A Novel Dual-Band LTCC Chip Antenna

Qing-Xin Chu¹, Hai-Ying Zou²

¹. College of Electronic and Information Engineering, South China University of Technology, Guangzhou, Guangdong, China. Email: qxchu@scut.edu.cn
². School of Electronic Engineering, Xidian University, Xi’an, Shanxi, China. Email: mermaidzhy@163.com

Abstract — In this paper, we proposed a novel dual band dielectric chip antenna for 2.45GHz Bluetooth and 5.25GHz WLAN applications, which consists of double strip meander conductor lines embedded in Low Temperature Co-Fired Ceramic (LTCC) structure. The dimensions of the proposed antenna are 5.2mm×2.0mm×1.27 mm. Equivalent circuit of the dual band chip antenna is presented for input impedance. The omni-directional chip antenna is suitable for mobile communication handsets where limited antenna size is a premium.

Index Terms — Dielectric chip antenna, dual-band, meander conductor, LTCC, Omni-directional antenna.

I. Introduction

The rapid expansion in mobile communication requires the development of antennas. External antennas such as whip or helical antennas gradually are replaced by built-in antennas, so the development of internal dielectric chip antennas for mobile communication handsets has become a hot issue. And LTCC technology provides great power for the development of dielectric chip antennas. Dielectric chip antennas have not only merits of small size, light weight and omni-direction, but also the economical advantage for mass production. There are two major types of the dielectric chip antennas. One is with a ground plane printed on the bottom of the dielectric base, and the other is without a ground plane. The latter type of ceramic chip antenna is operated as a monopole antenna [1]. Traditionally, built-in antenna is a monopole antenna based on λ/4 resonator theory, but adopting LTCC technology, the size of the antenna reduces dramatically. However, chip antennas tend to have a narrow bandwidth and low radiation gain. As a result, many papers are published to present techniques to improve the performance of the chip antennas [2]-[4].

Due to the rapid growth of the communication handsets, the chip antenna is tried to improve the performance and functionality. Dual-band chip antenna was proposed in [4], but its size is too large to satisfy the miniature trend of the cell phones. In this paper, we presented a novel dual band compact chip antenna in 2.45GHz Bluetooth and 5.25GHz WLAN bands. The main character of dielectric chip antenna is the compact structure of double strip meander conductor lines buried in LTCC structure. Thanks to this embedded structure, the stability of the chip antenna has been enhanced. Meander conductor line technology allows to designed antennas with a small size and provides wideband performance [5]. To provide a good and wide band impedance match at the port of the meander lines, a double-L structure is used as an impedance transformer during the feeding line and the meander antenna. The LTCC structure of the designed antenna is simulated by Ansoft HFSS software. The radiation patterns and return loss of the antenna are given. The equivalent circuit of the antenna for input impedance is presented. The return losses of the chip antenna simulated by HFSS and from equivalent circuit are in good agreement.

II. Structure and Equivalent Circuit

A. Structure

Figure 1 shows the geometry of dual band dielectric chip antenna. The overall size is 5.2mm×2.0mm×1.27 mm. The relatively permittivity of ceramic substrate is 15. The structure has two layers connected by vias filled with Ag. The Region 1 is two stacked double-L conductor lines in different layers, whose function is as a quarter-wavelength transformer to match the antenna input impedance. The Region 2 is the radiating patches which are consisted of two layers of the meander–line conductors stacked in different layers vertically. The current distribution on the meander line decides the radiation pattern. The y-oriented currents rarely influence radiation since they flow in opposite directions on the meander lines, while the x-oriented currents constructively contribute to the E-plane field. In theory, the sum of the lengths of its x-directed sections is about λ/4, but using LTCC technology, the size can dramatically reduce [6]. The value of wavelength is obtained by

$$\lambda = \frac{c}{f\sqrt{\varepsilon_r}}$$

where c is the velocity of light in free space, f is the resonant frequency, $\varepsilon_r$ is the relative permittivity of ceramic.
The resonant frequency of the radiation element on the first layer and the second layer is 2.45GHz and 5.25GHz, respectively. Figure 2 shows the equivalent circuit of the dual band dielectric chip antenna for its input impedance.

In Figure 2, the capacitances $C_1$ and $C_2$ parallel-connected the coupling inductances $L_1$ and $L_2$ are formed two parallel LC resonators which series-connected the radiation resistances $R_1$ and $R_2$, respectively. $C_3$ is the parasitic capacitance between chip and GND plane of the chip-mounted terminals.

In the Region 1, two double-L stacked structures take as inductance performance, but double-L structure at the same layer exist coupling capacitor. As a result, the coupling capacitor $C$ connects the parasitic inductance $L$ in parallel. The value of inductance $L$ is obtained by general formula as follows:

$$L = \frac{\mu N^2 A}{l}$$  \hspace{1cm} (2)

Where $N$ is the number of turns, $\mu$ is the permeability of dielectric, $A$ is the cross sectional area of the double-L, $l$ is the length of the coil. An approximate expression for the capacitance $C$ is given by [7]

$$C = \frac{\varepsilon_r + 1}{2W} l (A_1 + A_2)$$ \hspace{1cm} (3)

where $C$ is the capacitance per unit length along $W$, $\varepsilon_r$ is the relative permittivity of dielectric, $l$ is overlay length of double-L structure at the same layer, $A_1$=4.409×10^{-3} pF/mm, $A_2$=9.92×10^{-3} pF/mm. $W$ and $l$ are shown in Figure 1.

### III. Simulation and Results

The dielectric chip antenna has been designed and analyzed by Ansoft HFSS. According to the desired specification, the component values of the equivalent circuit can be adjusted to $L_1=4.1nH$, $C_1=0.56pF$, $R_1=122Ohm$, $R_2=880Ohm$, $L_1=1.06nH$, $C_1=0.76pF$, $L_2=2.8nH$, $C_2=0.22pF$, $C_3=0.41pF$. The comparison of return losses between structure simulation results and the equivalent circuit simulation results is presented in Figure 3. The first resonant frequency of the chip antenna is at 2.45GHz, and the -10dB return loss bandwidth is 150MHz (2.34GHz—2.49GHz). The second resonance frequency at 5.25GHz, and the -10dB return loss bandwidth is 380MHz (5.05GHz—5.43GHz). The structure and the equivalent circuit return loss results are in good agreement. Figure 4 and figure 5 show simulated radiation gain patterns at 2.45GHz and at 5.25GHz of the antenna, respectively. The maximum radiation gains are 1.31dBi at 2.45GHz and 8.25dBi at 5.25GHz.

### IV. Summary

A novel dual band chip antenna using meander conductor lines for 2.45 and 5.25 GHz applications has been proposed. Its equivalent circuit for input impedance has been given. It offers several advantages of compact size and easy fabrication. As a result, the simulated -10dB bandwidth and maximum radiation gain are 2.34GHz—2.49GHz (1.31dBi @ 2.45GHz) and 5.05GHz—5.43GHz (8.25dBi @ 5.25GHz).
Fig. 4 The radiation patterns of the proposed antenna at 2.45GHz

Fig. 5 The radiation patterns of the proposed antenna at 5.25GHz

References


