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Dual-frequency dual-polarized slot-coupled compact microstrip antenna for communication systems

G. S. BINOY†, C. K. AANANDAN†, P. MOHANAN† and K. VASUDEVAN*†

A new design of a dual-frequency dual-polarized square microstrip antenna fed along the diagonal, embedded with a square slot having three extended stubs for frequency tuning, is introduced. The proposed antenna was fabricated using a standard photolithographic method and the antenna was tested using the HP 8510C Vector Network Analyser. The antenna is capable of generating dual resonant frequencies with mutually perpendicular polarizations and broad radiation pattern characteristics. Such dual-frequency designs find wide applications in personal mobile handsets combining GSM and CDS 1800 modes, and applications in which different frequencies are used for emission and reception such as personal satellite communications and cellular network systems.

1. Introduction

Because of the capability to radiate at two separate frequencies in a single radiating structure, dual-frequency patch antennas have received much attention (Wong and Chen 1997). Many related dual-frequency designs have also been reported. Recently, patch antenna research has been concentrating on reducing the size of the patch, which leads to numerous applications in satellite communication and to other commercial applications. Among these reported designs, microstrip slot antennas have gained wide attention owing to their advantage of dual-frequency operation and broad radiation characteristics (Wong and Sze 1998, Lu 1999). It has been recently reported that the resonant frequency of a microstrip antenna can be significantly reduced by introducing a square slot having an extended tuning stub set into a square patch (Binoy *et al.* 2000), where it was observed that the tuning stub that makes the frequency trimming possible was the main means of area reduction. The studies were extended by including one more tuning stub to further enhance the area reduction (Binoy *et al.* 2001). In this paper we present a modified structure with a square slot having three tuning stubs centred in the square patch to lower the frequencies of the dual-band operation without much deterioration in gain. This corresponds to a reduction in antenna size for a given dual-frequency operation. The frequency ratio of the two frequencies can be trimmed by systematically varying the slot parameters. Here, the experimental results of patch size reduction on a modified structure are presented and analysed.

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†Centre for Research in Electromagnetics and Antennas, Department of Electronics, Cochin University of Science & Technology, Cochin, Kerala, India.
*Corresponding author. e-mail: kv@doe.cusat.edu

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2. Antenna design

The geometry of the antenna is given in figure 1. It consists of a square patch loaded in the centre with a placard-shaped slot having two extended arms (placed at right angles to the base arm), as shown in the figure. A square microstrip antenna with side dimension L_P is fabricated on a substrate of thickness h and relative permittivity ε_r (James and Hall 1989). The slot is centred in the antenna. It consists of a base slot of equal side dimensions $L_S = W_S$, with an arm of length L_a and width W_a ($L_a \gg W_a$) extending towards one of the edges of the square microstrip patch as shown in figure 1. Two additional stubs of the same dimensions L_a and W_a, at right-angles to the base arm of the placard slot, are also incorporated. By changing the dimensions of the base arm and stubs in a uniform manner the ratio of the operating frequencies can be lowered.

3. Experimental results and discussion

Several prototypes of the proposed antenna with various slot dimensions have been 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 13, 10 and 1.7 mm, respectively. From the plot it is observed that two distinct operating frequencies are excited. Here, the slot geometry creates another resonance near the fundamental resonance of the antenna, which will result in dual-frequency operation. The fundamental resonance frequency f_0 of the conventional unslotted square patch is ~1.8 GHz. With a square slot alone ($L_a = 0$), it is observed that the antenna

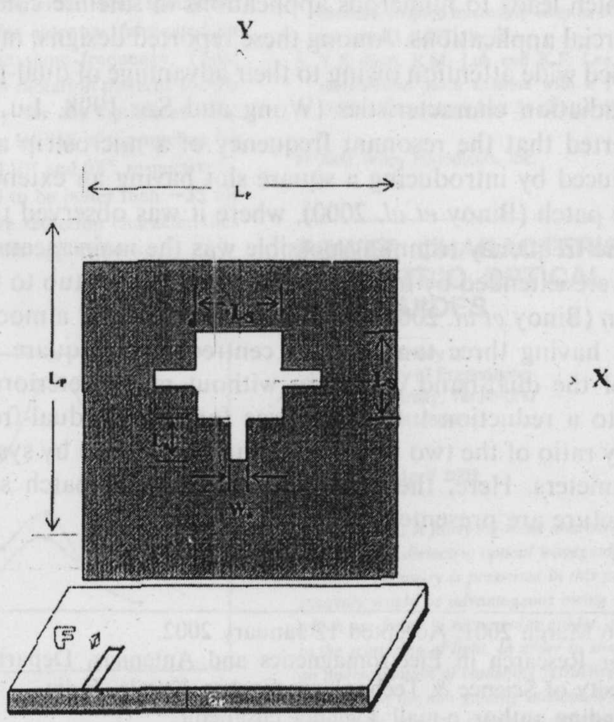

Figure 1. Geometry of the proposed dual-frequency dual-polarized slotted square microstrip antenna.

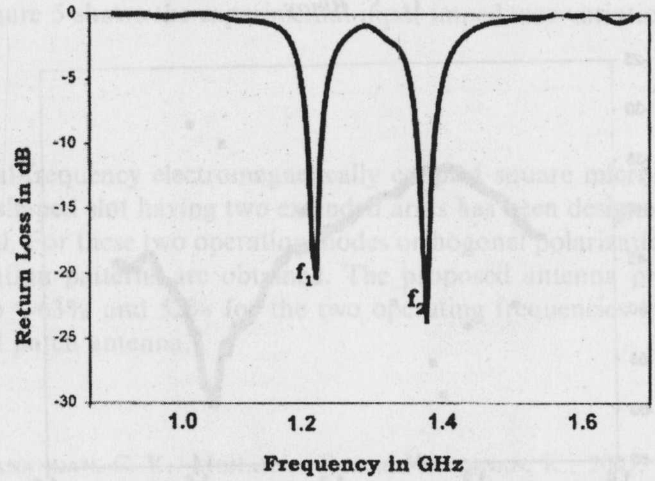

Figure 2. Measured return loss (S_{11}) for the proposed dual-frequency dual-polarized microstrip antenna: ——— S_{11} of the slot antenna (L_a = 10 mm); h = 1.6 mm, ε_r = 4.5, L_P = 40 mm, L_S = 13 mm, L_a = 10 mm, W_a = 1.7 mm.

is resonating at 1.611 GHz, whereas the introduction of the base arm and stubs initiates an additional resonance frequency f_1 at 1.21 GHz. It is also observed that the second resonance frequency f_2 is lowered from 1.61 GHz to 1.389 GHz. Hence, it can be concluded that the slot is effectively increasing the patch dimensions and hence lowering the resonant frequencies. Both resonant frequencies are well below the resonant frequency of the standard square patch.

By changing the length L_a of the slot arms, the frequency ratio of the proposed antenna can be effectively tuned. For the two operating frequencies of the proposed antenna, orthogonal polarization planes and broadside radiation patterns are obtained. The differences in antenna gain in the broadside direction for the two operating frequencies were also measured and found to be less than 2 dB for the proposed antenna. Typical measured radiation patterns at the two operating frequencies are plotted in figure 3. The transmission characteristics, showing the varia-

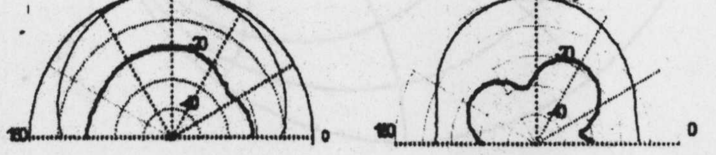

Figure 3. Measured E-plane and H-plane radiation patterns for the proposed antenna: ——— co-polar; ——— cross-polar. (1) f_1 = 1210 MHz: (*a*) H-plane; (*b*) E-plane. (2) f_2 = 1389 MHz: (*a*) H-plane; (*b*) E-plane.

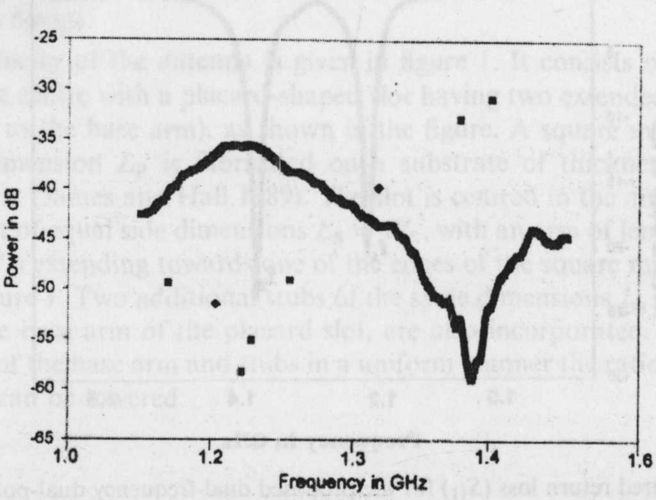

Figure 4. Variation of received power with frequency for the two orthogonal polarization planes: .... vertical polarization; ——— horizontal polarization.

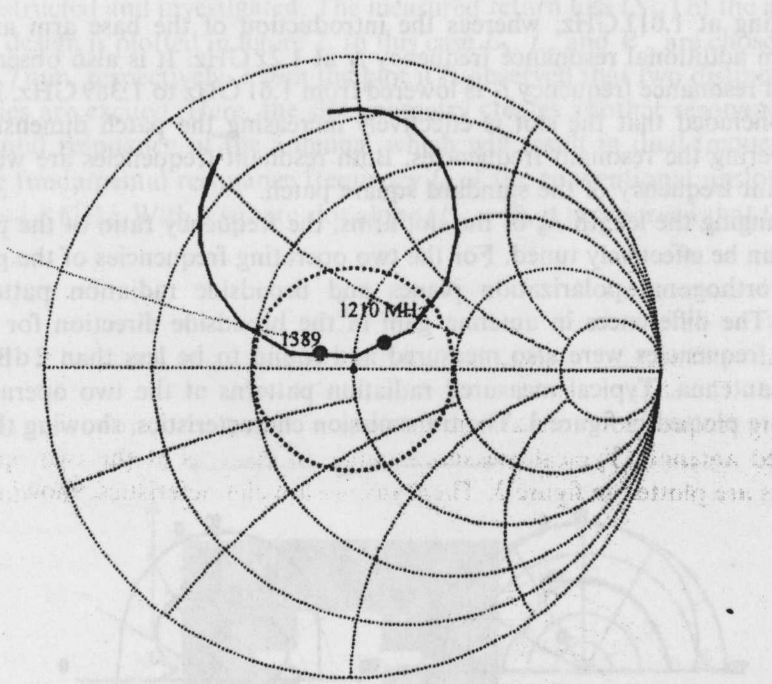

Figure 5. Measured input impedance on a smith chart for the proposed antenna.

tion of received power with frequency for the horizontal and vertical polarization planes of the antenna, S_{21}, are shown in figure 4.

The area requirements of standard patches operating at frequencies f_1 and f_2 of the new design are found to be greater; i.e., the dimensions of standard rectangular patches operating at 1.21 GHz and 1.389 GHz are 43.5 cm^2 and 33 cm^2 respectively. The proposed slot-loaded square geometry occupies only 16 cm^2 of area. Typically, when $f_1 = 1.21$ GHz and $f_2 = 1.389$ GHz, the reductions in patch area are ~63% and 52% respectively. It is observed that the percentage bandwidth remains almost invariant even when the slot arm dimensions are changed to reduce the operating frequencies. Figure 5 shows the experimental input impedance variation of the proposed antenna.

4. Conclusion

A novel dual-frequency electromagnetically coupled square microstrip antenna with a placard-shaped slot having two extended arms has been designed and experimentally studied. For these two operating modes orthogonal polarization planes and broadside radiation patterns are obtained. The proposed antenna provides a size reduction up to ~63% and 52% for the two operating frequencies in comparison with a standard patch antenna.

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