Design and realization of a GSM microstrip element with minimized radiation to the human head

Yves Schols [(1)], **Bastian Piepers** [(2)], **Guy Vandenbosch** [(3)]

[(1)] *K.U.Leuven, div. ESAT-TELEMIC, Kasteelpark Arenberg 10, B-3001 Heverlee, BELGIUM, Tel.: +32 16 32 18 31, Fax.: +32 16 32 19 86, E-mail: yves.schols@esat.kuleuven.ac.be*
[(2)] *Philips Industrial Activities N.V.,Pathoekeweg 11, B-8000 Brugge, Tel.: +32 50 45 52 46, E-mail: bastian.piepers@philips.com*
[(3)] *As* [(1)] *above, but E-mail: guy.vandenbosch@esat.kuleuven.ac.be*

ABSTRACT

In this paper the design and realization of a GSM microstrip element at 1800 MHz is proposed. This design is specially focused on reducing the electromagnetic fields at the back of the antenna in order to minimize absorption in the human head. After several design and simulation steps, a small patch antenna is obtained with two stacked patches: one directly excited by a probe, the other parasitically coupled. When the structure is realized, the measurements confirm what the simulations predict: the difference between the electromagnetic fields measured in front of the antenna and at the back is more than 10 dB.

INTRODUCTION

More and more scientific research nowadays is done on the biological effects and the possible harmful consequences that electromagnetic radiation at GSM frequencies has on the human health in general [1], [2]. In that context, the antennas of GSM base stations, mounted on large pylons in the vicinity of crowded neighborhoods and houses, are often mentioned by the people at large. In most cases however, measurements show that the level of electromagnetic activity originating from such base station antennas, does not exceed the ordinary level, because of the relatively large radiating distance. The little antennas in the mobile phones, however, are quite a different story. Obviously, they are placed near the human head and they often consist of nothing more than simple monopoles. In that way almost half of the irradiated power of the antenna in the GSM is directed towards and absorbed directly by the human head. Although the irradiated power of these little antennas is not as big as that of a base station antenna, it is clear that the absorbed power in the human head is considerably larger. The conclusion should be that the common concern and complaints about harmful effects, originating from GSM base station antennas, have often a psychological cause and that real damage is possibly done by the apparently harmless antenna of our little mobile phone.

Being confronted with this problem, it looks very useful to design antennas for GSM phones, which would reduce the radiation of power in the direction of the human head. In this way, the possible harmful effects will be reduced as well. In this paper the design and realization of such an antenna is proposed. It is very important to understand that, since the head of the user is situated in the near field of the antenna, one is not really interested in a far field characteristic like directivity. It is clear that for this kind of design, another, rather unusual design strategy has to be followed.

DESIGN STRATEGY

Since the radiation towards the human head, i.e. at the back of the antenna, should be minimized, a microstrip antenna is chosen for this design. Microstrip antennas essentially exist of a radiating patch, an intermediate dielectric layer and a metallic ground plate. It is easily seen that theoretically, with an infinitely large ground plate, the back of the antenna will be screened perfectly from electromagnetic fields emitted by the radiating patch. The idea is now to reduce the dimensions of this 'big' ground plate drastically until it fits in a mobile phone and then to look at what has happened to the screening effect in the near field of the antenna. Since the focus is on optimizing the backward screening effect, bandwidth considerations are not of primary interest.

The target frequency for the antenna is 1800 MHz. The dimensions of the metallic ground plate are chosen to be 13 cm by 5 cm, because these dimensions should fit quite easily in the housing of a modern mobile phone. For the design of the antenna, a full wave solver is used. This solver is based on the integral equation method and it makes use of the method of moments to calculate full wave electromagnetic solutions for planar 2.5D structures in stratified media [3], [4]. After several design and simulation steps, a first antenna structure is obtained of which the decomposition is shown in Fig. 1. The connection between different elements of the structure is indicated with a dashed line.

Fig. 1: Decomposition of design 1: with a single resonator, excited by a probe

Immediately on top of the metallic ground plate, shown in black on Fig. 1, there is a 1.905 mm thick layer of dielectric material (Rogers 6010.8), with a relative permittivity ε_r of 10.8. The choice for this high permittivity is necessary to obtain small antenna dimensions, which is very important in mobile technology. A square patch of 2.54 cm x 2.54 cm is situated on top of this dielectric layer and is directly fed by a probe, connected 3.36 mm off-centre to the patch and penetrating the ground plate and the dielectric. The patch is positioned 4 cm out of the centre of the dielectric and the ground plate. This off-centre position of the radiating patch is rather effective because the central area of the antenna is more likely to be covered by the users hand during a communication. In that way a large amount of electromagnetic radiation would be lost through absorption.

Although the structure presented above should already render a considerable screening effect, a further improvement is promised in [5] and [6]: the electromagnetic field at the back of the antenna will be reduced even more, when a second, quarter wavelength patch is short circuited to the first one. This idea is now applied in an innovative way in this design. Instead of short circuiting the second resonator, we rather make use of an ‘open’ structure with a half wavelength patch. This second patch is put on top of the original patch and a second, identical dielectric layer is put in between the two patches. In that way a new antenna structure with a parasitically coupled, double resonator is obtained. The decomposition of this structure is shown in Fig. 2. After optimizing this second design, the first and second patch are respectively found to be 2.34 cm x 2.34 cm and 1.90 cm x 1.90 cm. For the same reason as given above, they are both placed 4 cm out of the centre of the dielectric. The probe is situated 3.24 mm out of the centre of the patch.

Fig. 2: Decomposition of design 2: with a second, parasitically coupled resonator

SIMULATION RESULTS

To be able to compare the performance of both designs, one must know which antenna produces the smallest amount of backward radiation in its near field. Therefore a quantity, called ‘backward coupling’, is defined. This is the ratio of the electric field evaluated in a reference position, right in front of the radiating patch, to the electric field evaluated in a position at the back of the antenna. To calculate the behavior of the backward coupling at the back of the antenna, measurement points in the form of small, localized areas are inserted at different positions in the simulation environment. The point, placed 2 cm in front of the patch, is taken as a reference position. Two series of seven measurement points are placed respectively 2 cm and 5 cm behind the antenna. This configuration is shown in Fig. 3. The electric field in each point is obtained from the simulation results as the integrated electric field over the respective area. From that the backward coupling in each point is easily calculated.

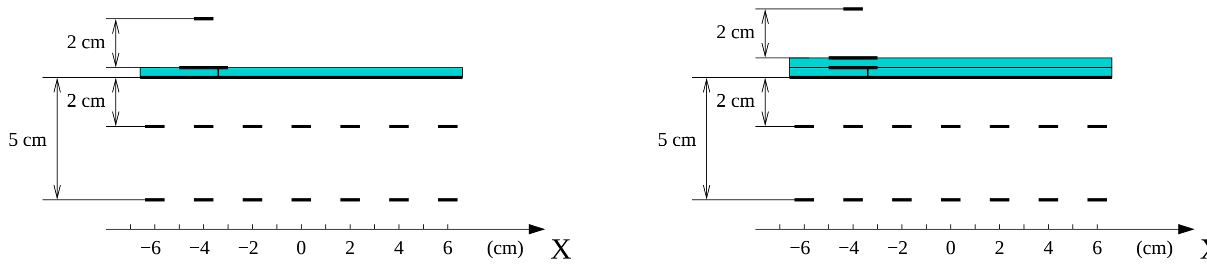

Fig. 3: Position of active patches in the surroundings of the antenna

The behavior of the backward coupling along the X-axis, evaluated at a respective distance of 2 cm and 5 cm behind both antennas, is presented in Fig. 4 and Fig. 5. It is clear that the simulated backward coupling is small, which means that a considerable backward screening effect is obtained. Another conclusion is that the modification of adding a second resonator to the design indeed enlarges the screening effect. For obvious reasons, design 2 will be realized. In the next section the measurement results will be presented.

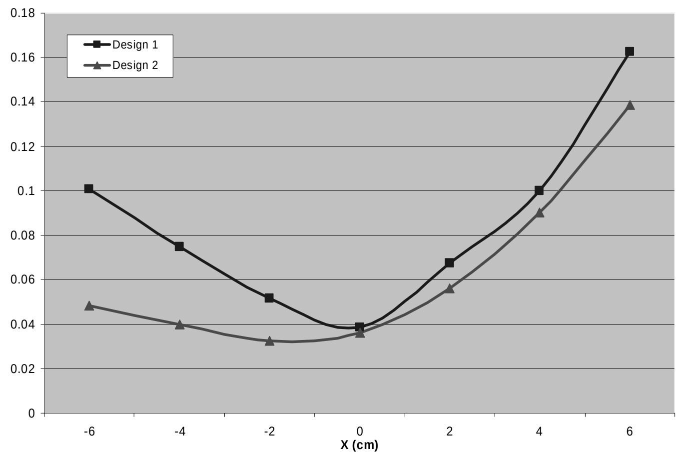

Fig. 4: Backward coupling evaluated at 2 cm behind the antenna

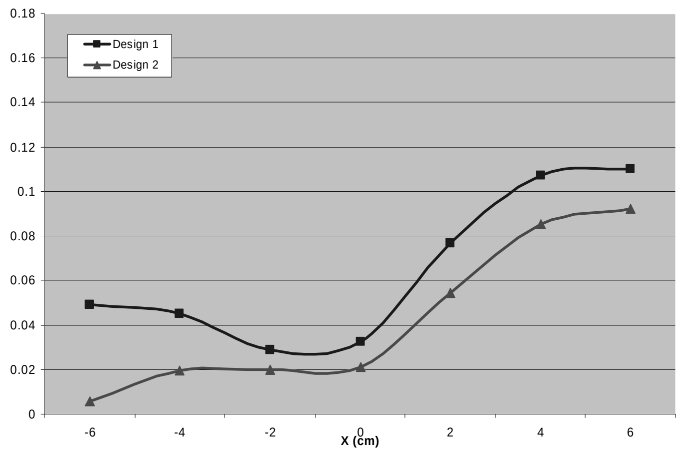

Fig. 5: Backward coupling evaluated at 5 cm behind the antenna

REALIZATION AND MEASUREMENTS

For the realization of the antenna, two stacked dielectrics are used, tightened together by plastic screws. Both patches are etched away from the copper surfaces of the dielectrics. In the lower dielectric a little hole for the probe is pierced and the probe is soldered to the patch. After the fabrication several characteristics of the antenna are measured. The realized working frequency of the antenna appears to be 1775 MHz, which is 25 MHz less than what it was designed for. The -10 dB bandwidth of 17.95 MHz is rather small. The antenna has a gain of more than 3 dB, which is sufficient for mobile applications.

The backward screening effect is measured in a special configuration using a network analyzer: the GSM antenna is connected to the first port, an auxiliary antenna to the second. The two antennas are positioned respectively 5 cm and 10 cm from each other. For each distance, the transmission loss from port 1 to port 2, S_{12}, is measured twice: once with the GSM antenna pointed straight to the auxiliary antenna, once pointed away from it. The difference between those two results should give an idea of the backward screening effect. At 5 cm the difference in S_{12} is -11 dB and at 10 cm this is -10.45 dB. The measurement results show that the realized backward screening effect is a bit less than predicted by the simulations, but altogether quite impressive.

CONCLUSION

The design and realization of a 1800 MHz microstrip patch antenna for a GSM mobile phone is presented. A special design strategy has been followed in order to reduce the backward screening effect in the near field of the antenna. After simulating two possible designs with a full wave solver, an antenna with a parasitically coupled, second resonator is realized. Eventually, the measurements on the antenna confirm what the simulations predict: the difference between the electromagnetic fields measured in front of the antenna and at the back is more than 10 dB. This realization is indeed a successful step in the evolution to more ‘healthy’ GSM antennas.

REFERENCES

[1] M. Taurisano, A. Vander Vorst, “Experimental thermographic analysis of thermal effects induced on a human head exposed to 900 MHz fields of mobile phones”, *IEEE Transactions on Microwave Theory and Technique,* Special Issue, vol. 48, pp. 2022-2032, Nov. 2000.

[2] O.P. Gandhi, G. Lazzi, C.M. Furse, “Electromagnetic absorption in the human head and neck for mobile telephones at 835 and 1900 MHz”, *IEEE Transactions on Microwave Theory and Technique*, vol. 44, pp 1884-1897, October 1996.

[3] G.A.E. Vandenbosch, A.R. Van de Capelle, “Mixed-potential integral expression formulation of the electric field in a stratified medium - Application to the case of a probe current source”, *IEEE Transactions on Antennas and Propagation*, vol. 40, pp. 806-817, July 1992.

[4] F.J. Demuynck, G.A.E. Vandenbosch, A.R. Van de Capelle, “The expansion wave concept - Part I : Efficient calculation of spatial Green's functions in a stratified dielectric medium”, *IEEE Transactions on Antennas and Propagation*, vol 46, pp. 397-406, March 1998.

[5] J.T. Rowley, R.B. Waterhouse, “Performance of shorted microstrip patch antennas for mobile communications handsets at 1800 MHz”, *IEEE Transactions on Antennas and Propagation*, vol. 47, pp. 815-822, May 1999.

[6] M. Amanowicz, W .Kolosowski, M. Wnuk, A. Jeziorski; “Microstrip antennas for mobile communications”, *IEEE Vehicular Technology Conference, Phoenix, Arizona, USA,* vol. 2, pp. 1182-1185, 4-7 May 1997.