SLOT-COUPLED SQUARE MICROSTRIP ANTENNA FOR COMPACT DUAL-FREQUENCY OPERATION

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ABSTRACT: *A novel dual-frequency design of a square microstrip antenna coaxially fed along the diagonal with a chip capacitor mounted at the bottom of the stub is introduced. This design provides enhanced area reduction and good cross-polarization levels. The antenna design can be used as a compact antenna system where limited size is a major requirement. The details of the antenna design and experimental results are presented.* Microwave Opt Technol Lett 32: 7–9, 2002.

Key words: *dual frequency; slot coupled; square microstrip; chip capacitor*
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INTRODUCTION

Dual-frequency microstrip antennas have widely been used in portable communication systems [1]. Recently, antenna researchers have been concentrating on slotted patch antennas which provide enhanced area reduction. Also, the use of a tuning stub has been shown to be effective in trimming the resonant frequency of microstrip antennas [2]. Due to the frequency-tuning ability of the stub, it is expected that, with a proper length, the resonant mode in the direction parallel to the stub can have a lower resonant frequency than that in the direction perpendicular to the stub orientation. Also, a number of publications reporting the characteristics of probe-fed slot-loaded short-circuited microstrip antennas [3] and antennas loaded with chip capacitors are available [4]. In order to meet the requirement of miniaturization of the mobile communication equipment, the design of dual-frequency mi-

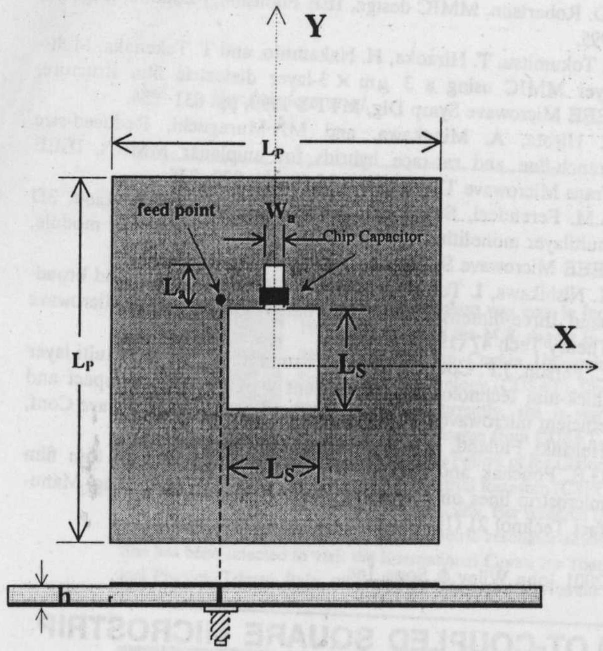

Figure 1 Geometry of the proposed dual-frequency dual-polarized slotted square microstrip antenna. Antenna parameters are given in Figure 2

crostrip antennas with reduced area becomes important. In this paper, it is proposed that, by mounting a chip capacitor of low capacitance, the overall antenna size can be reduced significantly for operation at a fixed frequency, with a negligible drop in gain. It is also seen that the antenna cross-polarization level can be considerably enhanced. Details of the antenna design and the resonant modes excited for the present proposed dual-frequency operation are described, and the experimental results for the obtained dual-frequency performance are presented.

ANTENNA DESIGN AND EXPERIMENTAL DETAILS

The geometry of the antenna is given in Figure 1. It consists of a square patch loaded in the center with a placard-shaped slot, as shown in Figure 1. A square microstrip patch antenna with side dimensions L_P is fabricated on a substrate of thickness h and relative permittivity ε_r [5]. The placard-shaped slot is centered in the square microstrip patch antenna. It consists of a base 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. A chip capacitor (with capacitance 4.7 pF at 1 kHz) is mounted toward the base of the tuning stub. Figure 2 represents the measured results of the return loss for the cases with and without capacitor loading.

It has been already shown that the dual-frequency operation, and hence the area reduction, are caused by the insertion of the tuning stub. [6]. There it was reported that the antenna is providing an area reduction of $\sim 51\%$ for the first resonant frequency.

The proposed antenna with various slot dimensions was constructed and investigated. From the plot, it is observed that two distinct operating frequencies are excited. Here, the slot creates another resonance near the fundamental resonance of the antenna, which will result in dual-frequency operation (TM_{01} and TM_{10} modes).

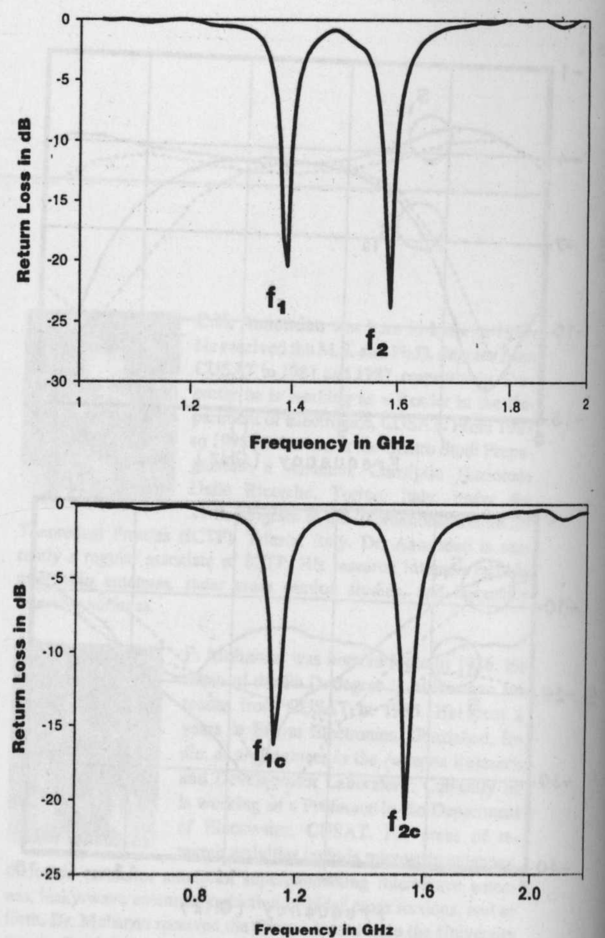

Figure 2 (a) Measured return loss (S_{11}) for the proposed dual-frequency dual-polarized microstrip antenna having slot arm length $L_a = 10$ mm without chip capacitor loading. (b) Measured return loss (S_{11}) with chip capacitor loading. $h = 1.6$ mm, $\varepsilon_r = 4.5$, $L_P = 40$ mm, $L_S = 13$ mm, $L_a = 10$ mm, $W_a = 1.7$ mm

The fundamental resonance frequency of the conventional unslotted square patch is ~ 1.8 GHz. With a square slot alone ($L_a = 0$), it is observed that the antenna is resonating at 1.6 GHz (f_2), whereas the introduction of the slot arm initiates an additional resonance frequency at 1.41 GHz (f_1). The chip capacitor is mounted across the base of the tuning stub, as shown in Figure 1.

The capacitor-loaded antenna is tested using an HP 8510C vector network analyzer. It is observed that the lower resonant frequency has been reduced to 1.19 GHz (f_{1c}). It is also noted that, by mounting the capacitor, only the first resonant frequency is affected, and the second resonant frequency (f_{2c}) remains almost invariant. An equivalent circuit taken along the diagonal of the square slot antenna is the parallel resonant circuit; when the loading capacitor is connected to the equivalent circuit, the resonant frequency decreases. The loading of the capacitor does not make any additional reduction in the gain of the antenna.

Both of the resonant frequencies are well below the resonant frequency of the standard square patch. The optimum feed position remains practically the same, even when the capacitor is loaded and the stub length is varied.

The radiation patterns of the proposed antenna at the two operating frequencies are also measured and plotted in Fig-

TABLE 1 Dual-Frequency Characteristic for Proposed Slot Antenna with a Chip-Capacitor Loading. Antenna Parameters are Given in Figure 2

L_p (cm)	L_s (cm)	L_a (cm)	W_a (cm)	Operating Frequency without Capacitor Loading		% of Area Reduction	
				f_1 (GHz)	f_2 (GHz)	f_1	f_2
4	1.2	1.0	0.02	1.41	1.61	51	35

Effect of Capacitor Loading on the Performance of the Patch Antenna

L_p (cm)	L_s (cm)	L_a (cm)	W_a (cm)	Operating Frequency with Capacitor Loading		% of Area Reduction	
				f_{1c} (GHz)	f_{2c} (GHz)	f_{1c}	f_{2c}
4	1.2	1.0	0.02	1.19	1.58	64	36

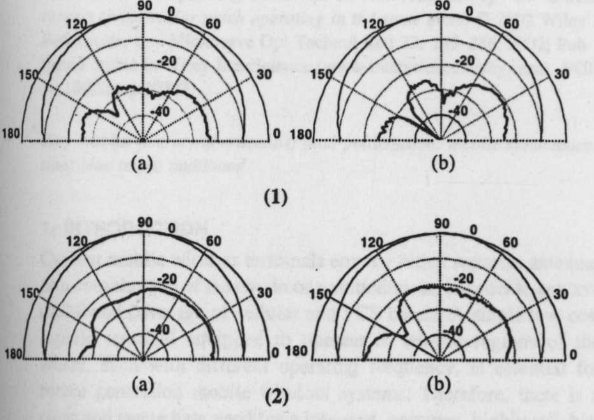

Figure 3 Measured *E*-plane and *H*-plane radiation patterns for the proposed antenna. ——— copolar, ——— cross polar. 1) f_1 = 1192 MHz: a) *H*-plane, b) *E*-plane. 2) f_2 = 1594 MHz: a) *H*-plane, b) *E*-plane

ure 3. It is seen that both operating frequencies have broad radiation patterns, orthogonal polarization planes [6], and a cross-polarization level of about 30 dB is also observed. The transmission characteristics of the new design have been studied, which reveal the orthogonal polarization characteristics of the proposed antenna, and are plotted in Figure 4.

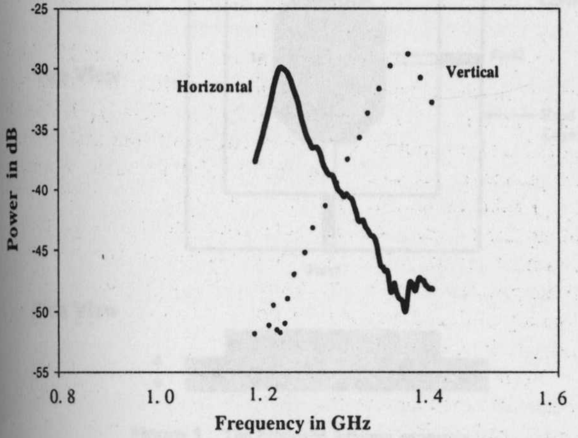

Figure 4 Variation of received power with frequency for the two orthogonal polarization planes. - - - - - - vertical, ——— horizontal

Bandwidths of about 2 and 2.1%, respectively, have been obtained in the two modes.

CONCLUSION

A small square slot antenna embedded with a chip capacitor is developed which provides an area reduction of 64 and 36% for the two resonant modes compared to a standard microstrip patch antenna with a reduction in gain of approximately 2 dB. It has an enhanced cross-polarization level and bandwidth. This novel antenna design finds application in realizing a compact antenna system where limited size is a major requirement.

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