minimal. Therefore, NF penalty is observed for large-signal power because the TBFs introduce losses in the system.

CONCLUSION
We have constructed a new EDFA configuration, namely, a dual-stage double-pass (DSDP) amplifier with bandpass filters. The experimental results show gain improvement in the small-signal range as compared to the DSDP amplifier configuration without filters. The highest gain of 52 dB is achieved at −50-dBm signal power with 90-mW pump power (180-mW total powers). This value corresponds to 18-dB gain improvement as compared to 34 dB of gain obtained with the same amplifier configuration without filters. There is no significant noise-figure penalty in the small-signal range, suggesting that the proposed configuration is suitable for high-gain (preamplifier) applications.

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INTERNAL COMPOSITE MONOPOLE ANTENNA FOR WLAN/WiMAX OPERATION IN A LAPTOP COMPUTER

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ABSTRACT: A novel composite monopole antenna suitable for 2.4/5.2/5.8-GHz wireless local area network (WLAN) and 2.5/3.5/5-GHz worldwide interoperability for microwave access (WiMAX) operation is presented. The composite monopole antenna comprises a ceramic chip radiating element as arm 1 of the antenna and a printed radiating element as arms 2 and 3 of the antenna. The three arms effectively control three excited wide resonant modes for WLAN/WiMAX operation, and the total area occupied by the composite monopole antenna is 8 × 19.5 mm² only, which is much smaller than that of a corresponding printed monopole antenna. Due to the compact area occupied, the proposed antenna is promising to be embedded within the narrow spacing between the casing of the laptop computer and the supporting metal frame of the display as an internal antenna. © 2006 Wiley Periodicals, Inc.
pole antenna (see arm 1 in Fig. 2) for generating the same resonant mode centered at about 2.5 GHz. This reduction in the antenna size is due to the internal helical metal pattern of the ceramic chip radiating element.

The printed radiating element mainly comprises arm 2, arm 3, and a central strip, all of which are printed on an 0.8-mm-thick FR4 substrate. Arms 2 and 3 are both arranged to be horizontal and connected to the vertical central strip for generating the second and third resonant modes, respectively. The second resonant mode is designed to be centered at about 3.5 GHz so as to cover the 2.4-/5.8-GHz WLAN and 5.2-/5.8-GHz WiMAX bands. The third resonant mode is designed to be centered at about 5.5 GHz so as to cover the 5-GHz WiMAX band. The second resonant mode is designed to be centered at about 2.5 GHz, 3.5 GHz, and 5.5 GHz with wide impedance bandwidths, which are effectively controlled by arms 1, 2, and 3 in the proposed antenna. The lowest resonant mode has a 10-dB return-loss impedance bandwidth of 347 MHz (2371–2718 MHz), which covers the 2.4-GHz WLAN and 2.5-GHz WiMAX bands and is mainly controlled by arm 1 of the antenna. The third resonant mode shows an impedance bandwidth of 841 MHz (5051–5892 MHz), which satisfies the required bandwidths of the 5.2-/5.8-GHz WLAN and 5-GHz WiMAX bands.

With the proposed arrangement of using both of the ceramic chip and printed elements as the major radiating portions, the composite monopole antenna studied here occupies a compact area of $8 \times 19.5$ mm$^2$ only, which is much smaller than that of a corresponding printed monopole antenna shown in Figure 2. Also note that for testing, the proposed antenna in the experiment, a 50$\Omega$ mini coaxial line was used across a feed gap of 0.5 mm, with its central conductor connected to point A (the feeding point) and its outer grounding sheath connected to point B (the grounding point).

3. EXPERIMENTAL RESULTS AND DISCUSSION

Based on the design dimensions shown in Figure 1, the proposed composite monopole antenna was constructed and studied. Figure 3 shows the measured and simulated return loss of the constructed prototype. The simulated results are obtained using Ansoft simulation software High-Frequency Structure Simulator (HFSS) [13], and agreement between the simulation and measurement is obtained. There are three resonant modes excited at about 2.5, 3.5, and 5.5 GHz with wide impedance bandwidths, which are effectively controlled by arms 1, 2, and 3 in the proposed antenna. The lowest resonant mode has a 10-dB return-loss impedance bandwidth of 347 MHz (2371–2718 MHz), which covers the 2.4-GHz WLAN and 2.5-GHz WiMAX bands and is mainly controlled by arm 1 of the antenna. The second resonant mode has an impedance bandwidth of 600 MHz (3192–3792 MHz), which covers the 3.5-GHz WiMAX band and is controlled by arm 2 of the antenna. The third resonant mode shows an impedance bandwidth of 841 MHz (5051–5892 MHz), which satisfies the required bandwidths of the 5.2-/5.8-GHz WLAN and 5-GHz WiMAX bands and is effectively controlled by arm 3 of the antenna.

Figure 4 shows a comparison of the measured return loss of the proposed composite monopole antenna and the corresponding printed monopole antenna (the reference antenna). The major difference of the proposed and reference antennas involves arm 1. In the proposed antenna, arm 1 is mainly formed by a ceramic-chip radiating element, while that for the reference antenna is formed by a relatively much longer printed radiating strip. In this case, the lowest or first resonant mode of the proposed and reference antennas is about the same (see Fig. 4). This confirms the compact size of the proposed composite monopole antenna, as compared to the conventional printed monopole antenna, for the desired WLAN/WiMAX operation in this study. However, it is also noted that the reference antenna shows no excited resonant modes at about 3.5 and 5.5 GHz for the desired WiMAX and WLAN operation. This behavior is largely due to the degrading coupling of arm 1 to arms 2 and 3 in the reference antenna, leading to poor impedance matching for frequencies in the desired 3.5- and 5.5-GHz resonant modes.

Radiation characteristics of the constructed prototype were also studied. Figures 5, 6, and 7 plot the measured radiation patterns at 2500, 3500, and 5500 MHz, respectively. In the azimuthal plane ($x$--$y$ plane), near-omnidirectional radiation patterns for the $E_\theta$...
component (vertical polarization) are obtained. In addition, it is observed that the amplitude of the $E_{\phi}$ component (horizontal polarization) is comparable to those of $E_{\theta}$ component. This radiation characteristic is advantageous, because the wave propagation environment is usually complex for WLAN/WiMAX operation in practical applications. Also note that the radiation characteristics at other frequencies over the impedance bandwidth of the antenna were also investigated. The measured results show radiation patterns similar to those plotted here. That is, stable radiation patterns are obtained for the proposed antenna. Figure 8 presents the measured and simulated peak antenna gain versus frequency. Agreement between the measured and simulated results is observed and good antenna gain is obtained. For the first resonant mode of the antenna, the measured antenna gain is in the range of about 2.2–3.1 dBi [see Fig. 8(a)]. For the second resonant mode, as shown in Figure 8(b), the measured antenna gain ranges from about 3.2 to 3.7 dBi. For the third resonant mode, as shown in Figure 8(c), the measured antenna gain is about 4.6–5.3 dBi.

4. CONCLUSION
A novel composite monopole antenna for application as an internal laptop computer antenna for WLAN/WiMAX operation has been proposed and experimentally studied. With the use of a ceramic-chip radiating element in the proposed composite monopole antenna, a reduced-size internal laptop computer antenna has been achieved, as compared to the conventional printed monopole antenna. In addition, three wide operating bands centered at about 2.5, 3.5, and 5.5 GHz have been obtained, which easily covers 2.4/5.2/5.8 GHz-WLAN and 2.5/3.5/5 GHz WiMAX operation.
For frequencies over the three operating bands, good radiation characteristics have also been obtained for the proposed composite monopole antenna.

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A WIDEBAND PRINTED MONOPOLE ANTENNA FOR 2.4-GHz WLAN APPLICATIONS

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ABSTRACT: A planar monopole antenna suitable for broadband wireless communication is designed and developed. With the use of a truncated ground plane, the proposed printed monopole antenna offers nearly 60% 2:1 VSWR bandwidth and good radiation characteristics for the frequencies across the operating band. A parametric study of the antenna is performed based on the optimized design, and a prototype of the antenna suitable for 2.4-GHz WLAN application is presented. The antenna can be easily integrated into wireless circuitry and is convenient for application in laptop computers. © 2006 Wiley Periodicals, Inc. Microwave Opt Technol Lett 48: 871–873, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21503

Key words: monopole antenna; wide band; WLAN antenna

1. INTRODUCTION
The rapid development of new multimedia communications demands the need of wideband or multiband antennas. The imperative need of low-profile, compact, and wideband antennas has attracted the attention of antenna researchers. Printed monopole antennas are very suitable to be integrated into system circuit board of communication device due to their attractive features of small volume and low fabrication cost. Several