DESIGN OF INTEGRATED MULTIBAND ANTENNAS FOR PERSONAL COMMUNICATIONS HANDSETS

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ABSTRACT

The advent of new, multi-standard mobile phone devices is a real challenge for antenna designers, as they have to implement integrated antennas with multiband operation within a volume that is rapidly shrinking. In this paper, some investigations concerning the input return loss, radiation characteristics and efficiency of novel internal, multiband patch antennas are presented.

INTRODUCTION

The evolution of the mobile phone market means ever harder constraints for terminal antenna design. Multiband operation, which is nowadays almost a common standard, requires the use of enhanced radiating elements. Moreover, other aspects such as small size, weight, and integration have a great relevance for the final design, and material and assembling costs must be kept as low as possible. The preferred solution is the use of radiating patches with multiple resonances, covering different bands, which are easily adapted to the shape of the handset, and can therefore be integrated within the back cover. This solution has a number of advantages: terminal designers can forget about the antenna when designing the external cover, the phone becomes more robust as there are no external radiating elements that could break of, and the antennas can be produced in a more cost-effective way. On the other hand, the antennas must operate in two or more frequency bands, but still be confined within a volume that becomes ever smaller. Therefore, the main goal of the antenna designer is nowadays how to achieve the miniaturisation of the radiating structure without loss of efficiency.
In this paper, some results concerning triple- and quadband integrated antennas for mobile phones are presented.

DESIGN CONSIDERATIONS

Printed antennas are nowadays an interesting alternative for mobile terminals, as current requirements are focussing on minimisation of the size and weight of the handsets. Moreover, the development of new standards and the user's mobility requirements make it necessary to extend the operation of a handset to cover two or more standards. Thus, it may be necessary to develop terminal antennas that implement different combinations of frequency bands. In many cases, one single feed point is required. Therefore, different resonant modes must be excited, each of them tuned to fit the centre frequency of the band of interest. Unfortunately, some of these bands overlap, like the GSM 1800 and PCS bands.
In this paper, a triple band and a quadband antenna for mobile handsets will be presented. To keep a realistic configuration, the antennas were developed within the limits of a 16mm x 36mm rectangular area, with a height of 8 mm over a 36 mm x 95 mm ground plane of FR-4 material, as depicted in Figure 1.

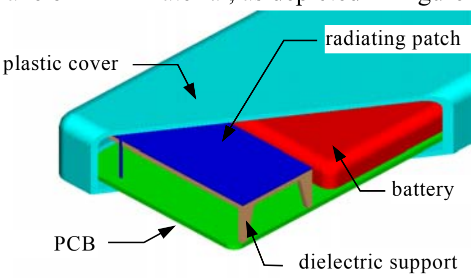


Figure 1: Integrated antenna configuration.

To assure the mechanical stability of the structure, the antennas were attached to an 8 mm-thick foam block without any significant change in its performance.

There are two possible alternatives to cover two standards with overlapping bands: to excite a single mode with a sufficient bandwidth, or two mutually coupled modes. If the latter strategy is chosen, it is essential to be able to perfectly control the coupling mechanism, since any modification in the geometry of the patch can result in an important loss of bandwidth. The main concern is then how to tune one of the bands without interfering with the performance of the others. Indeed, to implement these integrated multiband antennas, it is common to use structures that include parasitic elements, or a combination of patches and radiating slots.
As the volume available is utterly reduced, quarter wavelength concepts are used, based on the Planar Inverted-F Antenna (PIFA) [1]. The performance of the antennas was first investigated with the FDTD-based field solver Empire [2], and then the prototypes were measured using a HP8719D network analyser.

TRIPLE BAND ANTENNA (GSM900/GSM1800/PCS)

The triple band antenna consists of a probe-fed metal plate with a shorting pin, which provides a double resonance. This antenna is based on previous dual-band concepts [3], [4]. A shorted parasitic plate, capacitively coupled to the main radiator, was used in order to add a third resonance. The final structure is depicted in Figure 2.
Figure 3 shows the simulated and measured input return loss of the triple band patch. Both curves are in good agreement, although some shifting subsists, due to the discretisation of the structures, necessary for the simulation. In both cases, the triple resonance is clearly visible.

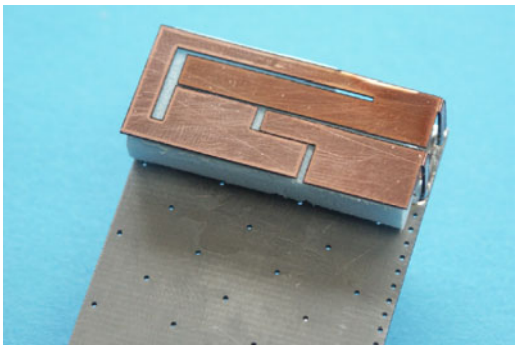


Figure 2: Triple-band antenna.

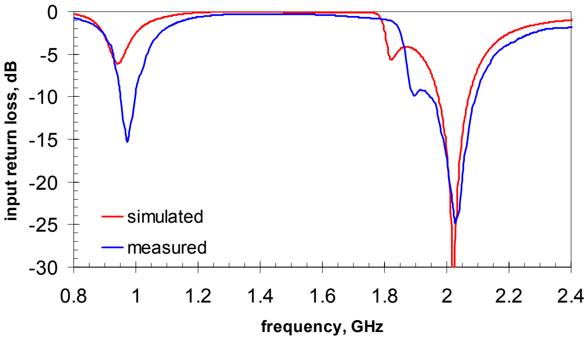
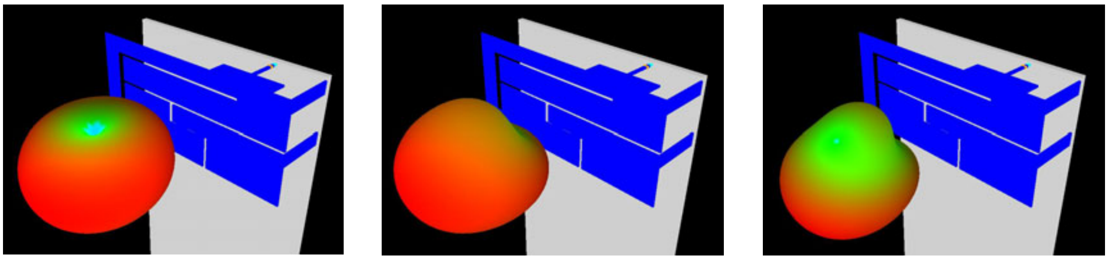


Figure 3: Input return loss of the triple-band antenna.

The simulated radiation patterns of the antenna in each frequency band are displayed in Figure 8. The antenna shows dipole-like behaviour for GSM 900, whereas in GSM 1800/PCS frequency bands, the patterns resemble those of typical PIFA antennas. In these bands, the effect of the PCB can also be observed, as a slight deviation of the radiation pattern with respect to the standard patch pattern.

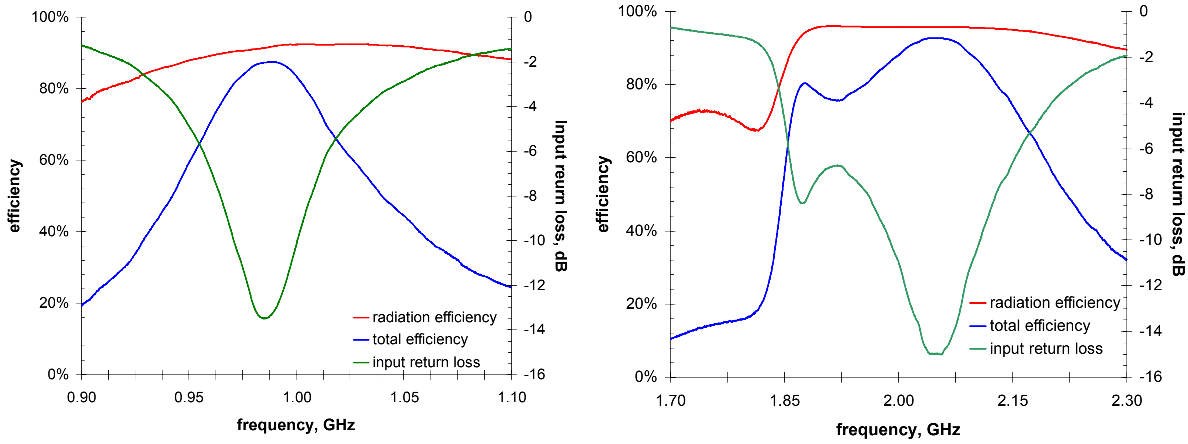


GSM 900 GSM 1800 DCS

Figure 4: Radiation patterns of the triple band antenna.

An improved Wheeler-cap method [5], [6] was used to determine the efficiency of the antenna. This represents an important parameter when determining the radiation performance of a mobile handset, as it gives the ratio between the power delivered to the antenna and the power that is actually radiated. The obtained results are displayed in Figure 5.
A distinction was made between radiation efficiency, determined by the patch itself, and the total efficiency, which includes the effect of matching losses. If the matching were perfect, both curves would be superposed. As radiation efficiency is higher, and more constant over the frequency than the total efficiency, bandwidth restrictions are not caused by the antenna itself but by mismatching. This effect is especially clear for GSM 1800. In this case, the use of a passive matching network would permit to increase the antenna efficiency. In any case, the performance of the antenna

is rather good, as the total efficiency remains above 60% for S11<-6dB (VSWR<3). Still, the frequency bands are still to be further tuned, to comply with the standards.



GSM 900 GSM 1800/PCS

Figure 5: Antenna efficiency versus input return loss of the triple band antenna.

QUADBAND ANTENNA (GSM900/GSM1800/PCS/UMTS)

To generate a fourth resonance, a slot was etched within the perimeter of the main patch of the triple band antenna, as shown in Figure 6. Thus, the frequency bands of four different standards can be covered, namely GSM 900, GSM 1800, PCS and UMTS, without increasing the overall size of the structure.

Figure 7 shows a comparison between the simulation with EMPIRE and the measured values. It can be observed how a good prediction of the resonance frequency was obtained for the GSM 900, GSM 1800 and PCS. Nevertheless, a frequency shift appears for the UMTS band, which corresponds to the slot.

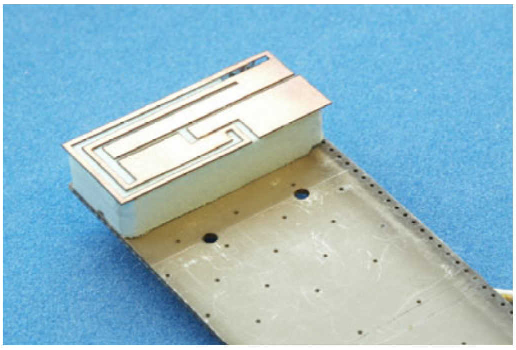


Figure 6: Quadband antenna.

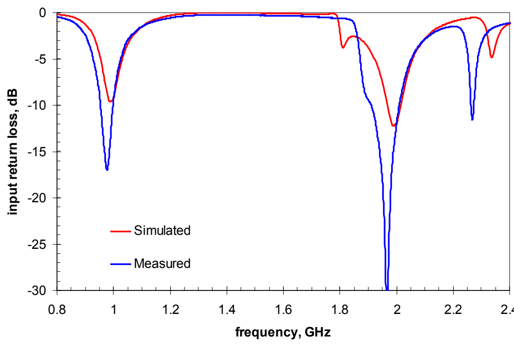
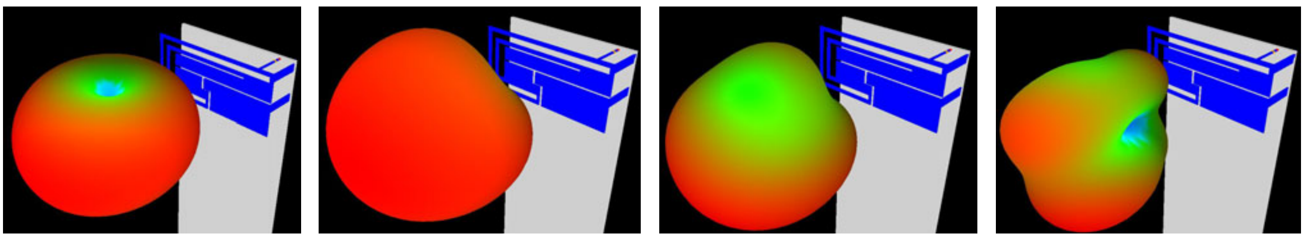


Figure 7: Input return loss of the quadband antenna.

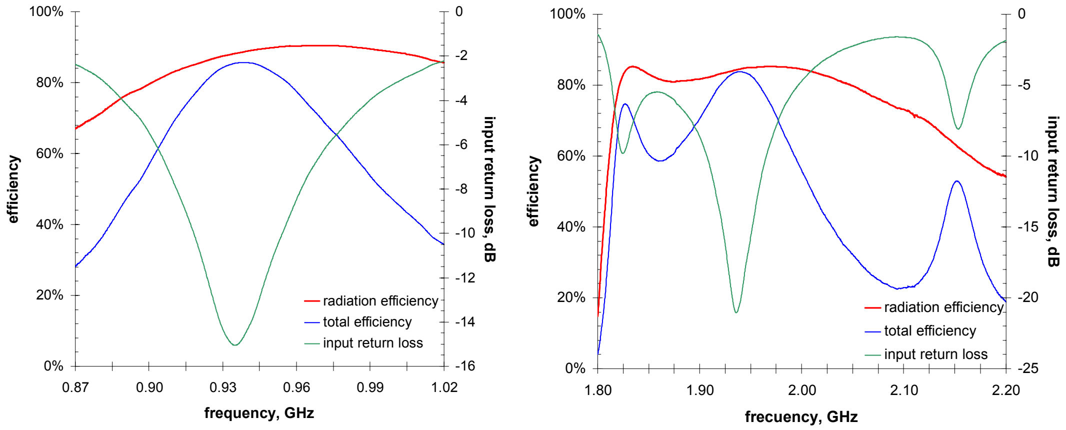
Figure 8 shows the simulated radiation patterns of the antenna in each frequency band. Since the introduction of the slot along the GSM 900 branch does not alter significantly the field distributions, the antenna shows similar characteristics to those of the triple band antenna in the GSM 900, GSM 1800 and PCS frequency bands. UMTS features a more irregular radiation pattern, due to the shape and the orientation of the slot. Nevertheless, this is not a main drawback for its use in mobile terminals, since their spatial orientation is totally arbitrary.



GSM 900 GSM 1800 DCS UMTS

Figure 8: Radiation patterns of the quadband antenna.

Again, the antenna efficiency was measured. The obtained results are displayed in Figure 9. The antenna efficiency remains over 60% in the GSM 900, GSM 1800 and PCS frequency bands, which correspond to the patch modes, and do not differ significantly from those of the triple band antenna. As for UMTS, the poor matching levels lead to a low efficiency, which has to be improved.



GSM 900 GSM 1800/PCS

Figure 9: Antenna efficiency versus input return loss of the quadband antenna.

CONCLUSIONS

In this work a triple and a quadband antenna have been presented, which fit into modern personal communications handsets. The multiband operation was achieved by combining active and parasitic patches, and a slot. The obtained results show a good behaviour of the antennas, regarding matching, radiation properties and efficiency. Nevertheless, the structure is mechanically quite unstable and requires a rigid support, the effect of which has to be further analysed.

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