Compact internal multiband antenna for mobile phone and WLAN standards

P. Ciais, R. Staraj, G. Kossiavas and C. Luxey

A novel internal planar inverted-F antenna (PIFA) suitable for handset terminals is presented. The structure combines shorted parasitic patches, capacitive loads and slots to achieve multiband operation. This compact antenna operates in the GSM, DCS, PCS, UMTS, HIPERLAN/2 and IEEE 802.11a bands within 2.5:1 voltage standing wave ratio (VSWR) and with good efficiency.

Introduction: The rapid increase of communication standards has led to a great demand in designing multiband antennas for handset devices. Internal planar inverted-F antennas (PIFAs) are very suitable in such applications since they are compact, low profile and easy to manufacture. Starting with a main shorted resonator, several techniques must be simultaneously applied to achieve multiband/wideband performances: addition of parasitic shorted patches and capacitive loads, and use of slots. Recently, quad-band antennas for mobile phones [1–4] and dual-band antennas for wireless local area network (WLAN) operations [5, 6] have been successfully designed. However, none of these antennas can simultaneously cover all the following communication standards: GSM (Global System for Mobile communications, 880–960 MHz), DCS (Digital Communication System, 1710–1880 MHz), PCS (Personal Communication Services, 1850–1990 MHz), UMTS (Universal Mobile Telecommunications System, 1920–2170 MHz), HIPERLAN/2 in Europe (HIgh PERformance Local Area Network—Type 2, 5150–5350/5470–5725 MHz) and IEEE 802.11a in the USA (Institute of Electrical and Electronics Engineers, 5150–5350/5725–5825 MHz). The antenna presented in this Letter is based on the quad-band structure reported in [4], and another technique is applied here to achieve the tuning of its higher-order resonances in the WLAN band.

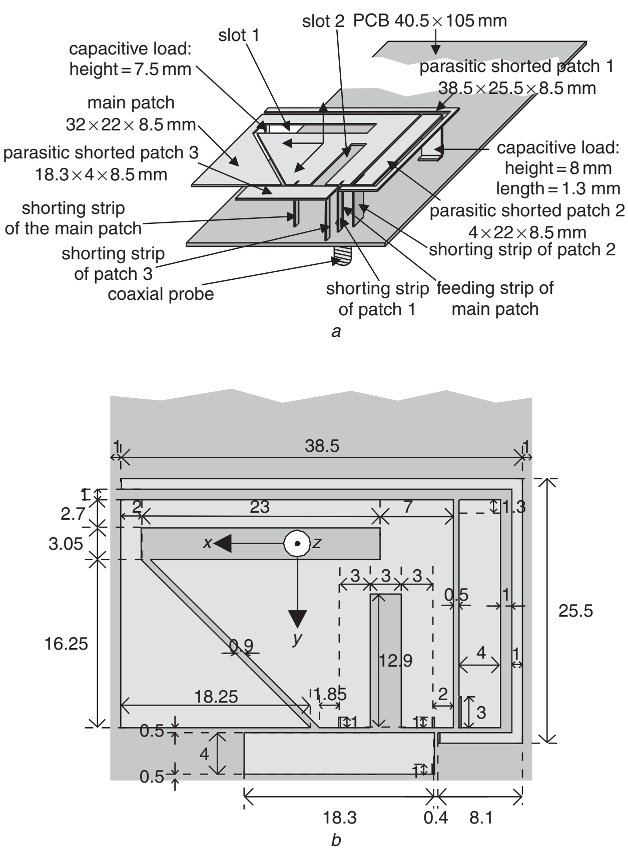

Fig. 1 *3D view of multiband antenna*
a 3D view *b* Top view (all dimensions in millimetres)

Antenna structure and design rules: The antenna consists of a main quarter-wavelength patch, with three additional parasitic elements (Fig. 1). This radiating structure has dimensions of 38.5 × 28.5 × 8.5 mm and is placed on the corner of a ground plane having a size approximately equal to that of the printed circuit board (PCB) of a typical mobile phone, i.e. 40.5 × 105 mm. The dielectric between all patches and the PCB is air, and its thickness is 8.5 mm. The formula

$$f_r = \frac{c}{4(L+H)}$$

is used as a starting rule for choosing the length of the main patch (where f_r = resonant frequency of the patch in the GSM band, c = velocity of light in free space, L = average length of the patch and H = height of the patch). The patch is coaxially fed via a metallic strip and its quarter-wavelength character is obtained thanks to a shorting metallic strip. Moreover, a slot is etched in this patch to obtain both a longer average current path and a strong capacitive effect between its metal facing surfaces to achieve a frequency decrease of its fundamental and higher-order mode resonances [4]. The optimisation is done using the commercial simulation tool IE3D, version 10.06, which is based on the method of moments. The resulting structure is a well-matched antenna in the GSM and the 2 GHz bands. Three quarter-wavelength type, parasitic shorted patches are then added to widen these bandwidths. Each one is connected to the ground plane by metallic strips and located near the main patch in order to be efficiently electromagnetically coupled. Parasitic elements 2 and 3 increase the upper bandwidth of the main patch, respectively, below and above its third resonance at 2 GHz. Parasitic element 1 increases the lower part of the GSM band. Vertically folding the end strips of parasitics 1 and 2 creates a capacitive loading and artificially increases their electrical lengths. The optimised structure of this second step is a quad-band GSM/DCS/PCS/UMTS antenna with a VSWR better than 2.5 [4]. The last step is now to cover the two WLAN standards without altering the previous resonances.

A meticulous simulated parametric study was conducted on each patch by independently changing their physical parameters in order to identify and control their higher-order modes around 5 GHz. It was found that the tuning and matching process of the resonances of all the parasitics led to only small modifications compared to the previous structure. However, it was necessary to find a way to decrease one higher-order resonance of the main resonator located above the 5 GHz WLAN frequencies. This goal was obtained by looking at the surfaces current of each resonant mode of the patch and adding a new slot in this main resonator at a position that increases the current path of this mode without modifying the first and the third ones (slot 2 in Fig. 1). Adding a slot in this area creates a capacitive effect, which has a strong influence on this mode because the facing metal surfaces are not at the same potential, and less effect on the lower modes because, at these frequencies, these surfaces are almost at the same potential.

Results: Fig. 2 shows the measured and simulated VSWRs of the antenna. Taking into account the complexity of the structure and the resulting manufacturing tolerance errors, reasonable agreement is observed between these curves. The measured bandwidths with a VSWR better than 2.5:1 are 70 MHz (870–940 MHz) in the GSM band, 476 MHz (1608–2084 MHz) in the DCS/PCS/UMTS band and 1128 MHz (4863–5991 MHz) in the 5 GHz WLAN band. The upper standard is obtained thanks to the use of the tuned frequencies of a higher-order mode of the main patch at 5.3 GHz and the seventh mode of parasitic element 1 at 5.9 GHz. The measured and simulated radiation patterns of the antenna are depicted in Fig. 3. Due to the dipole-like behaviour coming from the antenna–PCB combination, the 910 MHz radiation pattern in the x–z plane is omnidirectional. Some directivity appears and increases with frequency in both planes since the length of the PCB is larger than half a wavelength at 1850 MHz and about two wavelengths at 5350 MHz. The measured maximum gains are 1.2 dBi at 910 MHz, 3.9 dBi at 1850 MHz and 6.8 dBi at 5350 MHz while the simulated values are 1.4, 3.6 and 5.5 dBi, respectively. The discrepancies between theoretical and experimental results principally come from our measurement setup and especially the difficulty to correctly choke the feed cable of such antennas. The simulated total efficiency of the structure, taking into account reflection losses as well as ohmic losses, was computed to be above 63.4, 80.7 and 83.4% in the GSM, DCS/PCS/UMTS and 5 GHz WLAN bands, respectively. Using a Wheeler Cap technique, the efficiencies were measured to be above 61 and 78% in the two lower bands, but it was impossible to measure it around 5 GHz as the antenna is now larger than the Wheeler radiansphere $\lambda/2\pi$.

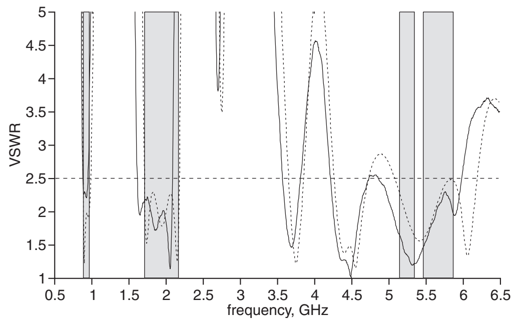

Fig. 2 *Measured and simulated VSWR of multiband antenna*

Standards bandwidth requirement in grey
—— measurement ------ simulation

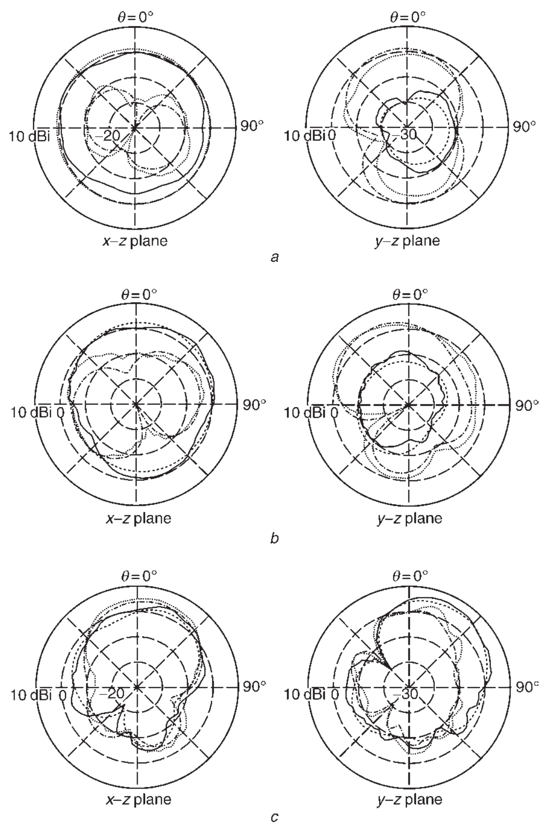

Fig. 3 *Measured and simulated radiation gain patterns of multiband antenna*

Antenna orientation given in Fig. 1
a 910 MHz *b* 1850 MHz *c* 5350 MHz
· · · · · · E_{theta}, measured ——— E_{phi}, measured
– · – · – E_{theta}, simulated ---------- E_{phi}, simulated

Conclusions: A novel miniature multiband antenna suitable for mobile phone and WLAN applications has been presented. To our knowledge, this is the first internal handset antenna radiating in the GSM, DCS, PCS, UMTS and 5 GHz WLAN bands with a VSWR better than 2.5 and good efficiency.

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