Multiband Antenna for GSM and 3G Mobile System

ABDURAHMAN M M OWAG

A project report submitted in partial fulfillment of the requirements for the award of the degree of Master of Engineering (M Eng. Electrical-Electronics and Telecommunications)

Faculty of Electrical Engineering
University Technology Malaysia

May 2006

Abstract

We propose a new design for built-in handset antennas in that metal strips as additional resonators are directly connected with a feed strip. With the new design scheme, a multi-band antenna for covering GSM900 and UMTS2000 bands for use in mobile built-in handsets are experimentally carried out. Compared with the parasitic form with a shorted strip placed away from the main radiator, the size of the proposed antennas can be reduced by an order of 10 20%, which is desirable since the size of mobile phones is becoming smaller according to consumer preferences. Moreover, the impedance matching for each band of the new antennas becomes easy. The new multi-band handset antenna is developed within the limits of a 36 *16* 8 mm^3 volume. The antenna is also analyzed using the finite-difference time-domain technique.

Abstrak

Kami memperkenalkan rekabentuk baru bagi antena dalaman telefon bimbit yang berjalur logam sebagai "resonator" tambahan dan ia telah disambung terus dengan penyuap berjalur. Eksperimen ini dijalankan untuk memastikan kegunaan antenna dalaman yang berjalur berbilang sesuai digunakan pada jalur GSM 900 dan UMTS 2000 pada telefon bimbit. Berbanding dengan bentuk parasitik dengan meletakkan jalur pendek daripada penyebar utama; size bagi antena yang dicadangkan dapat dikurangkan sebanyak 20%, dimana ia adalah diigini sebab size telefon bimbit menjadi semakin kecil dari semasa ke semasa mengikut kehendak antena pengguna. Selain daripada itu, kesesuaian galangan bagi antena tersebut dengan setiap jalur menjadi semakin senang ditentukan. Size bagi antena jalur berbilang telah dicadangkan dalam linkungan 36x16x18 mm^3. Antena ini juga akan dianalisa dengan menggunakan teknik "finite-difference time domain".

Table of Contents

List of Figures

List of Table

CHAPTER 1

INTRODUCTION

1.1 Introduction

With the rapid growth of wireless communications there is a growing demand for mobile phones that are small, attractive, lightweight, and curvy. This has resulted in the proliferation of handsets with antennas that are internal or hidden within the device. An internal antenna makes the handset look much nicer and compact.

The sizes and weights of mobile handsets have rapidly been reduced due to the development of modern integrated circuit technology and the requirements of the users. Conventional monopole-like antennas have remained relatively large compared to the handset itself. Thus, built-in antennas are becoming very promising candidates for applications in mobile handsets.

Most built-in antennas currently used in mobile phones are based on planar inverted-F antennas (PIFAs) [1]. In addition, since the antenna is inside the phone it is not prone to breakage or damage, which is commonly encountered with the socalled external stub-type antenna. Currently mobile phones with small internal antennas are already in the market.

Designing an internal antenna for a mobile phone is difficult especially when dual or Multiband operation is required. Although obtaining dual-frequency resonance is straightforward, satisfying the bandwidth requirement for the respective communication bands is difficult. Further complications arise when the antenna has to operate in close proximity to objects like shielding cans, screws, battery, and various other metallic objects. Currently, many mobile telephones use one or more of the following frequency bands: the GSM band, centered at 900 MHz; the DCS band, centered at 1800 MHz; and the PCS band, centered at 1900 MHz. Triple-band built-in antennas to operate at GSM900, DCS1800, and PCS1900 bands demonstrated in [2], [3] .

If merger of technologies is considered where both advanced mobile phone systems (AMPS) and global system for mobile (GSM) systems are integrated in one phone, triple-band or even quad-band antennas may be needed. For instance, consider a device that operates in the AMPS 800, GSM 900, and TDMA /GSM1900 MHz bands. This means that the device operates in the 824–894 MHz, 880–960 MHz, and 1850–1990 MHz bands making it triple band from antenna perspective. In the lower band the required bandwidth is 136 MHz or 15.25% which is almost twice as much of that required for GSM or AMPS alone.

1.2 Historical review

In 1897 Marconi demonstrate the first practical demonstration of wireless communication when he established a continues radio contact between shore and ship traveling in the English channel, and after years of research leads to mid of 20th century when the mobile communication industry was strictly limited by the size and weight of the early mobile phone and normally these based on the simple amplitude modulation technique.

After the World War II, the development of transistor reduces the power and space demand of the electronic devices and also mobile phone, the need of shrinking of the size of mobile radio system has continued to the present day.

1.2.1 Mobile communication

Mobile communication is one of the fastest growing and consider as the most important telecommunication application. it is the most powerful catalyst for change in lifestyle of the people.

The mobile communication was used in limited applications due to costly analogue technologies and restricted service (only phone calls were possible). The tiny high technologies are now become a necessary need of every individuals life.

1.2.2 The Wireless Revolution

The wireless revolution is creating a flood of new wireless devices that dramatically increase the availability of voice and data nearly anywhere in the world. While this revolution is significantly expanding the opportunity for new, smaller and better wireless communication terminals. It also requires the new and small antenna design.

1.3 Problem background

Traditionally most mobile phones and handset haven been equipped with the monopole antenna .monopole antenna are very simple in design and construction and are well suited to mobile communication application. The most ¼ monopole antenna is the wipe antenna, which can operate at range of frequencies and deal with most environmental conditions better than other monopole antennas.

However, the monopole antenna possesses a number of drawbacks. Monopole antennas are relatively large in size and protrude from the handset case in an awkward way. This problem with the monopole's obstructive and space demanding structure also complicate any efforts taken to equip a handset with several antennas to enable multilane operation. Monopole antennas also lack any built-in shielding mechanisms, to direct any radiating waves away from user's body, thus increasing the potential risk of producing cancerous tumors growth in the user's head and reducing the antenna efficiency.

In recent years, the demand for compact handheld communication devices has grown significantly. Devices smaller than palm size have appeared in the market .antenna size is a major factor that limits device miniaturization. In addition to solve the problem of broadening the antenna bandwidth to the required specification of the system, one has to worry about developing new structure for devices that require more than one frequency band of operation.

Multiband wireless phone has become popular recently because they permit people to use the same phone in multi network that have different frequencies. Table 1.1 lists a few useful wireless applications and their operating frequencies. Systems that require multiband operation require antenna that resonate at the specific frequencies. This only adds complexity to the antenna design problem.

Table 1.1: Frequency Bands for a few Wireless Applications.

Wireless Applications	**Frequency Bands (MHz)**
GSM-900	890-960
GSM-1800	1710-1880
GSM-1900(USA)	1850-1990
3G-(UMTS2000)	1885-2200

(WLAN)	2400-2483

Therefore, the problem statement of this project can be summarized as following:

The sizes and weights of mobile handsets have rapidly been reduced due to the development of modern integrated circuit technology and the requirements of the users.

The built-in antennas are becoming very promising candidates for applications in mobile handsets. Conventional monopole antennas are simple, omni-directional pattern and gain that is suited for mobile application.

But they have remained relatively large compared to the handset itself, and they have lack of shielding mechanisms, to direct any radiating waves away from user's body which causes potential harm to the user's health and causes cancers.

Currently many different wireless standards are available for mobile communication; therefore it requires that the same mobile phone can work for different frequency bands. Since it is not feasible to equip the device with many antennas for each frequency band, built-in antennas provide the feature of low profile and multi-band reception.

1.4 Objectives and Methodology of the Project

The fundamental aim of this thesis is to design a multi band antenna suitable for telephone handset. By using suitable antenna, the space demand of the antenna as part of a telephone handset can be minimized, thus reducing the obtrusiveness of the handset's appearance. This design has these primary objectives

Select and design an efficient, low profile and realizable antenna capable of operating at a number of frequencies bands (900MHz, 1800 MHz, 1900 MHz and 2000MHz) antenna for GSM and the third generation (3G) mobile system.

Verify the operations of the antenna at the prescribed frequencies in terms of input impedance and field patterns, using electromagnetic simulation software ZELAND FIDELITY which is based on Finite- difference. Discuss the simulated result in term of Return loss and Radiation pattern.

In order to achieve the first objective as set out above, a comprehensive literature review is required to obtain an antenna that requires minimal modification to suit the requirements of this design. As the process of optimizing an antenna's dimensions to meet a set of specifications is highly rigorous, fading an antenna that operates efficiently at the three required frequencies, as well being compact and having a low profile, is very much desired.

1.5 Organization of the Project

Chapter one includes the introduction part of the project, the problem background with the objectives, methodology and the implementation plan of this project.

Chapter two represents the literature review, including the historical developments and representing the latest techniques.

Chapter three includes an optimum design of compact antennas for mobile communications such as monopole antennas, planer antennas, microstrip patch antennas, planar inverted-F Antenna and Dielectric Resonator antennas

Chapter four represents an antenna design and structure, simulation procedure, introduction to Zeland fidelity software and overview on The Finite-Difference Time-Domain (FDTD) Technique.

Chapter five includes the result and the discussion of the simulation in terms of return Loss, effects of the additional strip position and its size, effects of the ground plane size, the three-dimensional far field patterns, the two-dimensional far field patterns and the antenna gain.

Chapter six represents conclusion and future.

BIBLIOGRAPHY

[1] K. Fujimoto and J. R. James, Eds., Mobile Antenna Systems Handbook, 2nd ed. Norwood, MA: Artech House, 2001.

[2] Z. Ying, “Multi frequency-band antenna,”, PCT application WO01/91 233, May 2001.

[3] M. Martinez-Vazquez and O. Litschke, “Design considerations for quad-band antennas integrated in personal communications devices,” in Proc. Int. Symp. Antennas (JINA), vol. 1, Nice, France, Nov. 2002, pp. 195–198.]

[4] Ali, M.; Hayes, G.J.; Huan-Sheng Hwang; Sadler, R.A.” Design of a multiband internal antenna for third generation mobile phone handsets” Antennas and Propagation, IEEE Transactions on Volume 51, Issue 7, July 2003 Page(s)

[5] Shun-Yun Lin;” Multiband folded planar monopole antenna for mobile handset” Antennas and Propagation, IEEE Transactions on Volume 52, Issue 7, July 2004 Page(s)

[6] Kin-Lu Wong; Gwo-Yun Lee; Tzung-Wern Chiou;" A low-profile planar monopole antenna for multiband operation of mobile handsets" Antennas and Propagation, IEEE Transactions on Volume 51, Issue 1, Jan. 2003 Page(s)

[7] Ciais, P.; Staraj, R.; Kossiavas, G.; Luxey, C.;" Design of an internal quad-band antenna for mobile phones" Microwave and Wireless Components Letters, IEEE [see also IEEE Microwave and Guided Wave Letters] Volume 14, Issue 4, April 2004 Page(s)

[8] Ciais, P.; Staraj, R.; Kossiavas, G.; Luxey, C.;" Compact internal multiband antenna for mobile phone and WLAN standards" Electronics Letters Volume 40, Issue 15, 22 July 2004 Page(s)

[9] Di Nallo, C.; Faraone, A.;" Multiband internal antenna for mobile phones" Electronics LettersVolume 41, Issue 9, 28 April 2005 Page(s)

[10] Yarasi, S.; Kadambi, G.R.; Hebron, T.;" Conformal shaped PIFAs for mobile communication applications" Antennas and Propagation Society International Symposium, 2003. IEEEVolume 3, 22-27 June 2003 Page(s)

[11] Yong-Xin Guo; Hwee Siang Tan;" New compact six-band internal antenna" Antennas and Wireless Propagation Letters Volume 3, Issue 1, 2004 Page(s)

[12] Leach, S.M.; Agius, A.A.; Saunders, S.R." Intelligent quadrifilar helix antenna";Microwaves, Antennas and Propagation, IEE Proceedings -Volume 147, Issue 3, June 2000 Page(s):219 - 223

[13] J. D. Kraus, Antennas, New York: McGraw-Hill Book Co., 1988.

[14] K. D. Katsibas, C. A. Balanis, P. A. Tirkas, and C. R. Birtcher, "Folded loop antenna for mobile hand-held units," IEEE Trans. Antennas Propagat., vol. 46, pp. 260-266, Feb. 1998.

[15] E. Lee, P. S. Hall, and P. Gardner, "Dual band folded monopole/loop antenna for terrestrial communications system." Electron. Lett., vol. 36, pp. 1990-1991, Nov. 23, 2000.

[16] K. Fujimoto and J. R. James, Mobile Antenna System Handbook, 2nd ed., Boston: Artech House, 2001.

[17] P. Haapala, P. Vainikainen, and P. Eratuuli, "Dual frequency helical antennas for handsets," in Proc. 1996 IEEE Vehicular Technol. Conf, pp.336-33 8.

[18] K. L. Wong, Planar Antennas for Wireless Communications, New Jersey: John Wiley & Sons, 2003.

[19] K. L. Wong, Design of Nonpianar Microstrz Antennas and Transmission Lines, New York: John Wiley & Sons, 1999.

[20] K. L. Wong, Compact and Broadband Microstrip Antennas, New York: John Wiley & Sons, 2002.

[21] C. A. Balanis, Antenna Theoiy: Analysis and Design, 2' ed., New York: John Wiley & Sons, 1997.

[22] G. Kumar and K. P. Ray, Broadband Microstrip Antennas, Boston: Artech House, 2003.

[23] R. Waterhouse, "Small microstrip patch antenna," Electron. Lett., vol. 31, pp. 604-605, April 13, 1995.

[24] D. M. Pozar and D. H. Schaubert, Microstrip Antennas: the Analysis and Design of Micrtostrip Antennas and Arrays, New York: IEEE Press, 1995.

[25] Z. D. Liu, P. S. Hall, and D. Wake, “Dual-frequency planar F antenna,” IEEE Trans. Antennas Propagat., vol. 45, pp. 1451-1458, Oct. 1997.

[26] C. R. Rowell and R. D. Murch, “A compact PIFA suitable for dual-frequency 900/1800-MHz operation,” IEEE Trans. Antennas Fropagat., vol. 46, pp. 596-598, April 1998.

[27] S. Tarvas and A. Isohatala, “An internal dual-band mobile phone antenna,” in 2000 IEEE Antennas Propagat. Soc. mt. Symp. Dig., pp. 266-269.

[28] C. T. P. Song, P. S. Hall, H. Ghafouri-Shiraz, and D. Wake, “Triple band planar inverted F antennas for handheld devices,” Electron. Lett., vol. 36, pp. 112-1 14, Jan. 20, 2000.

[29] A. Petosa, A. Ittipiboon, Y. M. M. Antar, D. Roscoe, and M. Cuhaci, “Recent Advances in Dielectric-Resonator Antenna Technology,” IEEE Antennas Propagat. Mag., vol. 40, no. 3, pp. 35-48, June 1998.

[30] M. W. McAllister and S. A. Long, “Resonant Hemispherical Dielectric Antenna,” Electron. Lett., vol. 20, no. 16, pp. 657-659, 1984.

[31] S. A. Long, M. W. McAllister, and L. C. Shen, “The Resonant Cylindrical Dielectric Cavity Antenna,” IEEE Trans. Antennas Propagat., vol. AP-3 1, no. 3, pp. 406-412, 1983.

[32] M. W. McAllister, S. A. Long, and G. L. Conway, “Rectangular Dielectric Resonator Antenna,” Electron. Lett., vol. 19, no.6, pp. 219-220, 1983.

[33] A. A. Kishk, A. W. Glisson, and X. Zhang, “Analysis of Dielectric Resonator Antennas Excited by a Coaxial Probe with Wideband Enhancement,” in 2002 IEEEAntennas Propagat. Soc. mt. Symp. Dig., pp. 568-571.

[34] R. A. Kranenbrug and S. A. Long, “Microstrip transmission line excitation of dielectric resonator antennas,” Electron. Lett., vol. 24, pp. 1156-1157, Sep. 1, 1988.

[35] J. T. H. St. Martin, Y. M. M. Antar, A. A. Kishic, A. Ittipiboon, and M. Cuhaci, “Dielectric resonator antenna using aperture coupling,” Electron. Lett., vol. 26, pp. 2015-2016, Dec. 1990.

[36] R. A. Kranenbrug, S. A. Long, and J. T. Williams, “Coplanar waveguide excitation of dielectric resonator antennas,” IEEE Trans. Antennas Propcigat., vol. 39,pp. 119-122, Jan. 1991.

[37] M. S. A. Salameh, Y. M. M. Antar, and G. Séguin, “Coplanar-Waveguide-Fed Slot-Coupled Rectangular Dielectric Resonator Antenna,” IEEE Trans. Antennas Propagat., vol. 50, no. 50, pp. 1415-1419, Oct. 2002.

[38] F. S. Hsiao, J. S. Kuo, T. W. Chiou, and K. L. Wong, “A very-high-permittivity broadband dielectric resonator antenna for WLAN application in the 5.2GHz Band,” Microwave Opt. Technol. Lett., vol. 32, pp. 426-427, March 20, 2002.

[39] T. K. Tam, Compact Dielectric Resonator Antennas for Wireless Communications, Master thesis, Hong Kong Baptist University, 1995.

[40] Y. D. Kim, M. S. Kim, and H. M. Lee, “Internal rectangular dielectric resonator antenna with broadband characteristic for IMT-2000 handset,” in 2002 IEEE Antennas Propagat. Soc. mt. Symp. Dig., pp. 22-25.

[41] Y. X. Guo and K. M. Luk, “On the Improving Coupling Between Coplanar Waveguide and Low-Permittivity Dielectric Resonator Antenna,” in 2002 IEEE Antennas Propagat. Soc. mt. Symp. Dig., pp. 486-489.

[42] K. Lan, S. K. Chaudhuri, and S. S. Naeini, “A Compact Wide-Dual-Band Antenna for Bluetooth and Wireless LAN Applications,” in 2003 IEEE Antennas Propagat. Soc. mt. Symp. Dig., pp. 926-929.

[43] M. B. Oliver, Y. M. M. Antar, R. K. Mongia, and A. Ittipiboon, “Circularly polarized rectangular dielectric resonator antenna,” Electron. Lett., vol. 31, pp. 418-419, March 16, 1995.

[44] K. P. Esselle, “Circularly polarized higher-order rectangular dielectric-resonator antenna,” Electron. Lett., vol. 32, pp. 150-151, Feb. 1, 1996.

[45] G. Drossos, Z. Wu, and L. E. Davis, “Circularly polarized cylindrical dielectric resonator antenna,” Electron. Lett., vol. 32, pp. 281-283, Feb. 15, 1996.

[46] C. W. Ling and C. Y. Huang, “Dual-band Circularly Polarized Dielectric Resonator Antenna,” in 2003 IEEE Antennas Propagat. Soc. mt. Symp. Dig., pp. 496-499.

[47] G. P. Junker, A. A. Kishk, A. W. Glisson, and D. Kajfez, “Effect of an Air Gap around the Coaxial Probe Exciting a Cylindrical Dielectric Resonator Antenna,” Electron. Lett., vol. 30, pp. 177-178, Feb. 3, 1994.

[48] H. G. Booker, “Slot Aerials and Their Relation to Complementary Wire Aerials,” .1. Inst. Elec. Engs., Pt III A, pp. 620-626, 1946.

[49] R. Garg, P. Bhartia, I. Bahi, and A. Ittipiboon, Microstrip Antenna Design Handbook, Boston: Artech House, 2001.

[50] W. R. Deal, Y. Qian, and T. Itoh, “Planar Integrated Antenna Technology,” Microwave Journal, pp. 128-144, July 1999.

[51] H. S. Tsai and R. A. York, “Multi-Slot Antennas for Quasi-Optical Circuits,” IEEE Microwave Guided Wave Lett.,” vol. 5, pp. 180-182, 1995.

[52] T. M. Weller, L. P. B. Katehi, and G. M. Rebeiz, “Single and Double Folded-slot Antennas on Semi-infinite Substrates,” IEEE Trans. Antennas Fropagat., vol. 53, pp. 1423-1428, Dec. 1995.

[53] H. C. Liu, T. S. Horng, and N. G. Alexopoulos, “Radiation of Printed Antennas with a Coplanar Waveguide Feed,” IEEE Trans. Antennas Propagat., vol. 43, pp. 1143-1 148, Oct. 1995.

[54] H. S. Tsai, R. A. York, “FDTD Analysis of CPW-Fed Folded-Slot and Multiple- Slot Antennas on Thin Substrates,” IEEE Trans. Antennas Propagat., vol. 44, pp. 2 17-226, Feb. 1996.

[55] E. A. Soliman, S. Brebels, P. Delmotte, G. A. E. Vandenbosch, and F. Beyne, “Bow-tie slot antenna fed by CPW,” Electron. Lett., vol. 35, pp. 514-515,1999.

[56] P. L. Chin, A. Z. Elsherbeni, and C. F. Smith, “Characteristics of Coplanar Bow- Tie Patch Antennas,” in 2002 IEEE Antennas Propagat. Soc. mt. Symp. Dig.

[57] A. Z. Elsherbeni, A. A. Eldek, B. N. Baker, C. E. Smith, and K. F. Lee, “Wideband Coplanar Patch-Slot Antennas for Radar Applications,” in 2002 IEEE Antennas Propagat. Soc. mt. Symp. Dig., pp. 436-439.

[58] H. D. Chen, “Broadband CPW-Fed Square Slot Antennas with A Widened Tuning Stub,” IEEE Trans. Antennas Propagat., vol. 51, pp. 1982-1986, Aug. 2003.

[59] M. Cho, I. Kim, T. H. Seo, J. G. Yook, and H. Park, “Modified Slot-loaded Triple-Band Microstrip Patch Antenna,” in 2002 IEEE Antennas Propagat. Soc. mt. Symp. Dig., pp. 500-503.

[60] F. Le Bolzer and A. Louzir, “Multi-Band Annular Slot Antenna for WLAN Applications,” in 2001 lEE ll Int. Conf Antennas Propagat., pp. 529-532.

[61] H. Tebrani, T. Y. Yun, and K. Chang, “A Multi-Frequency Micristrip-Fed Shorted Square Ring Slot Line Antenna,” in 1999 .

[62] H. Tehrani and K. Chang, “A Multi-frequency Microstrip-fed Annular Slot Antenna,” in 2000 IEEE Antennas Propagat. Soc. Int. Symp. Dig., pp. 632-635.

[63] J. S. Chen, “Triple-Frequency Annular-ring Slot Antennas Fed by CPW and Microstrip Line,” in 2003 IEEE Antennas Propagat. Soc. mt. Symp. Dig., pp. 557-560.

64 Yong-Xin Guo; Chia, M.Y.W.; Chen, Z.N.;” Miniature built-in quad-band antennas for mobile handsets”Antennas and Wireless Propagation Letters
Volume 2, Issue 1, 2003 Page(s)

65 D. Manteuffel, A. Bahr, D. Heberling, and I. Wolff, “Design consideration for integrated mobile phone antennas,” in Proc. 11th Int. Conf. Antennas and Propagation, Manchester, U.K., Apr. 2001, pp. 252–256.

66 Z. Ying, “Multi frequency-band antenna,”, PCT application WO01/91 233, May 2001