ICPA for highly integrated concurrent dual-band wireless receivers

C.C. Zhang, J.J. Liu and Y.P. Zhang

A single-feed dual-band integrated circuit package antenna (ICPA) is reported. The ICPA, intended for use in either single-chip or single-package highly integrated concurrent dual-band wireless receivers, is implemented in the format of a cavity-down ceramic ball grid array package of $15 \times 15 \times 1.9\ mm^3$. Results show that the ICPA achieved a frequency ratio of 2.2, return loss bandwidth of 1.67% and gain of −8 dBi at 2.4 GHz, and return loss bandwidth of 0.69% and gain of −2 dBi at 5.25 GHz.

Introduction: Multistandard wireless communications systems operate in the radio frequency range from 900 MHz to 5.8 GHz. Hence, the combination of two or more standards in one wireless receiver becomes rather desirable. For this purpose, dual- and even multi-band wireless receivers designed in either concurrent or non-concurrent configurations have been reported [1, 2]. In multi-band concurrent wireless receivers, simultaneous reception at different frequency bands is achieved by building multiple independent signal paths, while in non-concurrent wireless receivers, multi-band operation is realised through switching among different frequency bands to receive one band at a time. These conventional receiver solutions suffer from larger circuit footprint and higher power dissipation. To overcome these aforementioned problems, a new concurrent dual-band wireless receiver has been introduced more recently. The new concurrent dual-band receiver that employs an elaborate frequency conversion scheme for simultaneous reception at two different frequencies is suitable for high-level integration in deep submicron CMOS [3]. To better suit this innovative development in concurrent dual-band wireless receiver designs, we propose a dual-band integrated circuit package antenna (ICPA) in this Letter. The novel ICPA is implemented on a cavity-down ceramic ball grid array (CBGA) package that can carry a highly integrated concurrent dual-band wireless receiver.

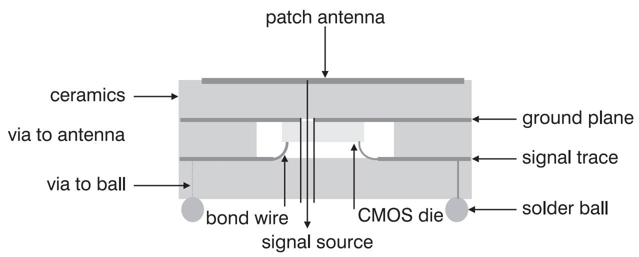

Fig. 1 *Cross-sectional view of ICPA*

Dual-band integrated circuit package antenna: Fig. 1 shows the configuration of the dual-band ICPA in a thin CBGA package format. The ICPA consists of three cofired laminated ceramic layers, with a bare chip cavity formed at the middle layer. There are two buried layers and one top-layer metallisation in the construction. The lower buried layer provides the metallisation for the signal traces, while the upper buried layer provides the metallisation for the ground plane of the ICPA. The radiating element of the dual-band ICPA, which can take any form of a printed circuit dual-band antenna, is realised with top-layer metallisation. There are 48 signal traces in the ICPA. These 48 signal traces follow the current designs of highly integrated wireless receivers where 48 input/output pads are often adopted. The outer ends of 48 signal traces are connected to 48 solder balls through 48 vias, while the inner ends of 48 signal traces are connected to the highly integrated wireless receiver through 48 bond wires. The signal traces have the same size of $1.27 \times 0.635\ mm^2$, the vias have the same length of 0.635 mm, the solder balls have the same volume of $0.129\ mm^3$, and the bond wires have different lengths from 3.2 to 4.2 mm. The highly integrated wireless receiver is attached upside down to the ground plane of the ICPA in the chip cavity. The chip cavity has the volume of $11.448 \times 11.766 \times 0.635\ mm^3$, which can accommodate the highly integrated wireless receiver of size up to $8.268 \times 8.586 \times 0.318\ mm^3$. The ground plane of the ICPA shields the highly integrated wireless receiver from the radiating-element of the ICPA. The feed of the radiating element of the ICPA from the carried highly integrated wireless receiver can be realised with a bond wire, a signal trace, and a via through an aperture on the ground plane of the ICPA in real implementation. The ICPA ceramic and metallic layers are alumina and copper, respectively. Alumina has a dielectric constant of 9.8 and copper has a conductivity of 3.7×10^7 S/m. The whole ICPA measures $15 \times 15 \times 1.9\ mm^3$.

Fig. 2 shows the geometry and the location of the radiating element on the top surface of the ICPA for dual-band operation at 2.4 and 5.25 GHz. As shown, the radiating element in our design is a modified slot-loaded microstrip patch antenna. This is because the conventional slot-loaded microstrip patch antenna can only yield a frequency ratio from 1.6 to 2 [3]. By introducing two insets, the modified slot-loaded microstrip patch antenna can increase frequency ratio to 2.2 to meet our design requirement. In addition, for ease implementation the feed of the radiating element is realised with a probe of an SMA connector through an aperture on the ground plane of the ICPA.

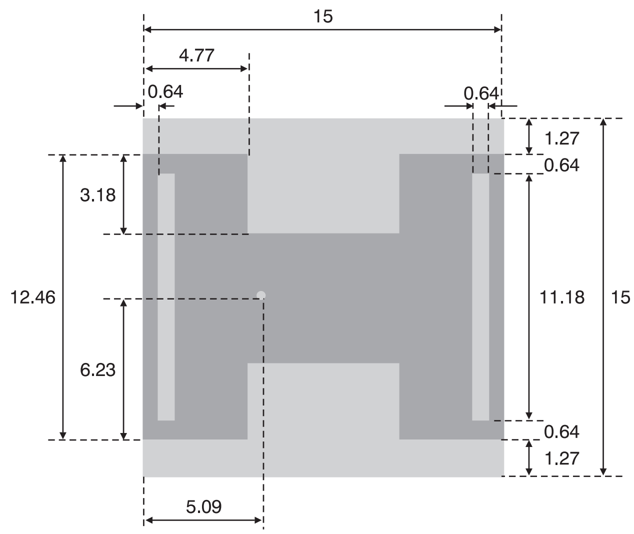

Fig. 2 *Geometry of modified slot-loaded microstrip patch antenna units in mm*

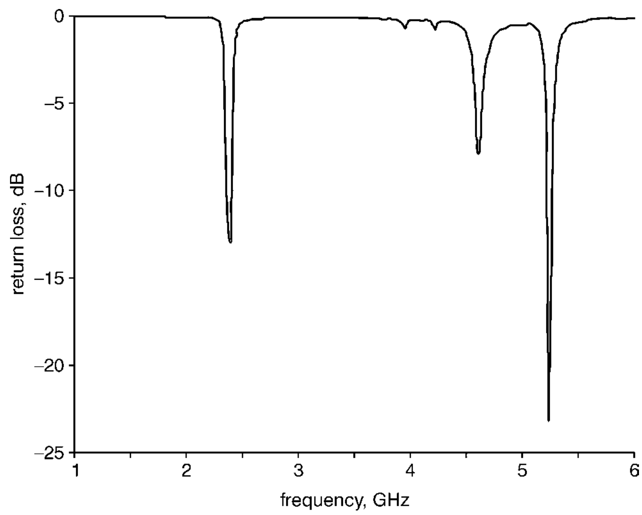

Fig. 3 *Measured return loss of ICPA*

Fig. 3 shows the measured return loss of the fabricated ICPA prototype. Two separate resonant modes with good impedance matching can be seen. The lower resonant mode at 2.4 GHz has a 10 dB return loss bandwidth of 40 MHz (1.67%). The higher resonant mode at 5.25 GHz has a 10 dB return loss bandwidth of 36 MHz (0.69%). The narrow bandwidth of the ICPA is because the effective thickness of the substrate for the slot-loaded microstrip patch is quite thin at 0.635 mm. Figs. 4*a* and *b* show the measured radiation patterns at 2.4 and 5.25 GHz, respectively. Notice that, in general, the radiation patterns are similar to those of a conventional dual-band slot-loaded microstrip patch antenna on a small ground plane. The measured gain is −8 dBi at

2.4 GHz and −2 dBi at 5.25 GHz. The gain is lower as the ICPA is made of high permittivity ceramic with a small size. Nevertheless, the gain is comparable with that of the dielectric chip antenna [4].

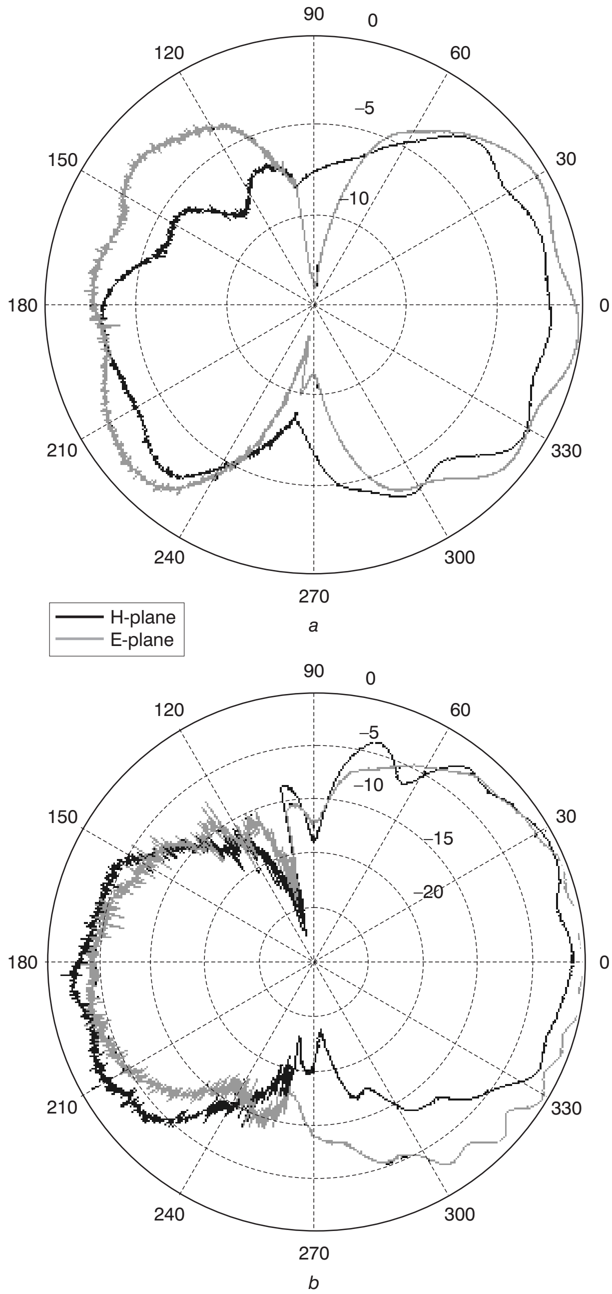

Fig. 4 *Measured copolar radiation patterns at 2.4 and 5.25 GHz*

a 2.4 GHz
b 5.25 GHz
——— H-plane
——— E-plane

Conclusions: A single-feed ICPA realised on a cavity-down CBGA package of $15 \times 15 \times 1.9\,mm^3$ has been proposed for use in highly integrated concurrent dual-band wireless receivers operating at 2.4 and 5.25 GHz. The ICPA offers the possibility to combine antennas and highly integrated wireless receivers into standard surface mounted devices, and thus, enjoy economical advantages of mass production and automatic assembly.

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C.C. Zhang, J.J. Liu, Y.P. Zhang (*Integrated Systems Research Laboratory, School of EEE, Nanyang Technological University, Singapore*)

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