DESIGN OF MULTIBAND ANTENNAS FOR THE INTEGRATION IN MOBILE PHONES WITH OPTIMIZED SAR

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ABSTRACT

In this paper the design of a tripleband antenna for the space efficient integration into mobile phones is presented. The antenna is matched to operate at GSM900/GSM1800/GSM1900 standards. In order to minimize the *SAR* value (Specific Absorption Rate), mainly in the GSM900 frequency range, the current distribution on the casing of the mobile is split by additional metal strips on latter casing. The investigations are based on numerical simulations using the FDTD (Finite Difference Time Domain) field solver EMPIRE^{TM} by IMST.

INTRODUCTION

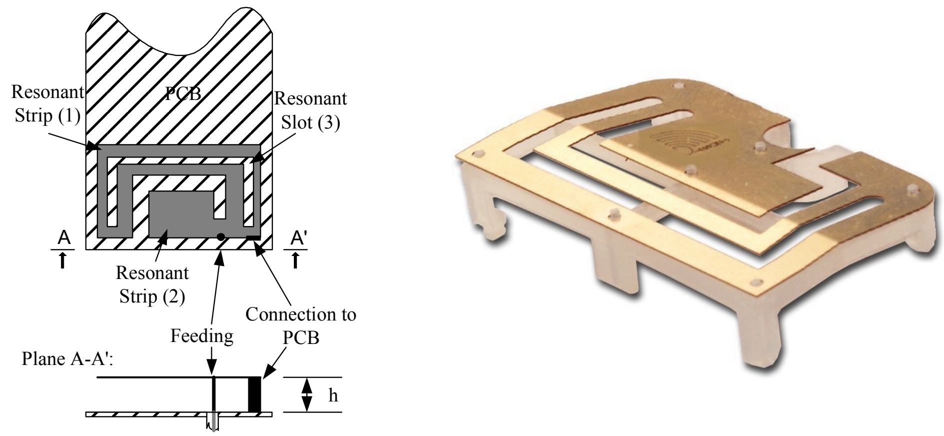
Integrated antennas have become very popular due to the advantages they provide with respect to the aesthetical design of mobile phones. Yet, a drawback is that the limited space for the antenna module within the casing of the cell phone generally results into narrow bandwidth antenna solutions. This problem becomes even more serious when a tripleband antenna has to be designed where the upper frequency bands overlap or are situated close to each other. E.g., a GSM900/1800/1900 antenna requires 9 % bandwidth to cover GSM900 and as much as 15 % bandwidth to cover GSM1800 and GSM1900 because both bands overlap in the frequency spectrum used. It has been shown in [1] that the maximum bandwidth of an antenna of a given size depends strongly on the dimensions of the mobile phone in which the antenna is installed. Furthermore, it has been reported that for a frequency around 1.8 GHz the maximum available bandwidth has a minimum for mobiles measuring around 100 mm in length. For this is a typical length for today's mobiles, it is obvious that new antenna concepts have to be investigated in order to meet the technical requirements of integrated tripleband antennas for such mobiles.

Regardless the fact that there is no conclusive scientific proof of a possible relation between the exposure to electromagnetic fields from mobile phones and physical health damages, there is still an ongoing public discussion. The growing request of customers for mobile phones which cause less *absorption* in the human head, adds low *SAR* values as a new item to the list of performance parameters, and forces the mobile manufactures to provide technical solutions which combine high output power with low *SAR* via a low cost concept.

SPACE EFFICIENT TRIPLEBAND ANTENNA CONCEPT

In order to achieve large bandwidth for the upper frequency range, the concept of parasitic resonances, known from the theory of microstrip antennas, is applied. Using a slot to generate a parasitic resonator, like originally proposed in [2] for a standard microstrip antenna, requires only minor increase in size of the antenna module compared to an additional metal strip as proposed in [3].

Fig. 1a shows a sketch of the general configuration. The antenna consists of an outer strip (1) that surrounds an inner strip (2), a slot (3) is cut into the outer strip (1). Fig. 1b shows a prototype of an antenna module based on this concept. The antenna consists of a embossed metal plate including the spring contacts for feeding and ground reference. The metallic structure is situated on a plastic support which can be clipped into the casing of the mobile phone.



a) General antenna concept. b) Realistic prototype of antenna module.

Fig. 1: General configuration of the tripleband antenna and a realized prototype.

Coming back to the general configuration, Fig. 2 shows the calculated impedance and return loss of the antenna together in one diagram. Three resonances can be observed. The electric nearfield under the antenna patch is displayed at the above mentioned three resonance frequencies. It can be observed that at 0.91 GHz a $\lambda/4$ resonance is excited on the outer strip(1). All other parts of the antenna are inactive because their dimensions are electrically small at this frequency. At 1.6 GHz a $\lambda/4$ resonance can be observed on the second strip (2). In this case additional coupling to the outer strip (1) has to be considered. At 1.95 GHz the slot, which is cut into the outer strip (1), causes a $\lambda/2$ resonance. In order to be able to excite this resonance, the placement of the slot has to be in correspondence with the current distribution on the outer strip (1) in which the slot is cut. With the present configuration the length of the outer strip (1) is slightly longer than $\lambda/2$. Although this mode cannot be excited on the strip due to the ground connection at the one end, it fulfills the resonance conditions of the slot which requires a current maximum at both ends and a minimum in the middle of the slot.

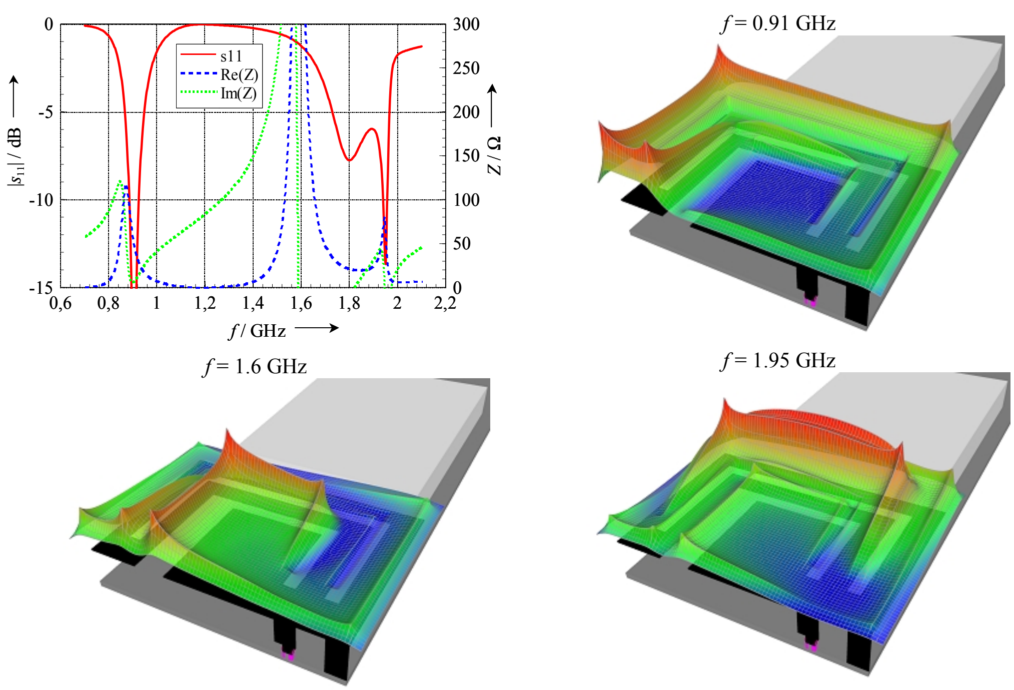
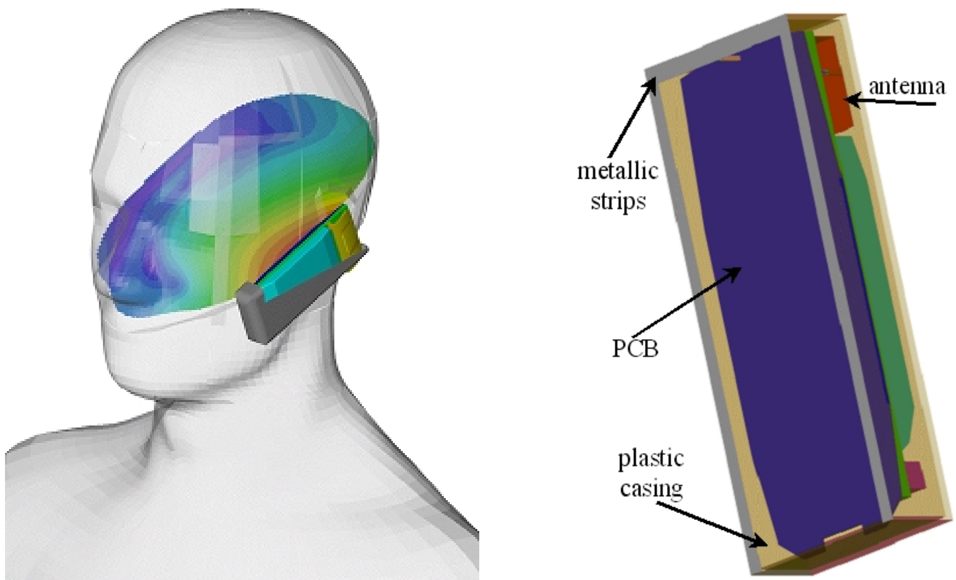


Fig. 2: Exemplary electric nearfield and impedance for the antenna concept investigated. Mobile: 100 mm × 40 mm; antenna module: 5 cm³

In order to understand the antenna concept correctly it has to be noticed that the upper resonances are not tuned to match GSM1800 und GSM1900 separately. The second resonance is placed below the GSM1800 frequency band and is characterized by a high real part of the impedance which varies smoothly within the desired range of matching. This smooth varying real part is caused by the slot resonance which has to be matched with a low impedance at the end of the GSM1900 band.

SAR CALCULATION AND OPTIMISATION

Fig. 3a shows the *SAR* in the human head excited by a mobile phone calculated using EMPIRE™ and a numerical representation of the SAM phantom (SAM - Specific Antropomorphic Mannequin). The SAM phantom is also used for compliance testing according to different standards, e. g. imposed by the FCC in [4]. While a measurement setup is used to assess the *SAR* value of commercially available phones, the numerical analysis offers more physical insight in fundamental aspects and the possibility to minimize the *SAR* during the design of a new mobile.



a) Numerical representation of the SAM. b) DASY measurement setup.

Fig. 3: Numerical representation of the SAM phantom and *SAR* distribution in the head calculated using EMPIRE™ and the Dosimetric Assessment System DASY for compliance testing.

It has been reported in [5] that in the GSM900 frequency range the maximum *SAR* in most cases is not related to currents on the antenna module but has its source in the current distribution which is excited by the $\lambda/4$ antenna module on the mobile phone itself (e. g. on the PCB). Therefore, in this frequency range, we do not find significant reduction in terms of *SAR* when an integrated antenna is used instead of a standard helical antenna, as it is displayed in [5]. In order to reduce the maximum *SAR* in the GSM900 frequency range, we have to change the current distribution on the mobile. Doing this, we have to keep in mind that the $\lambda/4$ antenna module needs the mobile as a counterpart. Therefore, it is a good choice to choke the current distribution on the mobile completely.

Fig. 3b shows a possible approach where additional metallic strips are attached to the casing of the mobile and contacted to the PCB in order to split the current distribution on the PCB. Shape, size and contact point to the PCB have to be optimized with regard to the specific mobile in order to minimize *SAR* and prevent the antenna from detuning.

Table 1 shows the maximum SAR_{1g} for a numerical model of a mobile equipped with the above tripleband antenna calculated using EMPIRE™ with a numerical representation of the SAM phantom before and after the optimization process described above. It can be observed that for the original configuration the *SAR* is high, especially in the GSM900 frequency range. Splitting the current distribution on the mobile results in a significant reduction. Note: the simulation model of the mobile is loss-less and the *SAR* is normalized to the nominal power of the specific standard. The *SAR* of a real mobile would be lower due to additional losses in the mobile and because of the fact that most mobile manufacturers design the amplifier to operate at a low output power in order to enlarge battery live.

SAR_{1g} [W/kg]	**0.91 GHz**		**1.8 GHz**		**1.9 GHz**		**2 GHz**	
	cheek	**tilted**	**cheek**	**tilted**	**cheek**	**tilted**	**cheek**	**tilted**
original	2.15	1.30	0.56	0.48	0.62	0.58	0.97	0.90
optimized	1.10	0.60	0.52	0.42	0.48	0.45	0.37	0.61
$\frac{orig. - opt.}{orig.}$ [%]	49 %	54 %	7 %	13 %	23 %	22 %	62 %	32 %

Table 1: Calculated maximum SAR_{1g} for standard left-side positions scaled to maximum output power of 33 dBm at 0.91 GHz and 30 dBm at 1.8 GHz – 2 GHz. Note: the numerical model of the mobile does not account for losses.

CONCLUSION

A space efficient concept of an integrated tripleband antenna has been presented. The antenna is designed to cover GSM900/GSM1800/GSM1900 but can easily be adapted to GSM900/UMTS.

A method to reduce the maximum SAR value for the GSM900 frequency range has been discussed and applied to a numerical model of a mobile equipped with the above tripleband antenna.

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