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A Method for Fine Tuning of Resonance Frequency of Patch Antenna

Rajeswar Lal Dua, Anjali Nigam, Pooja Yadav

Abstract: ***When a patch antenna is fabricated, size of the as-fabricated resonant patch may be slightly different from its designed value due to tolerances in the fabrication operations. This will alter the resonance frequency. To overcome this problem this paper presents a new method for fine tuning the resonance frequency by dielectric engineering. This approach is especially suited to LTCC and similar processes where the antenna dielectric is composed of several layers. Composite dielectric constant of this multilayer structure is altered in such away that the resonant frequency is set back to the designed value. A cavity is cut below the patch in one or more dielectric layers. This paper investigates the effect of cavity size on shift in resonance frequency. HFSS software has been used for simulations. Three different dielectric materials were investigated for several resonant frequencies. f/f_0 was plotted against Area Ratio (AR) to generalize the findings. Area Ratio is the ratio of area of cavity to the area of the patch, f is the resonance frequency for a given cavity area and f_0 is its value without any cavity. Depth of the cavity may be equal to either one or two dielectric layer thickness in a four layered dielectric structure. Very interesting results have been obtained. For all ε and all f/f_0 the curve can be described by the equation of the form $f/f_0 = \alpha R^2+\beta R+1$ where R is the area ratio. This mathematical model is true up to R=1.27. After this saturation effects set in and the curve changes to a straight line $f/f_0 = mR+\phi$. Further work is being carried out.***

Keywords:LTCC ,Composite Dielectric Constant,area ratio, multilayer structure.

I. INTRODUCTION

Every fabrication process has its tolerances. This results in slight change in dimensions of the fabricated parts. For the microstrip antenna (MSA), change in length of the patch results in change of resonant frequency (f_o). For some applications this may be critical. A method for fine tuning off$_o$ is therefore required.This paper presentsa new method for fine tuning of resonance frequency of patch antenna.

II. THE NEW APPROACH

In the proposed method f_o is tuned by making a cavity (in the antenna dielectric) just below the patch. Dimensions of the cavity determine the change in f_o that can be achieved. This paper also presents a mathematical model for estimating the effect of cavity dimensions on the shift in frequency that can be achieved.

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III. SDESIGN AND SIMULATION

For detailed investigations a series of antennas were designed and simulated using HFSS software. Dimensions of antenna patch were calculated using following standard equations:

$$W = \frac{c}{2f_0}\left(\frac{\varepsilon}{2}\right. \quad (1)$$

$$L_{eff} = \frac{c}{2f_0}\left(\varepsilon_{eff}\right. \quad (2)$$

$$\varepsilon_{reff} = 0.5(\varepsilon_r + 1) + 0.5(\varepsilon_r - 1)(1 + \frac{12W}{h})^{-0.5} \quad (3)$$

where the symbols have their usual meaning. This was done for varsious values of the resonant frequency (f_o), dielectric constant (ε_r) and thickness (h) of the substrate material. Fig (1) shows the antenna structure.

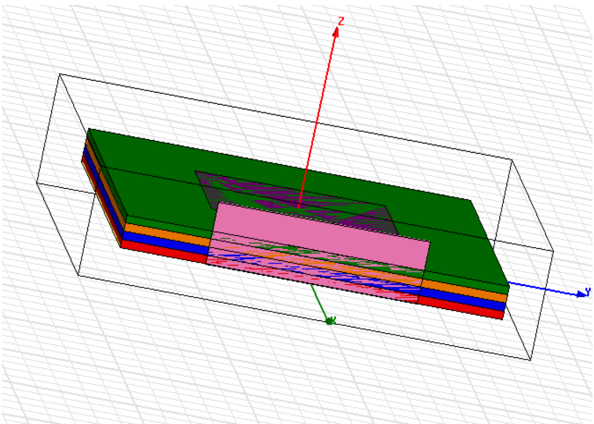
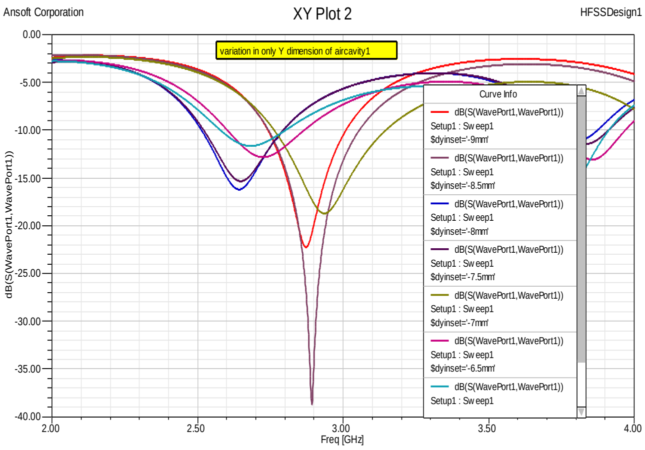


Fig.1:- Basic structure of four layer MS Antenna

Simulations were done for three values of f_o—1.6, 1.8 and 2.4 GHz. For each value of f_o, three values of ε_r— 2.2, 3 and 4.4 and two values of h —1.2 mm and 6.4 mm were taken. A cavity was made in the antenna dielectric just below the patch. Two values, h/2 and h/4 ,were considered



Fig(2) : Variation of f_o with L_c for various values of W_c

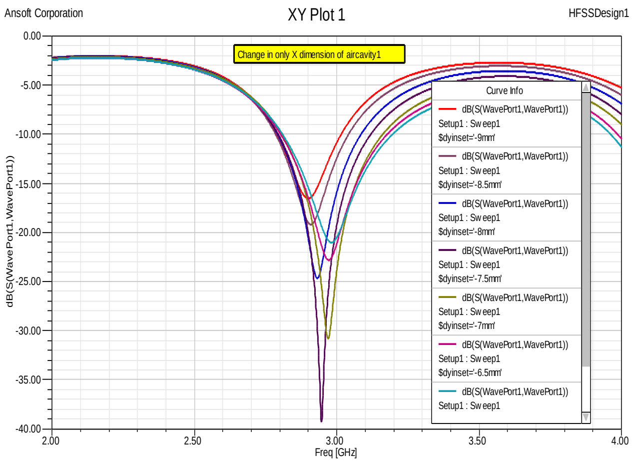


Fig (3): Variation of f_o with W_c for various values of L_c

for the depth (d_c) of the cavity. For each combination of f_o, ε_r, W, h and d_c, 256 values of cavity area were considered.HFSS simulations yielded the resonant frequency (f) of the structure. Results of > 2560 simulations were analyzed. Fig (2) shows the variation in f with length (L_c) of the cavity when all other parameters were kept constant. Fig (3) shows this variation with width (W_c) of the cavity.

IV. RESULTS AND DISCUSSIONS

Fig (4) shows dependence of f/f_o on L_c/L_p with W_c as parameter. f increases as L_c increases. Fig (5) shows the dependence of f/f_o on W_c/W_p with L_c as a parameter. Again f increases with W_c.Depth of the cavity seems to have little or no effect on the shift in the resonance frequency. Analysis of the results reported here indicate that when a cavity is made (in the antenna dielectric) just below the patch, the resonance frequency f of the structure

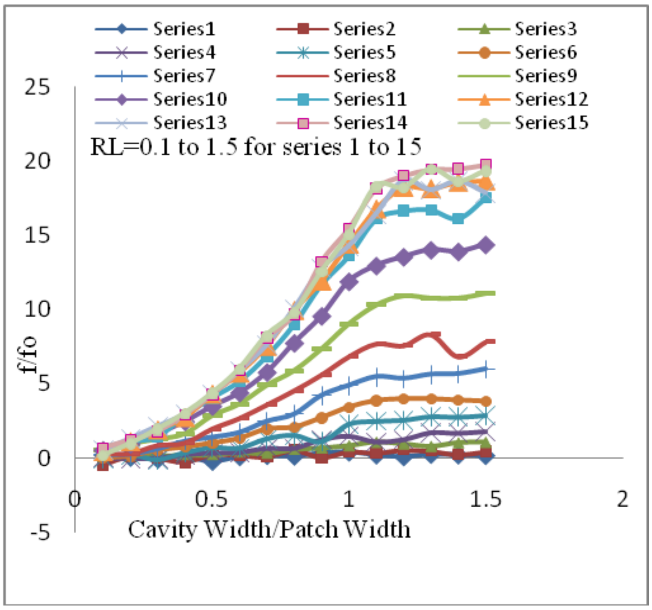


Fig (4): variation of resonance frequency with the width of the cavity. Ratio (RL) of Cavity Length to Patch Length is the parameter.

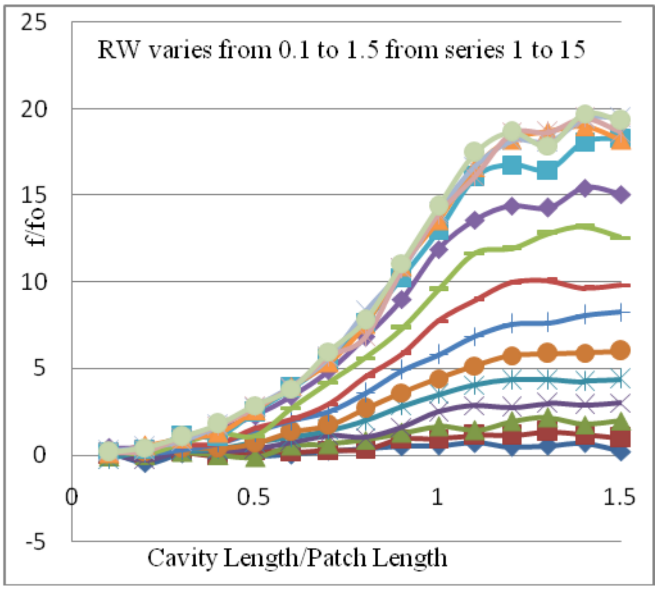


Fig (5): variation of resonance frequency with the length of the cavity. Ratio (RW) of Cavity width to Patch width is the parameter.

increases. Another important result is that the increasein f can be controlled by suitably selecting the cavity dimensions. Thus the resonance frequency of the antenna can be tuned during its fabrication. Thus the result of fabrication tolerances can be offset by following this proposed method.

As the size of the cavity increases, composite dielectric constant of the antenna substrate will decrease. This will result in an increase in f. This will continue to happen till the area of the cavity approximately equals the effective area of the patch (accounting for the fringing field effect). Further increase in the cavity area would have little or no effect on f. This paper proposes the following empirical relation between change in frequency and area of the cavity

$P(f) = \alpha R^2$, for $R \leq 1.27$ (4a)
$P(f) = m R + \beta$, for $R > 1.27$ (4b)

where $P(f) = \left(\frac{f-f_o}{f_o}\right) * 100$ (5)

$R = A_c/A_p$ (6)

α, m and β are constants

P(f) is the percentage change in the resonant frequency f_o when a cavity of cross-sectional area A_c is made under the patch. R is the ratio of areas of cavity and area of the patch (A_p) and α is a constant. For the cases analyzed here α = 11.2

For determining the dependence of f on A_c, P(f) was plotted against R for different combinations of f_o, ε_r, h, A_c, and d_c.

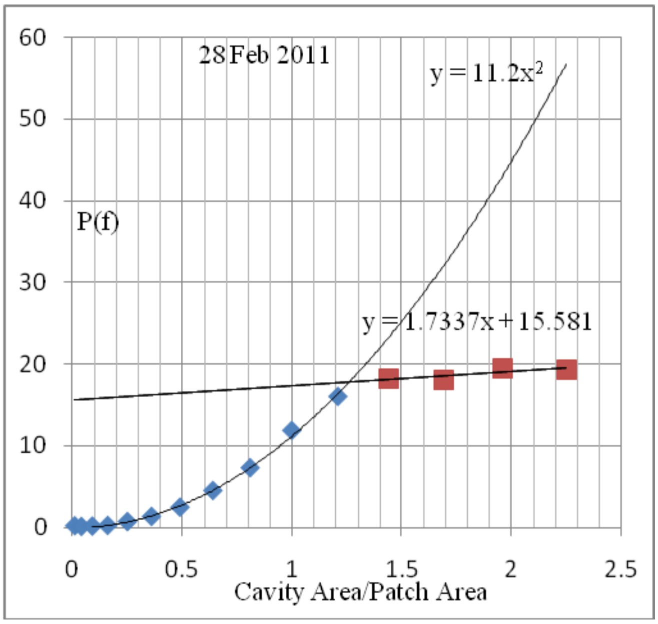


Figure (6): Lp = 27 mm, W_p = 38 mm, ε_r = 4.4, h = 6.4 mm, Cavity depth = h/4

Proposed model [Equation (4)] fits all cases. For R = 0 there is no cavity and f = f_o which is true. As R increases P(f) follows eq. (4a) up to R =1.27. After that P(f) varies linearly with R equation (4b)] indicating that f_o is not very much affected by A_c.

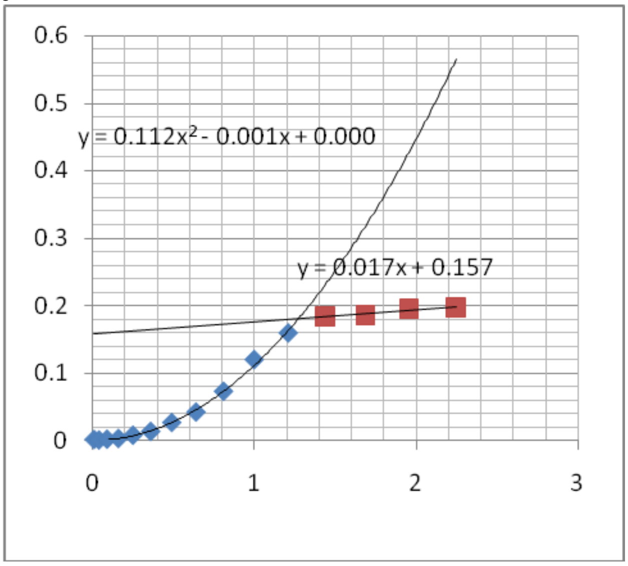


Figure (6): Variation of f/fo with R for depth of cavity = h/2

An interesting result of the present investigations is thatin each and every case the power law curve of equation (4a) and the straight line of equation (4b) intersect around R = 1.27, although the values of α and m vary slightly with the design parameters. Further work is being done to determine these dependences.

V. CONCLUSION

Dielectric engineering can be successfully used for fine tuning resonant frequency of microstrip antenna. Slight variation in effective dielectric constant can offset the effect of change in patch length. Cutting a cavity in the antenna dielectric below the patch is one way of doing so. Processes like LTCC using multilayer dielectric structure are useful in this method. Composite dielectric constant of this multilayer structure is altered in such a way that the resonant frequency is set back to the designed value. Effect of cavity size on shift in resonance frequency has been investigated. Three different dielectric materials were investigated for several resonant frequencies. f/f_0 was plotted against Area Ratio (AR) to generalize the findings. Area Ratio is the ratio of area of cavity to the area of the patch,f is the resonance frequency for a given cavity area and f_0 is its value without any cavity. Depth of the cavity may be equal to either one or two dielectric layer thickness in a four layered dielectric structure. Very interesting results have been obtained. For all ε and all f/f_0 the curve can be described by the equation of the form $f/f_0 = \alpha R^2+\beta R+1$ where R is the area ratio. This mathematical model is true up to R=1.27. After this saturation effects set in and the curve changes to a straight line $f/f_0 = mR+\phi$. Further work is being carried out.

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AUTHORS PROFILE

Professor Rajeshwar Lal Dua a Fellow Life Member of IETE and also a Life member of: I.V.S & I.P.A former "Scientist F"(Deputy Director) of the Central Electronics Engineering Research Institute (CEERI), Pilani has been one of the most well known scientists in India in the field of Vacuum Electronic Devices for over three and half decades. His professional achievements span a wide area of vacuum microwave devices ranging from crossed-field and linear-beam devices to present-day gyrotrons.

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In 1979 he visited department of Electrical and Electronics Engineering at the University Of Sheffield (UK) in the capacity of independent research worker, and Engineering Department of Cambridge University Cambridge (UK) as a visiting scientist. After retirement as scientist in 2003 shifted to Jaipur and joined the profession of teaching and from last eight years working as professor and head of electronics department in various engineering collages. At present he is working as head and Professor in the department of Electronics and communication Engineering at JNU, Jaipur.

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