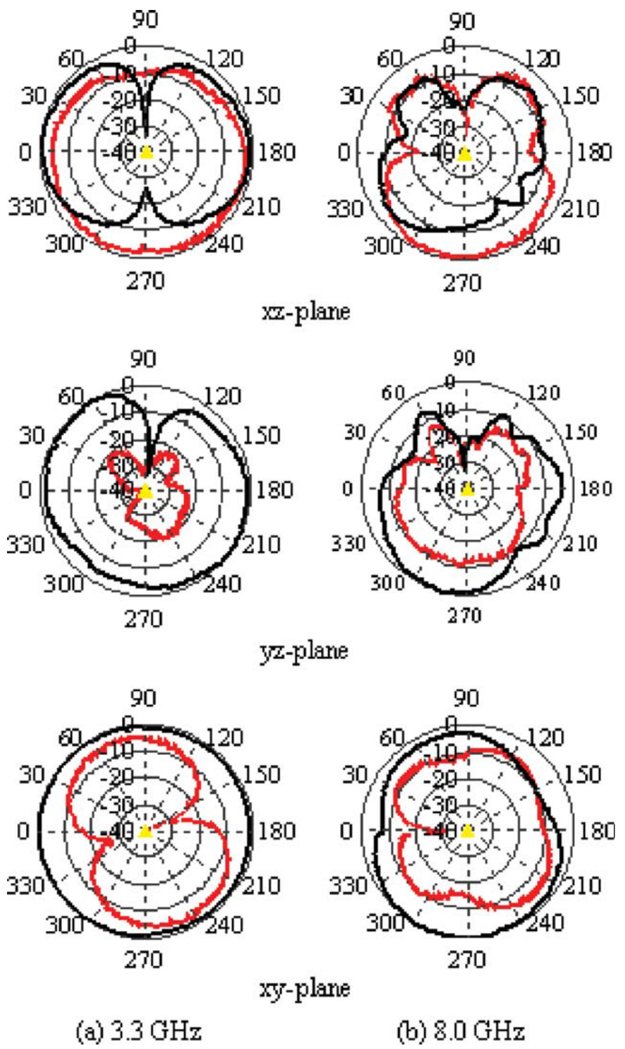

Figure 6 Measured radiation pattern at (a) 3.3 GHz and (b) 8 GHz [—E_θ----E_φ]. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

xz-plane at 3.3 GHz. These results show that the radiation patterns are quite stable over all UWB band.

4. CONCLUSION

A compact planar antenna with multi-slotted ground plane has been proposed and fabricated. The antenna having a total size of 30 × 22 mm^2 has simple structure and very easy to be integrated with microwave circuitry for low manufacturing cost. It is observed that the insertion of rectangular slots on the top side of the partial ground plane can be used to improve the impedance bandwidth of printed planar antenna. It is seen from the measurement that, the proposed antenna achieved an impedance bandwidth (VSWR $\leq$ 2) of 14.15 GHz (from 2.57 to 16.72 GHz), which cover the entire UWB band. The stable radiation pattern with a peak gain of 6.27 dBi makes the proposed antenna suitable for being used in UWB communication system.

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A COMPACT CPW-FED CIRCULAR PATCH ANTENNA WITH PATTERN AND POLARIZATION DIVERSITIES

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Received 27 July 2010

ABSTRACT: *A compact coplanar waveguide (CPW)-fed microstrip antenna with pattern and polarization diversities is proposed in this article. By making use of even and odd modes of a CPW feed network, a circular patch antenna operating at TM11 and TM01 modes can be excited, which results in broadside and conical monopole-like radiation patterns being achieved at an overlapping frequency range for 2.4GHz WLAN applications. The impedance bandwidth (VSWR $\leq$ 2) are 520 MHz (2.18–2.70 GHz, 21%) and 480 MHz (2.26–2.74 GHz, 20%) for broadside TM11 mode and conical TM01 mode, respectively. The measured isolation is better than 22 dB across the working bandwidth.*

The measured radiation pattern and gain of the proposed antenna are compared with simulation results. Microwave Opt Technol Lett 53:968–972, 2011; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.25932

Key words: *circular patch antenna; pattern and polarization diversities; monopole; compact CPW feed structure*

1. INTRODUCTION

In modern broadband wireless communication systems, the employment of pattern and polarization diversities is an efficient way to enhance system performance by mitigating multipath fading and increasing channel capacity [1, 2]. Due to compact size, light weight, and easy integration with circuit devices, microstrip patch antennas are widely applied [3]. However, the radiation pattern of conventional patch antennas is usually limited by the broadside TM11 mode. Conventional patch antennas inherently suffer from the disadvantages of limited types of radiation patterns and polarization. To resolve the limitations, wide-band circular patch antennas operating at TM01 mode with conical monopole-liked radiation patterns have recently been presented [4, 5]. The conical TM01 mode with vertical polarization can ensure adequate coverage along low elevation planes and has the advantage of a lower profile than the conventional quarter-wavelength monopole antenna. By supporting an L-probe coupled circular patch antenna with four metallic posts at appropriate locations, a wide-band microstrip patch antenna with broadside and conical radiation patterns is presented in [6], but it is difficult to achieve easy fabrication and mass production due to the large size and the complex feed and matching network.

In this article, a compact dual-port circular patch antenna with a broadside and/or conical radiation pattern is demonstrated for WLAN applications. The broadside TM01 and conical TM11 modes can be simultaneously excited in a circular patch by using a CPW feed system, which is attractive for providing hemispherical coverage for indoor mobile communication applications. Compared with the antenna reported in [6], this design has a more compact size and is easier to fabricate.

2. ANTENNA STRUCTURE AND ANALYSIS

Figure 1 shows the geometry of a circular patch antenna with a compact CPW feed network. The proposed antenna is fabricated on two Teflon substrate layers ($\varepsilon r = 2.65$, thickness = 0.5 mm) with a distance of h. It has a circular patch with an outer radius of $R1$ and a square ground plane with an area of 100 mm × 100 mm. A compact CPW feed network is applied to excite the circular patch. As mentioned in [7], the CPW feed network can support two orthogonal modes with high isolation, which are shown in Figure 2. When feeding from Port 1, the electrical fields have the same direction at both the left and right slots of CPW, shown in Figure 2(a). The currents distribution on the patch is shown in Figure 3(a), the circular patch operating at TM11 mode is excited by excitation of the two in-phased slots. As illustrated in Figure 2(b), the two slots have reversed electrical fields by feeding in Port 2, and TM01 mode of the radiating patch is excited by the radial electrical fields of the annular gap on the ground. Currents in the TM11 mode have the same direction at both the top and bottom edges of the radiating patch, providing maximum broadside radiation; while in the TM01 mode, they are aligned along the radial direction as a typical monopole and therefore this mode has a null in the broadside.

According to the circular cavity model [8, 9], the TM01 mode resonates at about twice the resonant frequency of the fundamental TM11 mode. To design the circular patch with the two resonant modes operating at an overlapping frequency range, a driven rod and a capacitive feed technique are used to reduce the resonant frequency of the TM01 mode. The impedance matching of the TM01 mode can be improved by increasing the size of the driven rod. The driven rod couples the electromagnetic energy to the radiating patch from a circular stub of the CPW structure through an annular gap on the ground. This capacitive feed technique introduces capacitance to compensate for a portion of the inductance caused by the driven rod, while shifting down the resonant frequency of the conical TM01 mode. The resonant frequency of the TM01 mode can be approximately tuned by the size of the circular patch, the air gap thickness, and the size of the capacitive circular stub.

Impedance matching for the TM01 mode can be achieved by adjusting the dimensions of the CPW structure and the driven

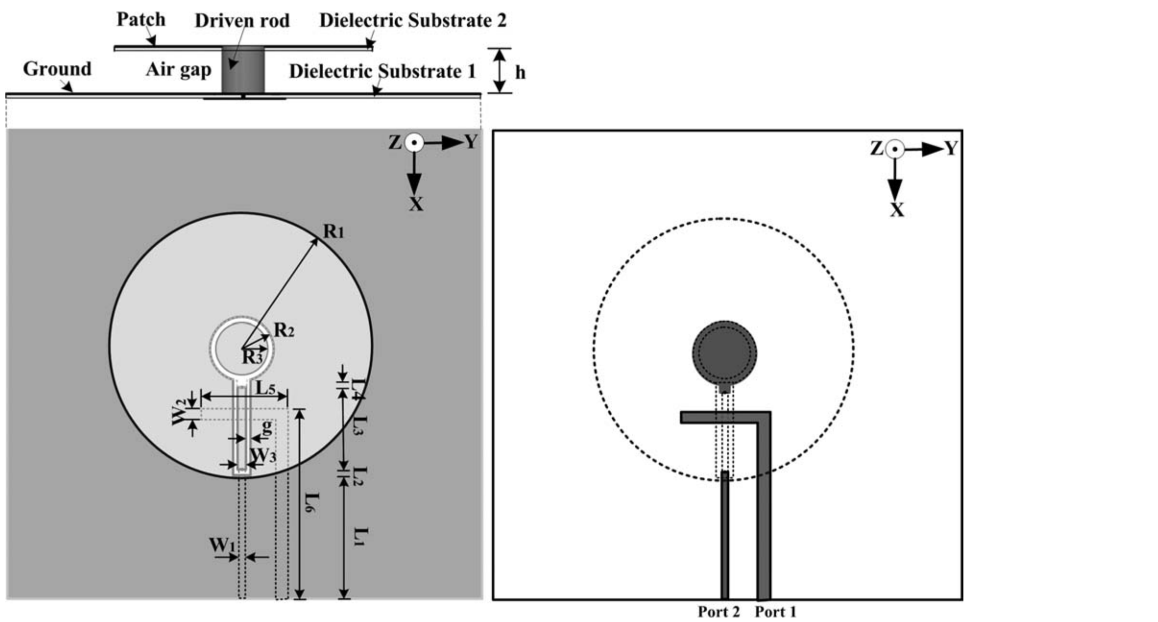

Figure 1 Geometry of proposed antenna

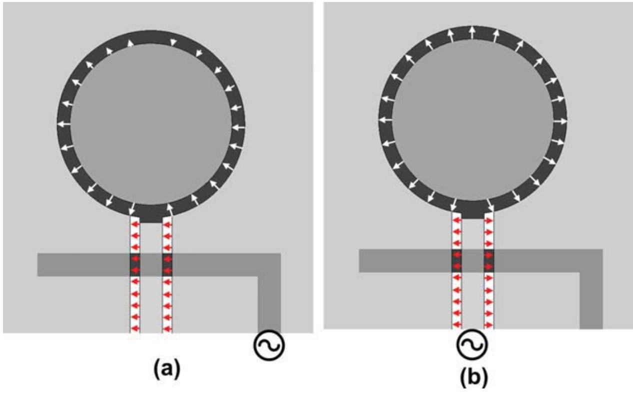

Figure 2 Modes in CPW feed network: (a) odd mode and (b) even mode. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

rod, while the optimum bandwidth of TM11 mode can obtained by the open-ended stub length *L*5. To minimize antenna dimensions, the antenna parameters have been optimized. The geometrical parameters of the compact dual-port diversity patch antenna are given in Table 1.

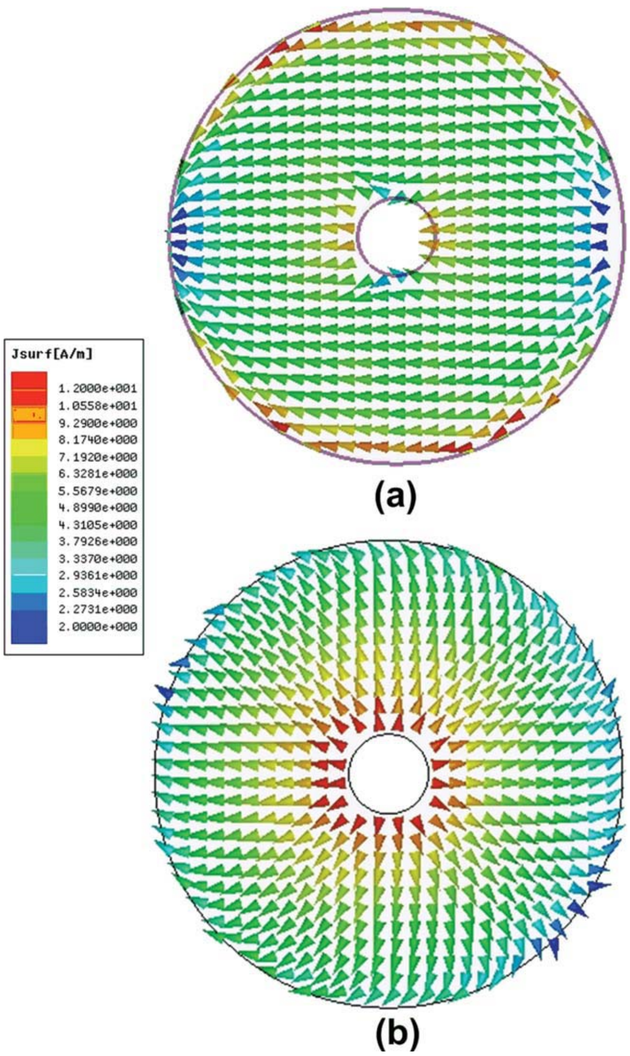

Figure 3 Current distribution of the circular patch: (a) Port 1 for TM11 mode and (b) Port 2 for TM01 mode. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

TABLE 1 Detailed Dimensions of Prototype (mm)

Parameter	$R1$	$R2$	$R3$	W_1	W_2	W_3	L_1
Value	28	5.1	4.6	1	1.4	1.4	23
Parameter	$L2$	L_3	L_4	L_5	L_6	h	g
Value	0.4	21.2	0.3	15	41.6	8	0.3

3. EXPERIMENTAL RESULTS AND DISCUSSION

A prototype of the proposed antenna, shown in Figure 4, is fabricated and measured. The dimensions of the proposed antenna are given in Table 1. The performance of the proposed antenna is measured by an Agilent E5071B Network Analyzer. Figure 5 shows the measured and simulated S-parameters of the constructed prototype. The measured data in general agrees with the simulated results obtained from Ansoft simulation software high frequency structure simulator (HFSS). The impedance bandwidth (VSWR$\leq$2) are 520 MHz (2.18–2.70 GHz, 21%) and 480 MHz (2.26–2.74 GHz, 20%) for broadside TM11 mode and conical TM01 mode, respectively. The measured isolation is better than

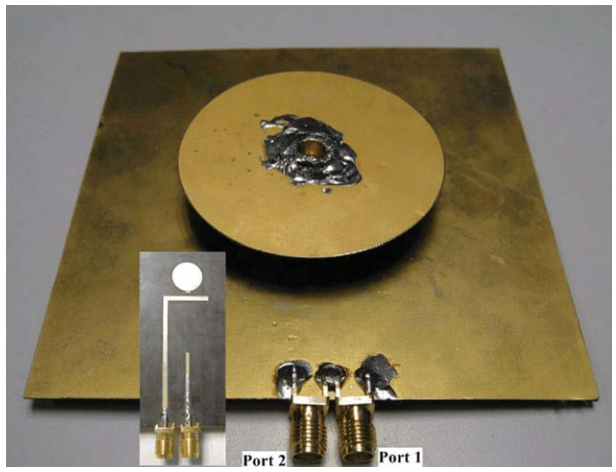

Figure 4 Prototype of proposed antenna. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

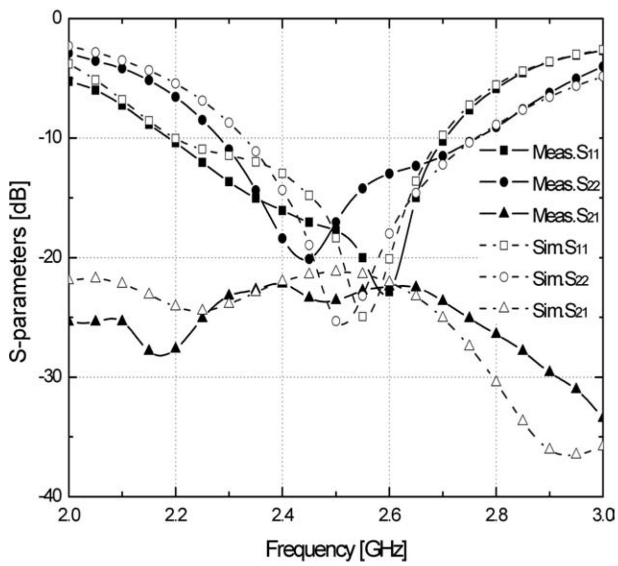

Figure 5 Measured and simulated S-parameters of proposed antenna

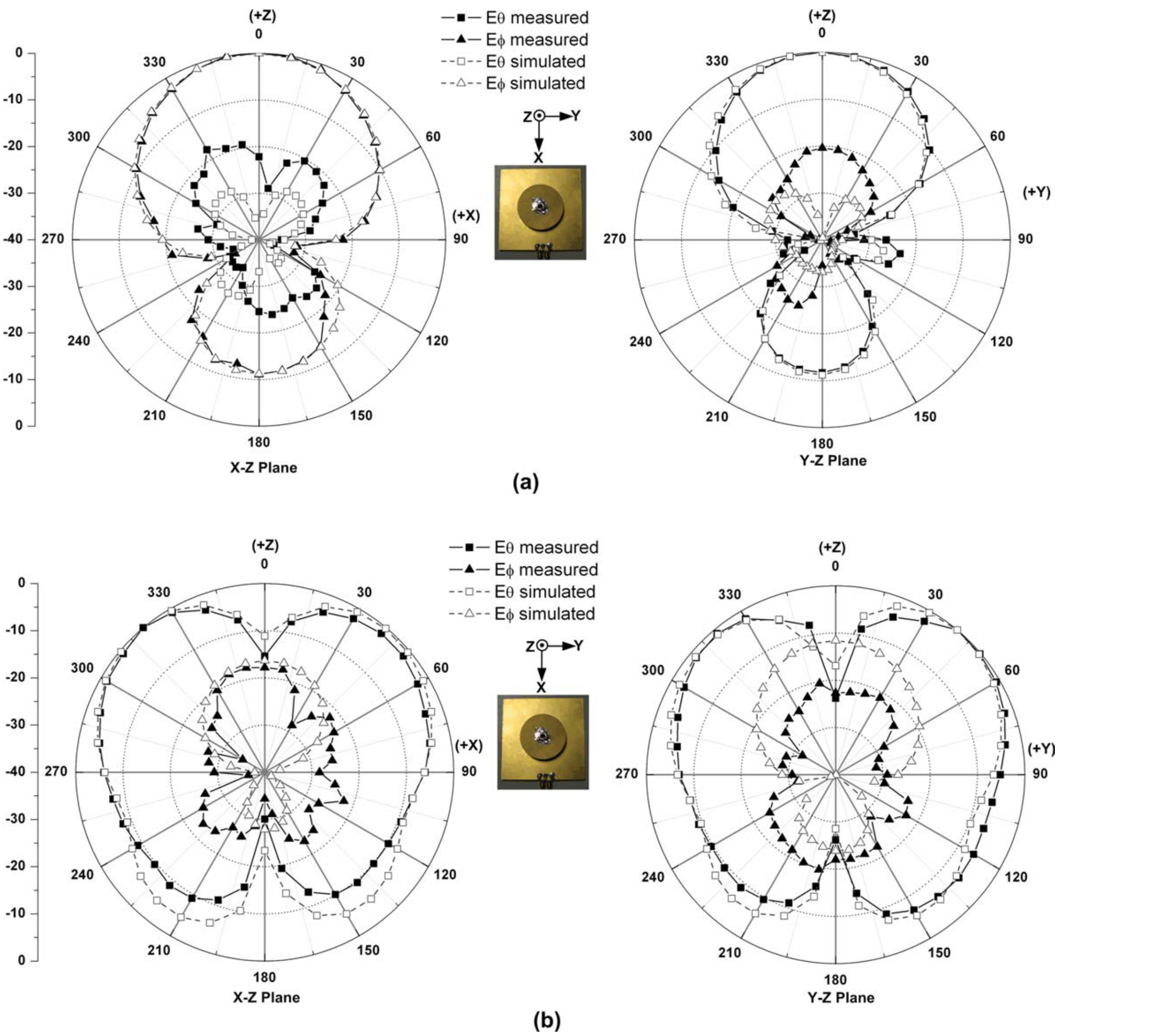

Figure 6 Measured and simulated radiation patterns at 2.44 GHz in *x*–*z* and *y*–*z* plane: (a) Broadside TM11 mode and (b) Conical TM01 mode. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

22 dB across the working bandwidth. The major challenge in designing the antenna is that it is difficult to tune the two resonant modes to resonate at the same frequency range. For the antenna, the overlapping frequency range, which could excite both modes, is from 2.26 to 2.70 GHz (17.8%).

Figure 6 show the measured and simulated radiation patterns for both TM11 and TM01 modes at 2.44 GHz. It clearly shows that the TM11 mode engenders good broadside radiation patterns and the TM01 mode shows conical monopole-liked radiation patterns. For the broadside TM11 mode, the main beam in the E-plane is toward the *z*-axis, which compensates for the broadside radiation null of the monopole-like TM01 mode. The measured and simulated antenna gain for operating frequencies within the impedance bandwidth is presented in Figure 7. Over the impedance bandwidth, the measured peak gain is about 7.4–9.2 dBi for broadside radiation and about 3.2–4.5 dBi for conical radiation. The discrepancy in antenna gain is mainly due to additional losses of the SMA connectors and cables during the prototype construction and measurement.

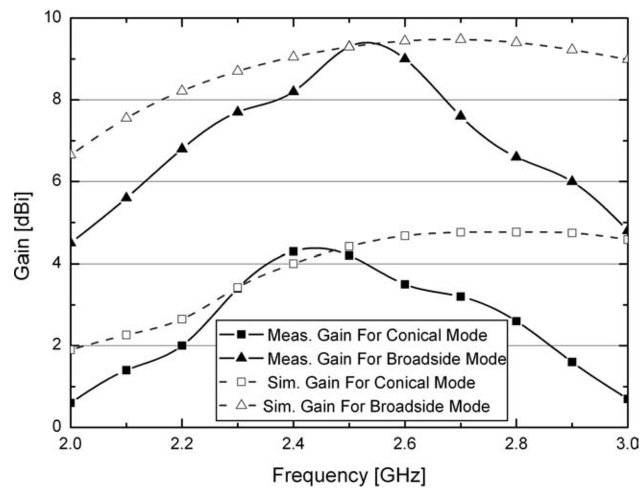

Figure 7 Measured and simulated gain of the proposed antenna

4. CONCLUSION

A novel CPW-fed circular patch antenna with different radiation characteristic has been proposed and implemented. By making use of a CPW feed network, the conical monopole-like TM01 mode and the broadside TM11 mode of the antenna can be obtained at an overlapping frequency band. It has been found that the main-beam positions of the radiation patterns are directed at elevation angles of 45° and 0° for both modes, respectively, which makes the antenna a good candidate for future pattern or polarization diversities applications in MIMO communications systems.

ACKNOWLEDGMENTS

This work is supported by the National Basic Research Program of China under Contract 2009CB320205, in part by the National High Technology Research and Development Program of China (863 Program) under Contract 2007AA01Z284, in part by the National Natural Science Foundation of China under Contract 60771009, and is also supported by the National Science and Technology Major Project of the Ministry of Science and Technology of China 2010ZX03007-001-01.

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QUASI OPTICAL PHASE SHIFTER USING CASCADED SPLIT SLOT RING FREQUENCY SELECTIVE SURFACES

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Received 27 July 2010

ABSTRACT: *In this article, a prototype X band scale model of a quasi-optical phase shifter is characterized to demonstrate the utility of the architecture proposed. The prototype arrangement utilizes three double layer split slot ring frequency selective surfaces. It is shown experimentally that the transmission phase of an incident linearly polarized signal can be varied from 0 to 2 π radians over the frequency range of 9.5–10.3 GHz in a linear manner. Over this frequency range, the insertion loss of the assembly varies between 2.5 dB, at 10 GHz, to 6 dB at 9.6 GHz, while axial ratio varies between 25 dB to a worst case value of 5 dB.* © 2011 Wiley Periodicals, Inc. Microwave Opt Technol Lett 53:972–974, 2011; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.25931

Key words: *quasi optical phase shifter; FSS; polarization converter; Fox-phase shifter*

1. INTRODUCTION

This article describes a frequency selective surface, FSS, quasi optical linear phase shifter, whose operation is based on the principle of the Fox waveguide phase changer, [1]. Phase shifters can be problematical to realize for operation at sub-millimeter wave and terahertz frequencies. In these regions, the application of quasi optical techniques to obtain phase shift is appropriate. This class of phase shifter types includes: cascaded metal grid structures [2] and crystal quartz techniques [3]. Some of the novel quasi optical phase shifters that have been suggested recently, involve CMOS technology [4] or active grating technology [5] to facilitate phase shifting. The phase shifter surface presented in this letter is a simpler alternative to the above stated methods, allowing phase shifting a quasi optical signal by simple mechanical adjustment. The phase shifter developed here is based on a new type of triple stacked, double layer FSS arrangement, a unit cell of which is shown in Figure 1. In this article, we describe the operation of an X-Band scale model for a quasi optical phase shifter based on this stacked FSS principle. The arrangement is suitable for microelectronic MEMS fabrication of the type reported in [6] and as such should be readily scalable for sub-millimeter wave or terahertz operation. The potential applications for the polarization control architecture proposed here relate to spatially fed phased-array antennas.

1.1. Principle of Operation

The operation of the FSS based phase shifter reported here is based on the Fox wave guide phase shifter architecture [1]. The FSS based phase shifter consists of three sections, Figure 1, which shows a unit cell. This comprises of, Section I, a fixed Δ90° phase shift section [7], Section 2 a Δ180° phase shift section [8], and, Section 3 a second Δ90° phase shift section. The phase shifter operates in the following manner. A linearly polarized, LP, input wave (which is tilted at 45° with respect to AA′)

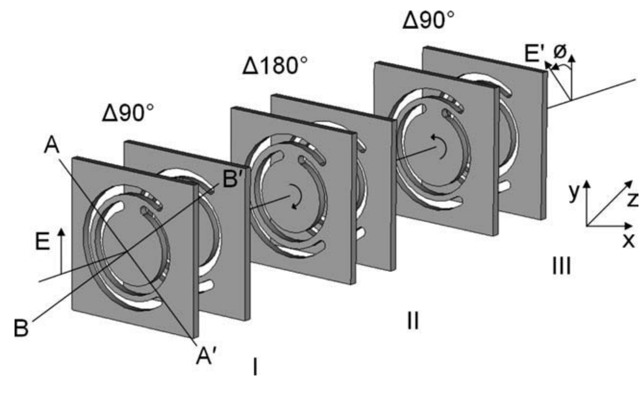

Figure 1 Multilayer FSS based phase shifter unit cell