DESIGN CONSIDERATIONS FOR QUADBAND ANTENNAS INTEGRATED IN PERSONAL COMMUNICATIONS DEVICES

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Abstract. *The rapid evolution of the mobile phone market requires the development of terminals, which can operate within different networks, and implement different standards. In most cases, these terminals feature multiband antennas. In this paper, some investigations on the influence of the casing on the matching and efficiency performance of a novel internal, quadband patch antenna are presented. The content of this work falls within the research framework of COST284.*

Résumé. *La rapide évolution du marché des téléphones portables exige le développement de terminaux pouvant opérer dans différents réseaux, avec des standards différents. Dans la plupart des cas, ces terminaux disposent d'antennes multibande. Dans cet article, on présente quelques résultats concernant l'influence du boîtier plastique sur les performances d'une antenne à quatre bandes, intégrée dans un téléphone portable, en termes d'adaptation et d'efficacité. Cette recherche s'inscrit dans le cadre du COST 284.*

1. Introduction.

The increasing demand of multi-standard personal communications handsets fosters the development of small-size integrated multiband antennas. The preferred solution is typically to use metallic patch structures with multiple resonances. These patches allow a great flexibility in the antenna design, as they are cost-effective and straightforward to produce, as well as easy to adapt to the shape of the handset. On the other hand, as they are integrated into the plastic casing, new losses and a shift in the resonance frequencies must be accounted for.

For solving such complex problems, antenna designers must rely heavily on electromagnetic (em) simulators, also called field solvers, which can be either custom made or commercial software packages. Customised simulators have the advantage to be conceived to solve one particular problem with a very high efficiency, but, on the other hand, any changes on the geometry or the features of the antennas are hard to incorporate. The use of commercial packages is thus justified by their greater flexibility [1]. The problem resides then in the selection of the algorithm that best enables to analyse each structure and calculate its required characteristics. A variety of em simulators, which in turn implement diverse numerical algorithms, are commercially available. Some problems related to the nature of the considered structures, the great number of unknowns and simulation time have to be confronted prior to the design phase.

3-D, full-wave em simulators are often preferred, for they allow the study of structures of any shape. They comprise packages implementing MoM (Method of Moments) and FDTD (Finite Differences, Time Domain) algorithms. The use of 3-D simulators with geometries featuring zones where very fine meshing is required can lead to problems hard to solve because of the high number of discretisation points. Often, simulators that can handle structures with any number of metal and planar dielectric layers can provide a good approach to the problem. In such cases, when dealing with 2-D currents but 3-D field characteristics are obtained, the term 2½-D has been adopted. With these packages 3-D structures with non-planar, finite dielectrics, cannot be considered, but they suffice often in a first step of printed antennas design, when using a full 3-D simulator would be excessively time-consuming.

In this paper, some of the experimental results obtained for a quadband (GSM 900/GSM 1800/PCS/UMTS) integrated antenna for mobile phones, designed using different em simulation suites, are presented.

2. Description of the structure.

In order to optimise the use of the limited space available for integrated antennas, most of the designs are based on a quarter wavelength concept. Among them, the Planar Inverted-F Antenna (PIFA) enjoys the largest acceptation [2]. This PIFA concept, which consists of a probe-fed metal plate with a shorting pin, was chosen as the basis for a dual-band antenna. A shorted parasitic plate capacitively coupled to the main radiator adds a third resonance. To generate a fourth resonance, a slot was etched within the perimeter of the main patch. Thus, the frequency bands of four different standards can be covered, namely GSM 900, GSM 1800, PCS and UMTS. This antenna is based on previous dual-band and triple-band developments [3]-[5].

The novel triple-band antenna was developed within the limits of a 16x36x8 mm^3 rectangular area, with a height of 8 mm over a 36x95 mm^2 ground plane of FR-4 material, as depicted in Fig. 1. As the patch antenna consists of only a metallic plate, it may need a plastic carrier to assure the mechanical stability of the structure. In a first step, the antenna was attached to an 8 mm-thick foam block, without any significant influence on its performance. To investigate the effect of the plastic casing, a 1 mm thick plastic cover was also considered. The plastic material has a permittivity of ε_r=2.9, and was located 0.5 mm over the antenna surface.

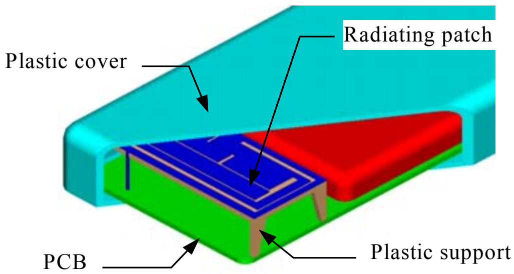

Fig. 1: Integrated patch antenna with a plastic carrier.

3. Simulated and measured results.

The behaviour of the antenna alone, and with its plastic cover, was investigated using different simulation packages: the FDTD-based field solver Empire [6], the 3D MoM-based Concept [7] and the 2½D MoM-based Ensemble [8]. Furthermore, a prototype of this antenna was built, and the input return loss measured using a HP8719D network analyser.

In a first step, no plastic cover was considered. A comparison between the simulation results, obtained with the different field solvers, and the measured input return loss is presented in Fig. 2. It can be observed that the use of a 2½D MoM based field solver leads to an accurate prediction of the resonance frequencies, although the matching values are quite pessimistic. When a 3D MoM or FDTD package was used, the agreement between simulation and measurement was very good for the first three resonant frequencies. Nevertheless, there was a frequency shift when the fourth mode, which corresponds to the slot, was considered.

Then, the effect of the plastic cover was investigated, and the measured input return loss was compared with the simulation results, as depicted in Fig. 3. In any case, the presence of the plastic cover causes a shift in the resonance frequencies, when compared with the antenna only. This shift must be taken into account during the design phase.

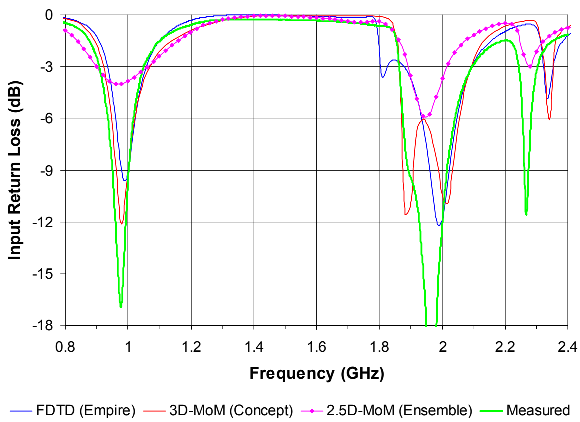

Fig. 2: Simulation vs. measurements, antenna only.

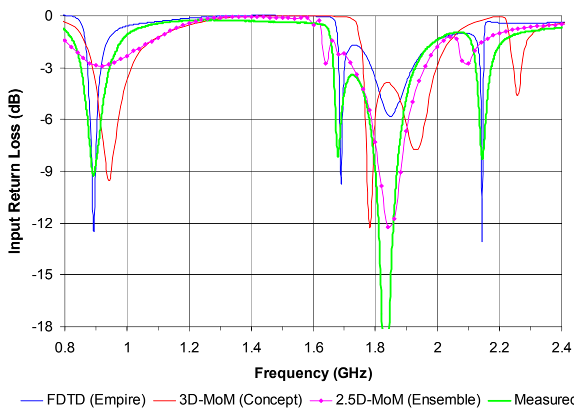

Fig. 3: Simulation vs. measurements, antenna with plastic cover.

It can be observed that the FDTD simulation predicts with a high accuracy the resonant frequencies, but not the bandwidth. The MoM results were also quite exact, with just a slight frequency shift of some of the modes. In any case, both for the antenna with and without cover, most of the simulation results were more conservative than the actual measured input return losses.

4. Antenna efficiency.

The use of a plastic cover has also an effect on the radiation properties of integrated antennas, as new dielectric losses are introduced. An important parameter when determining the radiation performance of a mobile handset is its efficiency: the ratio between the amount of power delivered to the antenna and the power that is really radiated. The Wheeler-cap method [9], [10] was used to characterise the radiation efficiency of the antennas. Fig. 4 and Fig. 5 illustrate the difference between the efficiency of the antenna with and without its plastic cover. In these figures, a distinction was made between the radiation efficiency, determined by the patch itself, and the total efficiency, which includes also the matching losses. If the matching were perfect, both curves would be identical.

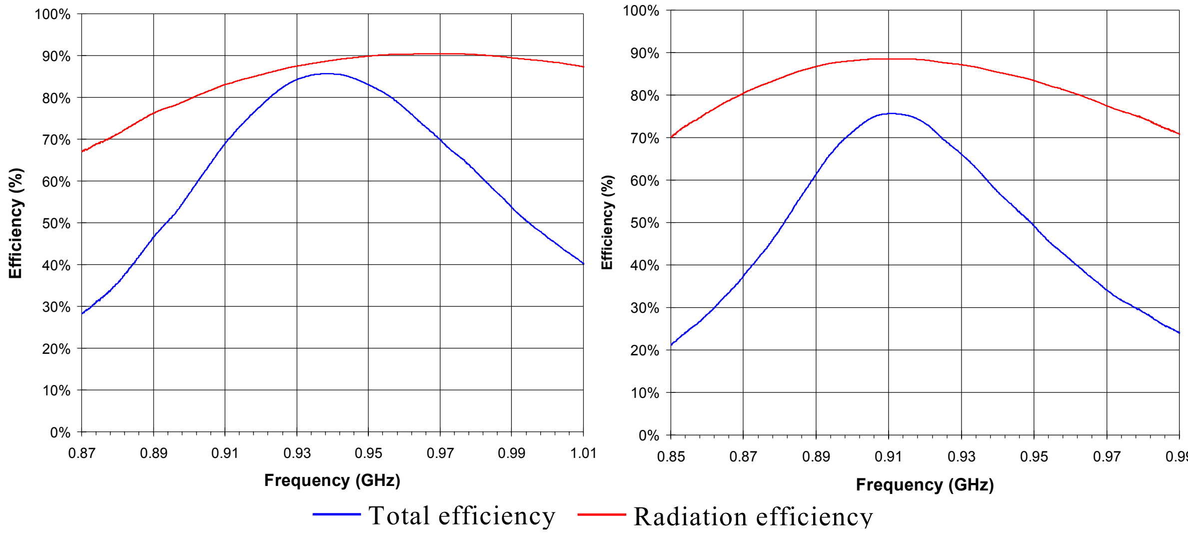

Fig. 4: Antenna efficiency for the GSM 900 frequency band, without (left) and with (right) plastic cover.

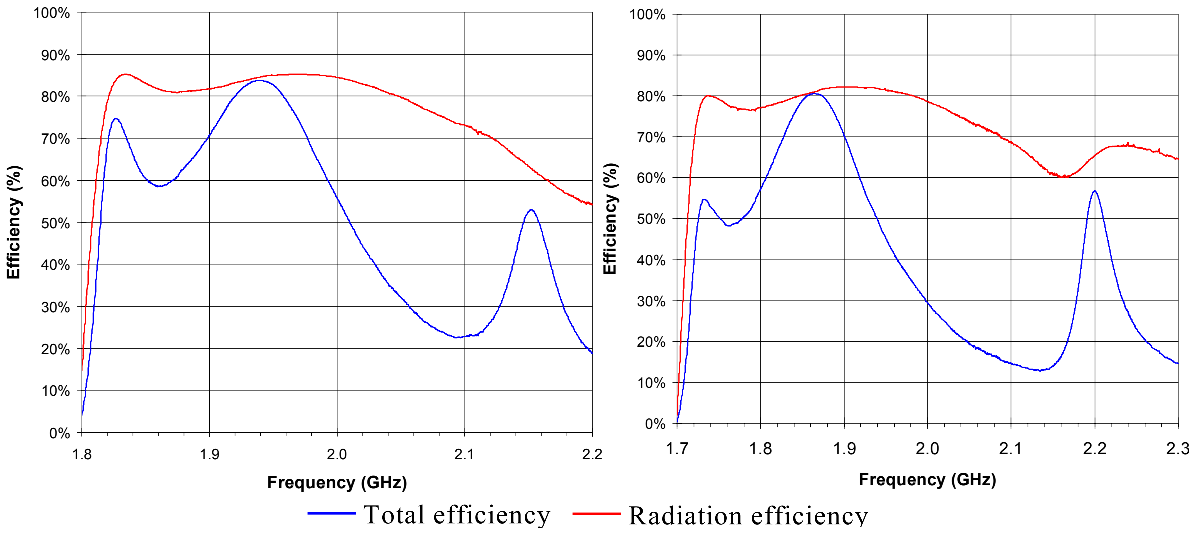

Fig. 5: Antenna efficiency for the GSM 1800/PCS/UMTS frequency bands, without (left) and with (right) plastic cover.

From these results, we can conclude that bandwidth restrictions are not determined by the antenna itself, but by mismatching. Indeed, the radiation efficiency is higher, and its behaviour is more constant over the frequency bands than the total efficiency. This effect is especially obvious for the first resonant mode in Fig. 5, which corresponds to GSM 1800. To optimise the performance, a passive matching circuit, composed of lumped elements, could be used.

The total efficiency with the plastic casing is about 5% lower than without it. This loss of efficiency can be attributed to dielectric losses. This difference remains almost constant with the frequency. Therefore, the bandwidth differences observed between simulated and measured input return losses come not from considering lossless materials, but due to inaccuracies in the simulation models.

In any case, the performance of the antenna without matching network is quite good, with a total efficiency better than 50%, although the frequency bands are still to be further tuned, to comply with the standards.

5. Conclusion.

This work has presented some investigations concerning quadband integrated antennas for personal communications handsets. With a combination of metallic patches and slots, four different standards can be covered with a single antenna, in a small volume. The effect of the plastic casing has also been illustrated, in terms of changes in the impedance matching, resonance frequencies and antenna efficiency. Further investigations will focus in more detail on interaction with the user, in terms of mismatching, efficiency loss and SAR.

6. References.

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