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A Frequency Reconfigurable and Beam Steering Micro-strip Patch Antenna with Triangular Slot for Wearable Fabric Applications

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Abstract- The design of frequency reconfigurable, beam steering micro-strip patch antenna with a triangular slot for wearable applications is proposed in this work. The wearable computing systems with wireless communication ability are gaining research interest very recently. The progress in electronic equipments and enhancement in wireless mechanisms have applying communication systems adjacent to human bodies. The proposed frequency reconfigurable and beam steered model is comprised of a micro-strip patch with a Triangular-slot designed on a fabric. The suggested design can steer the beam resonant at frequency of 2.4-GHz and 3.4-GHz at different states. The design of the proposed model is integrated with proximity-coupled feeding technique. The addition of two artificial switches between the proximity-coupled feed and the antenna patch, the antenna resulting in four beam directions respective to the modes (S0, S1, and S2 and S3).

Keywords- Wearable Antenna, Body Area Networks, Fabric Antenna, Antenna Design, Micro-strip Patch Antenna, Proximity Coupled Feed, Off-body Wireless Sensor Communication

I. INTRODUCTION

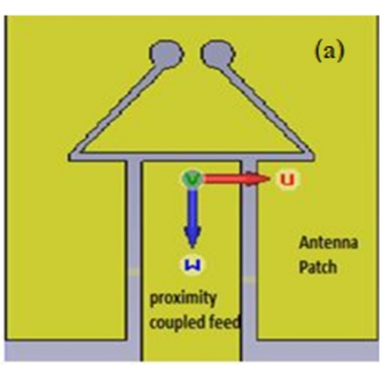
The major factors that influence the design of wearable antenna are compact in size, simple fabrication, mechanical elasticity, user's comfort and low expense. The integrating digital electronics with conductive fabrics and developed a method for wearable electronic circuits [1]. Wireless sensor networks incorporated with clothes permit low priced, reconfigurable gain pattern and atmosphere screening. These sensor systems are comprised of sensors, low energy integrated circuits and computing devices, and wireless conversation antennas for transmission and reception of signals [2-5]. Electro-textiles are commonly employed for fabrication of wearable antennas. They respond to large range of radio frequencies (RF) quite efficiently, vigorously and robustly [6-7]. The adopted techniques of transmission lines are suitable for electro-textiles [8]. When human body expose to electromagnetic (EM) waves, the change in temperature and affect of time varying electric and magnetic fields are the important parameters for human health [9]. The wearable antenna must be unsusceptible to the near field effects on the human body. It can be achieved by minimizing the detuning and to keep to safe operating conditions [10]. It normally has a reconfigurable gain pattern to assure confounding needs of changing environmental conditions. Moreover, the antenna must be small and adjustable for the user's satisfaction by lowering the Specific Absorption Rate (SAR) levels for safety [11]. The United States Food and Drug Administration (FDA) are overseeing wearable medical technology that evaluates the safety measure for wearable devices and associated software applications. FDA has advised the safe ranges of operation and power emission for such appliances. The directivity of beam can be controlled through physical moment of user [12]. Micro-Electro Mechanical Systems (MEMS) switches are integrated with antenna to achieve improved radiation pattern by varying the dimensions of antenna [13]. Pin diodes are inserted to the model as radio frequency (RF) switches to make antenna reconfigurable. The beam steering can be accomplished also accomplished by the RF switches [14-16]. The band achieved is operating in dual frequency modes [17-18]. When the electro textiles are integrated with wearable antennas conduction occurs [19]. Therefore the typical antennas are not a good source for designing of wearable applications so that the flexible materials are used for the designing of wearable antennas [20-21]. The curving effect of antenna operating at 2.5GHz is discussed in [22], that larger the area on human body and clothes the higher will antenna's gains and directivity [23]. A frequency reconfigurable beam steering with a triangular slot patch antenna for wearable fabric applications is proposed that is reconfigurable at 2.4 GHZ and 3.4 GHZ for ISM band and WIMAX applications respectively.

II. Antenna Design and Configuration

The patch is basically made in comparison of a U slot wearable patch antenna [24], a triangular-shaped slot in patch is proposed. The proposed model has a dielectric substrate made up of polyimide (εr = 3.4) and thickness "h" is 4mm and tangent loss is 0.0027. The size of fabrication substrate is (60 x 30) mm^2. The patch material is copper with specified length and width parameters are specified in Figure 1. Ground plane is above the bottom face of entire designed model. The typical characteristic impedance is 50-Ohm for the patch in order to determine the mismatching between antenna and transmission line. The antenna is fed by proximity coupled feed method. The antenna patch and proximity coupled are designed in order to configure two artificial switches. These two artificial switches perform switching at four states (S0, S1, S2 and S3). S0 denotes that both switches S1 and S2 are in ON state. S1 denotes S1 is OFF and S2 is ON. Whereas, S2 denotes switch S1 is ON and S2 is OFF and S3 denotes both S1 and S2 are in OFF states. A triangular slot is used to improve the scattering parameter and make the antenna reconfigurable in operating frequency and beam steering. The diameter of the hole is optimized at 1.8mm to achieve reconfigurable frequency goals. The geometry of antenna in CST MWS is shown as follows in Figure 1. The dimensions of frequency reconfigurable and beam steering patch antenna are described in table.1

TABLE I. DIMENSIONS OF FREQUENCY RECONFIGURABLE AND BEAM STEERING PATCH ANTENNA

Dimensions	Units (mm)
Width W	21.4
Length L	23.8
Effective Length Leff	23
Length of Ground Lg	60
Width of Ground Wg	30



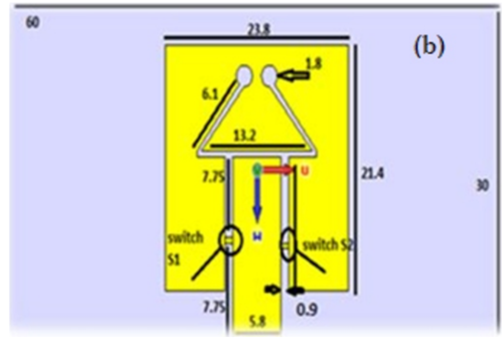


Fig. 1: Proposed design (a) feeding technique (b) proposed design in CST

III. Simulated Results and Discussion

Return loss

The proposed model is an improvement of a model as discussed in [24]. The designing of antenna is done in CST microwave suite. Its switching action in four states S0, S1, S2 and S3 is verified in order to achieve goals to operate antenna at different frequencies with the variation in switching states. Figure 2 shows the return loss achieved at S0 which provides a dual mode itself at frequency 2.4 GHz and 3.4GHz where the return loss S11 was at -20dB and -19dB respectively. At state S1 the operating frequency is 2.4 GHz and return loss S11 is -40.1db which is highly improved then in [25]. At state S2 the operating frequency is 2.4GHz with an improved return loss S11 is -40.75db and at state S3 it is -33db which is a new state in switching that is explored in proposed model.

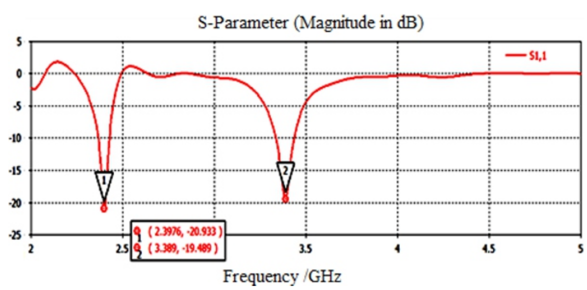


Fig. 2a: Return Loss S11 at switch state S0

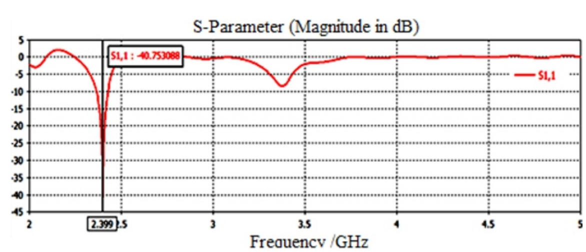


Fig. 2b: Return Loss S11 at switch state S1

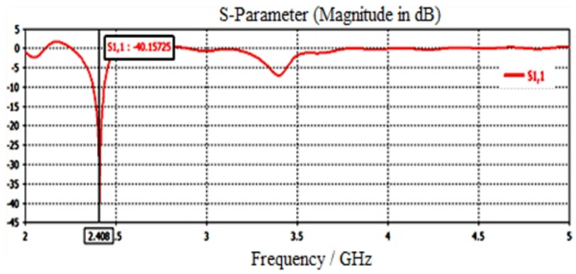


Fig. 2c: Return Loss S11 at switch state S2

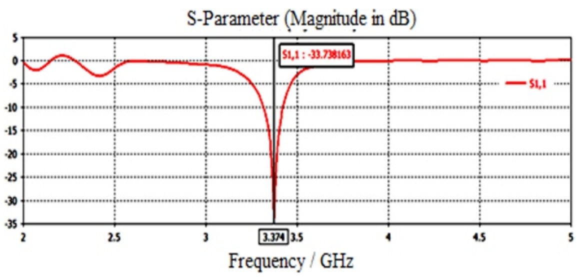


Fig. 2d: Return Loss S11 at switch state S3

Peak Gain

Figure 3 shows the simulated radiation pattern in 3-D. the peak gains are achieved by varying the states (S0,S1,S2,S3). The peak gain achieved at S0 is 4.28 and 5.3dbi. In S1,S2 and S3 the peak gain are 3.65. 2.92 and 5.61 dbi respectively.

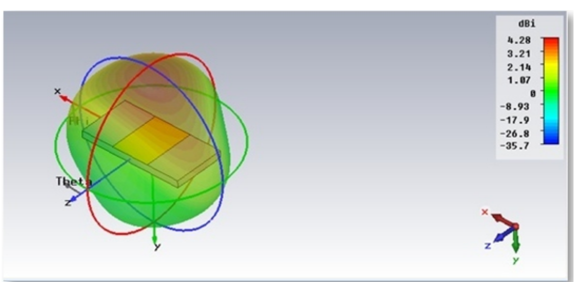


Fig. 3a: 3D Simulated Radiation Pattern

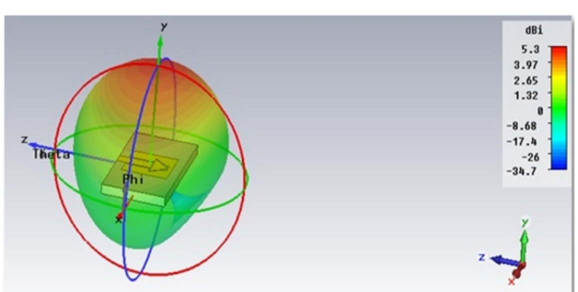


Fig. 3b: Simulated 3D Radiation Pattern at S0

Fig. 3c: Simulated 3D Radiation Pattern at S1

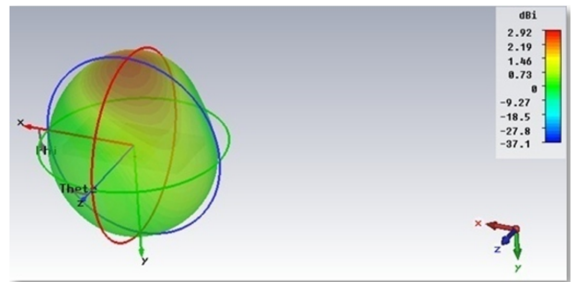


Fig. 3d: Simulated 3D Radiation Pattern at S2

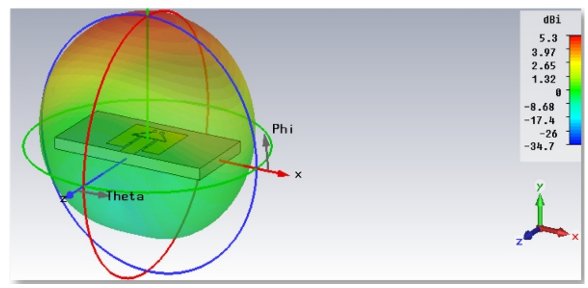


Fig. 3e: Simulated 3D Radiation Pattern at S3

Beem Steering

In Figure 4 and Figure 4a, S0 the maximum beam direction was θ=86,89 and φ=93,66. In Figure 4b, S1 the maximum beam direction was θ=87 and φ=84. In Figure 4c, S2 θ=86 φ=79 and in Figure 4d, S3 θ=89 and φ=41. All the results are clearly discussed with respect to switching states in Table I.

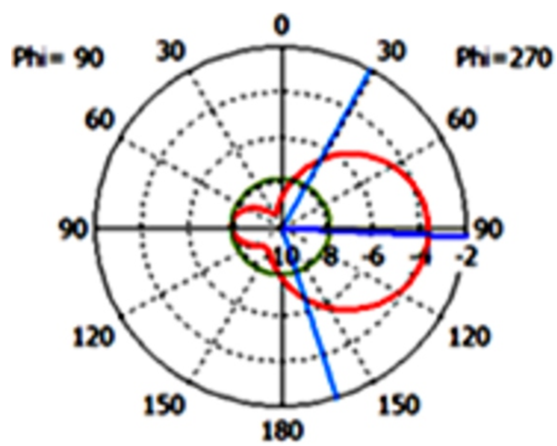


Fig. 4: Beam Steering

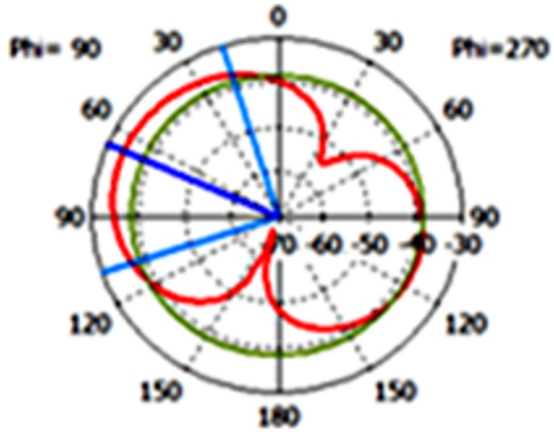


Figure 4a. Beam Steering at S0

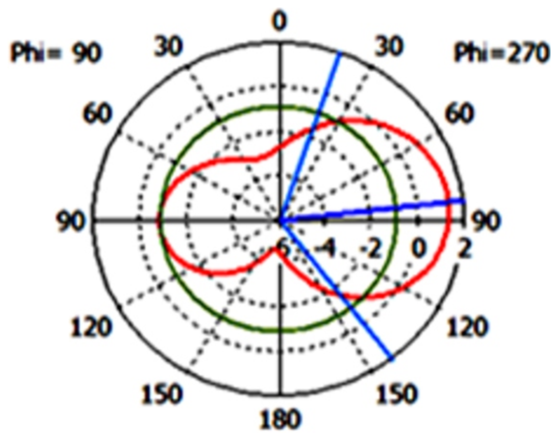


Fig.4b: Beam Steering at S1

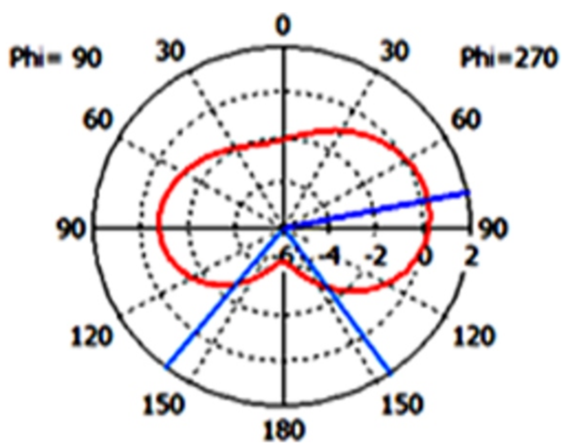


Fig. 4c: Beam Steering at S2

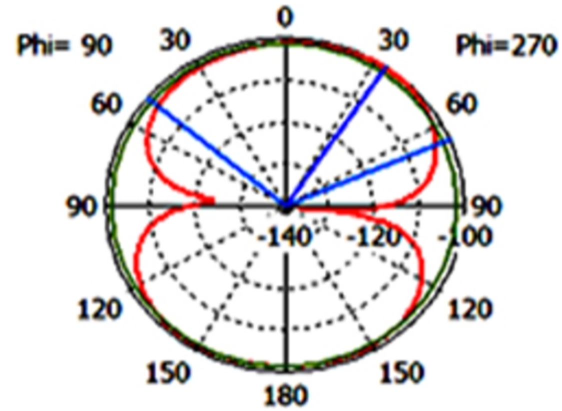


Fig. 4d: Beam Steering at S3

Frequency Reconfigurable

The proposed model has ability to reconfigure the operating frequency with respect to the switching states. At S0 the antenna has better performance at 2.4 Ghz and 3.4Ghz. At S1 and S2 the antenna is resonant at 2.4Ghz. At S3 the antenna is resonant at 3.4Ghz as shown in Table 1.

IV. Conclusion

A reconfigurable frequency and beam steering micro-strip wearable patch antenna with triangular slot is proposed. It is designed to approach the specific requirements of ISM band and the military applications. The functioning criterion of the proposed antenna is similar to the conventional patch antenna. The proposed model when compared to the model in [26-28] the return loss is highly improved for all the states S0, S1, S2 and S3 as -20 dbi, -40.1 dbi, -40.75 dbi and -33 dbi respectively. Therefore this variation shifts the operating antenna performance to 2.4GHz and 3.4GHz for So and 2.4GHz for S1 and S2 and 3.4GHz for state S3.The proposed model has been tuned at different operating frequencies by changing the pattern of slot in geometry and produce an effective beam steering at specifics angles.

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