ABSTRACT: In this paper, the design of a broadband dual-polarized microstrip patch antenna with excellent polarization purity is investigated theoretically and experimentally. Based on cavity-model theoretical analysis, a test dual-polarized microstrip patch antenna fed by double slot-coupled feeds with a 180° phase shift and a coplanar microstrip feed is presented. The simulated and measured results show that this antenna achieves a high isolation (<-41 dB) across the entire operating frequency and low cross-polarization level (<-30 dB). © 2005 Wiley Periodicals, Inc. Microwave Opt Technol Lett 44: 329–331, 2005; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20625

Key words: microstrip patch antenna; dual-polarized; isolation; cross-polarization

1. INTRODUCTION

Dual-polarization operation has been an important subject in patch-antenna designs and has found applications in wireless-communication systems. However, it is not easy to achieve high isolation and low cross-polarization due to the input ports, which are usually highly coupled to each other. Recently, substantial efforts have been made to overcome this problem, and a variety of feeding techniques to achieve high isolation and good cross-polarization have been studied [1–11]. The related feeding techniques include using a pair of slot-coupled feeds with two central crossed narrow slots or two offset narrow slots [1–7], or two L-shaped feeds [8], or a coupled feed and a slot-coupled feed [9], and so on [10, 11]. Among them, few designs for a single microstrip patch antenna have reported a high isolation of less than −40 dB, especially for X-band operation.

In this paper, a new design of a broadband dual-polarized microstrip patch antenna with excellent polarization purity is studied. Firstly, based on cavity-model theory, the anti-phase technique’s contribution to enhancing the decoupling between two input ports is presented. Then, a dual-polarized square microstrip patch antenna, fed by double slot-coupled feeds with a 180° phase shift and a coplanar microstrip feed, is designed and fabricated. The proposed antenna achieves a high isolation of better than −41 dB and a low cross-polarization level of less than −30 dB; the detailed results are presented and discussed.

2. THEORY

The cavity model was advanced by Lo et al. in 1979 [12]. A microstrip patch antenna with thin substrates (h ≪ λ0) can be termed a cavity model where the interior region is modeled as a cavity bounded by electric walls on the top and bottom, and magnetic walls all along the periphery. For a conventional square microstrip patch antenna using Maxwell’s equations and boundary conditions, as shown in Figure 1, the electric field in the patch cavity can be written as

\[ E_z = \sum_{m,n} B_{mn} \cos \frac{m\pi x_0}{a} \cos \frac{n\pi y_0}{a}, \]

where \( B_{mn} \) are the amplitude coefficients according to the electric field modes vectors,

\[ B_{mn} = jk_0 \epsilon_0 \delta_{nm} \frac{\delta_{0m}}{a} \left( \frac{a}{c} \right) \left( \frac{a}{2} \right) \cos \frac{m\pi x_0}{a} \cos \frac{n\pi y_0}{a}, \]

where \( \delta_{0m} \) and \( \delta_{nm} \) are functions of Neumann, \((x_0, y_0)\) is the exciting position, and \( d_0 \) is the width of the microstrip feedline.

A dual-polarized square microstrip patch antenna can excite two orthogonal modes, TM_01 and TM_00, which generate the vertically polarized electric field and horizontally polarized electric field, respectively. In addition, some higher modes can also be excited, such as TM_11, TM_02, TM_20, and so on (see Figs. 1(b)–1(e)). According to Eq. (1), when the feeding positions are on the central edge of patch, \( B_{11} \) is equal to zero and TM_11 cannot be excited; the electric-field vectors of TM_02 and TM_20 are maximal on the central edges, which results in mutual coupling between two input ports and seriously affects the patch’s polarization purity.

Comparing Figs. 1(a) and 1(b) with 1(c) and 1(d), for port H excitation, it is noted that the produced electric-field vectors of TM_02 and TM_20 excited on the right edge of the patch, are the reverse of those excited on the left edge. The electric-field vectors of TM_02 and TM_20 can cancel each other when the patch is fed on both the right and left edges at the same time [see Fig. 1(f)], thus the decoupling between the two ports is enhanced and the cross-polarization is suppressed as well.

3. ANTENNA DESIGN

Figure 2 shows the proposed broadband dual-polarized square patch antenna fed by double slot-coupled feeds and a coplanar microstrip line feed. The antenna consists of three dielectric substrate layers and two foam layers. All the substrates have same thickness \( h \) and permittivity \( \epsilon_r \). The upper square patch with a side length of \( a_1 \) is placed on the back of substrate 1, and the lower square patch with a side length of \( a_2 \) is placed on substrate 2; both radiating patches are separated by a foam layer of thickness \( h_1 \). Since the upper patch is inverted, substrate 1 also acts as the radome for environmental protection. The slot-coupled feed lines are placed on the back of substrate 3, while one ground plane is inserted between substrates 2 and 3. Due to the back radiation caused by the slots, a shielding metallization ground is placed at a distance of a quarter-wavelength from the ground plane in order to act as a reflector.
Port H is the slot-coupled feed with an H-shaped coupling slot cut in the ground plane and located below one side of the radiating patch. Two slots having the same sizes \(L, S, W_1, W_2\) and offset \(d\) are excited by two slot-coupled feeds with a 180° phase shift. Port V is the coplanar microstrip line feed that realizes the vertically polarized field.

4. SIMULATED AND EXPERIMENTAL RESULTS

Based on the numerical analysis, a test dual-polarized microstrip patch antenna fed by double slot-coupled feeds and a coplanar microstrip line feed is designed and fabricated. Its optimized parameters are: \(a_1 = 10 \text{ mm}, a_2 = 9 \text{ mm}, L = 7.4 \text{ mm}, S = 2.0 \text{ mm}, W_1 = 2.0 \text{ mm}, W_2 = 1.0 \text{ mm}, h = 2.8 \text{ mm},\) and \(d = 3.7 \text{ mm}.\) RT6002 substrate with permittivity \(\varepsilon_r = 2.94\) and thickness \(h = 0.508 \text{ mm}\) is adopted for the antenna.

Figure 3 shows the simulated and measured VSWR and isolation against frequency for the above antenna, the measured impedance bandwidth (VSWR \(\leq 2\)) is up to 17.1% for port V and 20.0% for port H, the measured isolation between two ports is better than \(-41 \text{ dB}\) across the entire operating bandwidth (8.5–9.5 GHz), and the highest is up to \(-50 \text{ dB}\) near the central frequency. It is also noted that the isolation is only about \(-25 \text{ dB}\) at the range of 8.2 GHz, which is caused by the resonance of the slots that radiate on both sides of the ground plane; this resonant frequency can be moved far away from the operating bandwidth of the antenna by adjusting the sizes of the slots.

Figure 4 plots the simulated and measured E-plane and H-plane radiation patterns at 9.0 GHz for port H and port V excitation. Good broadside radiation patterns with low cross-polarization are observed. The cross-polarization level is less than \(-30\) and \(-35 \text{ dB}\) for port H and port V, respectively.

5. CONCLUSION

A new design of a broadband dual-polarized microstrip patch antenna fed by double slot-coupled feeds with a 180° phase shift...
and a coplanar microstrip feed has been studied. Good agreement between the simulated results and experimental ones confirms the cavity-model theoretical analysis. The results also demonstrate that this proposed antenna achieves high isolation (better than −41 dB) for two polarizations in the entire operating bandwidth (8.5–9.5 GHz) and a low cross-polarization level of less than −30 dB.

REFERENCES


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SCATTERED FIELD IMPROVEMENT OF TAPERED SLOT ANTENNA USING A PARABOLIC-SHAPED SLOT

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ABSTRACT: This paper proposes a parabolic-slot geometry in order to improve the scattered field of tapered slot antennas (TSAs). The design is based on theoretical considerations. Slot dimensions are tuned using numerical experiments. The field measurements are in agreement with our numerical results: narrow beamwidths are obtained in the main planes and a low cross-polarisation level is observed in the D-plane. Although the feeding parts of the antenna are designed using closed-form expressions, a large bandwidth is achieved. © 2005 Wiley Periodicals, Inc. Microwave Opt Technol Lett 44: 331–334, 2005; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20626

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1. INTRODUCTION

A tapered slot antenna (TSA) is obtained by gradually increasing the slot size of an open ended slot line (Fig. 1). The first TSA, presented by Gibson [1] and called the “Vivaldi” aerial, corresponds to an exponentially tapered slot. Then, a linearly tapered slot antenna (LTSA) was introduced by Thungen et al. [2]. For the same substrate, length, and aperture size, the beamwidth of the LTSA appears to be narrower than the Vivaldi aerial’s beamwidth. It has been noticed that the directivity of an LTSA spreads between 11 and 17 dB. A variant of the LTSA, the constant-width slot antenna (CWSA), has been used in an imaging array [3]. In general, the CWSA is more directive than the LTSA, with a counterpart of higher side lobes. The side-lobes levels of TSAs are different in the E- and H-planes (the planes are depicted in Fig. 1). This unwanted characteristic is overcome by using another special slot shape, corresponding to the Fermi function [4].

One of the major drawbacks of TSAs is their level of cross-polarisation in the D-plane. It is reported that the lowest levels are achieved with the Vivaldi antenna (−15 dB in [5]). Unfortunately, this TSA exhibits poor directivity. As a trade-off, the broken tapered-slot antenna (BLTSA) was developed [6]. The latter has a gain of 13 to 14 dB for a cross-polarisation level of −11 dB, which is −2-dB less than its equivalent LTSA.

From this brief introduction, we notice that TSA characteristics are very sensitive to slot shape. Herein, we attempt to present a new TSA that has a high directivity and a low cross-polarisation level based on a parabolic tapered slot (yielding the PTSA). The choice of this shape is inspired by qualitative principles obtained from various experimental contributions. On the other hand, the slot dimensions are obtained using numerical methods [7, 8].

2. ANTENNA DESIGN

First, we determine the outer dimensions of the antenna. It is well known [3] that the directivity of a TSA is linear with respect to its length L (Fig. 1). The upper limit is fixed by the mechanical strength of the dielectric substrate because, without a ground plane, a too-long antenna bends under the effect of its weight. Given this consideration, we used an average length of L = 5.5λ0. The choice of the width H (Fig. 1) is dictated by Janaswamy’s experimental work [9], wherein it is said that TSAs exhibit interesting behaviour when they are made to be narrow. We retained H = 1.5λ0. The chosen dielectric substrate has permittivity εr = 2.95 and thickness d = 1.524 mm.

Gibson [1] states that the directivity of a TSA antenna is proportional to the rate at which the electromagnetic energy is