RF-MEMS Reconfigurable U-Slotted Patch Antennas for Dual Polarization

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Abstract

Research on reconfigurable antennas, which are antennas loaded in part with RF-MEMS switches, has advanced in recent years. The addition of RF-MEMS switches to an antenna allows its reconfiguration as a single device, leading to its increasing sophistication [1],[2]. The MEMS technique makes it possible to construct the switches and antenna as a monolithic unit, and confers the benefits of advanced capabilities and shrinking size and cost. In this paper, we propose a polarization reconfigurable antenna which can switch between two orthogonal polarizations via cantilever switches loaded on portions of a slotted patch antenna. It is presented an explanation of the operating principle of the antenna and, with a prototype, a polarization switching capability. Finally it is evaluated the characteristics of the antenna.

1. INTRODUCTION

MEMS (Micro Electro Mechanical Systems) is an electro-mechanical, micro-device-based system which fuses manufactured electronic and mechanical elements on a common substrate using semiconductor process techniques. RF-MEMS is applied to the high-frequency band, and devices such as switches, varactors, and inductors are being developed. Compared to conventional semiconductor switches using FET and diodes, RF-MEMS switches used for polarization reconfiguration in this paper have smaller transmission loss and are expected to greatly improve the performance and cost of wireless transmission equipment. As a result, their research and development is being pursued by many laboratories and businesses. Using RF-MEMS technology, reconfigurable antennas allow the sophistication of capabilities in a single antenna component.

This paper proposes a polarization reconfigurable U-slotted antenna which can switch between two orthogonal polarizations via cantilever switches loaded on portions of a slotted patch antenna. First we present the design, and explain the switching mechanism and operating principle of the polarization switching. Next, a prototype of the antenna is created, and its return loss and radiation characteristics are measured. These test results are compared with those of a simulation of the polarization switching, and it is confirmed that the antenna satisfies the desired characteristics.

2. OPERATING PRINCIPLE

The layout of the polarization reconfigurable antenna is shown in Fig.1. In the center of the square patch antenna, it is established a square, loop-shaped slot line, dividing the conductor into exterior and interior sections. MEMS switches are mounted in the areas enclosed by the dotted circles. Section A is shown that the exterior patch is connected to the interior patch with a bit of conductor line. Power is fed through feed pins from the backside of the center of the internal section of the conductor. The MEMS switches are ON in one direction and OFF in the other. A U-slot patch antenna is thus constructed. For example, when Switch 1 (SW#1) is ON and Switch 2 (SW#1) is OFF, the U-slot can be considered as open along the y-axis, as shown in Fig.2(a). The antenna radiates polarization along the y-axis during this time. Conversely, when SW#1 is OFF, and SW#2 is ON, the U-slot is formed sideways, and polarization is radiated along the x-axis, as shown in Fig.2(b). Therefore, under fixed conditions for the antenna, it becomes possible to switch between two orthogonal polarizations. Because the length of the short-circuit slot between the terminals on the open side of the U-slot is shorter than the polarization wavelength, unwanted resonance at operating frequency does not occur. Also, when both switches are ON, or both switches are OFF, the antenna and slot have no measurable resonance at the design frequency, and so the antenna does not function.

3. DESIGN

It is presented an antenna loaded with MEMS switches on a high-resistant Si wafer suited for the MEMS process (see Fig.1). The thickness of the Si wafer is 0.018 λ_0 (ε_r=11.9).

It explains the details of the MEMS switches. Fig.3 shows the structure of a switch. All-metal cantilever switch which shares the RF signal and DC control signal is used because all metal form allows the switch to be small and be loaded on top of the antenna. Also, the contact point and the drive electrode have the same electrical potential; there is almost no current flow even when the switch is on, so power consumption is extremely low.

To drive the switch, a DC line needs to be constructed. To provide power to a MEMS switch near the center of the antenna, a bias line is established across the external section of the conductor. But, as shown in Fig.4, to prevent dividing the patch conductor, the bias line is established such that it avoids at the air bridge the ends of the patches.

4. EVALUATION OF CHARACTERISTICS

Fig.5 shows the prototype. Fig.6 shows a magnified image of the MEMS switch and air bridge. The antenna described above is fixed to a bottom (base) board with an electrically conductive adhesive, and RF signal is fed via an SMA connector from the back of the antenna. In case which the bias line has a low-pass filter that consists of a bypass capacitor and an open stub, RF signal does not propagate on it.

Fig.7 shows the return loss measurement system. During measurement, polarization switching is performed by a switch before the DC power source. To prevent input of electrical surge into the antenna when the switch is applied, resistors and choke coils are inserted into the measurement bias line. Also, to prevent input of DC electricity into the network analyzer, bias TEE is inserted before the network analyzer.

It explains the evaluation of the characteristics of the antenna. Polarization switching does not succeed if, at the time of the operation of the switches, the antenna characteristics are not equal. Accordingly we measured the return loss and radiation characteristics at the switches at ON/OFF time, and investigated the polarization switching functionality.

Measured return loss is shown in Fig.8. Both SW#1: ON, SW#2: OFF and SW#1: OFF, SW#2: ON resonate at approximately $f/f_0 = 1.03$, thus showing approximately the same characteristics.

The radiation characteristics are shown in Fig.9(a)-(d). As shown in Fig.9(a) and (c), (b) and (d), identical radiation patterns were obtained in different planes by changing the configuration of the switches. Thus, it is confirmed that polarization switching is successful via configuration-switching of the switches under fixed conditions for the antenna.

Comparing the analytical antenna gain and cross polarization obtained from HFSS are good agreement with the measured results, thus confirming that the prototype achieves the desired characteristics.

5. CONCLUSION

An antenna capable of switching between two orthogonal polarizations was proposed via the loading of RF-MEMS switches onto a portion of a U-slotted patch antenna. A prototype was constructed, and from measuring the reflectivity characteristics, it was confirmed that the characteristics of the switching configurations were approximately the same. Then, obtaining identical patterns from different orthogonal planes when switching, confirmed that polarization switching was successfully implemented.

REFERENCES

[1] D. E. Anagnostou, et al., *Proceedings in 2004 IEEE AP-S International Symposium*, Monterey, June, 2004.

[2] S. Liu, et al., *Proceedings in 2005 IEEE AP-S International Symposium*, Washington, D.C., July 2005.

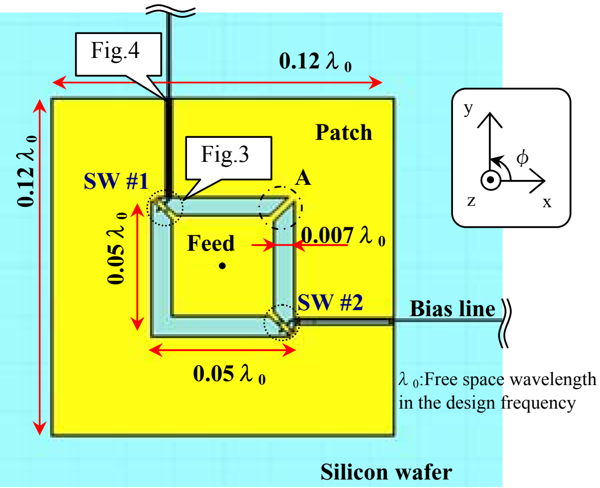
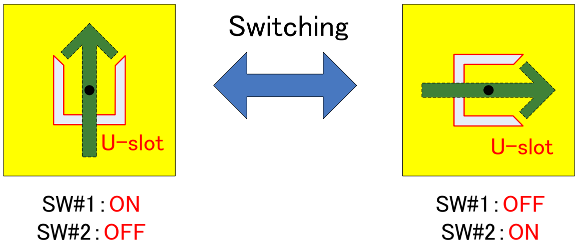


Fig.1 Design.



(a) (b)

Fig.2 Polarization switching.

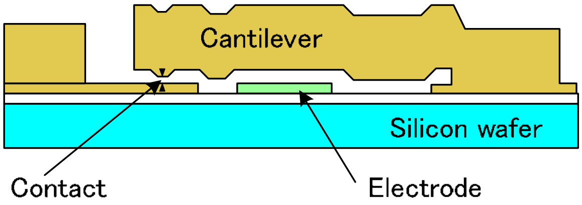


Fig.3 Enlarged diagram of MEMS switch.

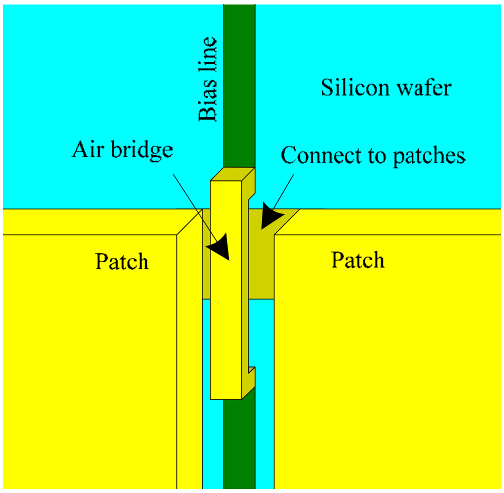


Fig.4 Enlarged diagram of air bridge.

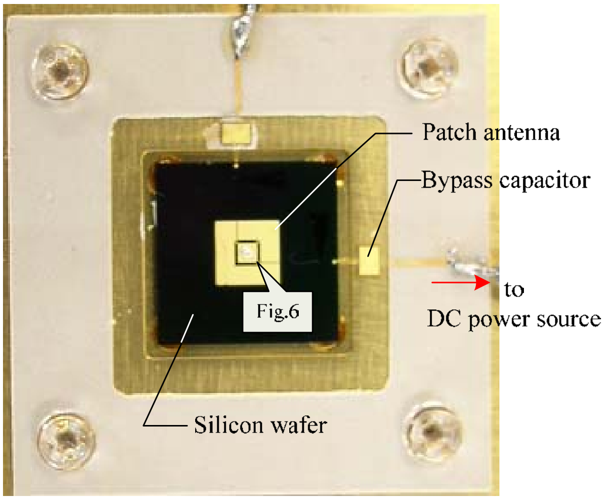


Fig.5 Prototype model.

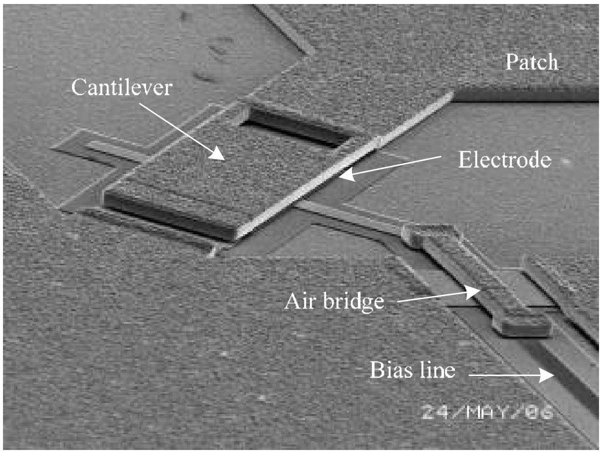


Fig.6 Magnified image of switch and air bridge taken by SEM.

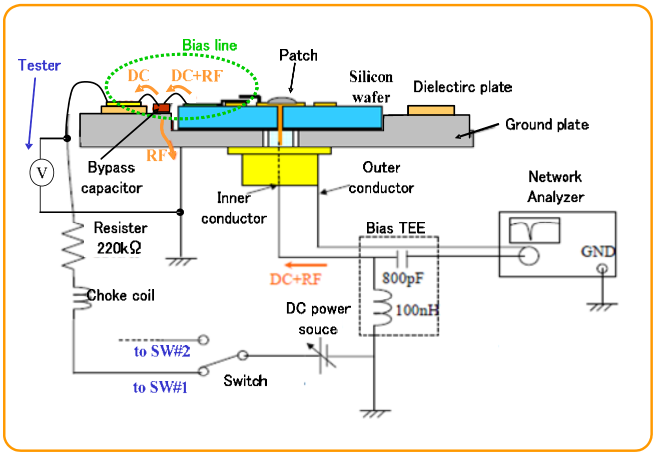


Fig.7 Return loss measuring system.

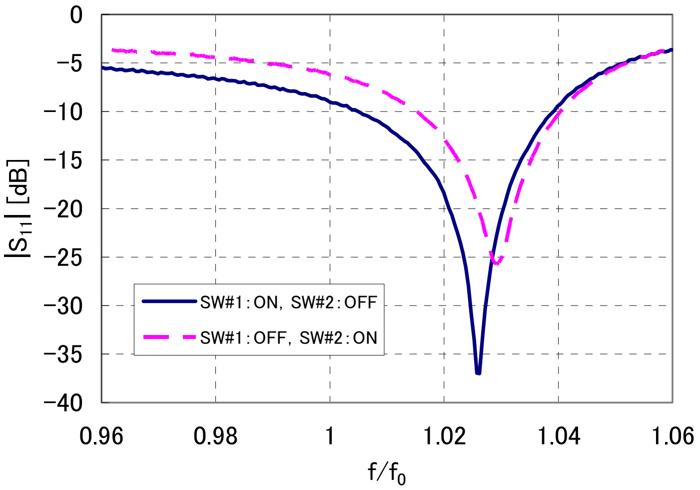
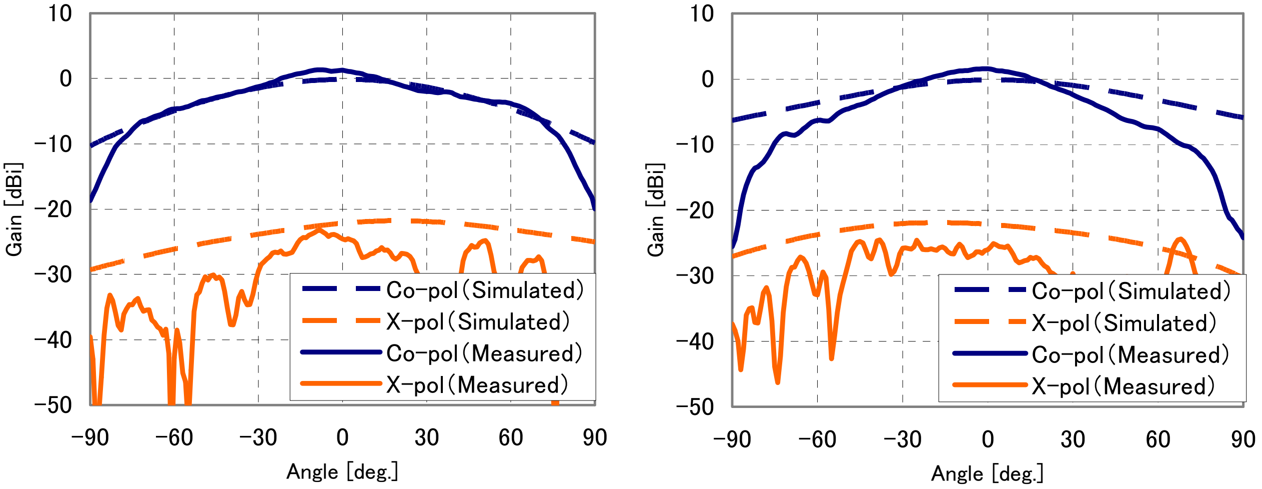


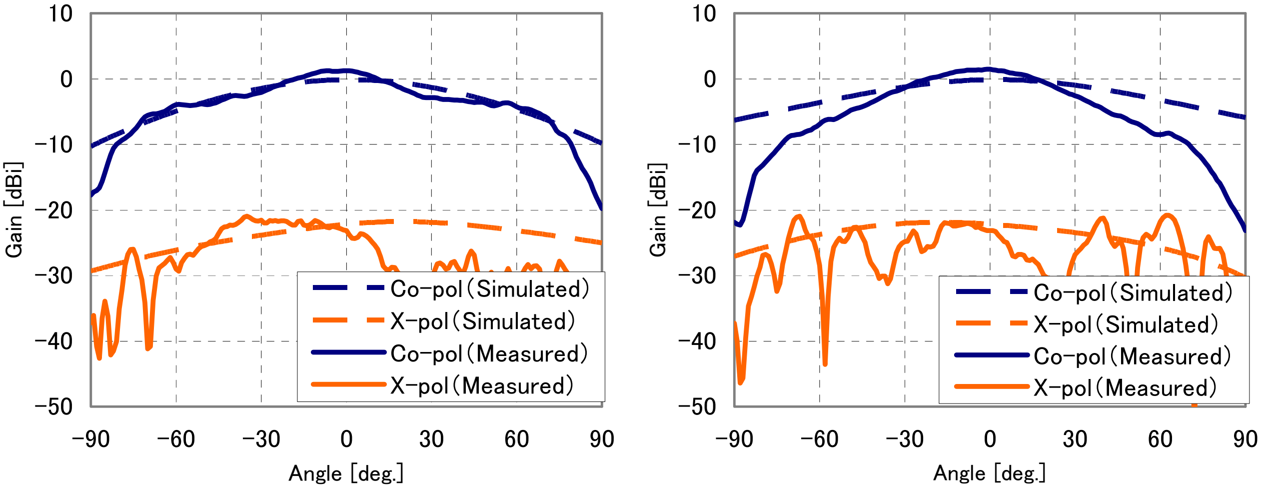
Fig.8 Measured return loss



(a) H-plane, x-z plane.

(b) E- plane, y-z plane.

Fig.9 Radiation characteristics（SW#1:ON, SW#2:OFF）.



(a) H- plane, y-z plane.

(b) E- plane, x-z plane.

Fig.10 Radiation characteristics （SW#1:OFF, SW#2:ON）.