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Design of Circularly Polarised Frequency Reconfigurable Wearable Microstrip Patch Antenna for Wireless Applications.

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ABSTRACT

In this paper a Novel structure of circularly Polarized frequency reconfigurable Microstrip patch antenna has been presented for 1.9GHz, 2.4GHz and 5.5GHz frequencies. Micro strip patch antenna carries attractive features like low profile, flexible, light weight, small volume and low production cost .This paper presents a frequency reconfigurable micro strip patch antenna of incisive design that can be consolidated with wearable technology with a Liquid crystal polymer substrate. The layers of Liquid crystal polymer (LCP) and mercury on conventional patch antenna achieves the frequency reconfiguration. The Proposed Structure was modeled and simulated using CST Microwave Studio and the antenna Parameters such as return loss, radiation pattern and efficiency are checked in free space. For Evaluating on Body Performance the antenna was simulated using numerical model of human body. The simulated output has the return loss of less than -10dB.

Keywords: Wearable antenna; CST simulation; Circular polarization; Return loss; Radiation pattern

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INTRODUCTION

Reconfigurable antennas are in demand for combining multiple wireless standards into a single unit. In general, antennas are reconfigured based on various parameters [1,2] such as; polarization, operating frequency and radiation pattern. The operating frequencies of the patch antennas can be reconfigured mechanically or electrically using PIN diodes [3] and RF varactor diodes [4]. Majority of frequency reconfigurable antennas are designed using PIN diodes because of low cost. However there are few demerits of PIN diodes such as high power loss, low linearity, low quality factor and high insertion loss limiting their use in practical applications. Instead of PIN diode RF MEMS Switches [5-7] are being used to overcome limitations.

The advantages of using MEMS switches [11] are higher quality factor, lower power losses, higher linearity and low insertion loss but the longer switching time is the only drawback.

Varactor diodes are well suited to tune antenna operating frequency continuously and also reduce the circuit complexity in many applications where multiple operating frequency bands are required. However, low dynamic range, high power loss and nonlinearity are disadvantages. Selection of substrate materials plays a vital role in antenna design and its performance. In [8], barium strontium titanate (BST) substrate was used to fabricate frequency reconfigurable patch antenna. By applying different voltages relative permittivity can be modified in BST which belongs to ferroelectric materials.

In [9], chip patch antenna chip capacitors were used across the slots, by using different capacitance values and the transmitting frequency was reconfigured. In [10], mechanically various movable parts are used for the fabrication of reconfigurable antenna. However depends on tuned frequency the size of the antenna was changed is a major stumbling block. Now a day's diodes, switches, tunable materials, capacitors are used to design frequency reconfigurable antennas. But every technique has some restraint. In this paper, mercury and liquid crystal polymer [1] materials are used for achieving frequency reconfiguration in conventional Microstrip patch antenna.

ANTENNA DESIGN AND STRUCTURE

The proposed structure was modeled and simulated in a powerful 3D electromagnetic simulator, CST Microwave Studio. Fig. 1 shows the top view of proposed antenna. The antenna is designed on Rogers RT 5870 substrate with permittivity (ε_r) of 2.33, thickness of 0.5 mm and tangential loss (*tan δ*) of 0.0012. The size of the antenna is 84x80mm^2.For performing frequency reconfiguration three frequencies of WLAN 1.9GHZ, 2.4GHz and 5.5GHz were selected. Three circular patches were then constructed corresponding to the above mentioned three frequencies. These three circular patches were then made detach from each other by constructing a circular gap of 0.5mm wide. The first circular patch has diameter of 9.8mm which corresponds to 5.5GHz frequency. The second circular patch has 23.1mm diameter which corresponds to 2.4GHz frequency. The third circular patch has 30mm diameter which corresponds to 1.9GHz frequency.

The Microstrip feed line has feed length of 35.5 mm and feed width of 1.17 mm. The gap or isolation (0.5 mm wide) between both the patches is filled with liquid crystal polymer (LCP) shown in Fig 1. The thickness of LCP's layer is also 35 µm. In the end 0.1 mm thick and 1 mm wide layer of mercury is placed on the top of LCP. The factors like High adaptability [17], Low tangent value (*tan δ*) (i.e. from 0.002 to 0.0045), inexpensive, excellent chemical protection extremely small thickness and very low moisture absorption ratio makes LCP as superior.

In this way, the diameter of radiating patch extends from 9.8 mm to 23.1 mm which corresponds to 2.4GHz frequency and the antenna starts radiating on this frequency. Similarly the diameter of radiating patch extends from 23.1 mm to 30mm which corresponds to 1.9GHz frequency and the antenna starts radiating on this frequency [1].

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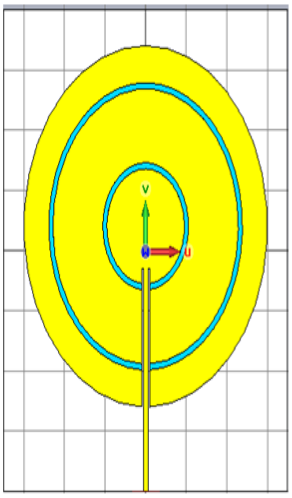
DESIGN



SPECIFICATION:

- SUBSTRTE MATERIAL : ROGERS RT
- GROUND PLATE : COPPER
- PATCH MATERIAL : COPPER
- SUBSTRATE DIMENSTION :84X80mm
- INNER PATCH :9.8mm
- MIDDLE PATCH :23.1mm
- OUTER PATCH : 30mm
- FEED LINE WIDTH :1.17mm
- PATCH THICKNESS :0.035mm
- SUBSTRATE THICKNESS :0.5mm
- LCP THICKNESS :0.035mm
- MERCURY THICKNESS :0.1mm

Fig. 1 Top view of the proposed frequency reconfigurable circular patch antenna

ANTENNA'S CONFIGURATION ON NUMERICAL MODEL OF HUMAN BODY

The proposed antenna structure was simulated both in free space and on body. Numerical model of human body was used to simulate the antenna in the on body. In this numerical model due to refraction and reflection of electromagnetic wave's antenna tends to downgrade the performance emerging from antenna and consuming in the body tissues. Model of human hand was used for studying the antenna performance in the on body, discussed in Fig. 2.

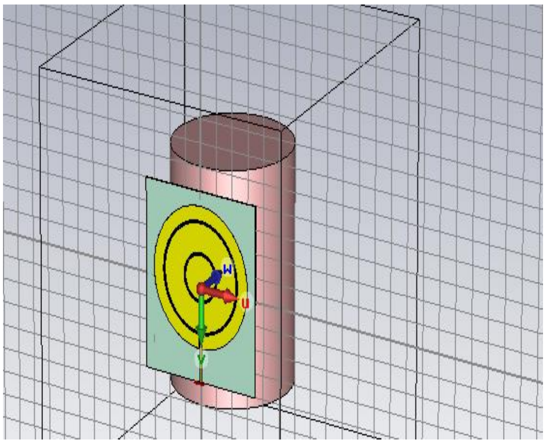


Fig. 2 Numerical model of the human hand

RESULTS AND DISCUSSION

The performance of proposed antenna structure is analyzed in terms of return loss, peak gain, efficiency and SAR (specific absorption rate).The simulated return loss results summary of the antenna in free space at 1.9 GHz, 2.4GHZ and 5.5 GHz are presented in Table I, Table II and Table III. From Fig. 3, Fig. 4 and Fig. 5, it can be seen that the return loss measured is -15.815 dB at 1.9GHz, -19.561dB at 2.4GHz and -21.337dB at 5.5GHz respectively. Similarly the on body simulated return losses on all the three frequencies are shown in Fig 6, Fig 7 and Fig 8.The output shows for on body performance, return loss has been improved for on-body configuration.

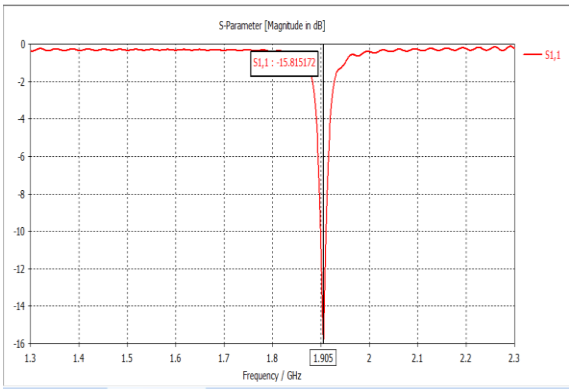


Fig. 3 S11 parameter result on 1.9 GHz

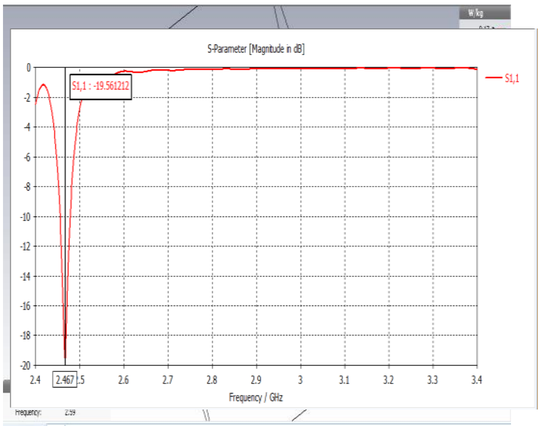


Fig. 4 S11 parameter result on 2.4GHz

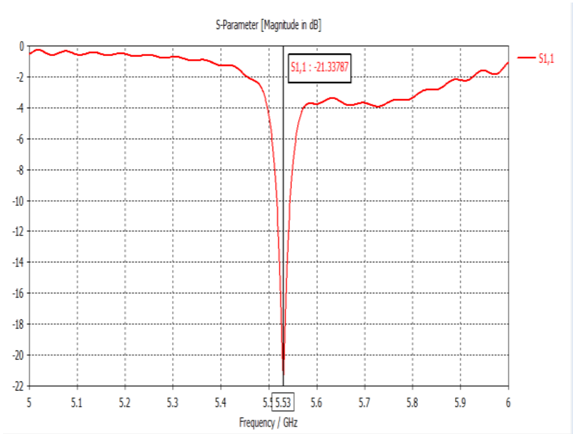


Fig .5. Simulated S11 parameter result on 5.5 GHz frequency

The proposed antenna also has excellent values of efficiencies in all the cases. The values of total efficiency and radiation efficiency are depicted in Table I, Table II and Table III. Specific absorption rate (SAR) is a measure of amount of RF (radio frequency) energy absorbed by the human body tissues. The simulated SAR averaged on 10 g of the body mass for 1.9 GHz is 0.1192W/Kg while for 2.4 GHz it is 0.1698W/Kg and for 5.5GHz is 0.3826W/kg. These values are within acceptable levels specified by the FCC and ICNIRP. Table I, Table II and Table III firmly acknowledges that the free space results showing that good antenna's performance in terms of return loss, peak gain, efficiency and SAR.

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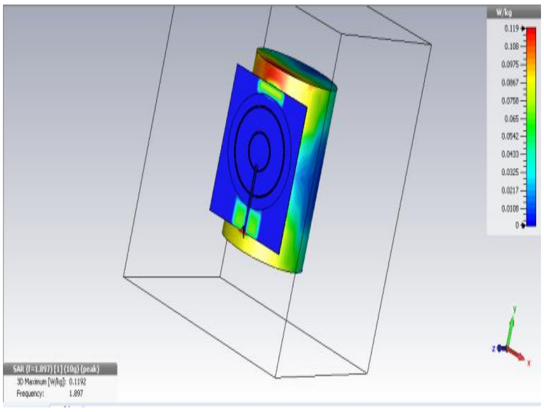

Fig. 6 on-body radiation pattern at 1.9GHz

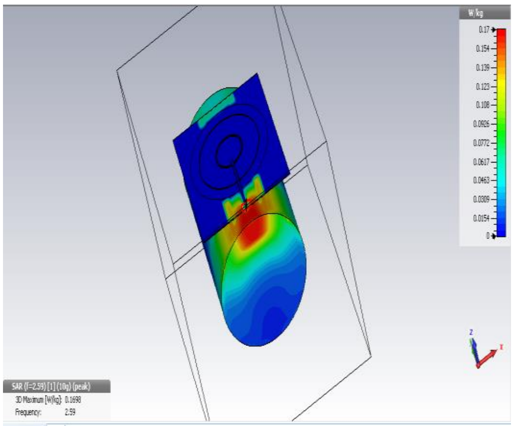

Fig. 7 on-body radiation pattern at 2.4 GHz

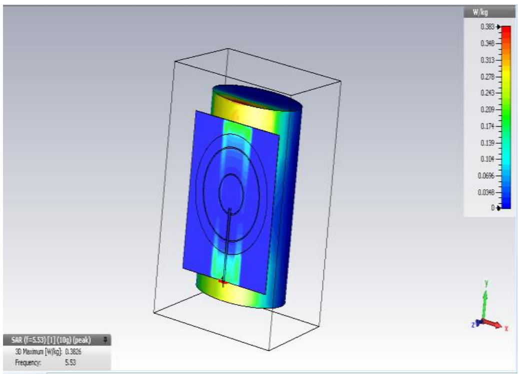

Fig. 8. On-body radiation pattern at 5.5 GHz

TABLE I .SUMMARY OF ANTENNA RESULTS AT 1.9 GHZ

Antenna Parameters	Simulated Results
S_{11} Parameter	-15.81
Peak Gain	4.586
Total Efficiency	-2.517
Radiation Efficiency	-2.401
SAR	0.1192

TABLE II SUMMARY OF ANTENNA RESULTS AT 2.4GHZ

Antenna Parameters	Simulated Results
S_{11} Parameter	-19.56
Peak Gain	4.461
Total Efficiency	-3.029
Radiation Efficiency	-2.981
SAR	0.1698

TABLE III SUMMARY OF ANTENNA RESULTS AT 5.5GHZ

Antenna Parameters	Simulated Results
S_{11} Parameter	-21.337
Peak Gain	3.261
Total Efficiency	-2.306
Radiation Efficiency	-2.274
SAR	0.3826

CONCLUSION

A low cost, efficient and compact frequency reconfigurable Microstrip patch antenna has been designed and analyzed. This paper concludes that by using layers of LCP and mercury on the top of conventional patch antennas, reconfiguration of patch antennas can be performed. The frequency reconfiguration procedure has been investigated and demonstrated. The free space performance of the antenna has been granted in terms of return loss, gain, efficiency, radiation pattern and SAR. These results show that the frequency reconfigurable antenna has better performance with excellent resonant frequencies and with appreciable return loss values. The antenna also offers high gain on all the three frequencies. Thus, the proposed frequency reconfigurable antenna operating on 1.9GHz, 2.4GHz and 5.5 GHz assures a great possible for WLAN applications [11].

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