A Scheme to Lower the Resonant Frequency of the Microstrip Patch Antenna

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Abstract—**Simple schemes are presented for lowering the resonant frequency of the rectangular patch antenna without changing its size. In particular, by placing a perturbance below the patch it is shown that as much as 30 percent decrease from the resonant frequency of the unperturbed patch can be achieved. The specific configurations considered include a cavity-backed and an aperture-backed patch and for each case design curves are presented.**

I. Introduction

In many cases, one is required to design a certain antenna or array which does not exceed given physical dimensions. Since the size of the antenna is typically determined by its operational frequency, restrictions on the physical dimensions of the antenna can present a challenge to the antenna designer. If the intent is to increase the patch's resonant frequency, there are a number of simple methods for accomplishing this [1]–[4], but there are no prevailing options for decreasing its operational frequency. In this letter, we consider two simple schemes to rather substantially lower the operational frequency of the rectangular microstrip patch antenna without altering its aperture size. They include the placement of some perturbance (cavity, depression or slot) in the cavity region below the patch, a scheme well known for controlling the cavity's resonant frequency [5], [6]. However, because of a lack of available CAD tools to treat such perturbances, the approach does not appear to have been explored for lowering the frequency of the highly resonant microstrip antennas. Moreover, traditional applications of these frequency control methods dealt with small shifts in the resonant frequency. A recently developed hybrid finite element-boundary integral method [7] is adaptable to geometrical and electrical irregularities in the substrate, and below we consider the effect of two different cavity configurations on the resonant behavior of a given patch residing at the aperture of the cavity.

II. Antenna Geometry

Consider the reference geometry illustrated in Fig. 1. The configuration consists of a square 4.45 cm × 4.45 cm patch residing in a square cavity whose aperture size is 6.625 cm × 6.625 cm and depth is 0.05 cm. The cavity is filled with a dielectric having a relative permittivity of $\epsilon_r = 2.17$ and we remark that its finite size has negligible effect on the resonance and input impedance of the patch.

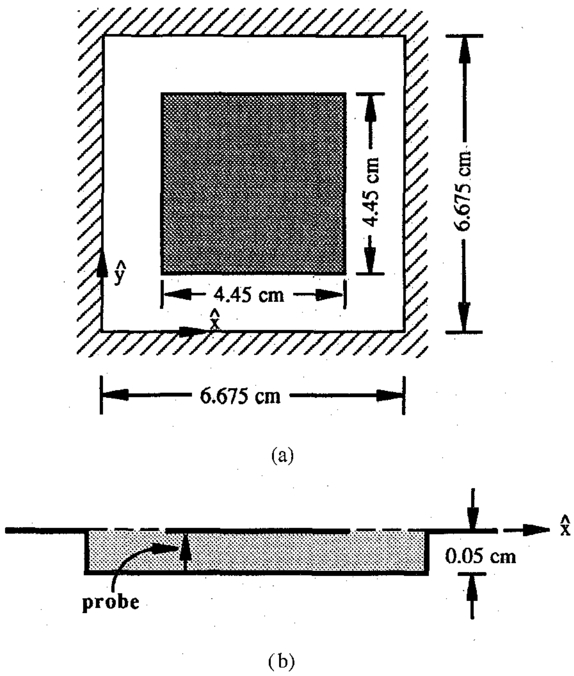

Fig. 1. Reference geometry of the microstrip patch in a metal-backed rectangular cavity.

With the goal of lowering the resonant behavior of this patch, we consider two modifications of the cavity. The xz and yz cross sections of these are illustrated in Fig. 2(a) and (b). They include a rectangular depression at the center of the original cavity or a second cavity that is aperture coupled to the original. In both cases the patch and aperture size is unchanged from the original antenna shown in Fig. 1.

The analysis of all three patch antennas depicted in Figs. 1 and 2 was accomplished via the hybrid finite-element–boundary-integral (FE–BI) method described in [7]. This method is theoretically exact and has been extensively validated.

III. Numerical Results

Plots of the resonant frequency associated with the configurations in Fig. 2(a) and (b) to be referred to as cavity-backed or aperture-backed antennas, respectively, are given in Figs. 3 and 4. In Fig. 3, we depict the resonant frequency as a function of the second (bottom) cavity depth with the aperture at the interface of the two cavities fixed at 3.56 cm × 3.56 cm. The

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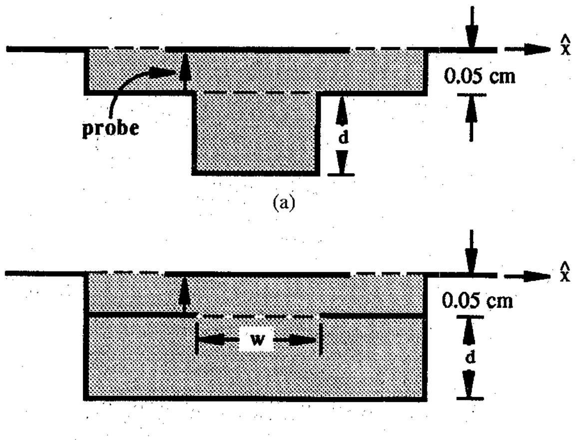

Fig. 2. Modified cavity configurations: (a) cavity-backed, (b) aperture-backed.

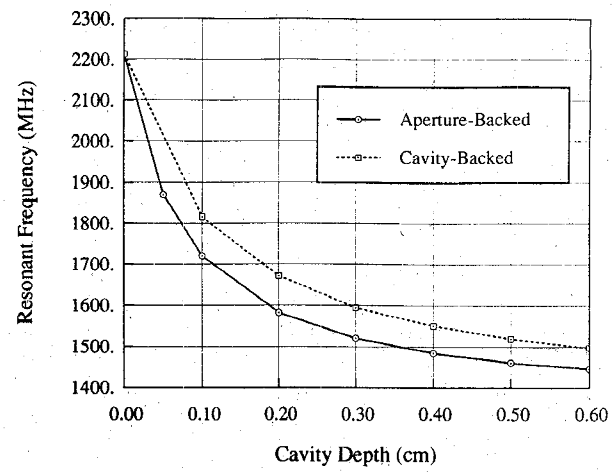

Fig. 3. Resonant frequency of the aperture- and cavity-backed patch configurations as a function of the bottom cavity depth d. Original cavity depth is retained at 0.05 cm and the entire cavity region is filled with a dielectric having ($\epsilon_r = 2.17$. Aperture of the second cavity is 3.56 cm × 3.56 cm.

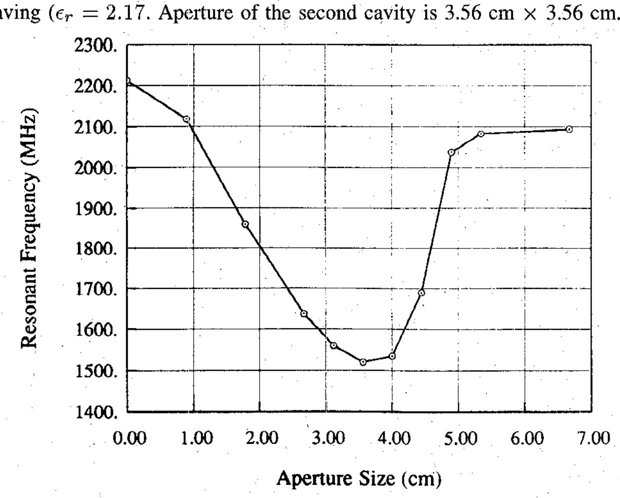

Fig. 4. Resonant frequency of the aperture-backed patch as a function of the square aperture dimension w. Depth of the bottom cavity was kept at $d = 0.3$ cm and all other parameters are the same with those used for Fig. 3.

plot in Fig. 4 illustrates the effect of the aperture size on the resonant frequency with the bottom cavity depth kept at 0.3 cm. From both figures, it is seen that by changing the aperture or depth of the bottom cavity the patch's resonant frequency can be decreased by as much as 30 percent. Consequently, one may construct a 30-percent smaller patch than the conventional one with the introduction of the second cavity. We have also verified that the RCS of the new antenna structure is nearly the same as that of the original patch when measured at their respective operational frequencies. It should be noted though that when the aperture of the second cavity becomes larger than the patch size, there is minimal frequency shift as can be concluded from the data of Fig. 4. The shift in the resonant frequency can be understood by resorting to a transmission line model of the patch antenna. In this case, the inserted aperture below the patch can be represented by an equivalent reactance placed between the admittances representing the patch terminations.

Unfortunately, the bandwidth of the cavity-backed and aperture-backed configurations was not altered although some minor differences were observed in the actual values of the input impedance. In closing, we remark that whereas depressions in the original antenna cavity result in lower resonant frequencies, a protrusion below the patch has the opposite effect. That is, its effect is similar to that of a shorting pin [2], [3] placed between the patch and the ground plane.

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