the GPS/K-PCS/ISM (2.4-GHz) triple-band. Satisfactory agreement between the simulated and measured results for the antenna patterns and impedance bandwidth have been achieved. Therefore, the proposed antenna is suitable for practical applications requiring a small chip antenna in mobile-communication handsets.

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INTERNAL MONOPOLE ANTENNA INTEGRATED WITH A SHIELDING METAL CASE FOR UMTS MOBILE DEVICES
Saou-Wen Su and Kin-Lu Wong
Department of Electrical Engineering
National Sun Yat-Sen University
Kaohsiung 80424, Taiwan

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ABSTRACT: An integration design of an internal monopole antenna and an RF shielding metal case for application in UMTS mobile devices is proposed. The monopole antenna is a low-profile (only 3.5-mm) T-shape strip monopole placed above and integrated (through short-circuiting) to the shielding metal case, which is flush with the top edge of the system ground plane of the mobile device. With the integrated shielding case, which provides a coupling-free region for the nearby components such as the RF module, RF circuitry, and battery in the mobile device, possible coupling between the monopole antenna and the nearby components can be avoided. The proposed integration design can thus lead to no degrading effects on the performances of the internal monopole antenna employed in the mobile device. © 2005 Wiley Periodicals, Inc. Microwave Opt Technol Lett 48: 162–165, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21293

Key words: antennas; internal mobile antennas; shorted monopole antennas; integrated antennas; UMTS antennas

1. INTRODUCTION
A variety of low-profile monopole antennas that are promising to be embedded inside the casing of a mobile device, such as mobile phones and personal digital assistant phones (PDA), as internal antennas have been demonstrated recently [1]. However, in the antenna design process, this kind of conventional internal monopole antenna has been mainly tested in the standalone condition. That is, no additional nearby components such as the shielding metal case of the RF module, RF circuitry, and battery have been considered in the antenna design. Thus, for practical applications, an isolation distance (usually about or larger than 7 mm) between the internal monopole antenna and the shielding metal case or other associated nearby components is usually required in order to avoid the degrading coupling effects on the performance of the internal monopole antenna. This isolation-distance requirement limits the effective usage of the internal spacing in a mobile device.
In this paper, we propose a novel integration design of the internal monopole antenna and the RF shielding metal case for mobile devices. The proposed design eliminates the isolation-distance requirement between the antenna and the nearby components. The internal monopole antenna studied here uses a low-profile T-shape strip monopole [2–4], which is placed above and short-circuited to the shielding metal case. In this case, the strip monopole and shielding metal case are integrated into a single element. Furthermore, with the presence of the shielding metal case (which can accommodate the associated nearby components), the possible coupling between the strip monopole and the nearby components is eliminated. Thus, no degrading effects on the performances of the strip monopole are expected. This can lead to a simpler design process for the internal monopole antenna for mobile devices. In this study, a design example of the proposed integrated low-profile strip monopole and shielding metal case for UMTS (Universal Mobile Telecommunication System, 1920–2170 MHz) operation is demonstrated. The details of the integration design are described, and a study on the effects of the shielding metal case on the performances of the strip monopole is also presented.

2. PROPOSED INTEGRATION DESIGN

Figure 1 shows the configuration and side view of the proposed internal monopole antenna integrated with a shielding metal case for UMTS operation in a mobile device; (b) side view of the configuration in (a).

In this paper, we propose a novel integration design of the internal monopole antenna and the RF shielding metal case for mobile devices. The proposed design eliminates the isolation-distance requirement between the antenna and the nearby components. The internal monopole antenna studied here uses a low-profile T-shape strip monopole [2–4], which is placed above and short-circuited to the shielding metal case. In this case, the strip monopole and shielding metal case are integrated into a single element. Furthermore, with the presence of the shielding metal case (which can accommodate the associated nearby components), the possible coupling between the strip monopole and the nearby components is eliminated. Thus, no degrading effects on the performances of the strip monopole are expected. This can lead to a simpler design process for the internal monopole antenna for mobile devices. In this study, a design example of the proposed integrated low-profile strip monopole and shielding metal case for UMTS (Universal Mobile Telecommunication System, 1920–2170 MHz) operation is demonstrated. The details of the integration design are described, and a study on the effects of the shielding metal case on the performances of the strip monopole is also presented.

2. PROPOSED INTEGRATION DESIGN

Figure 1 shows the configuration and side view of the proposed internal monopole antenna integrated with the RF shielding metal case, which is soldered onto the top portion and flushed to the top edge of the system ground plane of a mobile device. The monopole antenna is a T-shape strip monopole showing a low profile of 3.5 mm (less than 2.4% of the free-space wavelength at 2045 MHz, the center frequency of the UMTS band) to the shielding metal case, which allows the integrated strip monopole and shielding metal case to be easily concealed inside the casing of a mobile device as an internal element. In addition, the internal strip monopole can generate an operating bandwidth covering the UMTS band. The system ground plane is chosen to have a size of 70 × 100 mm², which is a reasonable size for the system or main ground plane of a practical PDA phone.

The low-profile T-shape strip monopole comprises a top horizontal strip of length 45 mm and width 5 mm, a central vertical strip of length 2.5 mm and width 2.5 mm, and an inverted-L shorting strip of length about 6 mm and constant width 1 mm. Note that the width of the top horizontal strip is set to 5 mm, which is the same as the height of the RF shielding metal case in this design example. The top horizontal strip is also parallel to the top-side surface of the shielding metal case and is connected to the central vertical strip to form a symmetric T shape. Also note that the top horizontal strip is arranged to be perpendicular to the central vertical strip such that a compact and low-profile internal strip monopole antenna for the mobile device is obtained.

For testing the antenna in the experiment, a 50Ω mini coaxial line is used. The central conductor and outer grounding sheath of the coaxial line are connected to point A (the feeding point) at the open end of the central vertical strip and at about the center of the top edge of the shielding metal case, respectively. Also, one end (point B, the shorting point) of the inverted-L shorting strip is connected to the shielding metal case such that the strip monopole is integrated to the shielding metal case. In addition, this short-circuiting can provide additional inductance to compensate for the...
large capacitive coupling arising between the monopole’s top horizontal strip and the shielding metal case. Improved impedance matching for the integrated strip monopole is thus obtained.

The shielding metal case has a height of 5 mm, length $L$, and width $W$. Since the shielding metal case is integrated to the T-shape strip monopole, it may have some effects on the performances of the strip monopole. To analyze the effects, the impedance matching of the strip monopole as functions of $L$ and $W$ is studied, as described in section 3 below. In addition, the distance $d$ of the shielding metal case to the side edge of the system ground plane may also be a factor affecting the impedance matching of the strip monopole. Its detailed effects will also be analyzed in the next section.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The proposed integration design of the internal monopole antenna and shielding metal case shown in Figure 1 was constructed and tested. Figure 2 shows the measured and simulated return loss of the constructed prototype. The simulated results are obtained using the Ansoft simulation software High-Frequency structure simulator (HFSS) [5] and agree with the measured data. It is seen that for frequencies over the UMTS band, the measured impedance matching is better than about 7.3 dB (2.5:1 VSWR), which is widely accepted and generally adopted as the internal-antenna design requirement for practical mobile-phone applications. If better impedance matching is further desired (such as 9.6-dB return loss or 2:1 VSWR), a larger spacing than that (3.5 mm) used here between the top horizontal strip and the shielding metal case is usually required. In this case, the strip monopole will become less promising to be concealed inside the casing of the mobile device.

Figure 3 plots the measured radiation patterns for the constructed prototype at 2045 MHz. The radiation patterns at other operating frequencies across the bandwidth were also measured, and radiation patterns similar to those plotted here were observed. Figure 4 presents the measured peak antenna gain. An antenna-gain level of about 4.2 dBi is seen for frequencies across the UMTS band.

To analyze the effects of the shielding metal case on the impedance matching of the integrated strip monopole, a simulation study using the Ansoft simulation software HFSS was conducted. The cases of the shielding metal case having various dimensions ($L$ and $W$) and mounted at various locations with distance $d$ to the side edge of the system ground plane were studied. Figure 5 shows the simulated return loss as a function of the length $L$ of the shielding metal case. The results clearly show that almost no variations in the simulated return loss for $L$ varied from 20 to 40 mm are seen.

On the other hand, as observed in Figures 6 and 7, the impedance matching is affected with a variation in the width $W$ and the location $d$ of the shielding metal case on the system ground plane. For the case studied in Figure 6, this is largely because the coupling between the strip monopole and the shielding metal case is varied, which introduces a variation in the input reactance of the antenna. The obtained impedance bandwidth is also seen to increase with a decrease in the width $W$. As for the case studied in

Figure 5. Simulated return loss as a function of $L$ ($W = 45$ mm, $d = 12.5$ mm). Other parameters are the same as given in Fig. 1

Figure 6. Simulated return loss as a function of $W$ ($L = 30$ mm, $d = 12.5$ mm). Other parameters are the same as given in Fig. 1

Figure 7. Simulated return loss as a function of $d$ ($L = 30$ mm, $W = 45$ mm). Other parameters are the same as given in Fig. 1
Figure 7, moving the integrated strip monopole and the shielding metal case along the top edge of the system ground plane is expected to result in a variation in the coupling between the strip monopole and the system ground plane. This variation in turn affects the impedance matching of the strip monopole, and it is seen that the obtained impedance bandwidth is larger for a smaller value of $d$. That is, when the shielding metal case is flush with the side edge of the system ground plane, a maximum impedance bandwidth can be achieved. Also note that for $d$ varied from 12.5 to 25 mm, the obtained results are the same as shown here due to the symmetric structure of the T-shape strip monopole, and thus the results are not shown here for brevity.

4. CONCLUSION

A novel design of an integrated low-profile T-shape strip monopole for UMTS internal antenna in a mobile device has been proposed. The low-profile strip monopole was short-circuited to the RF shielding metal case to form an integrated element, which can lead to a compact arrangement of the internal monopole antenna and associated nearby RF module and components in a mobile device. Good impedance and radiation characteristics of the integrated strip monopole over the UMTS band have been observed, and the effects of the shielding metal case on the performances of the integrated strip monopole have also been analyzed.

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ANTENNA-COUPLED INFRARED FOCAL PLANE ARRAY

F. J. González, J. L. Porter, and G. D. Boreman

1 Instituto de Investigación en Comunicación Óptica Universidad Autónoma de San Luis Potosí Álvaro Obregón 64 San Luis Potosí, SLP, México
2 Raytheon Missile Systems 1151 East Hermans Road Tucson, AZ, 85706
3 UCF–College of Optics & Photonics 4000 Central Florida Blvd. Orlando, FL, 32816

Received 18 July 2005

ABSTRACT: Uncooled bolometric detectors used in infrared-imaging systems have slow time constants (≈15 ms), which makes them impractical for fast-frame-rate applications. Antenna-coupled microbolometers are fast uncooled detectors with good sensitivity and directivity, and they can be polarization and wavelength selective. These detectors have collection areas in the order of 10 μm², which are too small for infrared imaging systems where a typical pixel area ranges from 20 × 20 μm² to 50 × 50 μm². To solve this problem, 2D arrays of antenna-coupled detectors, which can be used as pixels in infrared-imaging systems, are fabricated. In this paper, antenna-coupled pixels are fabricated on a commercial readout integrated circuit (ROIC), resulting in the first antenna-coupled infrared focal plane array (IR-FPA). Measurements made on this antenna-coupled infrared focal plane array show that the integration of antenna-coupled detectors to a commercial ROIC is possible. © 2005 Wiley Periodicals, Inc. Microwave Opt Technoll Lett 48: 165–166, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21294

Key words: IRFPA; focal plane array; antenna-coupled detectors; microbolometers; ROIC

1. INTRODUCTION

Bolometers are resistive elements constructed from materials with a high-temperature coefficient of resistance (TCR) so that a small amount of absorbed radiation will produce a large change in resistance. These bolometers are operated by passing a bias current through them and monitoring the voltage across them, a change in the output voltage will reflect changes in resistance [1].

The size of bolometers used in commercial infrared imaging systems is around 50 × 50 μm², which is the size of a typical pixel area. A bolometer of this size will have a time constant of around 15 ms, which is slow for certain applications [2]. By reducing the size of a bolometer, a lower amount of energy will be needed to increase its temperature, which will result in more sensitive detectors [3]. A smaller bolometer will also have a smaller time constant that can be useful for high frame-rate applications. The problem of reducing the size of a bolometer is that less energy gets collected, since bolometers use their physical size to collect radiation. A way to increase the collection area of a small bolometer is to couple an antenna designed to resonate at the desired wavelength; hence, we can have fast detectors without sacrificing collection area [3].

Different types of antennas have been coupled to sub-micron-sized bolometers and their performance has been tested [4]. These antennas have collection areas in the order of 10 μm², which is too small for infrared imaging systems since current readout integrated circuits (ROICs) have typical pitch sizes of 20 × 20 μm² to 50 × 50 μm². In order to solve this problem, 2D arrays of antenna-coupled detectors have been fabricated to cover a whole pixel area [5]. In this paper, 2D arrays of antenna-coupled detectors have been fabricated on a commercial ROIC, resulting in the first antenna-coupled infrared focal plane array (IR-FPA).

2. METHOD

Commercial ROICs were provided by Raytheon to integrate antenna-coupled pixels monolithically onto them and make an antenna-coupled IR-FPA. The ROICs provided had a 1.2-μm layer of SiO₂ and a 500-nm layer of Si₃N₄ as passivation layers. In order to avoid a high step profile between the detectors and the ROIC, this passivation layer was thinned down to 250 nm using CF₄-based reactive-ion etching (RIE). A CAD file in GDSII format for the top metal layer of the ROIC was also provided by Raytheon. Using this file, the exact coordinates of distinctive features on the ROIC (that is, letters, numbers or previous alignment marks) can be located in order to align to those features during the e-beam patterning process. Global and local alignment marks were then aligned to existing structures on the ROIC and placed using e-beam lithography and liftoff.

Openings on the passivation layer were made to uncover the ROICs contact pads by using CF₄-based RIE, the contact-pad