Reconfigurable Microstrip Patch Antenna with a U-Slot using Wearable Substrate

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ABSTRACT
Reconfigurable micro-strip patch antenna with a U-slot is proposed for wearable fabric applications. Fabric substrate is used for the proposed antenna for manufactured and designed to steer the beam directions at the operation frequency of 7.0 GHz. For design the proposed antenna the U-shaped slot and a proximity-coupled feeding technique are applied. By configuring two artificial switches between the proximity-coupled feed and the antenna patch, the antenna is given three beam directions (S0, S1, and S2). The maximum beam directions are steerable in the -plane (θ= 0 , 30 , and 331 , respectively. The gains at the maximum beam directions of S0, S1, and S2 were 6.62, 6.69, and 6.11 dBi, respectively. The HPBWs of S0, S1, and S2 were 60 , 55 , and 65 , respectively, and the overall HPBW of the three states was 115 .

Keywords
fabric antennas,patch antennas, U-slot, wearable antennas, micro strip patch antenna

1. INTRODUCTION
Research on “on-body” devices has provided new ideas for advanced application. In addition, interest in integrating clothing and electronic devices has led to various kinds of wearable antenna structures .There are some requirements in the wearable antenna design such as relatively light weight, flexible substrates, and a simple method of integrating the antenna into the clothing. Due to its close proximity to the human body the wearable antenna demands special design consideration. In other issues of the antenna segment, wireless systems employ many techniques that attempt to enhance the received signal, suppress all interfering signals, and increase the channel capacity [5]. Methods of improving performance are usually categorized as either adaptive array antenna or single antenna element.

The adaptive array antenna has been the most commonly used type of steerable antenna system, and it provides better gain than the switchable single antenna element. Recently, the size of the adaptive array antenna has to be reduced due to the space limitation of mobile applications, but such size reduction has been found difficult to realize. Therefore, the switchable single element antenna with beam-steering capability is required for practical applications. Also, the single antenna element is more suitable for integration into clothing because the method has the advantages of simplicity, small size, and easy radiation handling.

In this letter, a reconfigurable micro strip patch antenna that uses a micro strip patch for wearable fabric applications is presented. The proposed antenna can steer the maximum beam direction in the yz-plane using two artificial switches. We designed the antenna to be utilized in ubiquitous healthcare applications for patients in an indoor hospital environment. The service band is not determined yet in our project, and we just select the operating frequency at the 7-GHz band of the X- band for the “on-body” applications [6], [9]. The simulated results confirmed that the steering characteristic of the proposed antenna can be realized in wearable fabric applications.

2. ANTENNA DESIGN
2.1 Antenna Structure
The top view of the reconfigurable microstrip patch antenna that will fabricated on a fabric substrate with permittivity = 1.71 and loss tangent is 0.02 is shown in Fig. 1. The fabric substrate is selected from common clothes, such as pants and shirts. The detailed composition of the fabrics is polyester 66.2%, cotton 33.8%.The size of the fabric substrate is 60mm & 30 mm , and its thickness is 1.5 mm.

The overall dimensions of the antenna patch were 23.8mm & 21.4 mm . The ground was backed in the bottom plane. To maintain its flexibility the conductive part of the antenna will manufactured with silver paste . The silver paste is a mixture of silver powder and acrylic resin . The antenna consisted of an antenna patch part and a proximity-coupled feed. The antenna was fed by a proximity- coupled. The proximity-coupled was isolated from the antenna patch on the same plane. The gap between the proximity coupled and the antenna patch was 0.9 mm on its left and right sides and 0.5 mm on top.

The antenna patch and the proximity- coupled were designed to be connected using two artificial switches. There are three states in the configuration of the two artificial switches (S0, S1, and S2). S0 denotes that both switches (1 and 2) are in the OFF state. S1 denotes that only switch 1 is in the ON state, and S2 denotes that only switch 2 is in the ON state. The switch in the ON state means that the conductive line is connected between the proximity-coupled feed line and the antenna patch (short). The switch in the OFF state means that the conductive line is disconnected (open).

A U-slot was used to improve the input impedance matching of the antenna [2]. Two round holes of the U-shaped slot were designed to tune the operation frequency. When the diameter of the round. Holes was optimized to 1.8 mm, the operation frequency of the antenna was matched at 7 GHz.

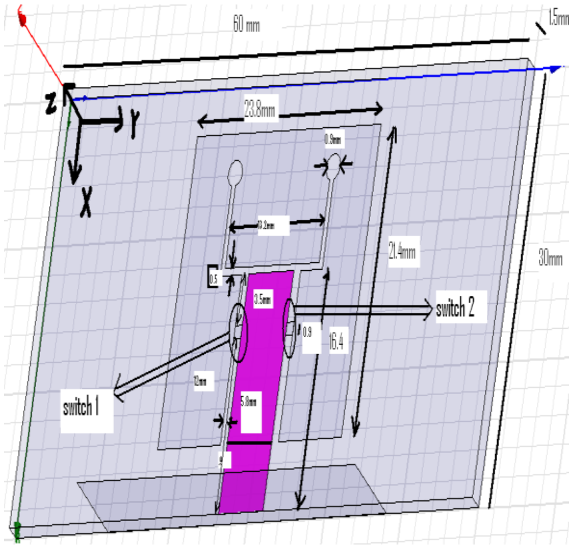


Fig. 1.Top view of the proposed antenna with dimensions

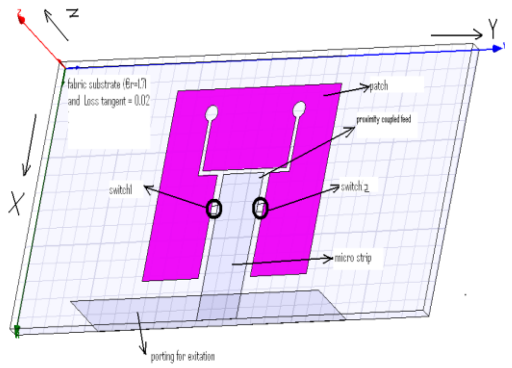


Fig. 2. Top view of the proposed antenna

3. SIMULATION AND MEASUREMENT RESULTS

Fig. 3 shows the simulated surface current distributions (J [A/m]) at the same operation frequency of 7 GHz. It is observed that the majority of the current distribution in S0 is symmetrical in the two round holes of the U-shaped slot. It was also found that the maximum beam direction of S0 is in the -axis due to the symmetrical current distribution. In S1, the current distributions are stronger on the right side of the antenna. Conversely, in S2, the current distributions were stronger on the left side of the antenna. With this asymmetrical current distribution in the asymmetric switch configurations of both S1 and S2. Fig. 4 shows the simulated 3-D radiation patterns (yz-plane). The maximum beam directions of the radiation patterns were clearly changed by state (S0, S1, and S2). In S0, the maximum beam direction was in the z-axis, and θ=0,ϕ = 0 and, the gain at the maximum beam direction was 6.15 dBi. In S1, the maximum beam direction was in the z axis and θ = 30 ,ϕ = 90 and the gain at the maximum beam direction was and 5.87 dBi. In S2, the maximum beam direction was θ=270 and ϕ = 330 and the gain at the maximum beam direction was 5.65 dBi. Fig. 5 shows the measured return losses of the antenna in free space (S0, S1, and S2). The antennas of all the states operated at the same frequency of 7 GHz. The bandwidth was about 280 MHz . The measured results shows that the antenna will almost unaffected by contact with the human skin. The resonant frequencies are almost same of the antenna “on the wrist” with the antenna “in free space,” and both reflection coefficients are below 10 dB at all the states (S0, S1, S2). In next step, we are planning the supplementary examination for the specific absorption rate (SAR) and designing the model including the RF switches.

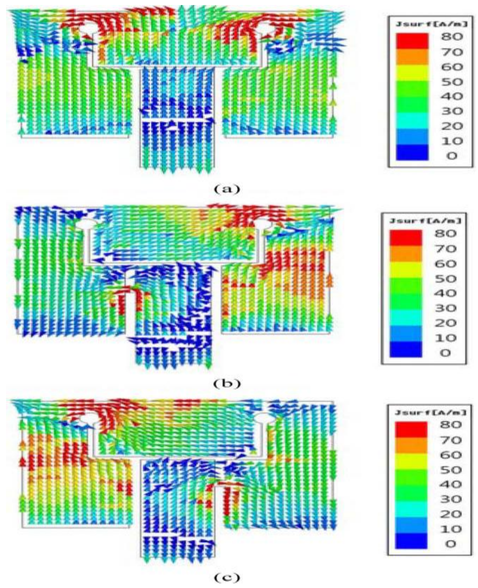


Fig. 3. Simulated surface current distribution on the conductive part (a) S0 (b) S1 (c) S2

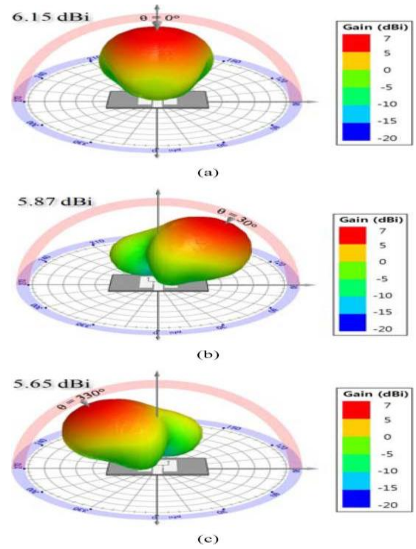
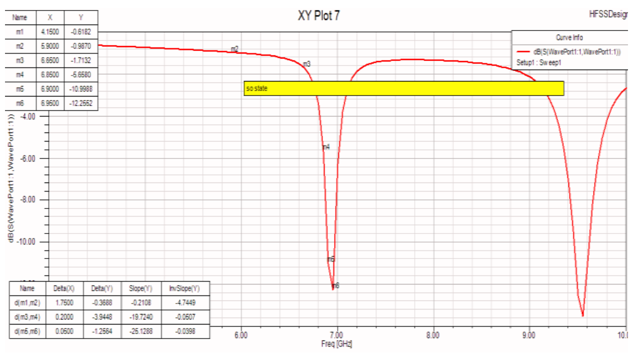
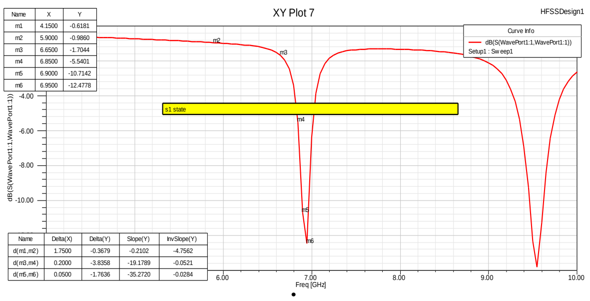


Fig. 4. Simulated 3-D radiation patterns (a) S0 (b) S1(c) S2



(A)



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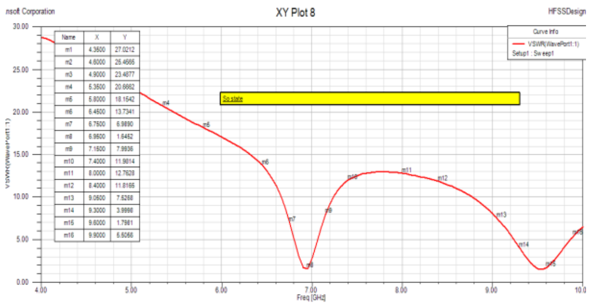
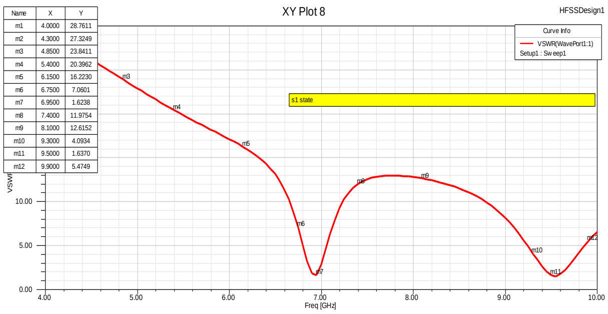
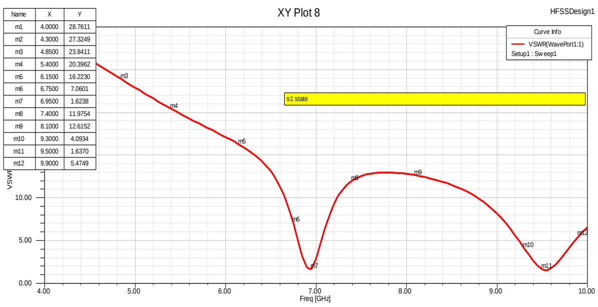


(a)



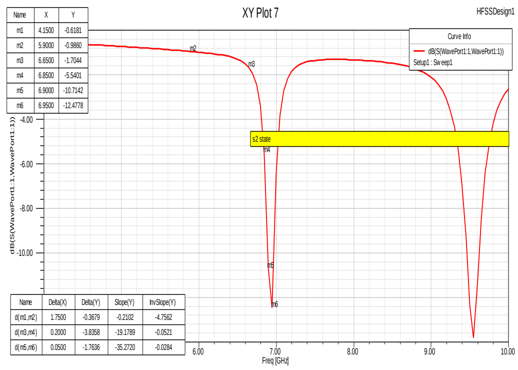
(b)



(c)

Fig 5 : Reflection coefficient and VSWR for S0,S1 &S2 STATES

Such as p-i-n diodes, as we think that the SAR value is an essential factor to evaluate an effect of the electromagnetic wave around human body in the design of an antenna for "on-body" applications. Fig. 6 shows the measured radiation patterns in the yz-plane, and the measured maximum beam direction, peak gain, and half-power beamwidth (HPBW) of each state are summarized. The maximum beam directions of S0, S1, and S2 were θ= 0, 30, and 331, respectively. The gains at the maximum beam directions of S0, S1, and S2 were 6.62, 6.69, and 6.11 dBi, respectively. The HPBWs of S0, S1, and S2 were 60, 55, and 65, respectively, and the overall HPBW of the three states was 115.



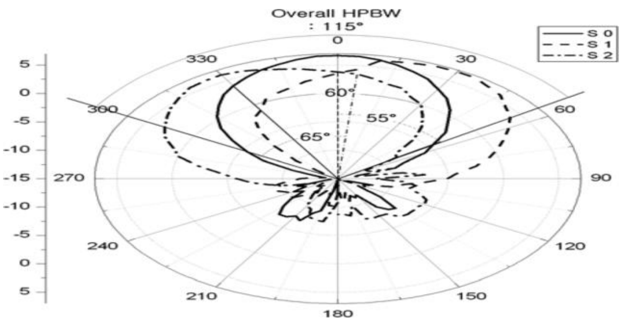


Fig. 6. Measured radiation patterns and overall HPBW (yz-plane) in free space.

4. CONCLUSION

In this letter, a patch antenna with a U-shaped slot was designed, and analyzed. The results proved that the proposed antenna can steer the maximum beam direction. It was also found that the operation frequencies of all the states (S0, S1, and S2) were identical. In addition, this study is assumed to be the first demonstration of a reconfigurable beam-steering method that uses a single patch antenna on a fabric substrate, and which was proven to be low-cost, easy to fabricate, and capable of integration with clothing.

5. REFERENCES

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