Effect of Rotating the Patch Antenna Close to the Human Body

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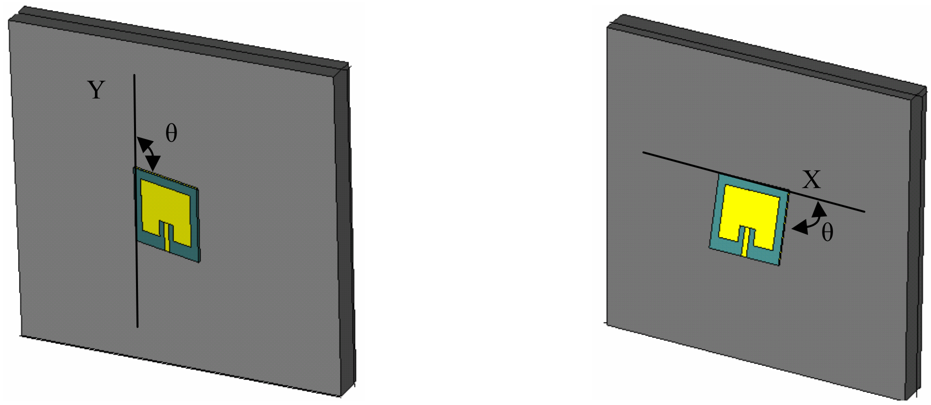
1. Introduction

Wearable antennas have been intensively investigated in the recent years. This paper presents one patch antenna rotating along two axes when in proximity to a phantom with similar electrical properties to the human body. The antenna performance at several different contact angles is reported. Measurements in both anechoic and reverberation chambers yield good agreement with simulations.

2. The Patch Antenna for Body Worn Network

Microstrip patch antennas are a good choice in wearable communication systems because they offer low profile, low back radiation and less detuning. Good antenna designs require controlled radiation patterns, high antenna efficiency and good tolerance of human movement. Antenna engineers must design for optimum performance in conjunction with not only the RF circuit but also for the specific application domain [1] [2].

Strong coupling occurs through the near field between the antenna and the human body in a wearable communication system. Any distortion, such as the separation adjustment or antenna rotation, has considerable effect in the near field. In general, the distance between the antenna and the human body surface refers to the degree of coupling intensity, which may be applied for a fixed incident antenna position and orientation. Considering the wave incidence at different angles, with various antenna orientations, the radiation performance will alter in terms of the maximum radiation direction, the antenna bandwidth and efficiency. In this paper we investigate a 2.45 GHz patch antenna rotating along two axes as shown in Figure 1. The patch antenna is based on Taconic RF-35, ε_r=3.5 with a substrate thickness of 1.52 mm which has a size of 46 mm × 46 mm. The phantom used in the simulation has a permittivity (ε_r) of 45, a loss tangent of 0.3, with dimensions of 200 × 200 × 20 mm [3]. The size of this body model was found after comparing the simulation results in terms of antenna performance when a larger model was used. No significant differences were found. The angle is formed by the ground plane of the patch antenna and the top surface of the phantom. In the initial situation, the patch antenna is located parallel to the phantom but having a 1 mm separation and in the following steps, the patch antenna is rotated individually along one edge, named x and y axes while keeping the separation from that axis edge to the phantom surface at 1 mm. The three angles (θ), 15^0, 25^0, 35^0, are chosen to check the radiation pattern and antenna efficiency. However some larger angles, such as 45^0, 60^0 or 75^0, could be verified, but this condition is not often met in practice. So only a limited range is selected in this paper.



(a) (b)

Figure 1: (a) Rotating the patch antenna along the *y* axis (b) Rotating the patch antenna along the *x* axis

3. Results

Electromagnetic simulations were performed using CST MICROWAVE STUDIO™. The antenna radiation patterns were measured using an anechoic chamber and the antenna efficiency was measured using a reverberation chamber. Extremely low loss foams were employed to generate the given angles shown as small white bricks in Figure 2. The antenna was attached to the lossy body phantom.

(a) (b)

Figure 2: The patch antenna on the phantom with a rotating angle along (a) the *y* axis and (b) the *x* axis

3.1 Rotating along the *y* axis

The patch antenna was rotated along the *y*-axis, the measured return loss remains stable although the simulation results give large variances, which means that the feeding structure is not sensitive to the rotation effect. The peak value of the antenna efficiency decreases 30% when it is in proximity to the phantom compared to free space which is attributed to the back radiation loss excited by the ground current. Although more space between the ground plane and the lossy phantom is provided duration rotation steps, there is no apparent increase in the antenna efficiency. Considering the radiation pattern after the antenna rotation away from the body shown in Figure 5, part of the energy, which should propagate into free space, is absorbed instead. The radiation direction is located and illustrated in Figure 5. Because the patch antenna offers peak radiation appearing in its normal direction, firstly, the maximum radiation shifts based on the rotation angle, both of which are very close; secondly, the pattern doesn't maintain symmetry on both sides. There is a noticeable range over which the amplitude drops quickly, which may become a serious problem if good horizontal coverage is necessary.

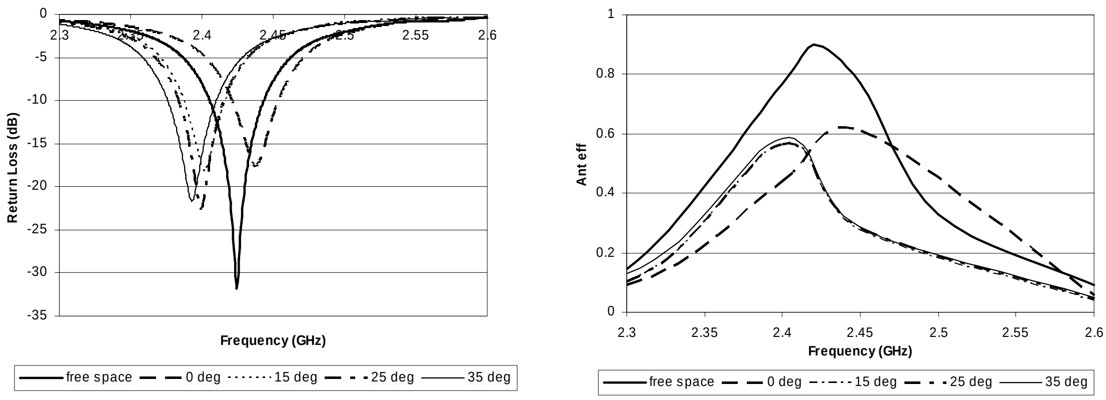


Figure 3: Simulated return loss and antenna efficiency using CST Microwave Studio™

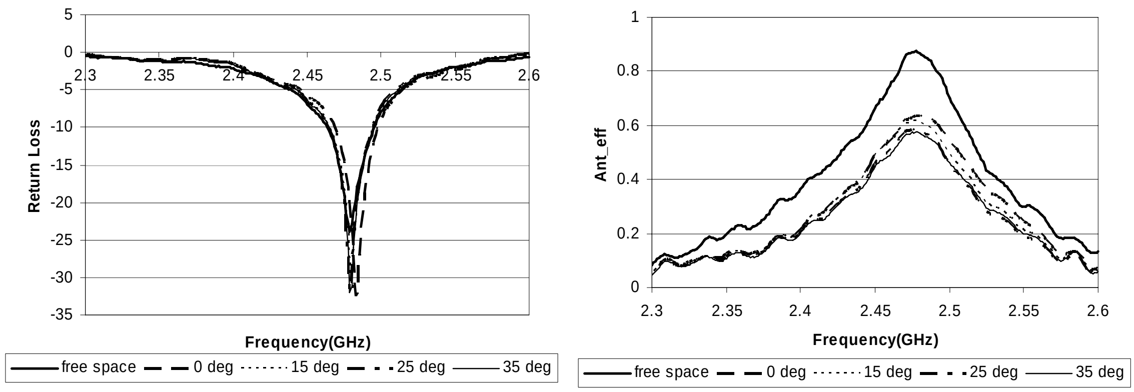


Figure 4: Measured return loss and antenna efficiency using a reverberation chamber

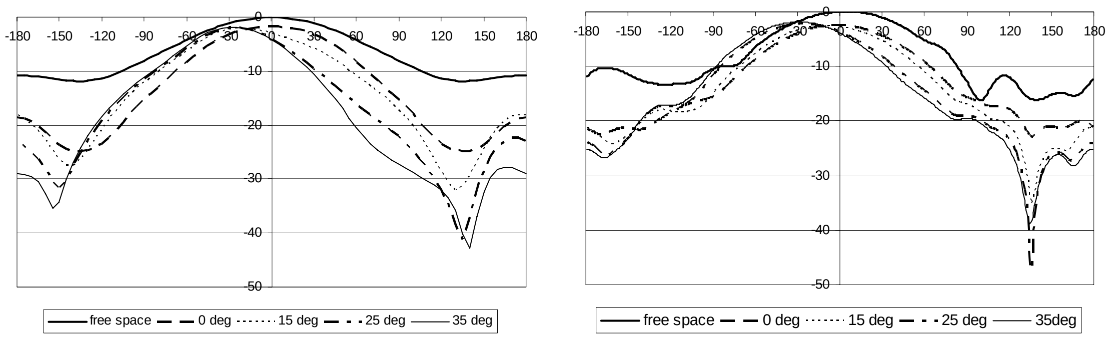


Figure 5: The simulated (left) and measured (right) H plane pattern

3.2 Rotation along the *x* axis

The analysis was repeated for the *x* axis. The measured return loss remains stable as in the previous situation. An interesting point occurs at a rotation angle of 35^0, where the antenna offers a higher efficiency around 74% with direct benefits to the wearable system. The reduced loss in this position may be due to lower coupling between the ground current and the phantom and less energy absorbed by the phantom at the forward side of the patch antenna.

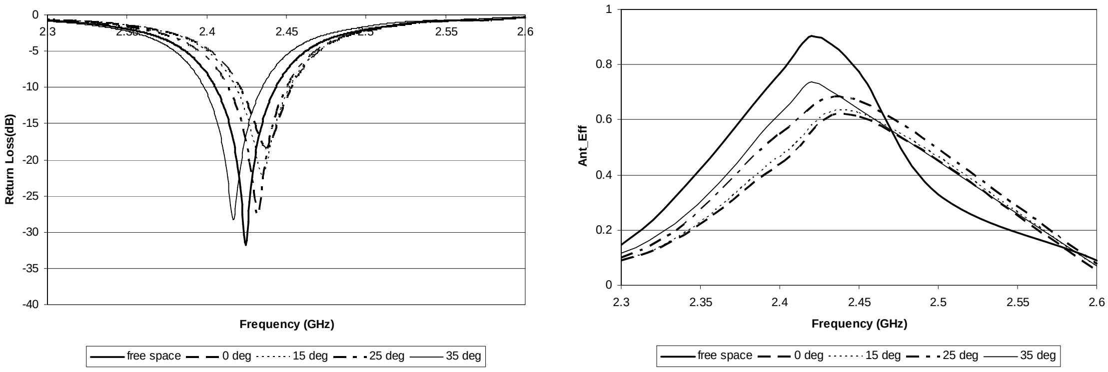


Figure 6: Simulated return loss and antenna efficiency using CST Microwave Studio^{TM}

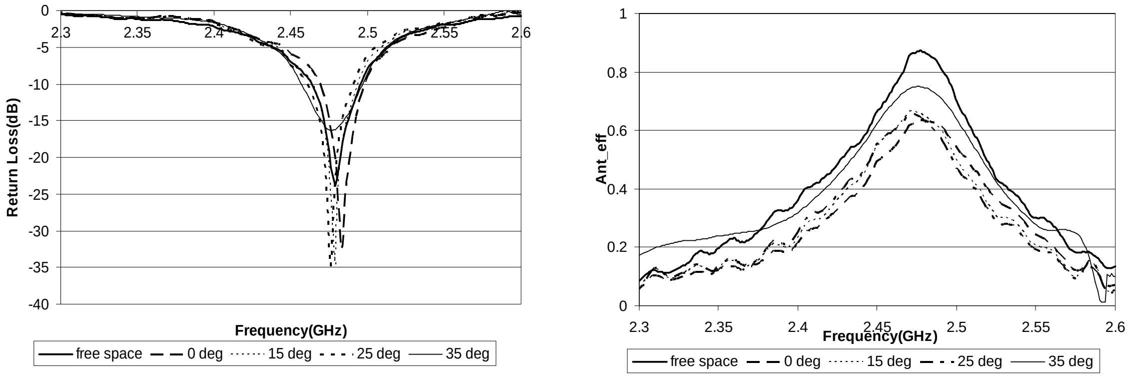


Figure 7: Measured return loss and antenna efficiency using a reverberation chamber

4. Conclusion

The effect of rotating a patch antenna in different axes away from a body phantom is reported in this paper. The patch antenna maintains resonance during rotation and the antenna efficiency has little variation. Optimum efficiency occurs at the 35^0 rotation along the *x* axis. In the future, detailed measurement will be carried out considering the performance of patch antennas on clothing.

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