SINGLE-FEED DUAL-FREQUENCY DUAL-POLARIZED SLOTTED SQUARE MICROSTRIP ANTENNA

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Received 5 January 2000

ABSTRACT: *A novel dual-frequency dual-polarized square microstrip patch antenna embedded with a slot is presented. The proposed antenna offers tunability of the frequency ratio between the two frequencies by adjusting the slot dimensions. This configuration also provides a size reduction up to ~51 and 35% for the two modes as compared to a square microstrip patch antenna.* Microwave Opt Technol Lett 25: 395–397, 2000.

Key words: *microstrip antennas; dual frequency; dual polarization; slot*

INTRODUCTION

Dual-frequency operating microstrip antennas find wide applications in GPS, regional mobile satellite arrays, large feed arrays for offset reflectors, and other common transmit and receive antennas [1, 2]. A compact dual-band dual-polarization microstrip patch antenna capable of generating two distinct frequencies with different polarizations recently has been reported [3]. In this letter, we present a novel design of a square-shaped microstrip antenna embedded with a square slot, with an arm extended giving dual-frequency operation with the polarization planes perpendicular to each other. This new design with a placard-shaped slot exhibits a reduction in antenna size for dual-frequency operation compared to conventional microstrip antennas. By changing the dimensions of the arm of the slot, the ratio of the two operating frequencies can be adjusted. Details of the antenna design, impedance, and radiation characteristics at the two resonant frequencies are described, and experimental results are presented.

ANTENNA DESIGN AND EXPERIMENTAL DETAILS

The geometry of the proposed slotted microstrip antenna for dual-frequency operation is depicted in Figure 1. A square microstrip antenna with side dimensions L_P is fabricated on a substrate of thickness h and relative permittivity ε_r [4]. The placard-shaped slot is centered in the square microstrip patch antenna. It consists of a slot of equal side dimensions $L_S = W_S$, with an arm having length L_a and width W_a ($L_a \gg W_a$) extending toward one of the edges of the square microstrip patch, as shown in Figure 1.

When the protruding slot is not present (i.e., $L_a = 0$), it is seen that the fundamental resonance is at 1.611 GHz. However, it is observed that, when L_s, L_a, and W_a are properly chosen, the excited patch surface current densities of the TM_{10} and TM_{01} modes are perturbed such that these two modes are excited for dual-frequency operation. Coaxial feeding is used, which is located along the diagonal of the patch, very close to the corner of the square slot, as shown in Figure 1.

The proposed antenna with various slot dimensions was constructed and investigated. The measured return loss (S_{11}) of the antenna for a typical design is plotted in Figure 2. In this case, L_s, L_a, and W_a are chosen to be 12, 10, and 1.5 mm, respectively. From the plot, it is observed that two distinct operating frequencies are excited. Here, the slot

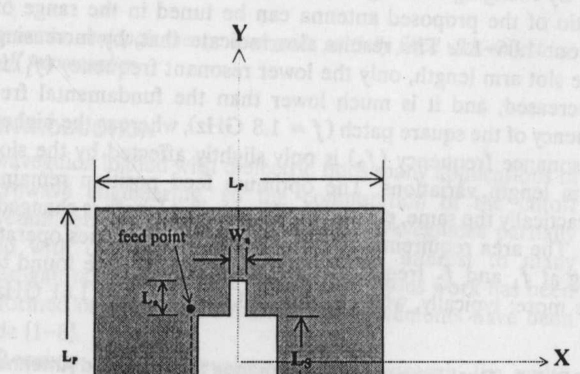

Figure 1 Geometry of the proposed dual-frequency dual-polarized slotted square microstrip antenna. Antenna parameters are given in Figure 2

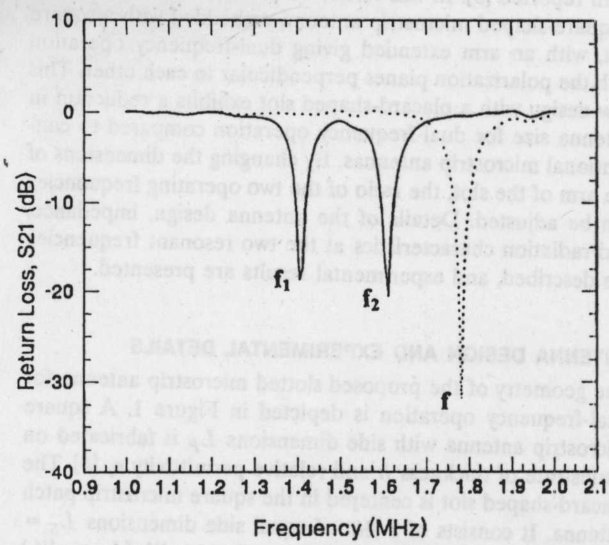

Figure 2 Measured return loss (S_{11}) for the proposed dual-frequency dual-polarized microstrip antenna having slot arm length $L = 10$ mm. —— S_{11} of the slot antenna ($L = 10$ mm), ... S_{11} of standard square patch. $h = 1.6$ mm, $\varepsilon_r = 4.5$, $L_P = 40$ mm, $L_S = 12$ mm, $L_a = 10$ mm, $W_a = 1.5$ mm

creates another resonance near the fundamental resonance of the antenna, which will result in dual-frequency operation (TM_{01} and TM_{10} modes). The fundamental resonance frequency of the conventional unslotted square patch is ~1.8 GHz (f). With a square slot alone ($L_a = 0$), it is observed that the antenna is resonating at 1.611 GHz, whereas the introduction of the slot arm initiates an additional resonance frequency at 1.411 GHz. It can be concluded that the slot effectively increases the patch dimensions, and hence we have the result. Both of these two resonant frequencies are well below the resonant frequency of the standard square patch.

By changing the length of the slot arm (L_a), the frequency ratio of the proposed antenna can be tuned in the range of about 1.06–1.2. The results also indicate that, by increasing the slot arm length, only the lower resonant frequency (f_1) is decreased, and it is much lower than the fundamental frequency of the square patch ($f \approx 1.8$ GHz), whereas the higher resonance frequency (f_2) is only slightly affected by the slot arm length variations. The optimum feed position remains practically the same, even when the arm slot length is changed.

The area requirements of ordinary square patches operating at f_1 and f_2 frequencies of the new design are found to be more; typically, when $f_1 = 1.39$ GHz and $f_2 = 1.61$ GHz, the reduction in patch areas is 51 and 35%, respectively. The variation of the two resonant frequencies, and hence the frequency ratio of the antenna for different lengths of the slot arm, are given in Table 1. The frequency ratio is found to vary from 1.06 to 1.2. From the table, it can be seen that, by changing the slot arm dimensions, we can merge or shift apart the resonating frequencies [5, 6]. The percentage bandwidth remains almost invariant, even when the slot arm dimensions are changed to reduce the operating frequency ratio (f_2/f_1). Figure 3 shows the measured resonant frequencies f_1 and f_2 and frequency ratio (f_2/f_1) against the slot arm length for the proposed antenna.

The transmission characteristic (S_{21}) of the antenna in the band for horizontal and vertical polarizations is shown in Figure 4. Finally, from the polarization planes, we can infer that the polarization planes of the two resonant frequencies are orthogonal to each other [7].

Radiation patterns for the proposed antenna for two tuning stubs are shown in Figure 5. The antenna also offers good cross-polarization characteristics, in contrast to ordinary square patch antennas. Like a rectangular or square patch, it is observed that the beam width is also large for the proposed antenna. The beam width along the E- and H-planes at 1.611 GHz are 112 and 82°, respectively; the corresponding values at 1.41 GHz are 124 and 88°, respectively. Bandwidths of 1.8 and 2.1%, respectively, have been obtained in the two modes.

CONCLUSION

A novel design of a dual-frequency dual-polarized square microstrip antenna embedded with a shaped slot is presented.

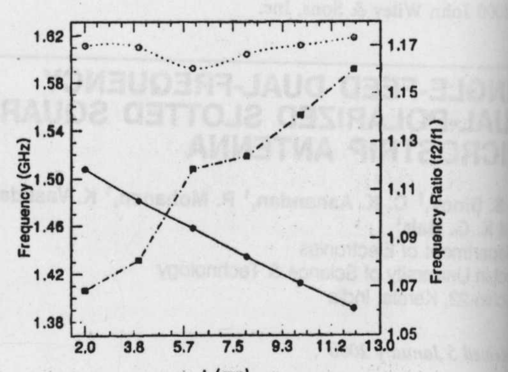

Figure 3 Measured resonant frequencies f_1 and f_2 and frequency ratio (f_2/f_1) against slot arm length. —●— f_1, ---○--- f_2, ---■--- f_2/f_1

TABLE 1 Dual-Frequency Performance for Proposed Antenna with a Shaped Slot with Various Slot Arm Lengths; Antenna Parameters are Given in Figure 2

Tuning Slot Length (mm)	First Resonance Frequency f_1 (MHz)	% Bandwidth	Second Resonance Frequency f_2 (MHz)	% Bandwidth	Frequency Ratio f_2/f_1
2	1507	1.61	1611	1.63	1.068
4	1480	1.68	1610	1.67	1.081
6	1450	1.73	1592	1.79	1.118
8	1433	1.81	1604	1.94	1.124
10	1411	1.74	1611	2.08	1.141
12	1390	1.68	1618	1.96	1.160

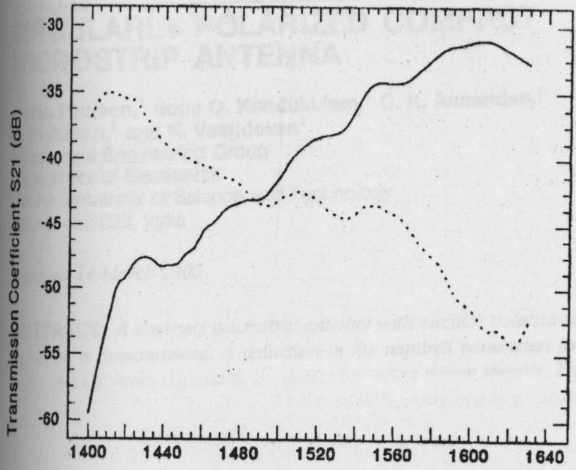

Figure 4 Variation of received power with frequency for the two orthogonal polarization planes. ---------- vertical, ——— horizontal

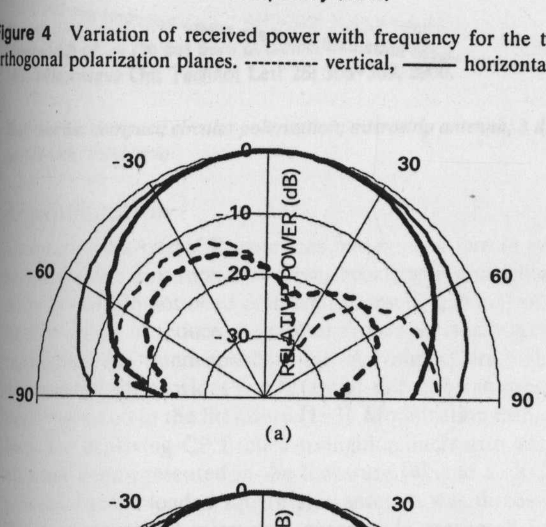

Figure 5 Measured *E*-plane and *H*-plane radiation patterns for the proposed antenna. (a) f_1 = 1411 MHz. (b) f_2 = 1611 GHz. —— ------- *E*-plane, ——— ---- *H*-plane

The proposed design uses the fundamental TM_{10} mode as well as the new resonant mode TM_{01} excited due to the slot for dual-frequency operation. This novel compact antenna design is suitable in applications where reduced-size antennas are needed, such as GPS and WLAN. The frequency ratio (f_2/f_1) of the two frequencies can be made as low as 1.06, which makes the proposed antenna suitable for applications where a low-frequency ratio is required.

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