Efficient two-port antenna system for GSM/DCS/UMTS multimode mobile phones

A. Diallo, C. Luxey, P. Le Thuc, R. Staraj and G. Kossiavas

The design of several two-port antenna systems for mobile phones is presented. All these structures are made up of two planar inverted-F antennas closely positioned on a small ground plane and radiating in the GSM900/DCS1800 and UMTS frequency bands. First, the antennas are simply associated at the top edge of the same printed circuit board. Thus, to improve their isolation and their total efficiency, a neutralisation effect is created by means of an optimised suspended line, which links the feeding strips of the radiators. The performance of these systems is measured and compared with theoretical results.

Introduction: Single-port multiband antennas are traditionally presented as possible radiators for modern mobile phones. The most practical concepts are usually made up of a carefully shaped planar inverted-F antenna (PIFA) (with or without parasitic elements) positioned above a small printed circuit board (PCB) as an internal antenna [1]. However, these elements should be designed as multiport components to match with the radio front-end modules currently available in the wireless industry market, especially to avoid the additional losses introduced by the front-end switches of the RF chain (as in W-CDMA receivers [2]). If the design of well-matched internal PIFAs co-located on the same PCB seems to be a reasonable task, improving their isolation and their total efficiency remains a big challenge, especially at frequencies where the phone chassis and its surroundings are contributing to the whole radiation mechanism. To the authors' knowledge, only a few publications address these issues still keeping the radiating elements closely spaced above a PCB [3–5]. Recently, we proposed a suitable technique to improve the isolation and the total efficiency of two closely spaced PIFAs positioned at the top edge of a PCB, radiating in the DCS1800 and UMTS standards [6]. It consisted in inserting a suspended line between the PIFAs to achieve a neutralisation effect. In this Letter, this method is now applied to a practical structure that can be encountered in realistic cellular handsets: two closely spaced PIFAs (0.003 λ_0 at 900 MHz) operating in the GSM900/DCS1800 and UMTS bands. Two antenna systems have been designed using the IE3D MoM-based software and then fabricated and measured to validate the proposed technique.

Design of two PIFAs: The two PIFAs were designed on a separate 100 × 40 mm PCB. Each antenna was positioned at the top edge and fed by a 1 mm-wide metal strip connected to an SMA connector. They were shorted to the ground by a second strip having the same width. The air thickness between the radiators and the ground plane was set to 8.5 mm. The dual-band antenna had to simultaneously cover the GSM900 (880–960 MHz) and the DCS1800 (1710–1880 MHz) frequencies with the lowest return loss. The 3G antenna had to cover the UMTS band (1920–2170 MHz) with the same requirement. The optimised GSM/DCS1800 antenna was obtained by slightly modifying the dimensions of a previous concept, extensively described in [1]. The main plate was found to be 32 × 29 mm to resonate at 940 and 1810 MHz. The length of the plate of the quarter-wavelength UMTS radiator was determined with the following analytical formula (28.3 mm at 2040 MHz):

$$f_r = c/4(L+H) \quad (1)$$

where f_r is the resonant frequency of the PIFA, c is the velocity of light in free space, L is the length of the plate, and H is the height of the PIFA. The optimised dimensions of this radiator were finally 25.75 × 6 mm. The measured return loss of both antennas satisfied the −6 dB matching criterion usually required by mobile phone manufacturers. The measured maximum total efficiency of both antennas reached 90%.

Association of PIFAs on same PCB: The two antennas were simply placed together at the top edge of the PCB (1 mm gap: 0.006 λ_0 at 1.8 GHz) with their feed called port1 for the dual-band element and port2 for the UMTS radiator (Fig. 1). The dimensions of both antennas were slightly modified to account for the observed small detuning effect. A prototype of this antenna system was fabricated using nickel–silver material: Cu, Ni, Zn alloy, conductivity 4 × 10^6 S/m. In the higher frequency bands (Fig. 2), a moderate agreement is seen between the theoretical and measured curves (measurement suffers from a 10% shift towards the low frequencies). An isolation level of 7.8 dB is measured, which is clearly lower than the expected one (11 dB). This was attributed to some unwanted coupling effect between the ferrite beads attached to the feeding cables of the PIFAs.

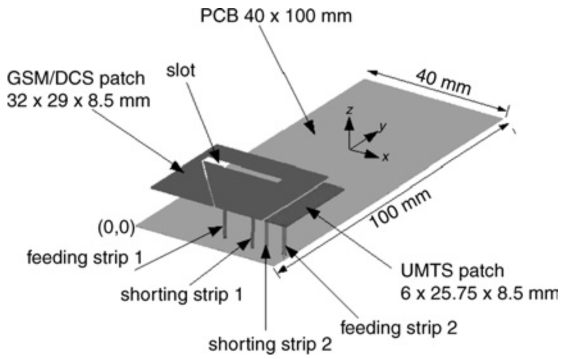


Fig. 1 *3D View of initial GSM/DCS and UMTS antenna system*

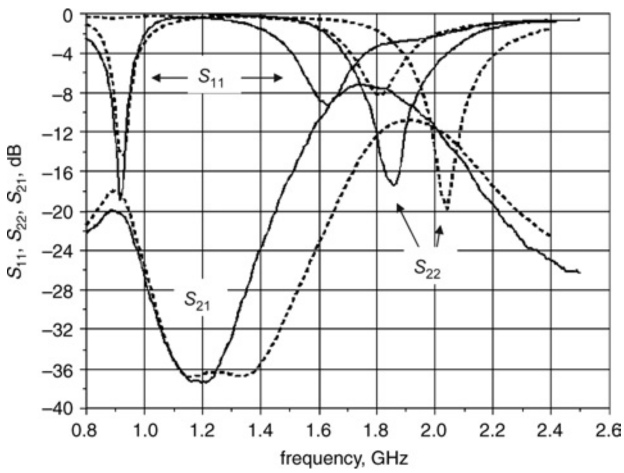


Fig. 2 *S_{ij} parameters of initial GSM/DCS1800 and UMTS antenna system shown in Fig. 1*

——— measurements
– – – – simulation

Enhancement of isolation and efficiency by neutralisation effect: The idea was to compensate for the existing complex electromagnetic coupling of this structure: a capacitive coupling between the plates, a magnetic coupling between the facing shorting strips and a strong coupling via the electrical currents flowing on the PCB from one port to another. This was supposed to be done by introducing a suspended line between the PIFAs picking up a certain amount of the signal on one antenna and bringing it back to the other with proper amplitude and phase [6]. A top view of the optimised structure is shown in Fig. 3 where a meandered suspended line at the same height as the antenna's plates links their feeding strips. It was also found beneficial to introduce a lowpass filter effect in the GSM band by short-circuiting this line to the PCB (black dot in Figure 3). Fig. 4 shows an enhancement of the isolation in the DCS-UMTS bands ($S_{21} = -15$ dB) at the expense of an increase of the S_{21} parameter to −12 dB in the GSM band (−15 dB in the un-neutralised antenna system). We have also measured the radiation efficiencies $\eta_{ray\,i}$ of these two structures with a home-made Wheeler cap setup. The total efficiencies $\eta_{tot\,i}$ were then deduced by using (2) and the measured S_{ij} parameters according to the definition given in [6]:

$$\eta_{tot\,i} = \eta_{ray\,i}(1 - |S_{ii}|^2 - |S_{ij}|^2) \quad (2)$$

In the upper band, the benefit of the neutralisation effect is directly translated into absolute increases of +24 and +18% of the respective maximum DCS and UMTS efficiencies (Table 1). This can be easily understood as we reduced the insertion loss between the two radiators. On the other hand, an absolute 4% deterioration of the maximum total efficiency in the GSM band is revealed because the S_{21} parameter is higher at 900 MHz than in the previous un-neutralised antenna system. However, the new prototype is still very attractive because the same efficiency values we obtain for the antennas designed alone on separate PCBs are now achieved — 90% (Table 1).

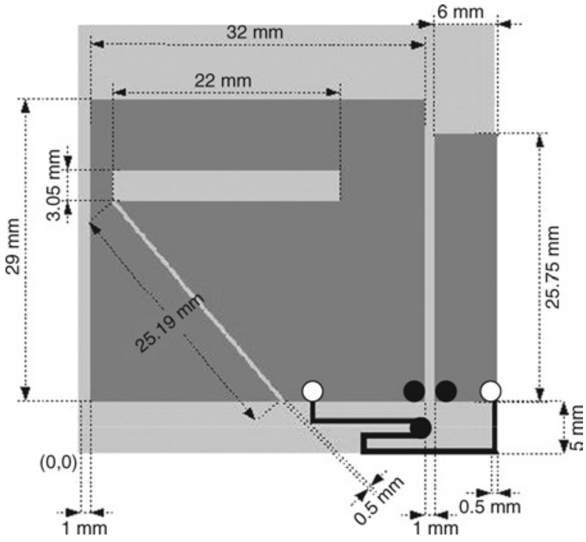


Fig. 3 *Top view of neutralised GSM/DCS1800 and UMTS antenna system*

● shorting points from PIFAs and suspended line to PCB
○ feeding point of each PIFA where feeding strips are connected

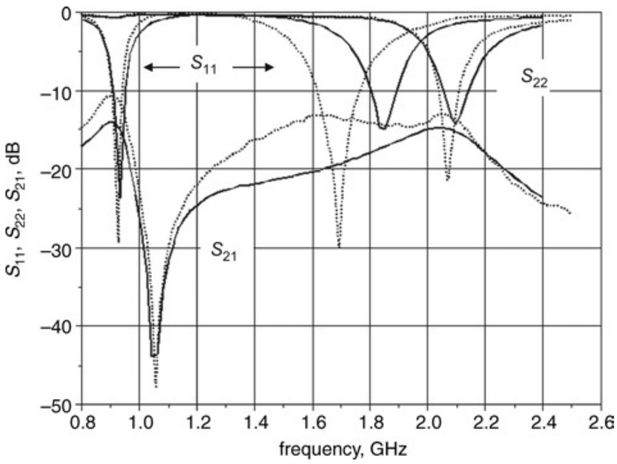


Fig. 4 *S_{ij} parameters of antenna system shown in Fig. 3*

——— measurements
.... simulation

Table 1: Measured total efficiencies of different prototypes (% and dB)

Prototypes	GSM900 (%)	GSM900 (dB)	DCS1800 (%)	DCS1800 (dB)	UMTS (%)	UMTS (dB)
Antennas alone on PCB	88	−0.55	92	−0.36	92	−0.36
Antennas on same PCB	92	−0.36	66	−1.8	73	−1.36
Neutralised prototype	88	−0.55	90	−0.46	91	−0.41

Conclusions: We have shown that the simple association of two very closely spaced PIFAs on a small ground plane was leading to poor isolation and low total efficiencies. To overcome these drawbacks, a neutralisation effect has been created by inserting a properly optimised suspended line between the antennas. Measurements have been carried out to validate the simulation results. The main advantages of our solution consist largely in its simplicity and the occupied space; the antenna structure is physically acceptable for practical implementations in realistic handsets.

11 January 2007
Electronics Letters online no: 20073911
doi: 10.1049/el:20073911

A. Diallo, C. Luxey, P. Le Thuc, R. Staraj and G. Kossiavas (*Laboratoire d'Electronique Antennes et Télécommunications, Université de Nice-Sophia Antipolis, 250 Rue A. Einstein, 06560, Valbonne, France*)

E-mail: aliou.diallo@unice.fr

References

1 Ciais, P., Staraj, R., Kossiavas, G., and Luxey, C.: 'Pentaband internal antenna for handset communication devices', *Microw. Opt. Technol. Lett.*, 2006, **48**, (8), pp. 1509–1512
2 Talvitie, O., and Pankinaho, I.: 'Radio device and antenna structure', International Patent Application, WO 2004/038857, 6th May 2004
3 Wong, K.-L., Chou, J.-H., Tang, C.-L., and Yeh, S.-H.: 'Integrated internal GSM/DCS and WLAN antennas with optimized isolation for a PDA phone', *Microw. Opt. Technol. Lett.*, 2005, **46**, (4), pp. 323–326
4 Su, C.-M., and Wong, K.-L.: 'Isolation between internal UMTS and WLAN antennas for a dual-mode wireless device', *Microw. Opt. Technol. Lett.*, 2006, **48**, (10), pp. 2001–2008
5 Li, Z., and Rahmat-Sami, Y.: 'Optimization of PIFA-IFA combination in handset antenna designs', *IEEE Trans. Antennas Propag.*, 2005, **53**, (5), pp. 1770–1778
6 Diallo, A., Luxey, C., Le Thuc, P., Staraj, R., and Kossiavas, G.: 'Study and reduction of the mutual coupling between two mobile phone PIFAs operating in the DCS1800 and UMTS bands', *IEEE Trans. Antennas Propag.*, 2006, **54**, (11), pp. 3063–3074

射 频 和 天 线 设 计 培 训 课 程 推 荐

易迪拓培训(www.edatop.com)由数名来自于研发第一线的资深工程师发起成立，致力并专注于微波、射频、天线设计研发人才的培养；我们于 2006 年整合合并微波 EDA 网(www.mweda.com)，现已发展成为国内最大的微波射频和天线设计人才培养基地，成功推出多套微波射频以及天线设计经典培训课程和 ADS、HFSS 等专业软件使用培训课程，广受客户好评；并先后与人民邮电出版社、电子工业出版社合作出版了多本专业图书，帮助数万名工程师提升了专业技术能力。客户遍布中兴通讯、研通高频、埃威航电、国人通信等多家国内知名公司，以及台湾工业技术研究院、永业科技、全一电子等多家台湾地区企业。

易迪拓培训课程列表：http://www.edatop.com/peixun/rfe/129.html

射频工程师养成培训课程套装

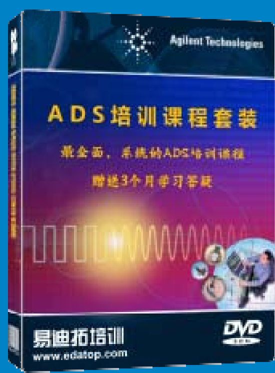
该套装精选了射频专业基础培训课程、射频仿真设计培训课程和射频电路测量培训课程三个类别共 30 门视频培训课程和 3 本图书教材；旨在引领学员全面学习一个射频工程师需要熟悉、理解和掌握的专业知识和研发设计能力。通过套装的学习，能够让学员完全达到和胜任一个合格的射频工程师的要求…

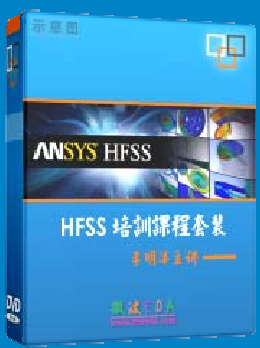
课程网址：http://www.edatop.com/peixun/rfe/110.html

ADS 学习培训课程套装

该套装是迄今国内最全面、最权威的 ADS 培训教程，共包含 10 门 ADS 学习培训课程。课程是由具有多年 ADS 使用经验的微波射频与通信系统设计领域资深专家讲解，并多结合设计实例，由浅入深、详细而又全面地讲解了 ADS 在微波射频电路设计、通信系统设计和电磁仿真设计方面的内容。能让您在最短的时间内学会使用 ADS，迅速提升个人技术能力，把 ADS 真正应用到实际研发工作中去，成为 ADS 设计专家...

课程网址： http://www.edatop.com/peixun/ads/13.html





HFSS 学习培训课程套装

该套课程套装包含了本站全部 HFSS 培训课程，是迄今国内最全面、最专业的 HFSS 培训教程套装，可以帮助您从零开始，全面深入学习 HFSS 的各项功能和在多个方面的工程应用。购买套装，更可超值赠送 3 个月免费学习答疑，随时解答您学习过程中遇到的棘手问题，让您的 HFSS 学习更加轻松顺畅…

课程网址：http://www.edatop.com/peixun/hfss/11.html

CST 学习培训课程套装

该培训套装由易迪拓培训联合微波 EDA 网共同推出，是最全面、系统、专业的 CST 微波工作室培训课程套装，所有课程都由经验丰富的专家授课，视频教学，可以帮助您从零开始，全面系统地学习 CST 微波工作的各项功能及其在微波射频、天线设计等领域的设计应用。且购买该套装，还可超值赠送 3 个月免费学习答疑…

课程网址：http://www.edatop.com/peixun/cst/24.html

HFSS 天线设计培训课程套装

套装包含 6 门视频课程和 1 本图书，课程从基础讲起，内容由浅入深，理论介绍和实际操作讲解相结合，全面系统的讲解了 HFSS 天线设计的全过程。是国内最全面、最专业的 HFSS 天线设计课程，可以帮助您快速学习掌握如何使用 HFSS 设计天线，让天线设计不再难…

课程网址：http://www.edatop.com/peixun/hfss/122.html

13.56MHz NFC/RFID 线圈天线设计培训课程套装

套装包含 4 门视频培训课程，培训将 13.56MHz 线圈天线设计原理和仿真设计实践相结合，全面系统地讲解了 13.56MHz 线圈天线的工作原理、设计方法、设计考量以及使用 HFSS 和 CST 仿真分析线圈天线的具体操作，同时还介绍了 13.56MHz 线圈天线匹配电路的设计和调试。通过该套课程的学习，可以帮助您快速学习掌握 13.56MHz 线圈天线及其匹配电路的原理、设计和调试…

详情浏览：http://www.edatop.com/peixun/antenna/116.html

我们的课程优势：

※ 成立于 2004 年，10 多年丰富的行业经验，

※ 一直致力并专注于微波射频和天线设计工程师的培养，更了解该行业对人才的要求

※ 经验丰富的一线资深工程师讲授，结合实际工程案例，直观、实用、易学

联系我们：

※ 易迪拓培训官网：http://www.edatop.com

※ 微波 EDA 网：http://www.mweda.com

※ 官方淘宝店：http://shop36920890.taobao.com