MULTIFUNCTIONAL PATTERN RECONFIGURABLE WRIST ANTENNA STRUCTURES BASED ON BISTABLE COMPOSITE CYLINDERICAL SHELLS FOR ON-BODY APPLICATIONS

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Extraordinary research on on-body devices has provided new ideas for medical instruments, health-monitoring systems and telemedicine communications. Many radio frequency (RF) engineers have developed wearable antennas in the form of wristbands or attachments to clothing [1]–[3]. However, these wearable antennas must have sufficient both structure and antenna performance to satisfy the requirements of the rapid development of electronic and wireless communication technologies. Radiation pattern reconfigurable antennas have the capability of enhancing system performance, reducing interference and providing larger coverage by steering the main beam. Bistable composite structures are growingly becoming attractive in developing morphing [4-6] and deployable [7] structures. A new deployable bistable composite tape-spring antenna for CubeSat communication was proposed by [8]. The antenna using bistable composites achieved the operating frequency reconfigurability rather than pattern reconfigurability [9].

In this paper, a multifunctional wrist antenna composed of an antenna layer, bistable GFRP composite shells and an Al film is proposed. The antenna structure is designed and numerically simulated by a commercial finite element code ABAQUS software and 3-dimensional electromagnetic simulation with CST Microwave Studio software. The simulated and measured stable geometrical configurations and electromagnetic properties (return losses, radiation patterns and gains) of the antenna structure are compared. The antenna structure can be acted as a Fitbit Flex of human wrist when it is in stowed state. The proposed antenna structure has potential applications in multifunctional, morphing and wearable structures.

The antenna structure is constructed using bistable glass fiber reinforced plastic (GFRP) cylindrical shells integrated with 1×8 microstrip antenna array. The lay-ups of the antenna structure are [antenna array/45/-45/90/45/-45/ground plane]. The microstrip antenna array is designed and simulated by CST Microwave Studio software. In this study, the operating frequency is a new WLAN bandwidth (5.0GHz). A schematic of 1×8 microstrip antenna array is shown in Fig.1 (a). The antenna structure has two stable states: stowed and extended states, when the curing process of the structure is complete. The antenna structure can be acted as a Fitbit Flex of human wrist when it is in stowed state, as shown in Fig.1 (b). The dimensions of the antenna structure are 200mm×40mm.

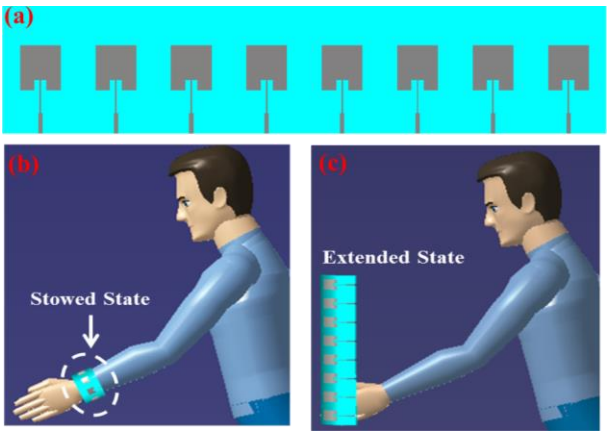

Figure 1: Schematic diagram of the antenna structure: (a) antenna array, (b) two stable states

Fig.2 shows the simulated reflection coefficient of the two stable states of the antenna structure. The antenna of the two stable states both operated at the same frequency of 5.0 GHz. The bandwidth is about 114 MHz (VSWR<2).

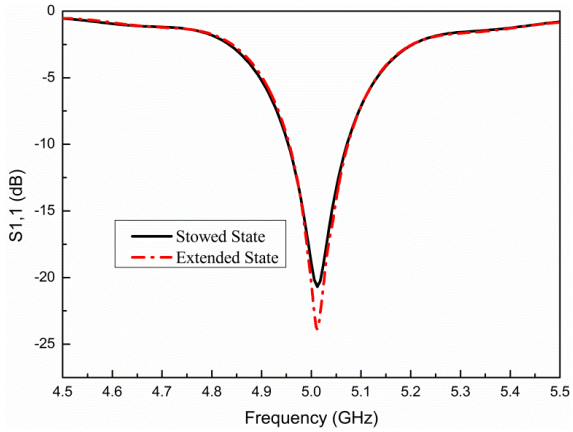

Fig.2. Simulated reflection coefficient of the two stable states of the antenna structure

The simulated 3D radiation patterns of the two stable states are shown in Fig.3. The results indicate that the radiation pattern of the antenna structure shows omnidirectionality in stowed state and has excellent directivity and anti-interference ability in extended state. The gains of the wrist antenna are -0.62 dB for omnidirectional mode (stowed state) and 9.46 dB for directional mode (extended state).

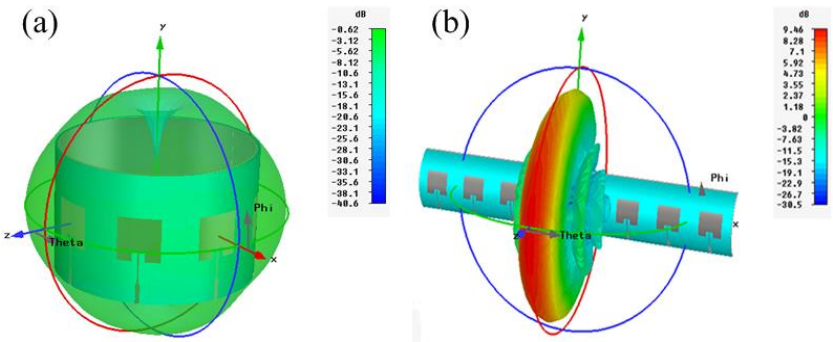

Fig.3. Simulated 3D radiation patterns of the wrist antenna in two stable states: (a) stowed state, (b) extended state

The H-plane radiation patterns of the two stable states of the antenna structure at 5GHz are shown in Fig.4. It is clear that a good omnidirectional radiation in the azimuth plane (H-plane) is obtained as shown in Fig.4 (a).

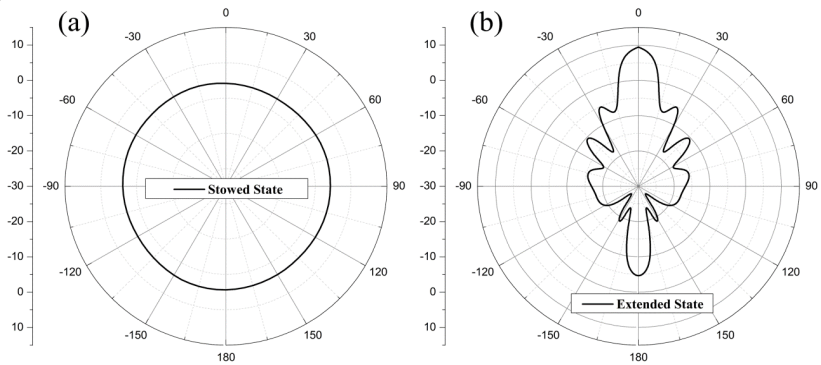

Fig.4. Simulated H-plane radiation patterns of the wrist antenna in two stable states: (a) stowed state, (b) extended state.

The omnidirectionality in the H-plane is defined as gain roundness which can be obtained from:

$$G_R = Max\{\left|G_{\max} - G_{avg}\right|, \left|G_{\min} - G_{avg}\right|\}$$

Where G_R denotes the gain roundness, $G_{\max}$, $G_{\min}$ and G_{avg} denote the max, min and average value of the gains in the H plane, respectively.

The simulated gain roundness of the radiation pattern of the stowed state is 0.51dB. This antenna structure can generate directional radiation patterns by changing its configuration from stowed state to extended state. The H plane radiation pattern of the extended state is shown in Fig.4 (b). The HPBW of H-plane patterns is about 13.7°, which indicates that the antenna has good directivity and anti-interference ability in extended state.

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