Enhancement of Both Gain and Bandwidth of LTCC Microstrip Patch Antenna with Metallic Bar

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Abstract

In this paper, high gain and broad band stacked microstrip patch antenna with a metallic bar and a stacked cavity operating at 40GHz is proposed. The stacked antenna is designed using 4 layers LTCC technology. It can be easily implemented by shorting LTCC substrates to the ground with multiple vias. It is found that both high gain and broadband performance of antenna can be obtained by varying the height of metallic bar and the size of a stacked cavity. The maximum gain and impedance bandwidth of 10dB return loss for the stacked patch antenna with a metallic bar and a stacked cavity are nearly 8.9dBi and 19% (37.3~45.1 GHz) which are 3.8dB higher and 9% wider than 5.1dBi and 10% for the stacked antenna without the metallic bar and the stacked cavity, respectively.

***Index Terms* — microstrip patch antenna, LTCC, millimeter wave**

1. INTRODUCTION

Millimeter-wave technology is being recognized as having potential for emerging markets, such as broadband radio links for cellular base station backhaul networking, WPAN(Wireless Personal Area Network) and automotive safety systems. There has been a widespread trend toward higher levels of integration in millimeter-wave system design, motivated by a desire to reduce cost, size and complexity.

As a result, LTCC (Low Temperature Co-fired Ceramics) multilayer technology is becoming more and more popular for the production of highly integrated, complex multilayer modules and circuits. This technology is appreciated for its flexibility in realizing an arbitrary number of layers with easy-to-integrate circuit components like via-holes and cavity-buried components.

Recently, the concept of integrating the antenna within the module is very attractive [1]-[3]. A microstrip patch antenna can be one of the candidates for the integrated antenna due to its low cost and lightweight structure. However, it's difficult to meet the bandwidth specification for broadband wireless communication such as IEEE 802.16 FWA(Fixed Wireless Access) due to the high dielectric constant of the LTCC material[4]-[5]. For the same reason, it can suffer from the diffraction of surface wave at the edge of finite substrates. To enhance the antenna gain, it is important to suppress an undesirable surface wave using periodic techniques such as PBG or EBG and artificial soft surfaces consisting of a single square ring of metal strip shorted to the ground[6]-[8].

In this paper, a stacked patch antenna with a metallic bar and a stacked cavity which can be easily implemented by shorting LTCC substrates to the ground with multiple vias is proposed at 40GHz. Generally, it is known that the common stacked-patch antennas on such an LTCC multilayer substrate can double the impedance bandwidth, as compared to a single-patch antenna with the same substrate, while maintaining a thin dielectric substrate.

Furthermore, by using the metallic bar and the stacked cavity, the bandwidth of the antenna can be improved. It is found that both high gain and broadband performance of antenna can be obtained by varying the height of metallic bar and the size of a stacked cavity. The maximum gain and impedance bandwidth of 10dB return loss for the stacked patch antenna with a metallic bar and a stacked cavity are nearly 8.9dBi and 19% (37.3~45.1 GHz) which are 3.8dB and 9% higher than 5.1dBi and 10% for the optimally designed stacked antenna without the metallic bar and the stacked cavity, respectively.

This design is applied to Dupont LTCC DP-943 substrate. Typical properties of that substrate material are the permittivity of 7.1, a loss tangent of 0.002 at 40GHz and one layer thickness of 100 μm. Silver paste with conductivities of about 55.1e6 siemens/meter is used for total metal layers

2. CONFIGURATION OF STACKED MICROSTRIP PATCH ANTENNA WITH METALLIC BAR

3-D overview of the geometry of the proposed microstrip patch antenna including the metallic bar and stacked cavity is shown in Fig. 1. The antenna comprises 4 dielectric layers with a total thickness of 400um, 5 metal layers (layer thickness=10um), a metal bar with aperture, a metal plate and via array. The lower patch is fed by strip transmission line. The stacked-patch array antenna, which is made by an electromagnetic coupling between the two patch resonators, is backed by a stacked cavity which consists of several metal layers (from metal layer 1 to metal layer 5) that are connected to the grounded planes by via array. In LTCC packaging technology, the sidewall of the stacked cavity can be easily realized through an array of vertical vias in order to minimize the losses at the cavity's metal walls. The stacked cavity suppresses the surface wave scattering from the substrates.

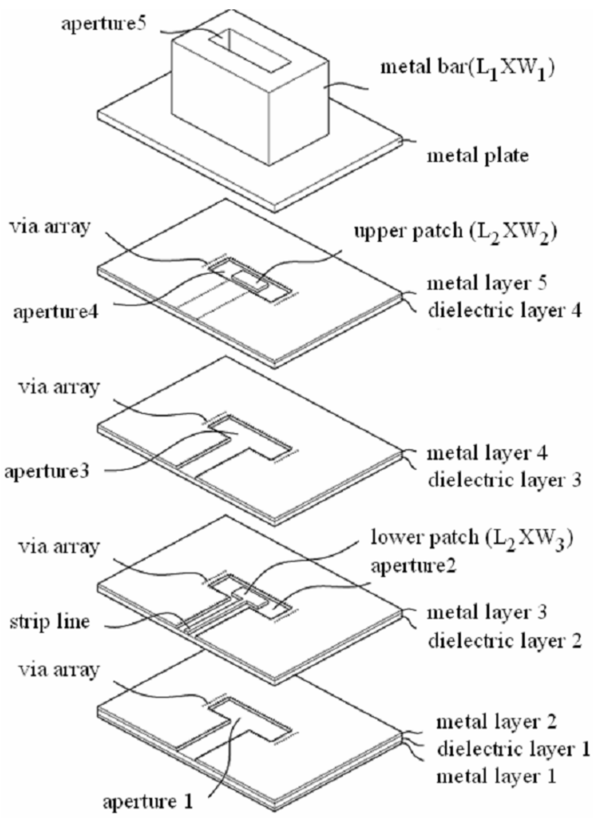

Fig. 1: The 3D view of the stacked patch antenna with a metallic bar and a stacked cavity

As shown in Figs.1 and 2, both lower and upper patches have slightly different resonance circuits with the correspondingly influence on the matching network which results in an increasing bandwidth. The dimension of the aperture (W1 x L1) is 5.7 mm x 2.8 mm, which is similar to the size of WR-22 standard waveguide. The height (h1) of the metal bar should be optimized for the maximum gain. In case of common stacked patch antenna using the same substrate, the optimized widths of each patch are nearly 1.8mm and 1.6mm, respectively. However, because the size of the aperture may affect the impedance characteristics and the resonant frequency of the antenna, the dimensions of upper and lower patches W2, W3 and L2 should be changed into 2.2mm, 1.4mm and 1.08mm for the optimum frequency and bandwidth, respectively. Via-to-via distance to construct the shorted wall is 400um (about λg/10).

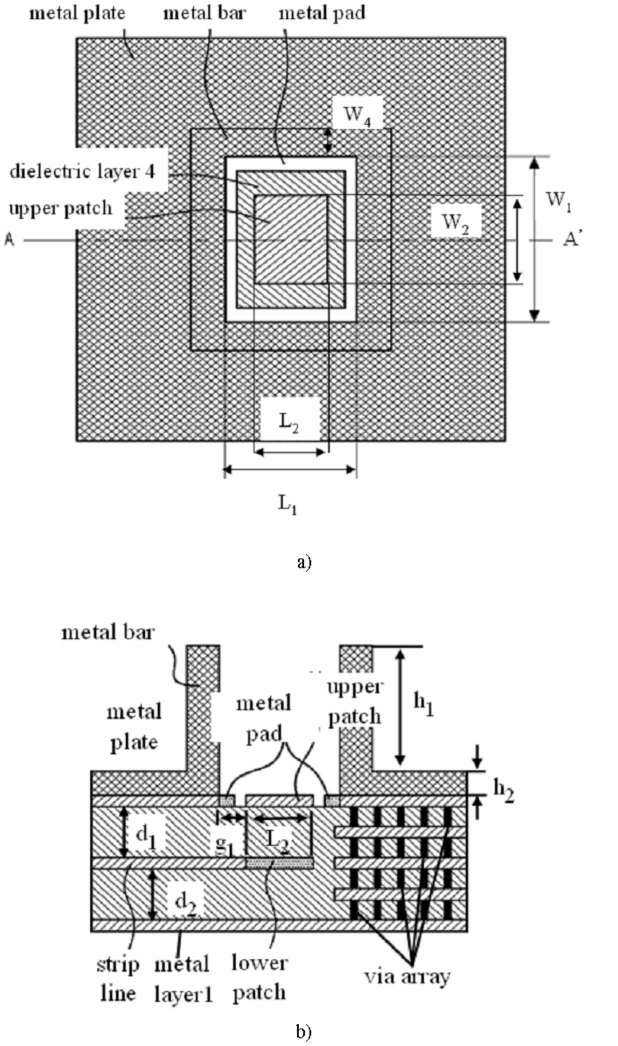

Fig. 2: a) The top view and b) cross-sectional view of the stacked patch antenna with a metallic bar and a stacked cavity

3. Simulation Results

Further insight into this phenomenon can be gained via a numerical solution. The stacked patch antenna with the metallic bar and the stacked cavity shown in Figs.1 and 2 is simulated with CST MW Sudio 5.0 based on the finite integration method.

The design parameters for the antenna operating at 40GHz band are listed in Table 1. Metal pad between the metal bar and antenna patches may be used for optimum impedance matching. However, in this paper, metal pad is not used.

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TABLE 1: FONT SIZES FOR PAPERS

d_1	0.2mm	L_1 x W_1	5.7x1.40mm^2
d_2	0.2mm	L_2 x W_2	2.2x1.08mm^2
h_1	6.5mm	L_2 x W_3	1.4x1.08mm^2
h_2	1.0mm	G_1	0.86mm

Note that the maximum gain for the stacked patch antenna with a metallic bar (h1=6.5mm) and a stacked cavity are nearly 8.9dBi which are 3.8dB higher than 5.1dBi for the optimally designed common stacked antenna without both the metallic bar and the stacked cavity.

In Fig. 3, the antenna gain for the stacked patch antenna having a metallic bar (h1=6.5mm) and a stacked cavity are compared with that of the antenna with a metallic bar but without a stacked cavity. It is shown that antenna gain is improved over 2 dBi.

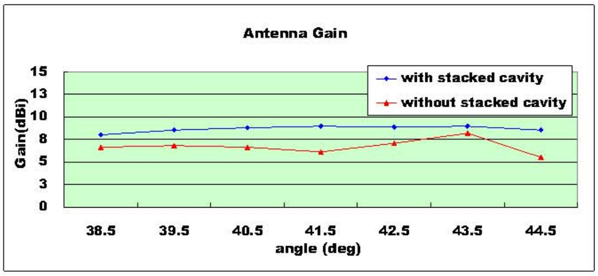


Fig. 3: Behaviour of antenna gain with and without the stacked cavity (with no via array)

The simulation result in Fig. 4 shows the calculated return loss of the antenna. The 10 dB impedance bandwidth of the antenna is about 7.8 GHz, giving a relative bandwidth of over 19 %. This is a remarkable good result, especially when keeping in mind the high dielectric constant of the material used.

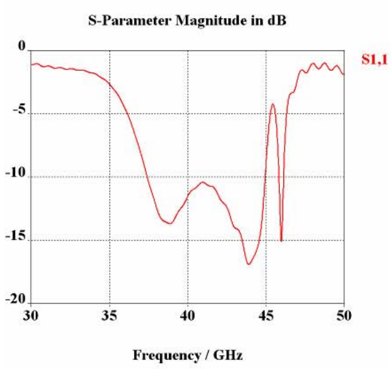
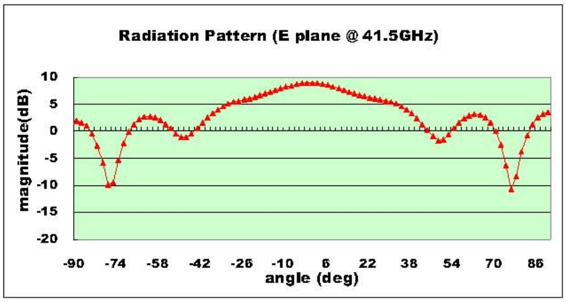
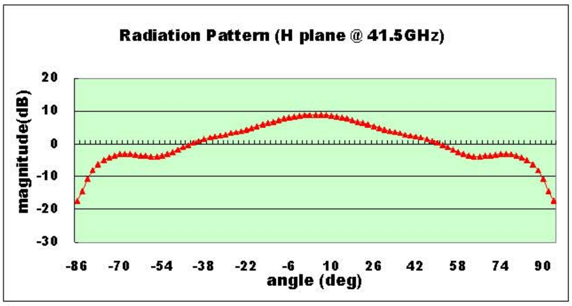


Fig. 4: Return loss of the antenna with the metallic bar and the stacked cavity

Fig. 5 shows the simulated radiation patterns of the antenna with the metallic bar and the stacked cavity at 41.5GHz.



a)



b)

Fig. 5: Radiation patterns of the antenna with the metallic bar and the stacked cavity: a) E-plane and b) H-plane

4. CONCLUSION

This paper deals with the design of high gain and broadband stacked patch antenna operating at 40GHz band based on 4 layers LTCC technology. Gain and impedance bandwidth of the antenna can be improved by using the metallic bar and the stacked cavity, which can be easily implemented by using LTCC substrates and vias.

Despite the high dielectric constant of the LTCC material, the presented concept exhibits high gain and broadband behaviour by exploiting the LTCC multilayer characteristics.

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