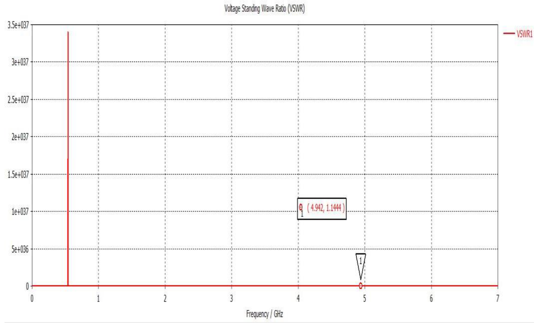

Fig 7. VSWR v/s Frequency graph

Far Field Analysis

Fig.8 shows the E-plane and H-plane. The major lobe direction in the E-plane is along 0 degrees, and its magnitude is 6.68 dBi, which is where the highest radiation occurs. The primary lobe in the H-plane has a direction of -12 degrees and a magnitude of 6.99 dBi, which is where the most radiation occurs.

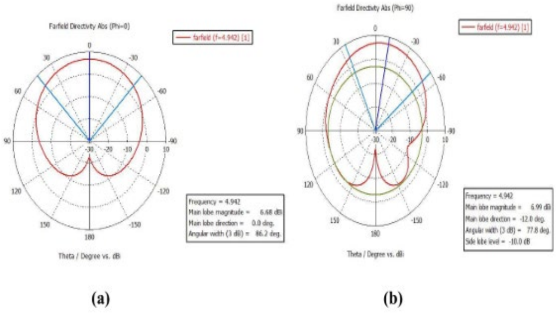

Fig 8. Far field radiation patterns (a) E-plane (b) H-plane

Result Analysis of Microstrip Patch Antenna Radiating At 2.1Ghz

Return Loss versus Frequency graph

Fig.9 shows the antennas resonance is at the resonant frequency of 2.1 GHz and the reflection characteristic of -45.38 dB is achieved which is less than -10 dB in the impedance bandwidth of about 39.38 MHz (1.9862 GHz- 2.38GHz).

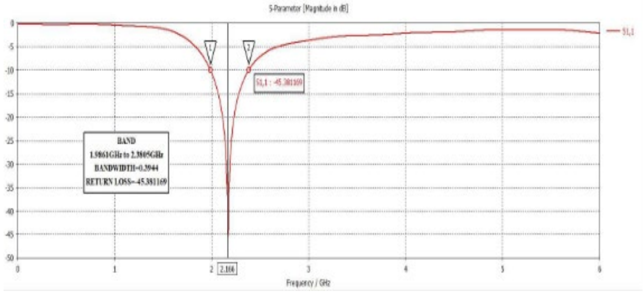

Fig 9. Return Loss and Bandwidth for 5GHz frequency

VSWR Versus Frequency Graph

Fig.10 shows the proposed antenna attains minimum value of VSWR at 2.1 GHz. It is observed that the VSWR value is 1.2687 at 2.1 GHz, which is less than 2 throughout the entire bandwidth.

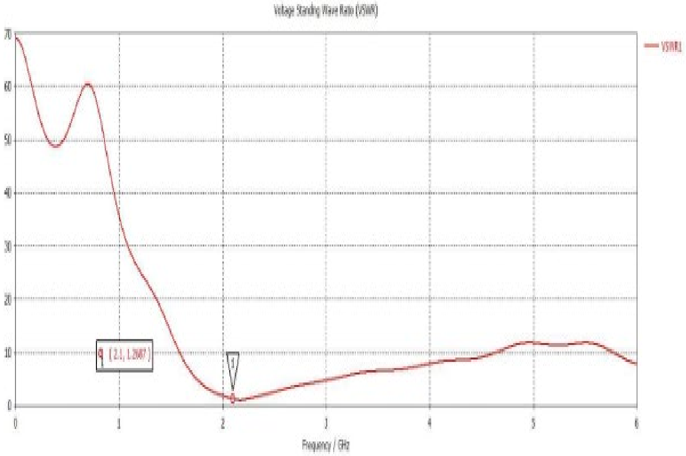

Fig 10. VSWR v/s Frequency graph

Far Field Analysis

In E-plane the main lobe direction is along 180 degree and its magnitude is 2.44 dBi where the maximum radiation takes place. In H-plane the main lobe direction is along 170 degree and its magnitude is 2.56 producing omnidirectional radiation pattern shows Fig.11.

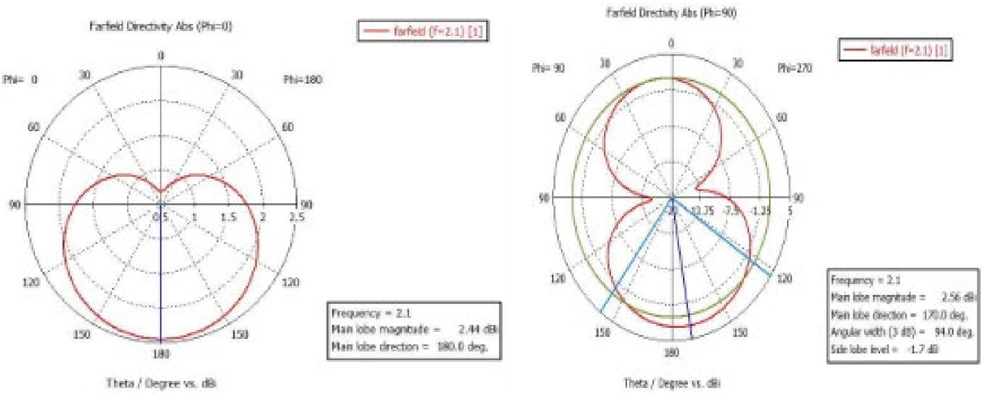

Fig 11. Far field radiation patterns (a) E-plane (b) H-plane

Result Analysis of Reconfigured Microstrip Patch Antenna Resonating At Multiple Frequency (1.8 Ghz, 2.29ghz, 3.655ghz)

Return Loss versus Frequency graph

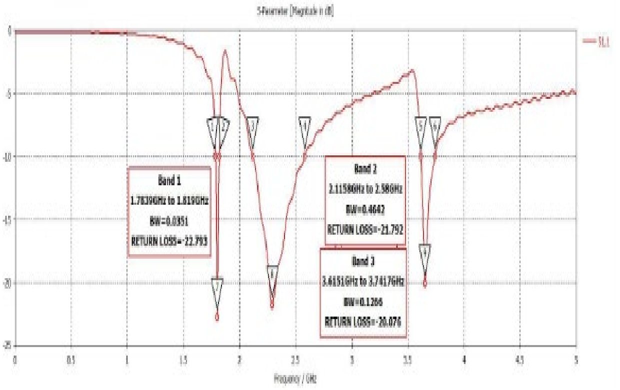

Fig 12. Return Loss and Bandwidth for 5GHz frequency

Fig.12 shows the antenna had the resonating at resonant frequencies of 1.8 GHz, 2.29GHz and 3.655GHz and the return loss of -22.793, -21.792 and -20.119 dB is achieved which is less than -10 dB. The bandwidths achieved is of 3.51 MHz, 46.42MHz and 12.66 MHz respectively (1.7839GHz- 1.819GHz, 2.1158GHz- 2.58GHz, 3.615GHz- 3.7417GHz).

VSWR Versus Frequency Graph

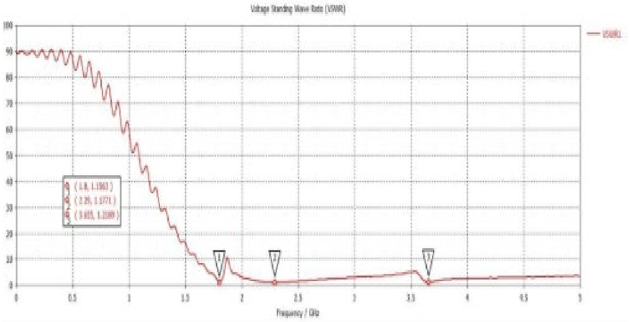

Fig 13. VSWR v/s Frequency graph

IV. CONCLUSION

The proposed microstrip antenna designs offer multiband operation with reduced size and maintaining considerable gain, VSWR and return loss in the operating frequency range for various wireless applications shows Fig.13. The return loss, VSWR, and radiation pattern of the suggested antenna are investigated as its functional features. The suggested antenna would operate on GSM, WLAN, and Bluetooth bands, making it possible to change the frequency for various wireless applications, including Wi-Fi, Wi-Max, GSM, and Bluetooth, using a single patch. The improvement in the return loss, bandwidth, VSWR and also size can be observed by altering the structure of patch, ground plane and substrate. The designed antenna is suitable for S-band and L-Band microwave frequency region for wireless applications.

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