Compact 3D-MEMS-meander monopole antenna

C.-U. Huang, I.-Y. Chen, H.J.H. Chen, C.F. Jou and S.R.-S. Huang

A MEMS meander monopole antenna is fabricated in the form of a folded microstrip on the upper and bottom surfaces of the substrate. This design is based on the meander line principle with a three-dimensional structure to achieve reduced size compared to many other small size printed antennas. The MEMS technologies, such as excimer laser drilling and copper electroplating were used in the fabrication of this antenna. This antenna can be mounted on the silicon wafer by anodic bonding technology. The design features 2.45 GHz operating frequency with 190 MHz bandwidth for WLAN applications. The geometric length of the antenna is 21 mm, and the width is 4 mm. Measured results have good agreement with simulation data.

Introduction: With the increasing demands of wireless systems, antennas have been required to have the characteristics of high performance, small size, broad bandwidth, and low cost. To meet these requirements, various kinds of structures and fabrication technologies have been investigated and developed, such as the meandered antenna [1] for broadband application, the fractal antenna [2] and shorting-posts [3] for miniaturisation of the dimensions, MEMS technologies [4] for monolithic integration etc. Among these antennas, the monopole antenna is suitable for mobile communication systems owing to its simple structure and omnidirectional radiation.

In this Letter, the idea of applying micro-electro-mechanical system (MEMS) technologies to fabricate a compact, high performance, and low-cost 3D monopole antenna is proposed. The coplanar waveguide (CPW)-fed configuration was used owing to its simple structure, wide bandwidth, and the ability of multi-band operation. To reduce the size, the meandered monopole antenna was fabricated on both sides of a Pyrex 7740 glass wafer, and the metal lines were connected through via holes, as shown in Fig. 1*a*. The ArF excimer laser micromachining technique for via holes formation was used in this study. The entire antenna was constructed with electroplated copper to lower its total resistance, and hence enhance its performance.

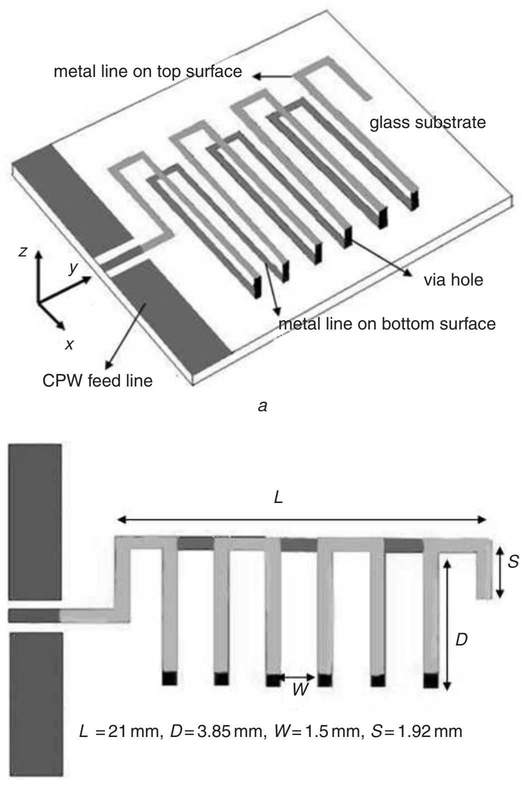

Fig. 1 *Structure of 3-D MEMS monopole antenna, and top view of antenna (not scaled)*

a Structure
b Top view

Antenna design and fabrication: The antenna is a meandered microstrip antenna [5]. The design analysis and simulation is performed using HFSS by the finite-element method (FEM). It was constructed by 15 μm-thick, 1 mm-width copper lines which folded on both the upper and bottom surfaces of the glass substrate, which has the dielectric constant $\varepsilon_r = 4.6$ and thickness $h = 500$ μm. When h is very small the electric length will be neutralised. The schematic diagram and topology of the proposed antenna, and its dimensions, are shown in Fig. 1. The geometric length of the antenna, L, is 21 mm, $D = 3.85$ mm is the width of the antenna, $W = 1.5$ mm is the spacing between two stripe lines, and $S = 1.92$ mm for achieving specified total radiating length. The radiation current distribution is along the longitudinal direction and hence excites the normal mode.

The fabrication processes of the proposed antenna are shown in Fig. 2. The ArF excimer laser, which is now commercial available, was used for via hole drilling. After via hole drilling, the glass wafer was bonded with a photoresist (PR) layer to a sacrificial substrate, which can be dissolved in acetone. The sacrificial substrate has a Cu/Ti seed layer for copper electroplating. Copper electroplating was performed to fill these via holes, and then removed the sacrificial substrate in acetone. Finally, copper electroplating on both sides of the glass wafer was performed to form the coils.

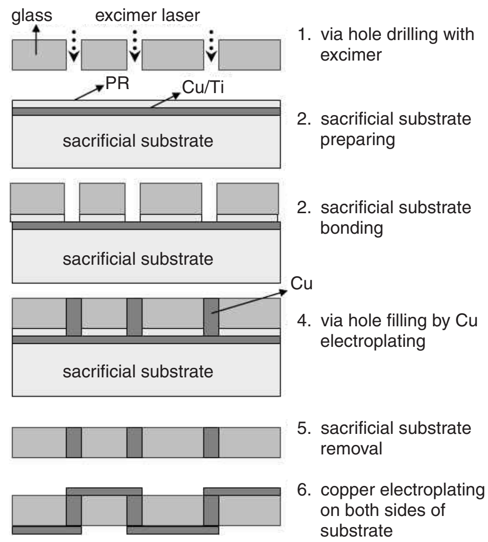

Fig. 2 *Process flow of 3D MEMS helical meander antenna*

From the above, we can establish that such a compact 3D MEMS monopole antenna not only has the benefits of simple structure and is easy to design but also has the benefit of low cost owing to its batch process. In addition, the resonant frequency can be tuned by its total length; hence, a multi-band antenna is also achievable [5].

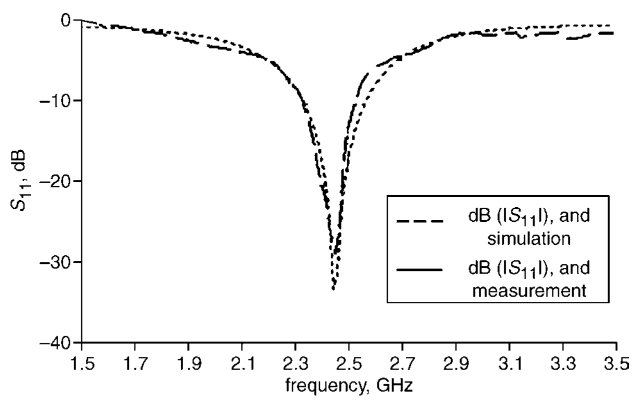

Fig. 3 *Measured and simulated return losses for proposed antenna*

Experiment results: The computed and measured input return loss S_{11} of the fabricated MEMS monopole antenna is illustrated in Fig. 3. The results are in excellent agreement, depicting a resonance at 2.4 GHz and a 190 MHz (7.9%) bandwidth, which easily meets the requirement for operation in the 2.4 GHz ISM band. The radiation characteristics of this monopole antenna system at 2.45 GHz for the two principal plane cuts (*x-z*, *y-z* and *x-y*) are shown in Fig. 4. The total electric field for both computed and measured results is plotted, normalised with respect to its maximum uniform azimuth cut, with a maximum gain of 3.4 dBi. In addition, the proposed antenna with Pyrex 7740 glass substrate has the possibility of using low temperature anodic bonding to silicon IC wafer, thus the forming of a system on package (SoP) module is possible.

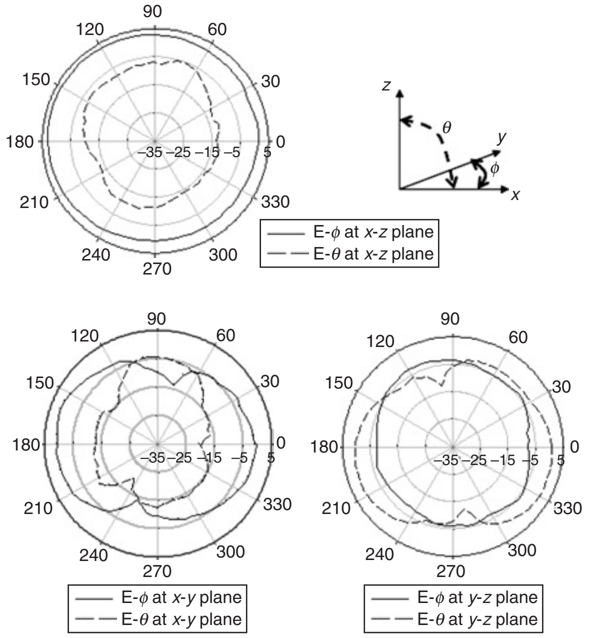

Fig. 4 *Measured radiation patterns for proposed antenna*

Conclusions: A compact three-dimensional MEMS antenna for WLAN (802.11b) has been designed, fabricated and measured. It was fabricated in the form of a folded meander line on both the upper and lower surfaces of the substrate in order to achieve smaller size and wider bandwidth compared to traditional microstrip antennas. Measured performances of the fabricated antenna are in good agreement with the designed values in terms of operating frequency at 2.45 GHz and bandwidth of 190 MHz. Moreover, the resonant frequency can be tuned by its total length; hence, a multi-band antenna is achievable. This small-size, low-cost, simple to fabricate antenna technology is suitable for mobile communication system applications.

 3 August 2005

Electronics Letters online no: 20052677
doi: 10.1049/el:20052677

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