

# Reconfigurable Beam Steering Using Microstrip Patch Antenna with U-slot for Wearable Fabric Applications

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## Abstract

Reconfigurable beam steering using the microstrip patch antenna with U-slot is proposed for wearable fabric applications. The proposed antenna is manufactured on a fabric substrate, and designed to steer the beam directions. By the configuration of two artificial switches, the antenna has three beam directions in the  $yz$ -plane.

**Keywords :** Textile Antenna, Patch Antenna, Wearable Application, On-body application, Beam-steering Antenna

## 1. Introduction

Recently, interest of integration between clothing and electronic devices has led to various kinds of wearable antenna structures [1-2]. Wearable antenna demands special design consideration due to close proximity of human body. Another issue in the antenna segment, the wireless system includes a large number of techniques that attempt to enhance the received signal, suppress all interfering signals and increase channel capacity [3]. Methods of the improving those performances are usually categorized as either switched-beam or adaptive-array systems. Switched-beam antennas are able to modify their pattern within a fixed number of directions [4-6]. The adaptive-array systems require that the RF path to each element has a number of splitters and phase shifter [7].

In this letter, we presented a single patch beam steering antenna with U-shaped slot for fabric applications. Due to their shape, low profile, and compactness, planar antennas of the microstrip patch type have proven to be best suited for integration into garments. Moreover, the antenna is fabricated on a substrate for wearable fabric applications. The proposed antenna is able to steer the maximum beam direction in the  $y$ - $z$  plane. Simulated results confirm that the steering characteristic is able to realize by using two artificial switches.

## 2. Antenna configurations

Figure 1 shows the composition of a proposed antenna. The composition is similar to the conventional patch antenna. But, the conductive part is manufactured by silver-paste which is a mixture of the silver powder with acrylic resin. We used silver-paste in the manufacturing process of the conductive part. It is necessary to maintain performance of wearability. Moreover, assembling the conductive part on a flexible substrate maintains overall flexibility of the antenna component. We selected the substrate which is a fabric with a relative dielectric permittivity of 1.71, and a thickness of 1.5 mm. Figure 2 is the detailed dimension of proposed antenna. Two artificial switches which are configured with just a line connection are located between the feeding line and the antenna patch to control the current distributions of the conductive part. There are three states,  $S_0$ ,  $S_1$ ,  $S_2$ , by using two artificial switches.  $S_0$  denotes that both switches (1) and (2) are in OFF-state.  $S_1$  denotes only switch (1) is in ON-state, and  $S_2$  denotes only switch (2) is in ON-state. The switch ON-state means that the line between the feeding line and the antenna patch connected (short). Also, the switch OFF-state means that the line is disconnected (open). U-shaped slot is

designed to divide current distributions asymmetrically. The round parts of U-shaped slot are designed to match the operation frequency. If there are no round parts, the antenna operates two separate frequencies, for example 5.9GHz and 6.1GHz. When the round parts are approximately optimized, the operation frequencies are matched up a one point. Figure 3 shows the photograph of fabricated prototype antennas (*S 0, 1, 2*) and the antenna mounted on the human-wrist.

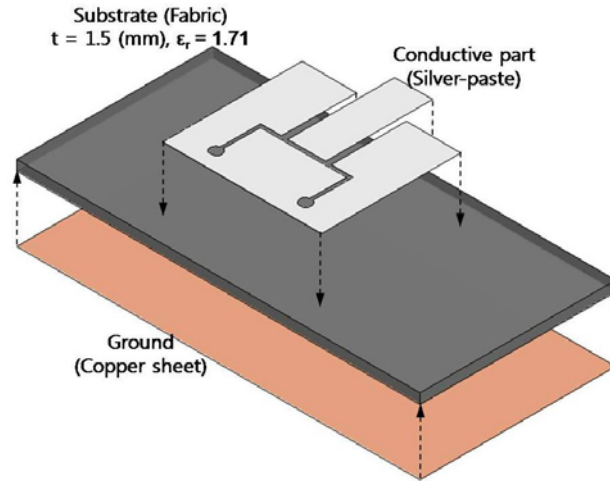


Figure 1: Composition of a proposed antenna

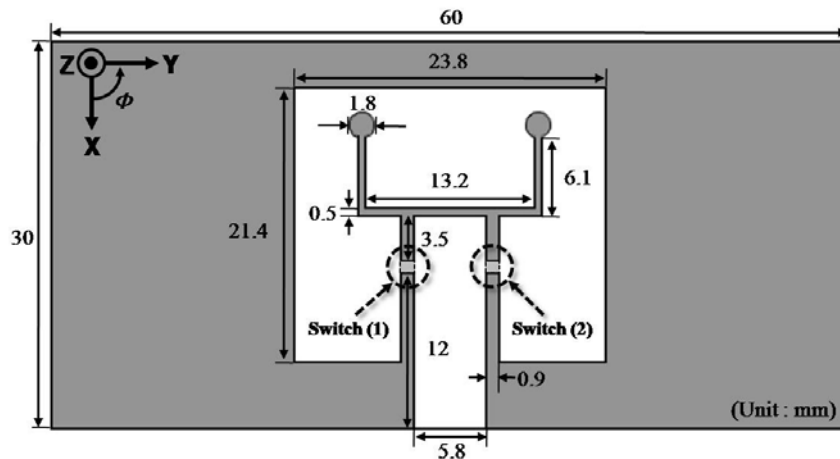


Figure 2: Dimension of a proposed antenna

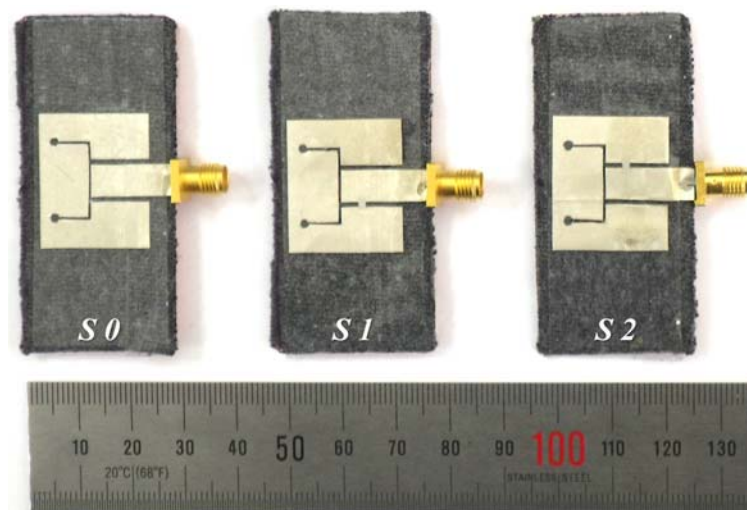


Figure 3: Photograph of fabricated antenna

### 3. Simulation and measurement results

Figure 4 presents the simulated surface current distributions ( $J$  [A/m]) at the same operation frequency of 6 GHz. It is observed that the majority of the current distribution in the  $S 0$  is symmetrical in the both round shape holes of the U-slot. We found that the maximum beam direction of the  $S 0$  is in the  $z$ -axis due to the symmetrical current distribution. In the  $S 1$ , the current distributions are stronger on the right side of the antenna. Conversely, in the  $S 2$ , the current distributions are stronger on the left side of the antenna. By this asymmetric current distribution by the asymmetric switch configurations of both  $S 1$  and  $S 2$ , the maximum beam directions are tilted from  $z$ -axis to  $+y$  direction and  $-y$  direction. Figure 5 shows the measured return losses of the antenna in the state of  $S 0, 1, 2$ . The antennas of all the states operate at the same frequency, 6 GHz. The bandwidth is about 280 MHz (VSWR < 2). Figure 6 shows the measured radiation patterns in the  $yz$ -plane, and the measured maximum beam direction, peak gain. The maximum beam direction of  $S 0, 1, 2$  is  $\theta = 0^\circ, 30^\circ, 331^\circ$ , respectively. The gain at the maximum beam direction of  $S 0, 1, 2$  is 6.62, 6.69, 6.11 dBi. The HPBW of  $S 0, 1, 2$  is  $60^\circ, 55^\circ, 65^\circ$ , and overall HPBW of three states is  $115^\circ$ .

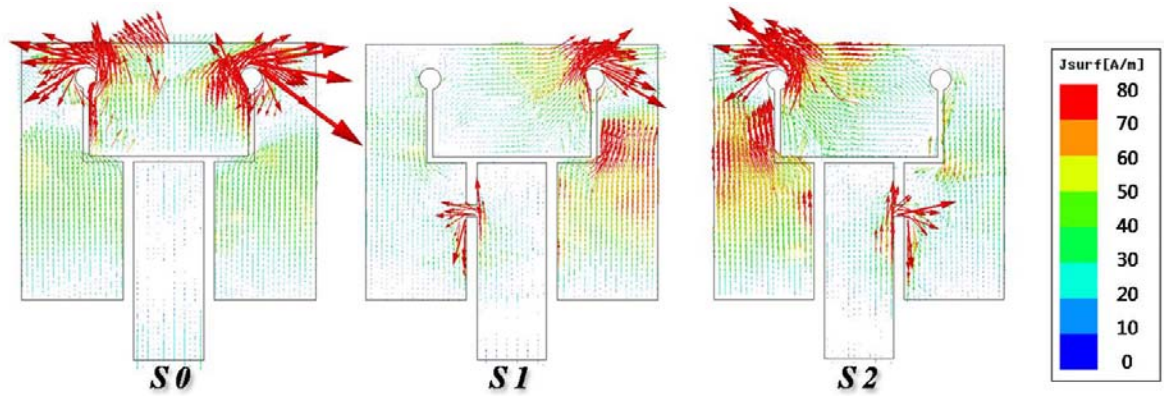


Figure 3: Current distributions on the conductive part

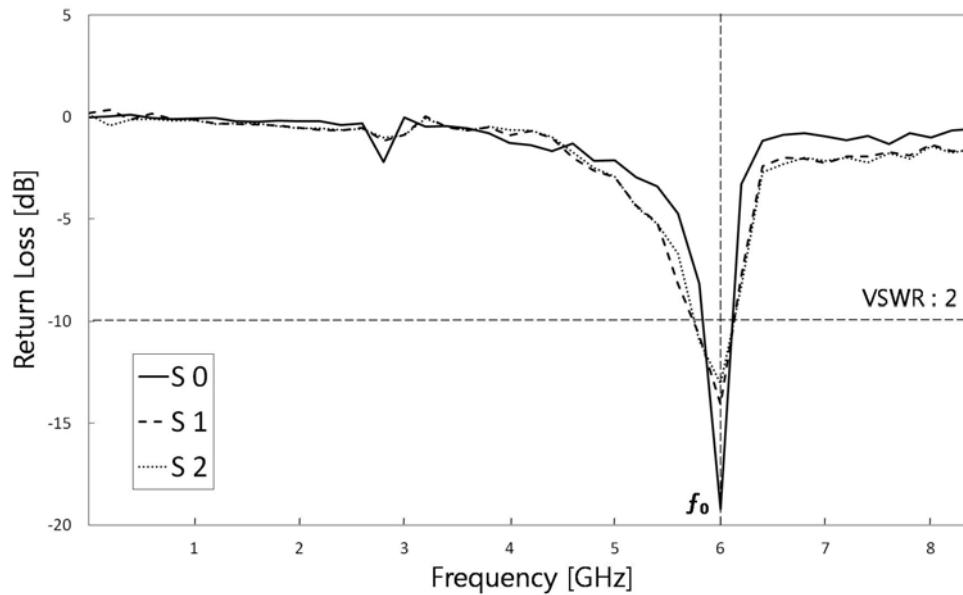


Figure 4: Measured return losses

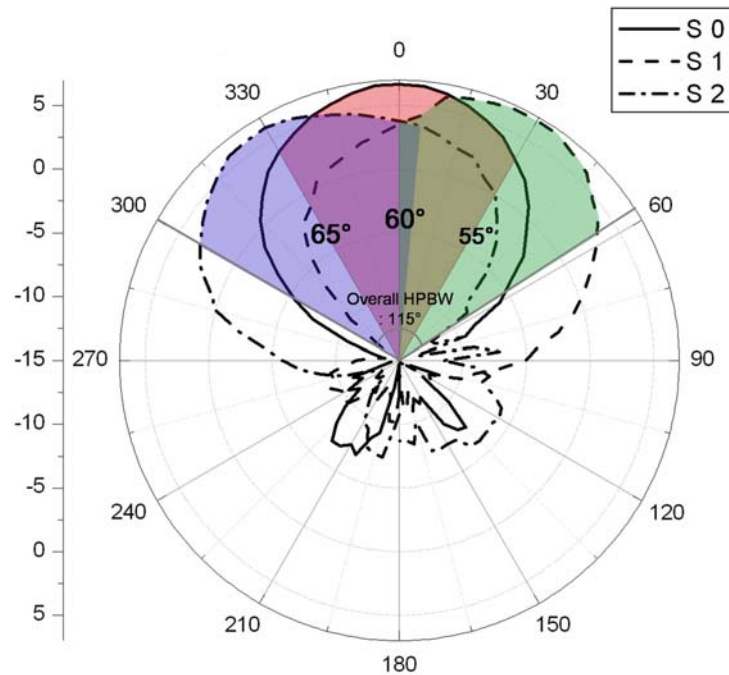


Figure 5: Simulated radiation patterns (y-z plane)

## 4. Conclusions

In this paper, the beam steering method using a patch antenna with U-slot is designed, fabricated and analyzed. The measured results prove that the proposed antenna is able to steer the maximum beam direction. We also found that operation frequencies of all the states ( $S 0, 1, 2$ ) are identical. In addition, our works are assumed to be the first demonstration of a reconfigurable beam steering using single patch antenna on the fabric substrate, which is proven low cost, ease of fabrication and capability of integration with clothing.

## References

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