China under contract numbers NSC 96–2752-E-009–001-PAE, NSC 95–2221-E-009–043-MY3, by the Ministry of Economic Affairs of Taiwan under contract number 96-EC-17-A-05-S1–020, and by MoE ATU Program under contract number 95W803.

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A COMPACT SPIRAL STRIPLINE-LOADED MONOPOLE ANTENNA WITH A VERTICAL GROUND PLANE

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Received 9 June 2007

ABSTRACT: *In this letter, we propose a compact spiral stripline-loaded monopole antenna on a vertical ground plane. The measured results show that the antenna has a fractional bandwidth of 12.1% for a voltage standing wave ratio (VSWR) less than 2 at the center frequency of 1.10 GHz, as well as a good omni-directional radiation pattern. The small size of 0.04 $\lambda_o \times 0.04\ \lambda_o \times 0.04\ \lambda_o$ makes it promising for use as an internal antenna in mobile handsets.* © 2007 Wiley Periodicals, Inc.

Microwave Opt Technol Lett 50: 250–252, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23043

Key words: *small antenna; spiral stripline-loaded monopole antenna; disk-loaded monopole antenna; electromagnetically coupled feed*

1. INTRODUCTION

Increasing consumer demand for small handheld transceiver units has spurred the rapid development of compact and broadband antennas [1]. Many antenna structures have been proposed for this application, such as a compact helical antenna using the normal-mode of two helix wires [2], a disk-loaded monopole antenna

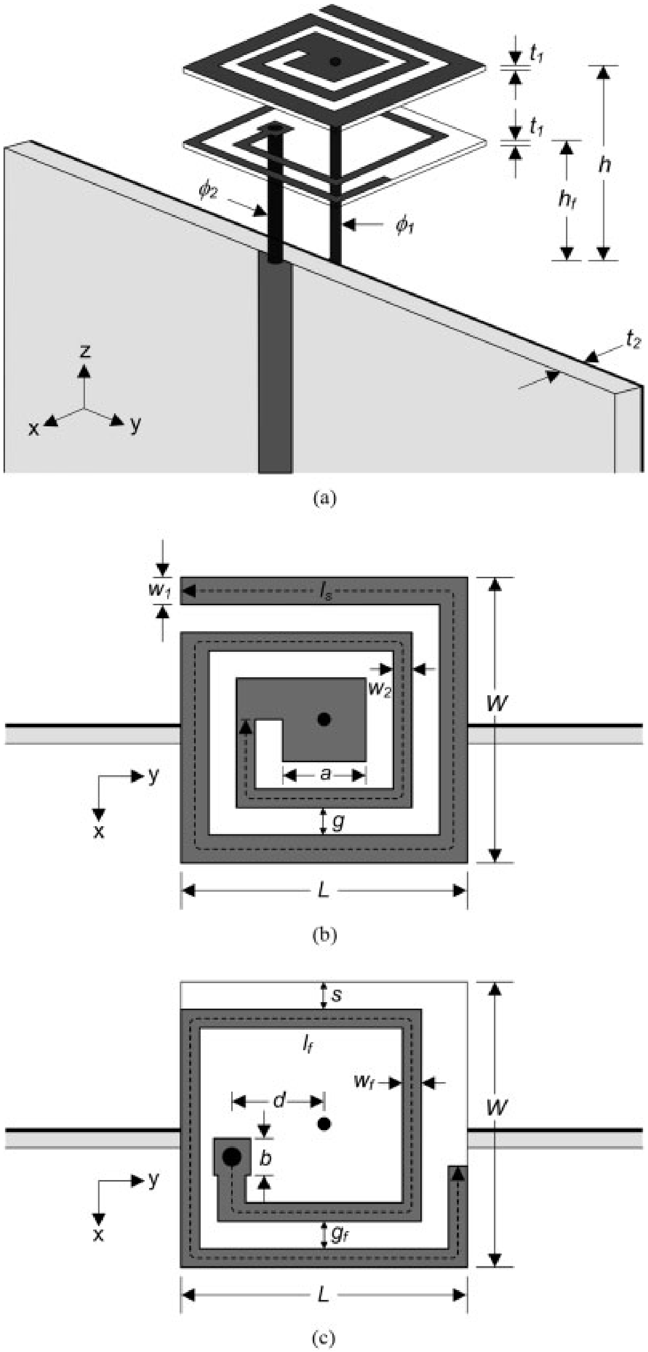

Figure 1 Antenna structure: (a) 3-dimensional view, (b) top view of the upper spiral stripline, (c) top view of the lower spiral stripline

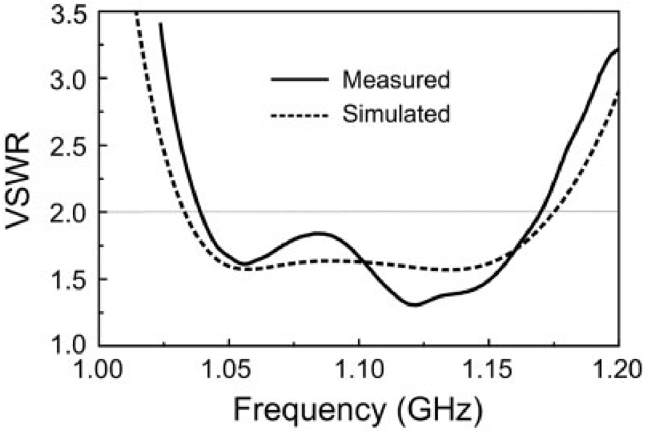

Figure 2 VSWR of the antenna

using parallel stripline elements [3], and a planar inverted F antenna with various feeding structures [4]. While these antennas have good antenna characteristics, however, their large size makes them difficult for use as internal antennas.

It is well-known that the resonance frequency of an antenna for a given size can be effectively reduced by maximizing the current path on the conductor in the antenna. A spiral-shaped conductor is a good candidate to obtain such characteristic [5]. In addition, it has shown that the bandwidth of an antenna can be improved by using mutual coupling between two radiators located in very close proximity [6]. In this letter, we present a small spiral stripline-loaded monopole antenna that uses these techniques to achieve significant size reduction, while maintaining relatively large bandwidth. The proposed antenna is constructed on a vertical ground plane. It consists of a shorting post with a rectangular spiral stripline, and a probe with a rectangular spiral stripline. The antenna with an electrical dimensions of only $0.04\ \lambda_0 \times 0.04\ \lambda_0 \times 0.04\ \lambda_0$ has 134 MHz of the impedance bandwidth for a voltage standing wave ratio (VSWR) less than 2 with the center frequency of 1.10 GHz, which is ~12.1% of the fractional bandwidth.

2. ANTENNA GEOMETRY AND RESULTS

The geometry of the proposed antenna is shown in Figure 1. The antenna consists of two spiral stripline-loaded monopoles. Each spiral stripline is etched on a 12×12 mm^2 substrate with a dielectric constant of $\varepsilon_{r1} = 3.38$ and a thickness of $t_1 = 0.203$ mm. The upper spiral stripline is located at a height $h = 12$ mm from the top edge of the ground plane. It is connected to the ground plane with a shorting pin that has diameter $\phi_1 = 0.7$ mm. The outer and inner line widths of the upper spiral are $w_1 = 1.2$ mm and $w_2 = 0.9$ mm, respectively, and the length of the upper spiral stripline is $l_s = 73.9$ mm. The gap between the upper spiral striplines is $g = 1.1$ mm. The antenna is excited with a 50 Ω microstrip line through a probe pin with a diameter of $\phi_2 = 1.0$ mm that is connected at the end of the lower spiral stripline located at a height $h_f = 9.1$ mm from the top edge of the ground plane. The length and width of the lower spiral stripline are $l_f = 61.3$ mm and $w_f = 0.8$, respectively. Other design parameters for lower spiral stripline are $g_f = 1.1$ mm and $s = 1.1$ mm. The square patches at the ends of the upper and lower spiral striplines have sizes of $a = 3.4$ mm and $b = 1.4$ mm, respectively. The shorting pin and probe pin are separated by distance $d = 4.1$ mm. The antenna is constructed on a 40×55 mm^2 vertical ground plane, the substrate of which has a dielectric constant of $\varepsilon_{r2} = 3.38$ and a thickness of $t_2 = 0.508$ mm.

Before the antenna is fabricated, the CST Microwave Studio full-wave electromagnetic simulator was used to predict the frequency response of the antenna. It was found that the shorting pin with the upper spiral stripline monopole provides the lower resonance frequency, while the probe pin with the lower spiral stripline monopole provides the higher resonance frequency. The impedance variation of the antenna can be made small over a wide frequency range by controlling the resonance frequencies of these monopoles. The performance of the antenna was measured by using an Agilent E5071B network analyzer. Figure 2 shows that the measured VSWR is close to the simulated one. A measured impedance bandwidth of 134 MHz (1.036 ~ 1.17 GHz) is obtained for a VSWR <2. This is a fractional bandwidth of ~12.1% for the centre frequency of 1.1 GHz. The co-polarized and cross-polarized components of the electric field plotted in Figure 3 show a good

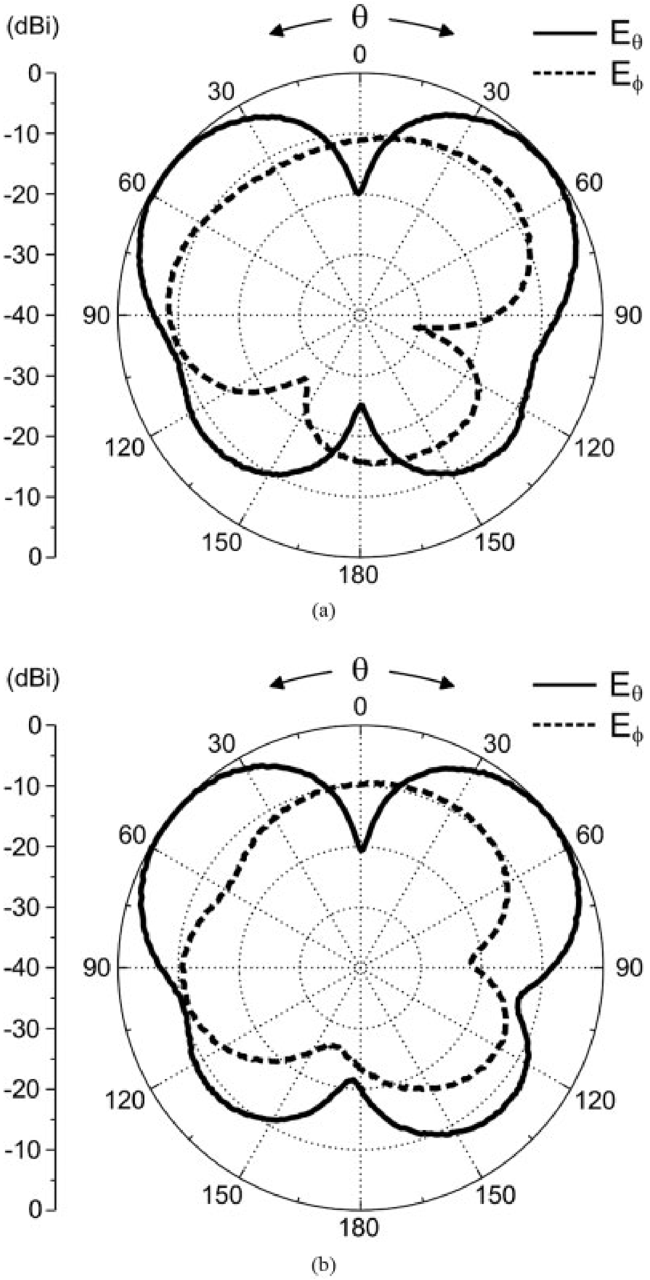

Figure 3 Measured antenna radiation patterns at 1.1 GHz: (a) *x-z* plane, (b) *y-z* plane

omni-directional radiation pattern. The measured gain of the antenna is -0.1 dBi with the maximum value at about $\theta = 50^\circ$.

3. CONCLUSION

A small broadband monopole antenna that uses two spiral striplines has been presented. A significant size reducing is achieved by maximizing the current path on the loaded element using a spiral-shaped conductor. The antenna with an electrical dimensions of $0.04\ \lambda_0 \times 0.04\ \lambda_0 \times 0.04\ \lambda_0$ has a bandwidth of 12.1% for VSWR <2 at the center frequency of 1.10 GHz. The antenna has a good omni-directional radiation pattern.

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RECONFIGURABLE MICROSTRIP RECTANGULAR LOOP ANTENNAS USING RF MEMS SWITCHES

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Received 9 June 2007

ABSTRACT: *In this article, a low-actuation voltage DC contact RF MEMS switch is developed for a reconfigurable microstrip rectangular loop antenna implementation providing frequency tunability. Electromechanical design optimization, microfabrication through the PolyMUMPS commercial process, and RF simulation is presented. The application of such RF MEMS switches to frequency-tunable reconfigurable microstrip loop antennas is subsequently investigated by electromagnetic full wave analysis simulation tool. The physical perimeter of the loop antenna is electronically varied by controlling the ON/OFF states of the MEMS switches. The resonance frequency of the microstrip loop antenna is shown to be reconfigurable linearly by 56% with the linear change of the physical perimeter while the radiation pattern is almost invariant.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 252–256, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23042

Key words: *reconfigurable; microstrip loop antenna; RF MEMS switches; frequency tunable*

1. INTRODUCTION

Rapid developments in the wireless communication industry continue to drive the requirements for small, compatible, and affordable reconfigurable antennas and antenna arrays. Multielement antenna arrays are employed in today's communication systems to achieve adaptive beams by employing switches that can switch between the desired radiating elements [1]. Therefore, electronic switching assumes a critical position in ensuring receiver performance and reconfigurability for beam shaping and beam steering [2]. Further, frequency tunability in an antenna is an important feature that enables its use for a range of frequencies [3].

In reconfigurable antennas, RF MEMS switches have demonstrated unique advantages [4]. RF MEMS (Micro-Electro-Mechanical-Systems) form a rapidly growing segment of the MEMS industry which is based on integrating mechanical elements, sensors, actuators, and electronics on a common silicon substrate through microfabrication. The microfabrication process normally involves a lithography-based micromachining, fabricated on batch basis, which offers great advantages of high precision with low cost when manufacturing in large volume.

MEMS technology offers highly integrated systems with low cost. As a result, it continues to gain significant attention for fabricating integrating RF circuits for wireless and personal portable electronic applications. Switches fabricated by MEMS technology (i.e. RF MEMS switches) have displayed numerous advantages [1, 4, 5]. Excellent switching characteristics such as very low insertion loss (0.1–0.2 dB) when signal is passed (switch is ON) and high isolation (25–35 dB) when signal is rejected (switch is OFF) over an extremely wide band (DC to 40 GHz) make RF MEMS switches attractive for use in multi-element antenna systems [6]. Further, the low-loss nature of MEMS switches can eliminate the need for power amplifiers behind antenna elements, which is inevitable when P-I-N diode or FETs are used as switching components, making the overall system cheaper and more robust. In addition, zero power consumption, small size and low weight of RF MEMS switches also enable a longer battery life.

From the antenna side, microstrip antennas are well known for their features such as low profile, light weight, low cost, conformability to planar and nonplanar surfaces, rigid, and easy installation [7]. They are most commonly incorporated into mobile communications devices because of low cost and versatile designs. For some time now, the alteration of the radiating configuration of such antennas through electronic means has been of significant interest in the antenna community [7]. For simpler wire type resonant antennas this can be achieved by adjusting the length of the antenna. For low-power applications, MEMS switches are used to connect antenna segments to make antennas 'reconfigurable. ' RF MEMS switches have been successfully demonstrated to enable this reconfigurability in antenna design [7-9].

In this article, we consider DC contact RF MEMS switches for reconfigurable antenna applications with an added advantage of frequency tunability. DC contact switches (metal-to-metal) typically provide very low contact resistance and hence high isolation

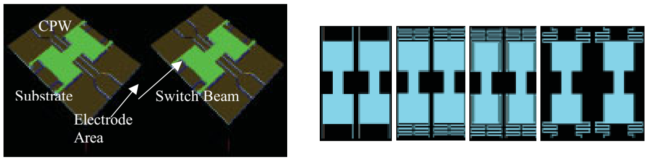

Figure 1 Illustration of the DC Contact RF MEMS switch and proposed switch beam structures. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]