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# FDTD Analysis of Mutual Coupling between Microstrip Patch Antennas on Curved Surfaces

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# FDTD Analysis of Mutual Coupling between Microstrip Patch Antennas on Curved Surfaces

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**Abstract**: The effect of curvature on mutual coupling between microstrip antennas on curved surfaces is studied by using the conformal FDTD method. The method has shown excellent versatility. The method is also applied to antennas mounted on flat and orthogonal substrates for comparison. The results show the strong effect of the different shaped substrates on the mutual coupling.

## 1. Introduction

Microstrip patch antennas find many practical applications in which they are mounted on curved surfaces such as those of aircraft and missiles, because of their major advantage of conformability. However, curved microstrip antennas show different properties from planar ones. Several theoretical and experimental studies of such antennas have been reported [1]-[5] and the curvature effects on the resonant frequency, input impedance, and radiation pattern have been investigated. Although the related studies are mainly of single patch antennas, scant results for the mutual coupling between two microstrip antennas on such structures are available.

In this paper, we study the mutual coupling between two microstrip patch antennas on a curved surface using the conformal FDTD (CFDTD) method. The method is also applied to antennas mounted on flat and orthogonal substrates for comparison, which has been presented in several papers [6,7].

## 2. Modeling of Microstrip Antennas

The top view of two coupled microstrip antenna patches is shown in Fig. 1. The feed points are adjusted for the H-plane configuration. Fig. 2 shows the three different two-element microstrip antenna array fed by probe. The results from a planar antenna were calculated as a reference. The conventional FDTD algorithm was used to simulate the antennas on flat and orthogonal substrates as shown in Fig. 2. For the antennas on a circular cylindrical substrate, the curved surface can be handled by staircasing in the conventional FDTD. However, this approach introduces discretization errors, which cannot be neglected. As in [8], for modeling curved conducting surfaces, the magnetic field is computed by using the electric field values along the distorted contour that is appropriately weighted with the lengths of the contours. However, the curved surfaces in dielectric materials require a modification from the perfectly conducting case.

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With a little modification of the 2D material structure modeling proposed in [9], 3D dielectric case by using weighted averages of the distributions of permittivities of the distorted cells.

A feed point of each radiation element is connected to a coaxial cable having a characteristic impedance of 50Ω. The feed points were adjusted to minimize the return loss at a center frequency of $f$ when the individual elements lay on an approximately infinite substrate.

## 3. Numerical Results and Discussions

The simulation is performed to measure the mutual coupling coefficients for the patches printed on three different substrate structures, as shown in Figs. 1 and 2, with parameters L=12 mm, W=10.5 mm, Ds=2.08 mm, and $\varepsilon_r$=2.2. The thickness of the substrate is 0.5mm. The feed position is $W_p$=5.25 mm and $L_p$=3 mm. The arrays, accordingly, take an H-plane arrangement. For the circular cylindrical substrate, the diameter of the circular cylinder is 16 mm.

The reference planes of the S-parameters were set to the ground planes to which each coaxial cable outer conductor was connected. Fig.3 shows the calculated mutual coupling ( $|S_{21}|$ dB ) as a function of frequency for each case in Fig.2. The mutual coupling level with the circular cylindrical substrate is about 2.868 dB smaller than that with the flat one, because the coupling through the space and surface wave is slightly decreased. The mutual coupling level with the orthogonal substrate is about 8.307 dB smaller than that with the flat one. The reason for this is that the fringing fields of the elements are perpendicular to each other for the orthogonal substrate case and the substrate is not even continuous. Fig.4 shows the calculated mutual coupling ( $|S_{21}|$ dB ) for E-plane configuration as a function of separation between patches. The parameters are the same as the ones used for Fig. 3. It is observed that the coupling for flat substrate is less than that for circular cylindrical substrates.

## 4. Concluding Remarks

The effect of curvature on the mutual coupling between two rectangular microstrip patch antennas fed by coaxial cable on a cylindrical structure has been calculated by using the CFDTD method. The CFDTD method has been successfully applied on the curved PEC and dielectric material modeling as well. It has been observed that the mutual coupling level is strongly affected by the different shaped substrate structure. The presented results for the mutual coupling of three different substrate structures are useful for the rigorous analysis of microstrip antenna arrays on conformed substrates in real-world applications.

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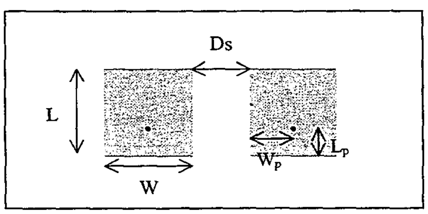


Fig. 1. Top view of two coupled microstrip antenna patches

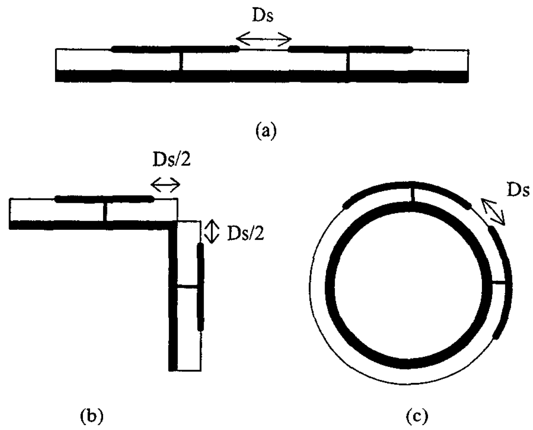


Fig. 2. H-plane coupled rectangular microstrip patch antennas on (a) flat substrate (b) orthogonal substrate (c) circular cylindrical substrate.

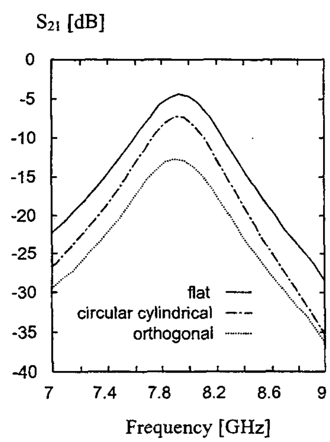


Fig. 3. H-plane mutual coupling ( $|S_{21}|$ ).

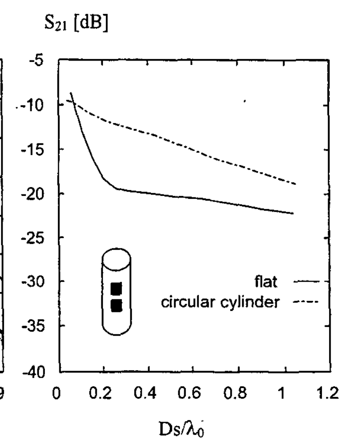


Fig. 4. E-plane mutual coupling ( $|S_{21}|$ ). $f_0$ = 7.89 GHz.