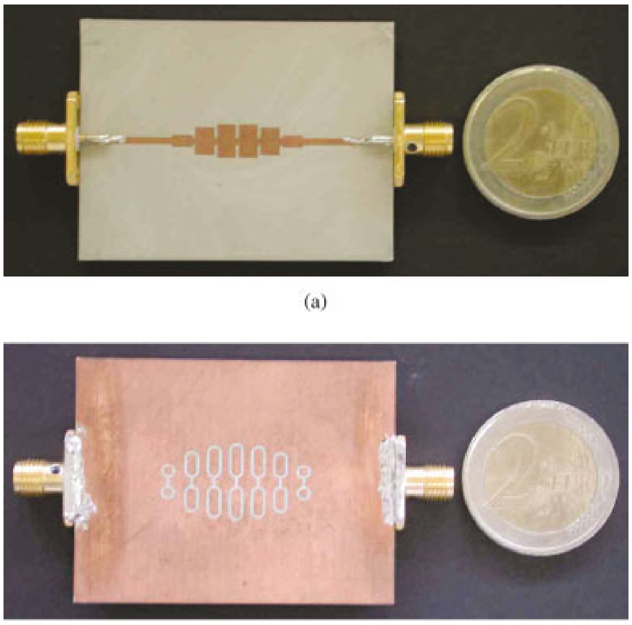

(a)

(b)

Figure 9 Fabricated DGS Chebyshev low-pass 7th-order filter and 0.1-dB ripple. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

4. CONCLUSIONS

In this paper, a simple method to implement low-pass filters by modifying both sides of the microstrip guiding structure has been presented. The method is based on the modeling of DGSs used as series inductances at lower frequencies by changing basically the outer perimeter of each particular defect.

The obtained filters are highly competitive with other filters, shortening the length keeping the electromagnetic features in the pass and rejected bands.

Two low-pass filters have been designed, fabricated, and measured and good performance is shown.

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TRIPLE-BAND TRIANGULAR-SHAPED MEANDER MONOPOLE ANTENNA WITH TWO COUPLED LINES

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ABSTRACT: *A novel compact monopole antenna for triple-band operation is proposed in this paper. The proposed antenna is designed to operate at 900, 1800, and 2450 MHz, and is realized by loading two coupled lines on a triangular-shaped meander line. The longer coupled line controls the excitations of the first two resonant modes, and the shorter one controls the excitation of the third resonant mode. Good impedance bandwidth performance for the three bands is observed.*

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Key words: *monopole antenna; triple-band operation*

1. INTRODUCTION

Due to the rapid development and widespread usage of cellular communications, many dual-band antennas for applications in GSM (900-MHz band) and DCS (1800-MHz band) systems have been implemented and widely used in practical designs [1–2]. Recently, the wireless Bluetooth (2450-MHz band) technique, which can be employed to provide wireless connection between cellular phones and other electronic devices such as cellular phones, computers, etc. [3], has been generating much interest. With the introduction of the Bluetooth applications, future mobile communication devices will be required to provide the dual services of cellular and Bluetooth wireless communication. As a result, a need exists for a single antenna unit capable of operating in three separate frequency bands, especially at 900, 1800, and 2450 MHz. However, only a limited number of methods for obtaining such applications are available in the literature [4–6]. The designs shown in [4–6] all use the planar inverted-F antenna (PIFA) to achieve the desired triple-band operation. Although these antennas are compact in size, their main drawback is their narrow bandwidth, which makes them unsuitable for practical applications.

In this paper, a novel design method using a microstripline-fed monopole antenna for obtaining 900-, 1800-, and 2450-MHz triple-band operation is proposed. The proposed antenna consists of a triangular-shaped meander line and two coupled lines. By selecting the lengths of the two coupled lines and the spacings between the coupled lines and the triangular-shaped meander line, the antenna can be tuned to operate at the desired three operating frequencies with good impedance matching. Also, due to the presence of the longer coupled line in the proposed design, the antenna is small. Details of the antenna design are described, and experimental results are presented and discussed.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed triple-band triangular-shaped meander monopole antenna with two coupled lines. The antenna has compact dimensions 28×20.5 mm^2 and is fabricated on an inexpensive FR4 substrate with thickness of 1.6 mm and dielectric constant of 4.4. A 50Ω microstrip line is used to feed this antenna. The finite ground plane is selected to be 30×60 mm^2 in

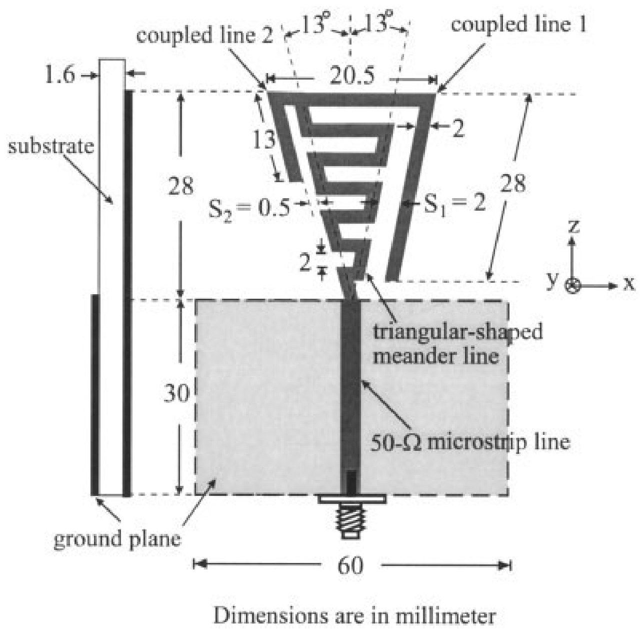

Figure 1 Geometry and dimensions of the triple-band triangular-shaped meander monopole antenna with two coupled lines

the experiment, and is printed in the back of the substrate. The basis structure of the radiating element is a triangular-shaped meander line, which has seven horizontal sections with a 13° angle connection and a spacing of 2 mm between two adjacent sections. Note that a triangular-shaped meander line is only suitable for single-band operation. For achieving the triple-band operation studied here, two coupled lines with different lengths are introduced and placed in parallel to two sides of the triangular-shaped meander line. The two coupled lines and the triangular-shaped meander line have the same conductor width of 2 mm.

There are two resonant paths in the proposed design: paths 1 and 2. Path 1, formed by the longer coupled line (coupled line 1) and the triangular-shaped meander line, generates the first two resonant modes of the proposed antenna. Here, the coupled line 1 increases the current path of the antenna's first resonant mode, which reduces the required size of the proposed antenna for a fixed operating frequency. On the other hand, path 2, formed by the shorter coupled line (coupled line 2) and the triangular-shaped

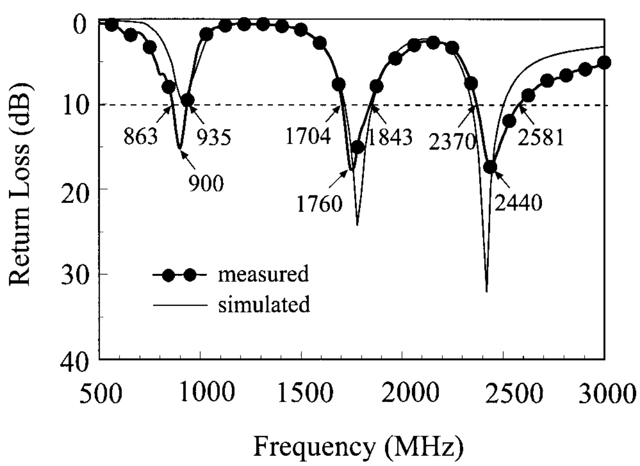

Figure 2 Measured and simulated return loss for the proposed antenna

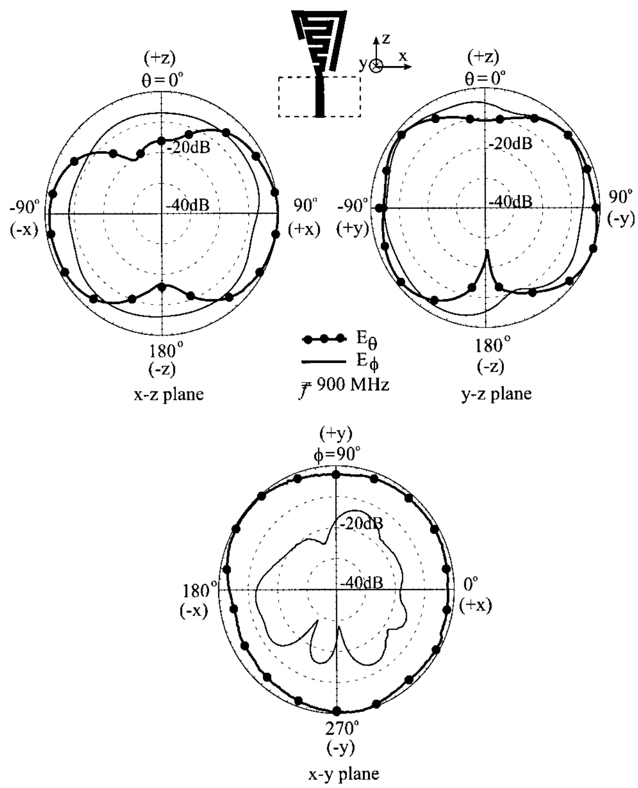

Figure 3 Measured radiation patterns at 900 MHz for the proposed antenna

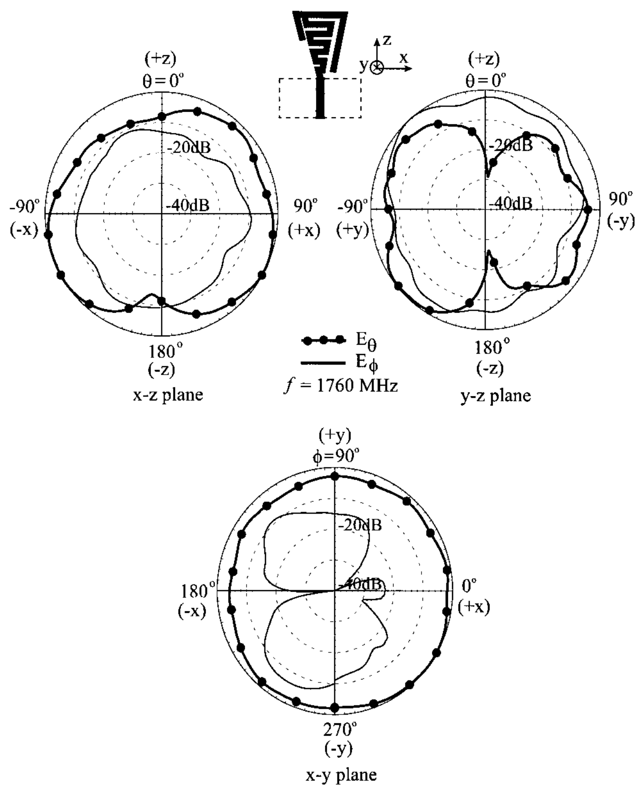

Figure 4 Measured radiation patterns at 1760 MHz for the proposed antenna

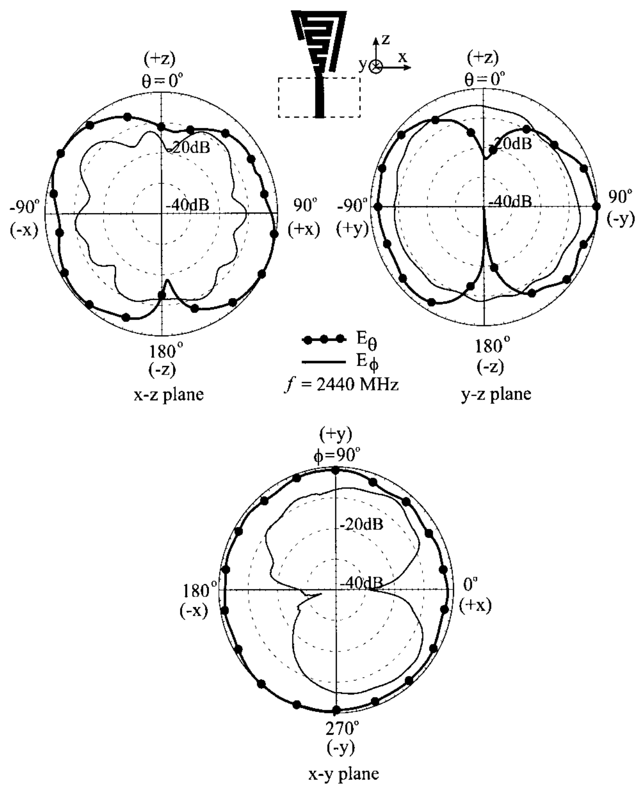

Figure 5 Measured radiation patterns at 2440 MHz for the proposed antenna

meander line, generates the third resonant mode. The capability of the impedance matching to a 50Ω microstrip line for the three resonant modes is considered first. The spacings (S_1 and S_2) between the two coupled lines and the triangular-shaped meander line are selected to be small, thus the two coupled lines are effectively electromagnetically coupled with the triangular-shaped meander line, which leads to the three resonant modes excited with good impedance matching. In this design, the spacing S_1 (or S_2) is less than approx. 4 mm. When the spacing S_1 (or S_2) is greater than 4 mm, it is difficult to obtain good impedance matching for the first two (or the third) resonant modes.

A simple design procedure is applied to achieve the triple-band antenna operating at three desired frequencies. First, by adjusting the length of the coupled line 1, the first resonant frequency can easily be tuned to operate at about 900 MHz. Next, by selecting the spacing of S_1 in the range of 0.5 mm to 4 mm, only the second resonant frequency is affected and the first resonant frequency remains almost invariant, which indicates the tunability of the first two resonant frequencies. In this study, the spacing $S_1 = 2$ mm is chosen in order to fine-tune the monopole's second resonant frequency to around 1800 MHz. As for the third resonant frequency (2450 MHz in this design), adjusting this resonant frequency to be the desired one can be easily achieved by tuning the length of the coupled line 2 with the spacing $S_2 = 0.5$ mm fixed. With the method mentioned above and using the design dimensions given in Figure 1, a prototype was constructed and studied. Results are shown in the following section.

3. EXPERIMENTAL RESULTS

The measured and simulated return losses of the constructed prototype are shown in Figure 2. The simulated return loss is obtained from IE3D™ simulation software. Reasonable agreement between the measurement data and the simulated result is observed. It is also seen that three distinct resonance modes at 900, 1760, and 2440 MHz are excited with good impedance matching. The impedance bandwidths, determined from the 10-dB return loss, are about 72 MHz (about 8%) for the 900-MHz band and 139 MHz (about 7.9%) for the 1800-MHz band, which are very close to the required bandwidths of the GSM and DCS systems, respectively. On the other hand, the 2450-MHz band has a bandwidth as large as 211 MHz (about 8.6%) and covers the Bluetooth frequency band. Note that the obtained bandwidths for the three operating bands are also greater than those presented in [4–6].

Figures 3 to 5 plot the measured radiation patterns in the $x - y$ plane, $y - z$ plane, and $x - z$ plane at 900, 1760, and 2440 MHz, respectively. Measurements at other operating frequencies in the above three bands have similar radiation patterns, as shown in Figures 3–5. For the 900-MHz and 2440-MHz cases, monopole-like radiation patterns are observed and good omnidirectional radiations in the $x - y$ planes are seen. For the 1760-MHz case, the $x - y$ plane pattern is also approximately omnidirectional radiation. The antenna gain for the frequencies within the operating bandwidths was also measured. The peak antenna gains are about −0.2 dBi, 1.1 dBi, and 0.8 dBi in the 900, 1800, and 2450-MHz bands, respectively.

3. CONCLUSIONS

Using a triangular-shaped meander line and two coupled lines, a novel compact monopole antenna suitable for triple-band operation at 900, 1800, and 2450 MHz has been proposed. A prototype of the proposed antenna has been successfully implemented, and the antenna occupies a small area of 28 × 20.5 mm^2. The obtained bandwidths almost cover the required bandwidths of the GSM, DCS, and Bluetooth systems. Good radiation characteristics for frequencies within the operating bands have also been obtained.

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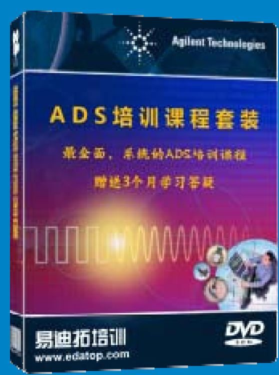

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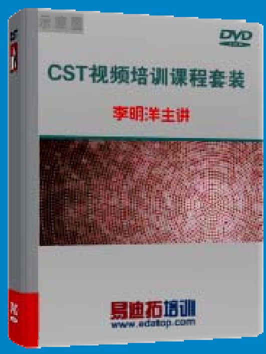

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