Microstrip Patch Antennas on Micromachined Low-Index Materials

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Introduction

Microstrip patch antennas have been used extensively in vehicle and communication systems in the past several decades. These antennas provide low profile, low-weight, and low-cost along with easy integration into planar circuit designs and array configurations [1]. The conventional planar microstrip geometry, however, has limited bandwidth (2-5%) and poor efficiency as well as limited power capability when probe fed or microstrip fed. There are several factors which influence these parameters, the patch geometry and medium directly, and feeding structure indirectly.

The patch antenna is primarily influenced by the dielectric constant and thickness of the substrate material. With this in mind, the highest bandwidth will be observed in designs implemented on thick, low index materials [2]. The efficiency of the antenna is affected primarily by the excitation of substrate modes. While these modes are inherently excited in the substrate and for that reason cannot be eliminated entirely, reduction will result in improved performance since the energy lost to these modes will now be available as useful power [3]. Surface waves in low index materials are lower than those excited in high index ones thereby making them the preferred medium.

Currently, designs are often implemented on low index materials for high patch efficiency, and wide bandwidth which can be increased further using wideband impedance matching networks and or aperture coupling methods [2]. In contrast, circuit application requirements for high density and compactness are best achieved on thin high index materials. As mentioned above however, these can have adverse effects on the patch performance. Since patch antennas are relatively simple to implement in many applications, it is important to address the requirements of both the antenna and feeding structures. In the past certain design trade-offs were acceptable due to technology limitations. However, with the aid of new emerging technologies and the vast knowledge of the patch antenna behavior, these issues can now be addressed effectively. A variety of approaches have been proposed [4] for improved antenna efficiency where material underneath the patch is modified to alter its electrical properties.

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Herein, an alternative approach is proposed which allows for easy implementation using micromachining. The goal of this approach is to develop an "effective" low index material underneath the antenna while the feeding circuit is kept on the high index one. The design of a conventional patch antenna fed by a microstrip is developed using micromachining techniques to decrease the height of the high index material underneath the patch while the material under the feedline remains unaltered. This approach reduces the value of the effective dielectric constant only in the area under the antenna, since it is comprised of a mixed dielectric medium of high index material and air.

Design/Fabrication Approach

The patch geometry was initially designed using PCAAD CAD tool [5] for resonances at 20 GHz. This CAD tool is based on the uses a cavity model which determines the antenna resonant length (1/2 guided wavelength) and width for a given substrate material and thickness. Since a center probe fed excitation is assumed in PCAAD, for a planar configuration, an inset microstrip is used to match the antenna to the given feedline impedance. This design is implemented to provide a symmetric antenna design.

The objective of this work is to explore the implementation of planar designs on localized low index materials. Initial investigation is implemented at 1.07 GHz on stycast, having ε_r=12, with thickness of 6.6 mm. These are chosen to simulate the response of a patch on silicon substrate of thickness 350 microns at desired operating frequency of 20 GHz. Since the actual circuit will be used in a planar configuration with horizontal feeding structure, the microwave model is excited by using a coaxial probe to feed a inset microstrip feed line. The geometry is shown in Fig.1 where the feed line is located on 100% material while the patch is located on 50-50 percent stycast - air dielectric material. When two pieces are brought into contact, the air region runs directly underneath the patch antenna and extends horizontally into the substrate material as shown in the lower geometry of Fig.1 dashed lines.

At the desired operating frequency, the design is implemented using micromachining etching processes to chemically remove the material from underneath the patch. A detailed description of this procedure is described in [6]. An additional wafer is mounted underneath to enclose the cavity below the patch and provide the microstrip ground plane. The circuit wafer consists of high resistivity silicon with ε_r = 11.7 and thickness of 350 microns while the ground plane wafer can be a low resistivity material. The microstrip feed in this arrangement is excited through a coplanar waveguide transition.

Results and Conclusions

In Fig.2, a comparison is shown between the microwave model and the theoretical results for the return loss of the patch. The theoretical results are based on finite difference time-domain method for the microstrip inset fed antenna. The FDTD [7] results presented correspond to a patch design with a silicon substrate and are compared to the modeled results on the stycast material. The measured and theoretical results have similar shape although there is a 100 MHz difference in the resonant response. This resonance shift can be improved by implementing a finer mesh in the direction normal to the cavity where the 50-50 material-air interface lies.

The above design will be implemented next on silicon using micromachining techniques. The presentation will describe the fabrication and measurement procedures utilized and will present measured and theoretical results on the performance of the micromachined antenna. This design offers the advantage of reducing the effects of surface wave excitation which can result in improved bandwidth and antenna efficiency.

Acknowledgments

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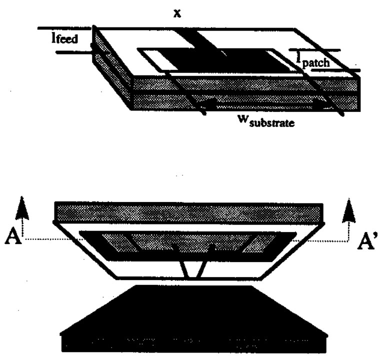
Figures



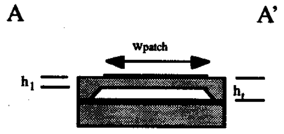


TABLE 1. Dimensions

Parameter	Value(mm)
l_{feed}	50.88
l_{patch}	68.26
x	4.76
$w_{substrate}$	153.03
w_{patch}	65.09
h_t	6.6
h_1	3.3

Figure 1. Micromachined patch antenna with effective low index material.

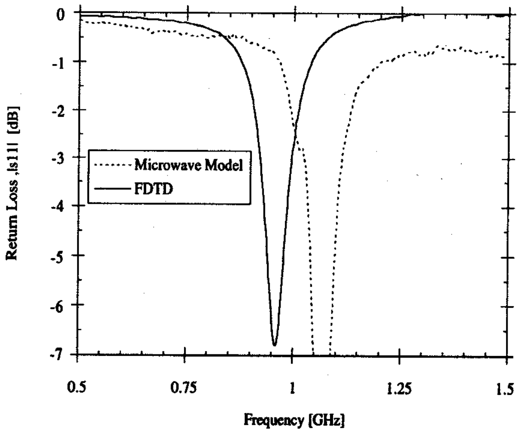


Figure 2. Measured and theoretical results of a microwave model on stycast material.