antenna performance, including stabilisation from environmental effects. Some examples have been previously given [1, 2]. The present analysis also correctly predicts the reported [8] behaviour of dielectric resonator antennas regarding the optimum type of excitation and its position. In mobile handset applications there is a need to reduce magnetic near fields to increase the incident wave impedance ([4], p. 352) and minimise specific absorption rates (SAR) in the user's head and body. For this requirement an antenna having a material coating with a higher permeability and lower permittivity, together with a predominantly electric source, is applicable.

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Realisation of printed-on-display antenna for mobile terminals

Chi-Fang Huang and Li Chen

A design method is presented for a printed-on-display (POD) antenna, which is intended to replace the traditional antennas installed on diverse wireless mobile terminals which have both an antenna and an electronic display. The POD antenna is composed of printed radiators which are made of a material being both electrically conductive and optically transparent.

Introduction: Based on the advanced wireless communication technologies, many diverse applications have been merged into mobile personal handsets designed for voice communication. Examples referred to are data browsing (stock market broadcasting), Internet access, GPS [1] navigation, downloading of entertainment and personal data assistant (PDA) operation, etc. In these circumstances, the handset display plays a very important role for the human–data interface. Especially, when the 3G era comes, the display will be required to show more sophisticated information in multimedia communication. Therefore, instead of merely functioning for voice communication, a so-called product mobile terminal will be required.

Many current mobile terminals, e.g. GSM and GPS handsets, have adopted LCD [2] as the data display device. According to the concept of printed antenna, the metal line on a dielectric slab can be employed as the current source of radiation. In this Letter we present a realisation of a printed-on-display (POD) antenna specially for mobile terminals by printing a material which is both electrically conductive and optically transparent on the glass. The purpose of this development is to replace the usual monopole or helical antennas used in mobile terminals, since the latter are associated with disadvantages such as being easily damaged and costly in assembly. Mechanically, being hidden, the POD antenna achieves the goal of elegant product appearance. It is worth noting that the concerned mobile terminals have a unique feature in which a data display and an antenna are equipped simultaneously. Consequently, the proposed POD antenna also integrates these two different electronic functions in a single hardware module.

In addition to measurement validation of the POD antenna unit, it is also integrated into an ordinary GSM handset to provide a real operation test.

Realisation: To put the POD antenna on a display, the material used must be both conducting and transparent. The well-known one of this category of material is indium oxide doped with tin oxide (ITO) [3], which has been widely adopted as the electrode films in planar displays. It should be emphasised that the POD antenna may be manufactured in the same process line of LCD production. This is a very significant value-added factor from the standpoint of LCD panel makers.

In the realisation presented, the POD antenna is fabricated on the outer surface of the glass of the display. Being formed as strip shape, the ITO film serves as the antenna radiator. To enhance antenna efficiency and to meet the required radiation pattern, optimal shape is searched for.

There are two approaches to fabricating the ITO film as the POD antenna on a glass. One is to use the vaporisation or sputtering technique to form it on a masked glass in a vacuum chamber. The other approach is to use the chemical etching method to apply it on the commercial ITO glass which is masked before being processed. An ITO radiator with trapezoid shape based on this chemical process is shown in Fig. 1. For further study, by removing the original monopole antenna this radiator is integrated into a GSM handset as shown in Fig. 2 to become a real POD antenna in a system.

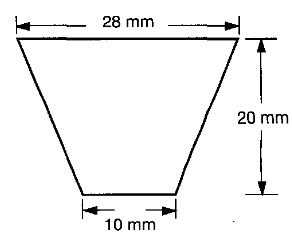

Fig. 1 *ITO radiator with trapezoid shape*
Thickness of ITO film = 120 nm; thickness of glass = 0.7 mm

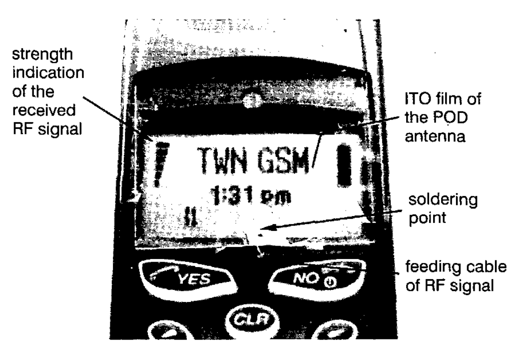

Fig. 2 *Real POD antenna on GSM handset*

For feeding, a 50 Ω microcable links the antenna and the RF front-end circuit inside the handset.

Measurement and analysis: Usually, an omni-directional radiation pattern is requested for an antenna used in the mobile communication terminal. To check whether a POD antenna may have such a feature, first an ITO strip forming a monopole with 38 mm length and 3 mm width is vertically installed on a 30 × 30 mm metal ground plane. By operating the antenna at 1.8 GHz, the radiation pattern with its vertical polarisation is measured and observed to be quite omni-directional. Therefore, this innovatory concept of antenna design offers the radiation characteristics of a common monopole antenna. As shown in the LCD display in Fig. 2, the GSM handset employing a POD antenna achieved full RF strength from the base station and operates very satisfactorily.

For purpose of comparison, another ITO trapezoid radiator, similar to that in Fig. 1 yet with top width 28 mm, down width 20 mm and height 20 mm, was also fabricated by a sputtering approach. At 1.8 GHz its measurement of the radiation pattern of vertical polarisation is shown in Fig. 3. The property of the omni-directional pattern is maintained.

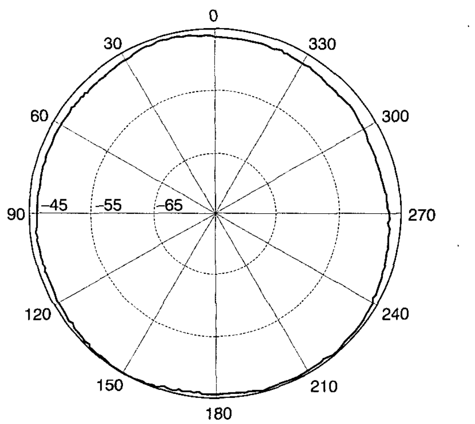

Fig. 3 *Radiation pattern generated by ITO radiator made by sputtering process*

Regarding the characteristics of input impedance, Fig. 4 shows the measured S_{11} parameter of the ITO radiator in Fig. 1. 1.8 GHz is chosen as the operating frequency in the radiation measurements since that is the RF carrier of the GSM system. This radiator has better resonant condition at around 2.2 GHz: even so, under the same measuring condition, it has been found that its maximum received directional power is 2.33 dB less compared with a normal 1.8 GHz GSM monopole antenna. Thus, the POD antenna is regarded as a good candidate for mobile terminals in wireless communication. However, for a better matching operation with the RF front-end of mobile terminals the ITO radiator should be further tuned up in shape or other configuration.

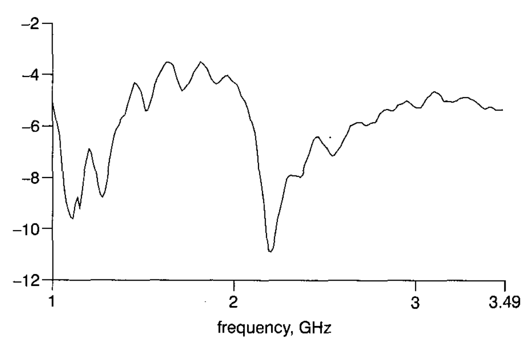

Fig. 4 *Measured* $|S_{11}|$ *of ITO radiator in Fig. 1*

Conclusion: An innovatory printed-on-display (POD) antenna is reported. The purposed this new type of antenna is to increase the product value of the LCD panel since it combines the antenna and display functions together as a hardware module.

Because of its embedding feature, the POD antenna is also suitable to be applied on a terminal which operates with multi-RF systems for multi-purposes at the same time, e.g. GSM plus GPS, GSM plus bluetooth and so forth. It may be applied for either one of these multi-functions.

The final goal of this proposal is to commercialise the POD antenna in the display industry; consequently, the electrical interface between the display unit and circuit board may be standardised to ensure a signal path for the POD antenna and the RF circuit on the board.

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Size reduction of microstrip antenna by elevating centre of patch

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A new structure of microstrip patch antenna with considerable reduction in its size and wide impedance bandwidth, with marginally degraded antenna performances, is proposed. These merits are obtained by elevating the centre of the radiating metallic patch, and thus increasing the electrical length of that patch more effectively. These, for purpose of example, the proposed size-reduced antenna has been designed and tested at 3 GHz and 53% of size reduction is achieved compared with the conventional one. It showed the possibility that the non-planar antenna structure can provide new design opportunity for compact devices.

Introduction: Microstrip antennas are the most common form of printed antennas and are used in a broad range of applications owing to their simplicity, conformal nature, low manufacturing cost, and easy analysis and design using several field simulators [1, 2]. However the size of microstrip antennas becomes too large for low frequency applications, especially for handheld devices since this antenna is a kind of resonant antenna. Several techniques have been previously demonstrated to reduce the size of the patch antenna, including: the use of high permittivity substrates; modifying the patch shape; and the use of shorting posts [3, 4]; and recent studies have proposed a corrugated patch antenna in order to overcome limitations of these size-reducing techniques [5]. However, the simple corrugation of the metallic patch without considering distributions of fields or currents on an antenna cannot reduce the antenna size dramatically. In this Letter we present a new patch shape with the properly located elevation so that it can maximise the effects of capacitance C and inductance L of the patch on the size reduction of a conventional planar patch antenna much more than the corrugated patch antenna. Through this new type of design, the reduction of antenna length by at least 50% for a given resonant frequency is possible.

Proposed antenna: The proposed antenna structure is shown in Fig. 1. The discontinuity of the height of the radiating metallic acts as an inductive load in series with an equivalent transmission line and reduces the effective phase velocity of the propagating wave. Moreover, this patch with an elevation on its centre (see Fig. 2) increases the electrical length of the antenna more effectively than a simply