INVESTIGATION ON INTEGRATED ANTENNAS FOR GSM MOBILE PHONES

DIRK MANTEUFFEL[(1)], ACHIM BAHR[(1)],
INGO WOLFF [(1)]

[(1)]IMST GmbH
Carl-Friedrich-Gauss-Str. 2
47475 Kamp-Lintfort
Germany
Email: manteuffel@imst.de

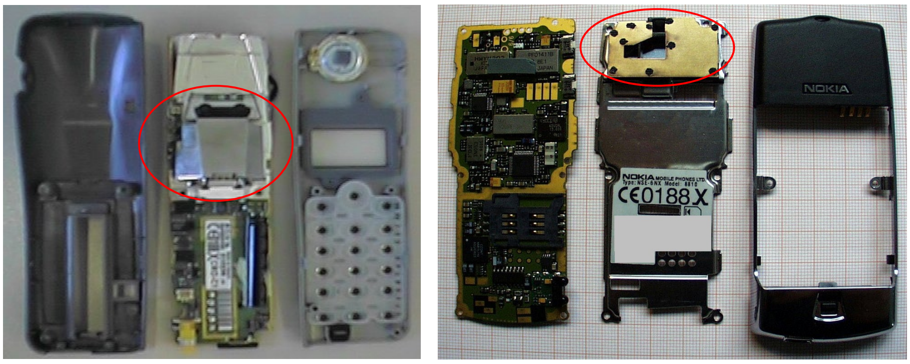
ABSTRACT

The objective of the study was to compare different types of integrated antennas for mobile phones working at the GSM 900 standard on the same realistic platform. To realise a small integrated antenna resonant at 925 MHz two different concepts to handle the lack in length were investigated: a rectangular patch antenna which was capacitively loaded at the end of the radiator, and a folded antenna in the shape of a c-patch. Achievable impedance bandwidth and worst case SAR (Specific Absorption Rate) of both types are compared. All antennas were situated in the same position on the same model of a modern mobile phone. Two variations of the antenna volume were investigated in all cases. As a results it can be stated that for both configurations the impedance bandwidth of the c-patch antenna is larger than the one of the capacitively loaded patch antenna. Contrary to this the worst case SAR, assessed by a Dosimetric Assessment System (DASY), of the capacitively loaded patch is lower compared to the c-patch. In a further step the impedance bandwidth of the antenna was investigated as a function of the physical length of the mobile by means of numerical simulations based on the Method of Moments (MoM). The study showed that the impedance bandwidth of the antenna system is strongly influenced by this length as the metallic part of the mobile acts as the counterpart for the quarter wave antenna module.

INTRODUCTION

There is a remarkable trend towards the development of integrated antennas for mobile phones. Although this trend is mainly forced by marketing and design aspects there are also some physical advantages of integrated antennas compared to externally mounted antennas. Using the principle of patch antennas the interaction with the user's head in talk position is less than using e.g. short helical antennas and thus results in lower SAR [3]. On the other hand there are many problems to cope with. One main problem is that the bandwidth of an integrated patch antenna is usually to small to cover the whole GSM 900 frequency band. Therefore, additional switching circuits are often used that provide matching in rx- or tx-mode but introduce additional losses in the switching components. The bandwidth problem becomes more critical because the allowed antenna volume is strongly limited as future mobiles become smaller and smaller.

As most concepts for integrated antennas are based on resonant quarter wave structures the physical antenna length for GSM 900 is too large (~8 cm) for the implementation in a small mobile. Because of this it is necessary to reduce the size of the antenna module. From basic antenna theory [1][2] there are at least three main principles to reduce the overall antenna size: 1) the use of a dielectric substrate, 2) capacitive loading at the end of the radiator or 3) folding of the antenna structure to achieve a resonant path on a smaller area. Today's mobile phones with integrated antennas make use of these principles. For example, the *Hagenuk Global Handy* uses a patch antenna on a dielectric material, the *Sony CMD-C1* uses a capacitively loaded patch and the *Nokia 8810* provides a folded C-patch antenna structure. Fig. 1 shows the implementation of the integrated antennas in the mobile phone. It can be noted that there are more differences than the antenna type only. The different implementations vary also in size, position and orientation of the antenna-module in the mobile. Furthermore, the size of the mobile itself varies. These different implementations make it hard to compare the antenna concepts itself. In this study we investigated integrated antennas for GSM mobile phones based on the concepts of a capacitively loaded quarter wave patch antenna and a c-patch antenna structure on the same realistic model of a modern mobile phone. This platform contains realistic restrictions to the antenna volume, the positioning of the antenna module and interaction to other components of the mobile phone like the battery pack. This procedure made it possible to compare the different concepts on this generalised platform and enabled the extraction of some relevant parameters for future antenna designs with regard to small sized antenna modules. Although this study is restricted to singleband antennas operating at the GSM 900 resonant frequency of 925 MHz, the results are useful for future development of integrated dualband– and multiband-solutions.



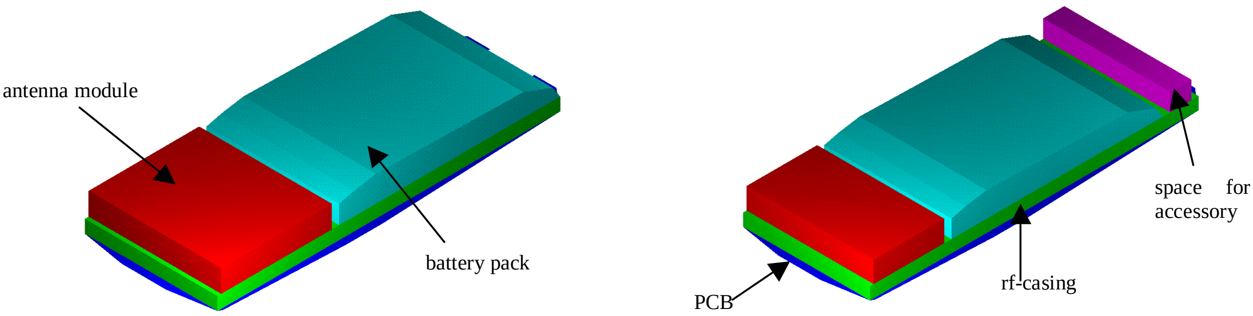
a) Sony CMD-C1 b) Nokia 8810

Fig. 1: Mobile phones with integrated antennas.

FOLDED AND UNFOLDED ANTENNAS

The volume that can be allocated by the antenna in a modern mobile phone is strongly limited. The best suited location in many phones is a position above the rf-shielding in the upper part of the phone. But even at this position especially the height is limited. Furthermore, the antenna module is located in close vicinity to the battery pack. In many cases the minimum distance is less than 3 mm.

In this study we deal with two different configurations for each antenna type. In both situations the antenna module is located above the rf-shielding. The first configuration uses an antenna module with a volume of 36 x 30 x 6 mm^3 which will be called "*large module*" in the following. In the second configuration the volume is restricted to 36 x 20 x 6 mm^3 which we call "*small module*" in the following. The practical constraint for this smaller volume could be e. g. the need to implement a vibrator or a blue tooth module in addition without enlarging the overall size of the mobile. For this first investigation the total length of the metallic parts of the mobile is 100 mm.



a) Mobile with large antenna-module (36x30x6 mm^3). b) Mobile with small antenna-module (36x20x6 mm^3).

Fig. 2: Mobile with two different restrictions to the antenna volume.

Fig. 2 shows both models for the numerical simulations. For simplicity the specific antenna shapes are replaced by a *small* or a *large* antenna module in Fig. 2. Both models include a Printed Circuit Board (PCB) which defines the total length of 100 mm, a rf-shielding that covers nearly the whole PCB, a battery pack and the antenna module. The battery pack is modelled as a metallic block connected to the mobile at its bottom surface. The distance between the edge of the antenna module and the top of the battery pack is 2 mm. For the *small module* there is also a certain volume allocated by the above mentioned accessory at the bottom of the phone.

In a first investigation antennas, based on both concepts, were developed to operate at the GSM 900 center-frequency of 925 MHz, and matched to have a maximum of bandwidth in the specific configuration. The results for the impedance bandwidth coming out of a loss-less simulation, based on the MoM, are shown in Fig. 3.

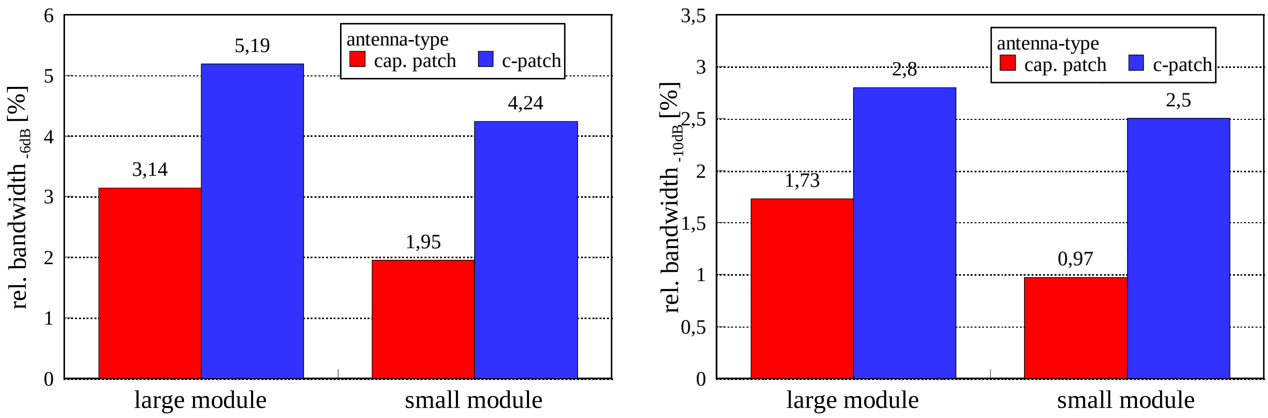


Fig. 3: Relative impedance bandwidths (925 MHz) of capacitively loaded patch and c-patch (simulation).

It can be stated that the bandwidth for the folded antenna is higher in both configurations. Furthermore, the relative decrease in bandwidth from the *large module* to the *small module* is less strong for the c-patch.

The SAR was measured with a DASY system for the *small model* only. For feeding the antenna a cw-power of 0.25 W was provided which corresponds to 2 W averaged over eight time slots according to the GSM 900 standard. Because of the fact that no casing has been used for prototyping the assembly was located with 5 mm distance to the ear piece of the phantom in the test positions defined by the CENELEC standard [4]. The worst case SAR was found in "touch" position. Detailed values are given in Table 1.

	Worst case SAR [W/kg]	
	1g	**10g**
C-patch	1.4	0.9
Cap. patch	1	0.7

Table 1: Measured worst case SAR for the *small module*.

In contrast to the bandwidth results the lowest SAR appears for the capacitively loaded patch. One explanation of this result is that the shorting edge at the top of the phone is large (36 mm) for this antenna concept. This results in a lower current density and therefore in a lower magnetic field strength that is related to the SAR coming from this portion.

RELATION BETWEEN THE LENGTH OF THE MOBILE PHONE AND THE IMPEDANCE BANDWIDTH

Due to the quarter wavelength principle of the above described concepts the antenna module that is located at the top uses the whole metallic part of the mobile as the counterpart for radiation. In this way the whole mobile has to be treated as the antenna system and should act more like an unsymmetrical dipole than a patch antenna above a large ground plane. Because of this there must be a strong influence of the mobile size on the antenna parameters. The effect of a small ground counterpart has also been studied in [5] in a different context. In this study the influence of the length of the mobile on the impedance bandwidth of the antenna system is investigated using numerical simulations based on the MoM. This was done by enlarging the battery pack in length to ensure that other parameters like the distance between the antenna and the top of the battery pack are not altered. The investigation was carried out for both types of antennas in both configurations according to Fig. 2. Fig. 4 shows the results for a length of the mobile ranging from 80 mm to 150 mm. For each configuration the antenna was tuned to 925 MHz. To achieve this it was necessary to modify the end-capacitor of the patch and to change the shape of the c-patch slightly. The position of the feeding has to be modified for each situation, too. According to Fig. 4 a strong effect can be observed. The impedance bandwidth of the antennas rises until the mobile reaches a certain length that is related to the resonant frequency. Fig. 4 indicates that this behaviour is similar for both antenna types.

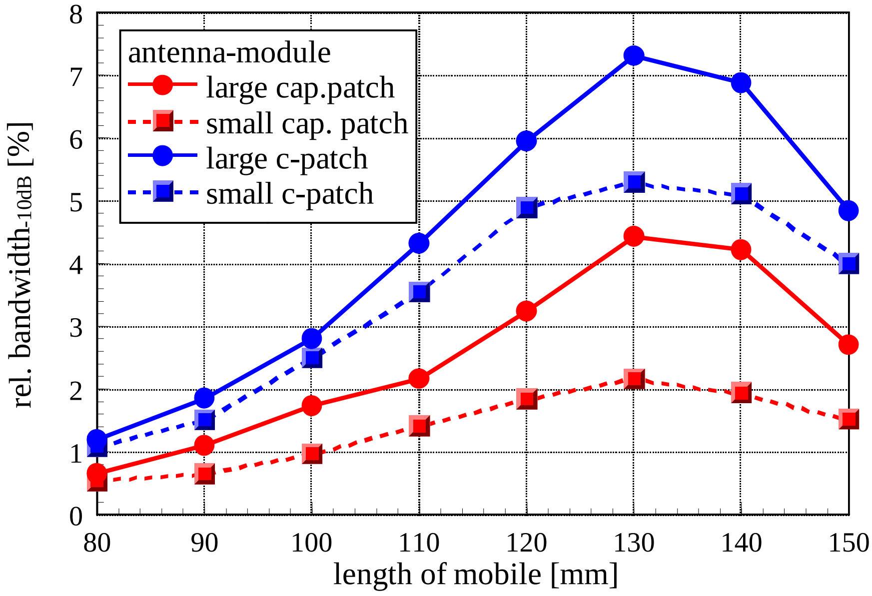


Fig. 4: Relation between impedance bandwidth and length of the mobile (simulation).

Although the effect can be observed for both antenna types the quantitative results differ. In this respect the study shows that the difference in bandwidth is only small for the different sized c-patch modules on a short mobile (up to a length of 100 mm). As a general conclusion it must be stated that the problem of narrow bandwidth using integrated antennas becomes even harder if the size of future mobiles is further reduced.

CONCLUSIONS

The study shows that a folded c-patch structure is more suited by means of impedance bandwidth than a capacitively loaded patch integrated in the upper part of a mobile phone. In contrast to this the SAR is higher for the c-patch configuration. A strong effect of the mobile length on the impedance bandwidth can be regarded that has to be considered when implementing an antenna in a short mobile phone.

REFERENCES

[1] Fujimoto, K.; James J. R.: Mobile Antenna System Handbook, Artech House, Inc., 1994

[2] Hirasawa, K.; Haneishi, M.: Analysis, Design and Measurement of Small and Low-Profile Antennas, Artech House, Inc., 1992

[3] Bahr, A.; Schneider, M.; Manteuffel, D.; Heberling, D.: Recent Trends for Mobile Phone Antennas with Special Emphasis to the Interaction with the User; accepted paper to AP2000, Davos Switzerland, April 2000

[4] European Specification ES59005: Considerations for Evaluation of Human Exposure to Electromagnetic Fields (EMFs) for Mobile Telecommunication Equipment (MTE) in the Frequency Range 30 MHz – 6 GHz; CENELEC, 1998

[5] Garcia, S. G.; Baggen, L.; Manteuffel, D.; Heberling, D.: Study of Coplanar Waveguide-Fed Antennas Using the FDTD Method, Microwave and Optical Technology Letters, vol. 19, no. 3, 1998