Efficiency enhancement of microstrip antenna by elevating radiating edges of patch

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A new structure for a microstrip patch antenna fabricated on a highly lossy and thin FR4 substrate is presented. Elevated radiating edges of the metallic patch with notches as inductive loading form the patch antenna. This structure effectively reduces the dielectric loss and enhances the radiation efficiency. The proposed antenna has been designed and tested at 3.1 GHz as an example. It showed increased radiation power levels of more than 3 dB in both *E*- and *H*-plane radiation patterns when compared with those of a conventional planar patch antenna, indicating enhanced radiation efficiency.

Introduction: Microstrip antennas are the most common form of printed antennas and are used in a broad range of applications due to their simplicity, low manufacturing cost, and easy analysis and design using several field simulators [1–2]. However, FR4 or high resistivity silicon (HRS), as a lossy substrate, when used as a planar antenna substrate, results in low radiation efficiency. For this reason, particularly in MEMS applications, several methods have been reported to overcome this problem, including: making a cavity [3]; synthesising a substrate [4]; and producing trenches along the radiation edges of the patch [5]. In our first work, we thought that we could reduce dielectric losses only by elevating two radiating edges of patch, where the magnitude of *E*-fields bounded is relatively high. But the simple elevation in a thin substrate without considering the difference of capacitance value between elevated and non-elevated parts of the patch cannot reduce dielectric losses dramatically. In this Letter we present a new patch shape with properly located elevation and inductive loading added so that it can improve the radiation efficiency more easily and effectively.

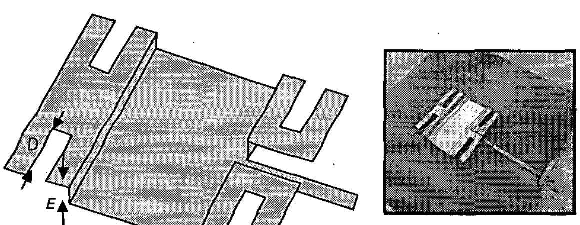

Fig. 1 *Configuration of proposed antenna*

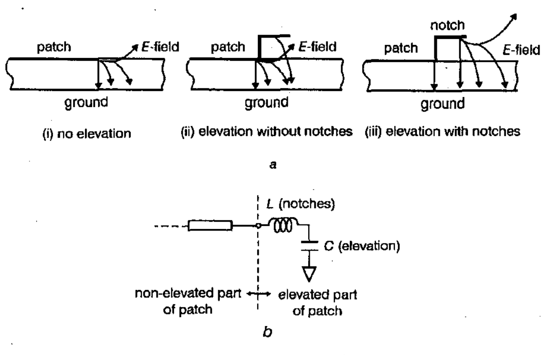

Fig. 2 *Comparison of conventional and proposed patches*
a Edge field radiations
b Equivalent circuit of proposed patch (iii)

Proposed antenna: The configuration of a proposed antenna on a FR4 substrate is shown in Fig. 1 with the picture of the fabricated antenna. From the viewpoint of the transmission line model of the patch, as shown in Fig. 2*b*, the elevated edge of the patch acts as a capacitive load in parallel with an equivalent transmission line. Since the capacitance of this load is smaller than that of the transmission line, most of the fields are still bounded below the edge of the non-elevated part of the patch as is similar to the case of a conventional patch in spite of the increase in patch length through the elevation. But the notch on the elevated edge of the patch as an inductive load in series with the above capacitive load makes the capacitance seen from the non-elevated part of the patch comparable to that of the equivalent transmission line, which makes it easier for the electromagnetic fields to radiate since they are mostly in air [6, 7]. It can be seen from Fig. 2*a* that the localised fields of a microstrip patch are less bound to the substrate than they would be if (i) no elevation was performed as is conventional or (ii) if the elevation was performed without notches. The physical parameters of antennas used in this Letter for a fixed resonant frequency are shown in Table 1.

Table 1: Physical parameters of antennas used

	Reference	Proposed
Patch size (mm^2)	22.7 × 30	32 × 30
Resonant frequency (GHz)	3.13	3.13
Elevation, *E* (mm)	—	1
Notch depth, *D* (mm)	—	12

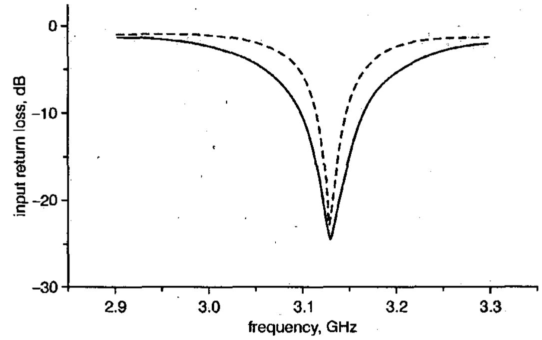

Fig. 3 *Measured input return losses*
——— without elevation (conventional)
– – – – – with elevation (proposed)

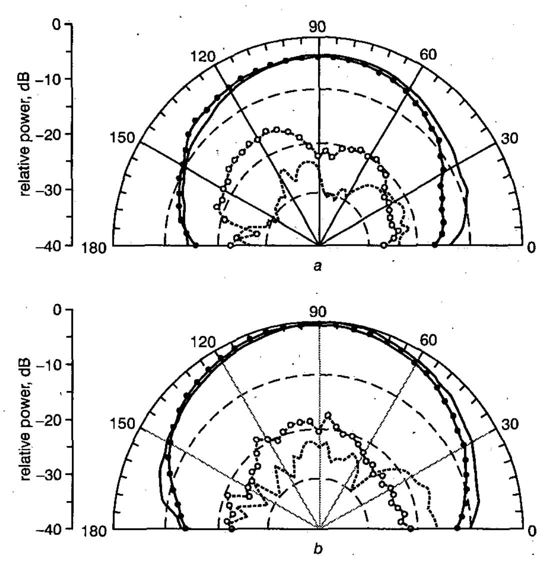

Fig. 4 *Measured antenna radiation patterns*
a Without elevation (conventional)
b With elevation (proposed)
——•—— *H*-plane co-polarisation pattern
– – -o- – – *H*-plane cross-polarisation pattern
———— *E*-plane co-polarisation pattern
– – – – – – *E*-plane cross-polarisation pattern

Results: To verify the effects of the proposed shape of the patch on the radiation efficiency and performances of the antenna, input return loss and radiation patterns are measured and then compared with the conventional planar patch (reference) antenna. In designs, the FR4 substrate of dielectric constant 4.6, thickness 0.7874 mm, and loss tangent 0.02 at 3 GHz is used. Fig. 3 shows the measured input return loss of two patches both resonating at around 3.1 GHz, one with elevated radiating edges (along with notches on it) and the other without. It can be seen that the edge-elevated patch has a narrower operating bandwidth than the conventional flat patch due to the notches. Fig. 4 shows the effects of edge-elevation on the radiation patterns. It can be seen that the relative radiation power levels of the edge-elevated patch are approximately 3.1 dB higher for both the E-plane co-polarisation pattern and the H-plane one than those of the conventional flat patch. In the measurement, two patches under test were well matched (almost the same input return loss less than -20 dB) and identical input power and test structure were used. Because the two antennas have almost the same directivity values, these results indicate that the higher radiation efficiency has been achieved in the edge-elevated patch.

Conclusions: A new structure of the efficiency-enhanced patch antenna is proposed. By elevating two radiating edges of the patch, below which most of fields are bounded, and the use of a notch as an inductive loading, we can observe increased radiation power levels for both E- and H-plane radiation patterns. These results suggest that non-planar antenna structures may offer new design opportunities for high radiation efficiency on lossy substrate as FR4 or silicon.

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