

# A Wideband Aperture Coupled Parasitic Patch Array on LTCC Substrate

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## ABSTRACT

One of the major challenges in next-generation, highly integrated, wireless system-on-packages (SOP) is to integrate the antenna into the package. The multilayer low temperature cofired ceramic (LTCC) is an attractive technology in this domain as it offers desired integration of antenna as well as miniaturization due to the high dielectric constant of substrate material. Antenna design for wide band applications is also a major challenge. This paper presents design of an aperture coupled microstrip patch antenna on LTCC substrate operating in the 24.125 GHz ISM band. Bandwidth of more than 5 GHz is achieved by adding gap coupled parasitic patch elements on all four sides of the fed patch and by cutting cavity beneath the patch elements.

## General Terms

Aperture Coupled, Embedded Cavity, Gap Coupled Parasitic Patch Array, LTCC

## 1. INTRODUCTION

TCC is a multilayer substrate technology which has excellent electrical properties at microwave and millimeter-wave frequencies. It has dielectric constant between 5 to 20 and low loss factor (typically around 0.004 at 3 GHz) that enables in achieving size reduction of components as well as better efficiency. The multilayered structure of LTCC enables 3D system integration by implementing embedded passive components and circuits, conducting vias and lines, cavities etc. [1, 2]. In RF System-on-Package (SoP) domain LTCC technology offers heterogeneous integration of technologies. Integration of antenna in a RF module is a major concern [3] – [5]. High dielectric constant of LTCC material sometimes produces poor antenna performance matrices such as gain, bandwidth, and radiation efficiency. Different types of gain and bandwidth enhancement techniques like stacked patch, parasitic patch, etc. can be implemented easily in LTCC technology. Moreover LTCC technology offers added advantage over conventional PCB technology in the sense that dielectric constant of substrate can be modified (better known as dielectric engineering) by cutting cavity, drilling holes etc. in one or more layers [6] – [10]. By cutting cavity in the LTCC substrate beneath the patch the effective dielectric constant seen by the antenna could be reduced resulting in improved gain and bandwidth performance. Additionally, substantial reduction in surface waves can be achieved by the embedded cavity structure.

Aperture coupled feeding of patch antenna is generally preferred for better antenna performance compared to contact feed methods. The layered structure of aperture coupled microstrip antenna is quite suitable for implementing in multilayer LTCC technology [11].

In this paper an aperture coupled antenna has been designed using Dupont 951 LTCC substrate ( $\epsilon_r=7.8$ ). For bandwidth enhancement gap coupled parasitic patch elements have been

used on all four sides of the fed patch. The coupling between the multiple resonators has been optimized by placing the parasitic patches with a gap smaller than  $2h$  ( $h$  being height of substrate). The gap between the fed and parasitic patches depends primarily on  $\epsilon_r$  and height of the substrate. If the spacing is too small, then the coupling between the patches is more likely to lead to a bigger loop size in the impedance loci, which comes out of the  $VSWR = 2$  circle. On the other hand, a larger gap reduces the loop size thereby reducing the bandwidth. The spacing increases with height and decrease with  $\epsilon_r$  [12] – [15]. Further improvement in bandwidth has been achieved by creating cavity beneath the patch elements. The proposed antenna operates in the 24.125 GHz ISM band.

Rest of the paper presents antenna design in section II, simulation results and discussion in section III followed by conclusions in section IV.

## 2. ANTENNA DESIGN

The proposed antenna is shown in Fig. 1. In the design presented, the feed substrate has thickness of 0.4 mm and the patch substrate is 0.8 mm thick. The total height of the structure is 1.2 mm. The gap between the fed patch and the parasitic elements is optimized to be 0.15 mm for non-radiating edges and 0.22 mm for the radiating edges. It has been investigated that if the gap is lower than the optimum value the bandwidth of the antenna is high but if the gap is larger the gain of the antenna is improved but at the cost of bandwidth. Normally the gap for radiating edges is taken higher than the gap for non-radiating edges for the optimum results of gain and bandwidth. The air cavity has been created in two layers beneath the patch with overall height of 0.4 mm. The length and width of the cavity is taken about 0.7 mm larger than the total length and width of the fed patch and parasitic elements together to cover fringing effects.

The optimized dimensions of the proposed antenna are presented in Table I. Simulations have been performed on Ansoft's HFSS [16].

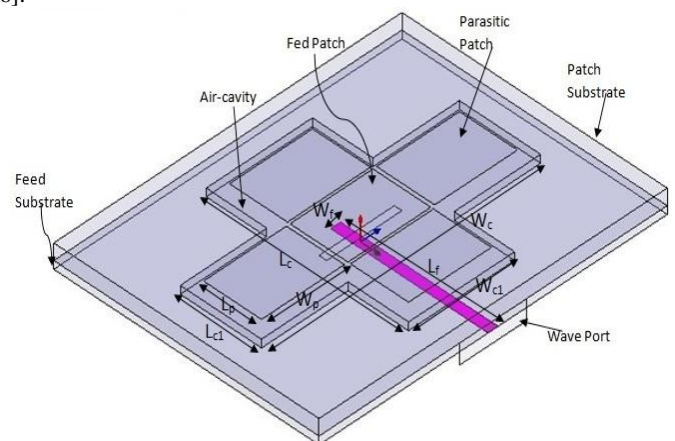


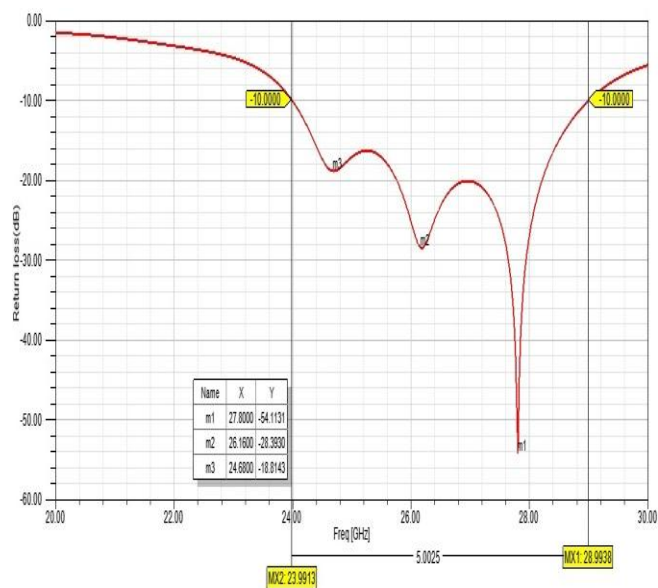
Fig. 1. 3D view of proposed four gap coupled microstrip antenna array with air-cavity

**Table 1. Dimensions of Array Antenna**

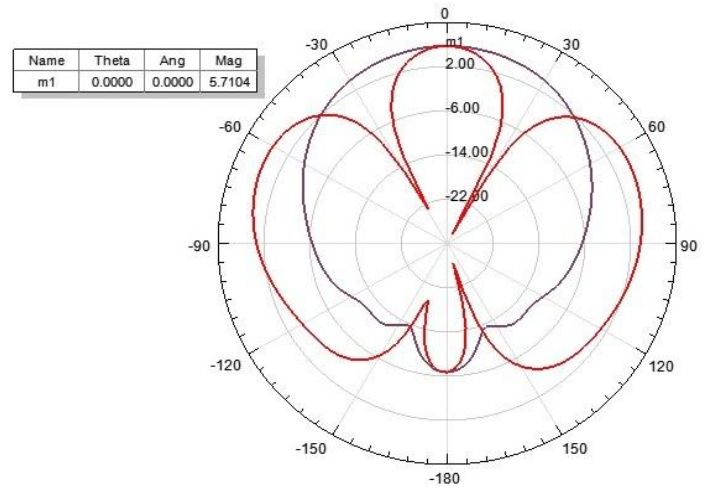
Parameters	Dimensions(mm)
$L_P$	5
$W_P$	3.5
$L_C$	12.2
$W_C$	16.84
$L_{C1}$	4.9
$W_{C1}$	6.4
$L_f$	9.5
$W_f$	0.6
length of aperture	4.54
width of aperture	0.454
height of cavity	0.4
height of patch	0.8
substrate	
height of feed	0.4
substrate	
length of substrate	21
width of substrate	16

### 3. RESULTS AND DISCUSSION

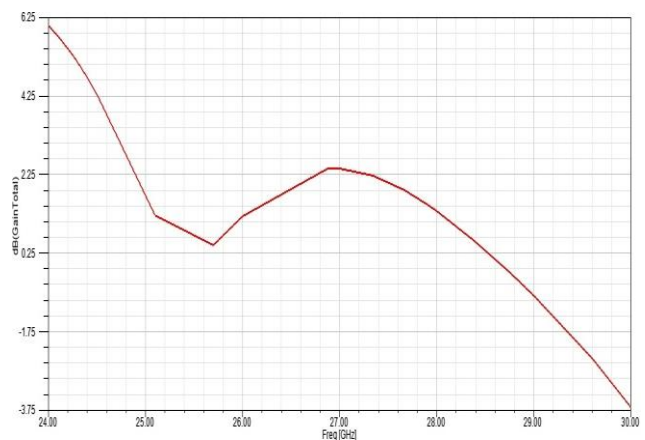
Fig. 2 shows the return loss plot of the proposed antenna. The lower -10dB frequency is obtained at 23.9913GHz while upper -10dB frequency is achieved at 28.9938GHz. Maximum return loss of -54 dB achieved at 27.8GHz. Overall impedance bandwidth of more than 5 GHz has been achieved. Fig. 3 presents the E-plane and H-plane radiation patterns at 24.125GHz. The maximum gain of 5.7104dB has been obtained in both the planes. Fig. 4 shows the variations in the gain with respect to frequency. It is observed that the gain performance of the proposed antenna is satisfactory within the desired frequency range. Fig. 5 shows the 3D polar plot obtained at 24.125GHz. The red color shows the maximum field intensity in the broadside direction. The other parameters such as peak directivity, peak gain and radiation efficiency are shown in Table II.



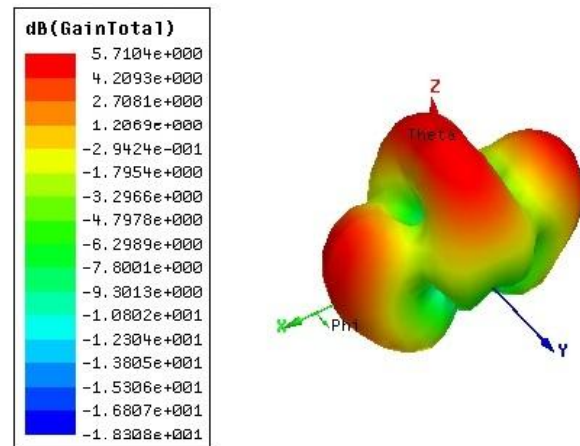
**Fig. 2. Return loss plot**



**Fig. 3. E and H plane radiation patterns**



**Fig. 4. Gain v/s frequency curve**



**Fig. 5. 3D polar plot**

**Table 2. Other Simulated Results**

Parameters	Simulated Results
Peak gain	3.7115
Peak directivity	4.2131
Radiation efficiency	0.88095

#### 4. CONCLUSIONS

in this paper design of a wide band aperture coupled antenna has been presented using ltcc substrate. improvement in bandwidth has been achieved using gap coupled parasitic elements and by cutting cavity in the substrate layers beneath patch elements. the technique is especially suited to ltcc substrates as cutting of cavity in a substrate layer is done on green tape. compared to other array configurations employing parallel or series feed networks the losses due to large feed networks are avoided in the proposed design. moreover overall size of the antenna structure is smaller than that achievable using corporate feed and series feed array configurations. the results are very encouraging and the bandwidth obtained also covers lmds (local multipoint distribution services) band of 27.5 – 28.35 ghz.

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