Reconfigurable Cavity-Backed Slot Antennas using Fluid Dielectric

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***Abstract* - Reconfigurable cavity-backed slot antennas (CBSAs) using fluid dielectric is proposed in this paper. On one hand, dielectric post, i.e., distilled water, can produce an effective permittivity ε_{eff} of the resonant mode, and varying amount of the dielectric can achieve controlled ε_{eff} as well as the resonant frequency. On the other hand, the energy of the resonant mode can radiate through the slot on the top wall. Thus, a reconfigurable cavity-backed slot antenna can be realized. Besides, as the resonant mode is only affected by the dielectric post along the direction of the corresponding electric field, three cavity modes with orthogonal electric field, i.e., TE_{101}, TE_{011}, and TM_{110}, can be used to design reconfigurable tri-band slot antenna.**

***Keywords* —Reconfigurable antenna, cavity-backed slot antenna, fluid dielectric.**

I. INTRODUCTION

Reconfigurable antennas have been widely applied to wireless communication systems with operation of varying and multiple frequency bands. A variety of reconfigurable antennas have been designed and implemented on planar structure by utilizing electronically-controlled devices, such as microstrip antennas [1]-[2] and SIW slot antennas [3]-[4]. However, these reconfigurable antennas often suffer from low power-handling capacity and high noise behaviors. Recently, the reconfigurable antennas based on dielectric fluids [5]-[6] and liquid metal [7]-[8] were investigated to partly overcome these issues. In [9], a tunable evanescent-mode cavity slot antenna using piezodisk was reported. However, this method suffers from the sensitive fabrication of the micro gap, which may reduce the power-handling capacity. In this aspect, the metallic tuning screws have been used to design tunable cavity-based slot antenna in our previous work [10]. However, the solid property of the metal screws results in lower tuning speed.

The fluid material can increase the tuning speed. In [11], the fluid dielectric was used to design reconfigurable cavity filter, as the dielectric post (distilled water post) can produce effective permittivity on the cavity mode, and then can achieve the frequency tuning. Based on this reconfiguration technique, reconfigurable cavity-backed slot antennas are presented and designed in this paper, including reconfigurable single-band and tri-band slot antennas.

II. PROPOSED RECONFIGURABLE ANTENNAS

A. Reconfigurable Single-Band Antenna

The single-band cavity-backed slot antenna with tuning water post is shown in Fig. 1. The feeding slot excites the TE_{101} mode (E_y), and then radiates through the slot on the top plane. The water post (WP) is used to tune the frequency. The simulated $|S_{11}|$ with different post length is plotted in Fig. 2 (a), the working frequency of the antenna shifts to low frequency when the length of the post increases. As the post only influences the electric field around the post, the electric field near the top plane remains pure *y*-axis direction, and then excites the radiation slot. Thus, the electric field distribution on the radiation slot basically remains unchanged when modifying the post length, as shown in Fig. 2 (b). It can be further predicted that the radiation patterns

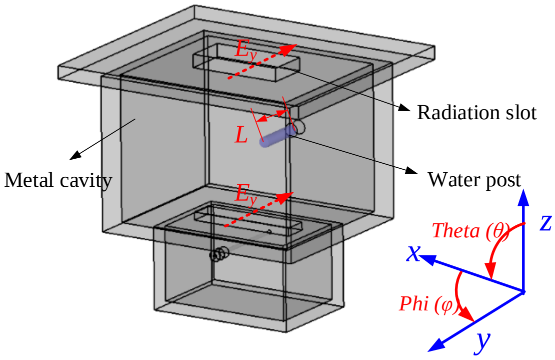


Fig. 1 Configuration of the reconfigurable single-band antenna.

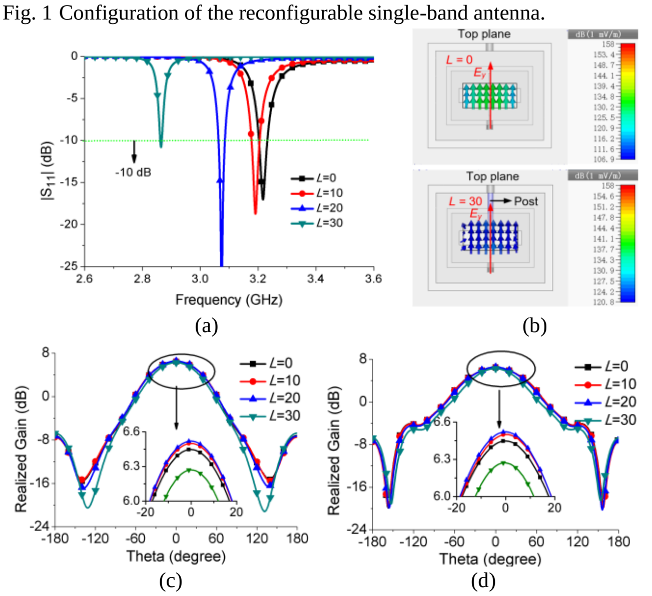
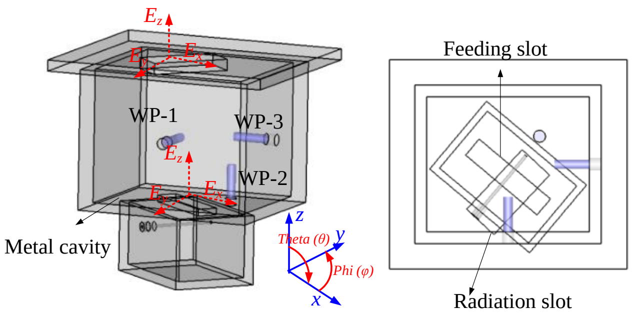
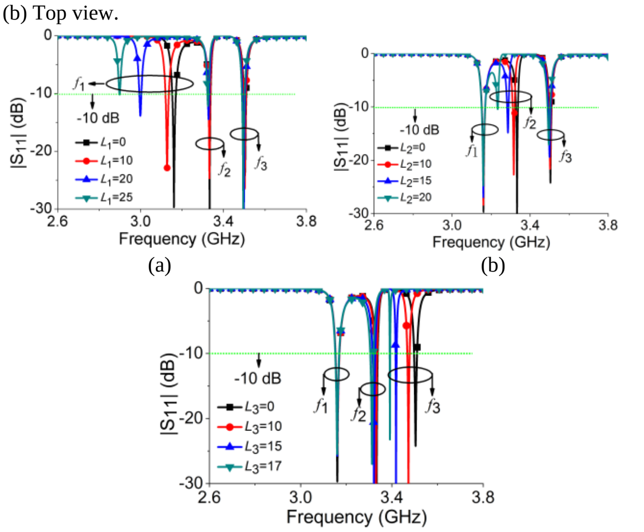


Fig.2 (a) $|S_{11}|$ versus different post's lengths, (b) Electric field distribution at top plane with post length L=0 and L=30, (c) Radiation pattern at *xz*plane (φ = 0), and (d) Radiation pattern at *yz*-plane (φ = 90).



(a) (b)

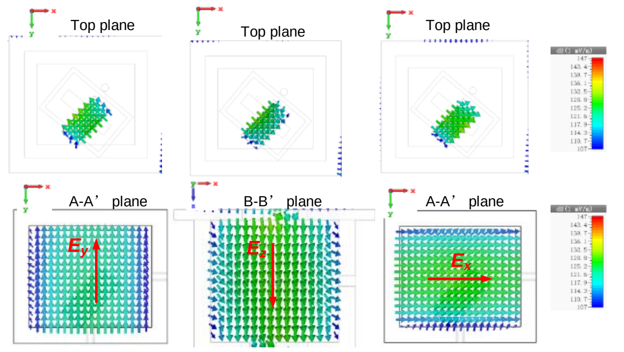
Fig. 3 Configuration of the reconfigurable tri-band antenna: (a) 3D view, (b) Top view.



(a) (b)

(c)

Fig.4 Simulated $|S_{11}|$ of the tri-band antenna versus different posts' length : (a) WP-1's length L_1, (b) WP-2's length L_2, and (c) WP-3's length L_3.



(a) (b) (c)

Fig. 5 Electric field distributions of the three modes in radiation slot on top plane and in cavity: (a) f_1 (E_y), (b) f_2 (E_z), and (c) f_3 (E_x).

basically remain unchanged with the small deterioration of the radiation gain. As shown in Fig. 2 (c) and (d), the radiation patterns at both *xz*-plane and *yz*-plane with four different post lengths are almost identical. The maximum gain has only 0.3 dB deterioration. Besides, the tuning range is from 3.217 GHz to 2.864 GHz.

B. Reconfigurable Tri-Band Antenna

The feeding slot and radiation slot of the single-band antenna only works on the TE_{101} cavity mode. If both of them are set to excite and radiate all the three modes, i.e., TE_{101}, TE_{011} and TM_{110}, which have electric field along *y*-axis, *x*-axis, and *z*-axis, as discussed in [11], a tri-band antenna can be achieved. Then, three water posts (WP) are set along *y*-axis, *x*-axis, and *z*-axis, a reconfigurable tri-band antenna can be realized, as shown in Fig. 3, where the feeding slot and radiation slot are set with a rotation angle. WP-1 and WP-3 are placed at the center of the plane, while WP-2 is placed with an offsetting due to the position of the feeding cavity. The lengths of them are represented as L_1, L_2, and L_3, respectively. The feeding slot excites three orthogonal modes f_1 (E_y), f_2 (E_z), and f_3 (E_x), then each mode can radiate energy through the slot on the top plane.

The simulated $|S_{11}|$ of the proposed reconfigurable tri-band slot antenna is plotted in Fig.4. As can be seen from the figures, the three operating bands can be individually tuned by modifying their corresponding post's lengths without affecting other operating bands. Fig.5 shows the electric field distributions of the three modes. It can be seen that the electric fields of three modes on the radiation slot have same polarization, although the electric field of modes themselves are orthogonal.

III. CONCLUSION

Reconfigurable cavity-backed slot antennas based on fluid dielectric are presented. The loaded fluid dielectric, i.e., distilled water, produces an effective permittivity corresponding to the cavity mode, and then realize the frequency tuning. Then, reconfigurable single-band and tri-band cavity-backed slot antennas are designed with good performance. The distilled water allows an easy, fast and flexible tuning mechanism by controlling the micropump to inject or remove accurate amount of water in the tubes.

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