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SLOT-COUPLED PATCH ANTENNA WITH COPLANAR WAVEGUIDE FEED

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ABSTRACT

Two slot-coupled feeding techniques for exciting a patch antenna with a coplanar waveguide (CPW) were experimentally investigated. In the first technique, a CPW with two notches on both sides of the slot lines is used to couple power to the antenna through a narrow rectangular slot. In the second technique, a grounded CPW with a series gap in the center strip conductor is used to couple power to the antenna through a 'dumbbell' slot. Results indicated that both techniques are feasible and yield high coupling efficiency.

INTRODUCTION

Previous work on slot-coupled patch antennas concerns mainly with feed structure of microstrip type. Only recently, slot-coupled feeding technique with coplanar waveguide (CPW) feed has been demonstrated [1]. Compared to direct probe feeding approach, slot-coupled feeding requires no physical contact with the antenna, has wider bandwidth, and allows independent optimization of antennas and feed networks by using substrates of different thickness and permittivity. Further, the use of CPW as transmission media can reduce circuit radiation losses, and facilitates monolithic microwave integrated circuit (MMIC) device integration.

In this paper, we report two feeding techniques where the patch antenna is excited by coupling power electromagnetically through a slot from a CPW feed. The two techniques differ from each other in the CPW feed structure and slot designs. The first technique uses a grounded CPW with notches on both sides of the slot lines and a narrow rectangular slot, while the second technique uses a CPW with a series gap in the center strip conductor and a 'dumbbell' slot. The latter permits insertion of solid state devices in the series gap of the CPW and thus, is suitable for use in active antenna or quasi-optical combiner/mixer designs. To optimize the coupling efficiency, three different slot/gap designs have been tested.

DESIGN DESCRIPTION

Figure 1 (a) shows the slot-coupled patch antenna excited by a CPW with notches on both sides of the slot lines. The patch and the CPW feed structure are fabricated on separate substrates with the rectangular slot located in the common ground plane directly above the notches. The slot width and length are initially chosen to be 0.254 mm and $\lambda_{g(slot\ line)}/2$ respectively, where λ_g is the wavelength of an uniform slot line [2]. The slot length is then

slightly reduced to account for the slot end effects. The notch has a width of 0.762 mm and an end-to-end distance approximately equal to the slot length. To ensure good coupling and odd mode operation, the CPW is terminated in a short circuit at a distance of approximately $\lambda_{g(cpw)}/2$ from the center of the notch, and a pair of bond wires is inserted on both sides of the notches.
Figure 1 (b) shows the slot-coupled patch antenna excited by a CPW with a series gap in the center strip conductor. The inset in Figure 3 shows the three different slot/gap designs tested. In the first design, the dimensions of the series gap and the rectangular slot are (L_1, S) and (L_2, W_2) respectively. In the second design, the width of the series gap is enlarged from S to S_1 by flaring the center strip conductor of the CPW near the gap location. In the third design, the rectangular slot is replaced by a 'dumbbell' slot of identical length and width. The design parameters are given in the figure caption.

RESULTS AND DISCUSSIONS

Measured input impedance on Smith chart for the patch antenna with CPW/notch feed structure is shown in Figure 2. At the best impedance match frequency of 14 GHz, the return loss is greater than 20 dB and the 2:1 VSWR bandwidth is 4.2 %. Figure 3 shows the measured return losses for the three different feed configurations. As indicated, the return losses are improved from -8.2 dB for (a) to -13.2 dB for (b) to -16.9 dB for (c). Results indicate that the coupling efficiency was improved by more than 3 dB each by using an enlarged series gap or a 'dumbbell' slot. However, the geometrical change in the series gap and slot of the feed structure produced a slight change in the resonance frequency. Measured H- and E-plane patterns for the patch antenna excited by a CPW through notch/slot and gap/slot coupling are displayed in Figure 4 (a) and (b) respectively. The patterns appear symmetrical. The measured front-to-back ratio is about 14 dB which is typical for slot-coupled antenna configurations.

CONCLUSION

Two slot-coupled techniques for exciting patch antennas with CPW feeds have been demonstrated. Techniques for improving coupling efficiency are also described and discussed. Measured results indicate excellent patterns and coupling efficiency.

REFERENCES:

[1] R. N. Simons, R. Q. Lee and G. R. Lindamood, "Electromagnetic coupling between coplanar waveguide and microstrip antennas," to be published in the Microwave and Opical Technology Letters, Vol. 5, February 1992.
[2] R. N. Simons, "Suspended slot line using double layer dielectric," IEEE Trans. Microwave Theory Tech., Vol. MTT-29, No. 10, Oct. 1981, pp. 1102-1107.

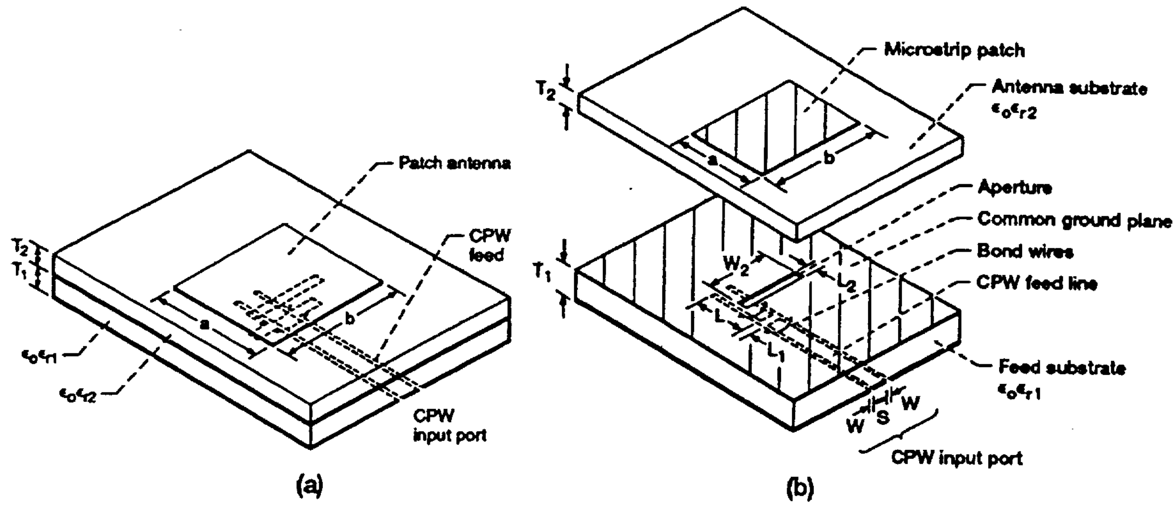

Fig. 1 Schematic of the CPW fed patch antenna with:
(a) notch/slot coupling and (b) gap/slot coupling
L_1=0.025 cm, L=0.711 cm, L_2=0.025 cm, W_2=0.69 cm,
a=0.76 cm, b=1.14 cm, T_1=0.051 cm, T_2=0.025 cm,
S=o.076 cm, W=0.025 cm, ϵ_{r1}=2.2, ϵ_{r2}=2.2

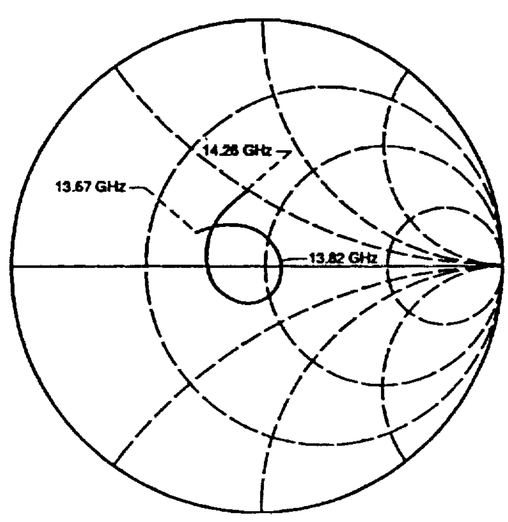

Fig. 2 Measured input impedance of the CPW fed patch antenna with notch/slot coupling.

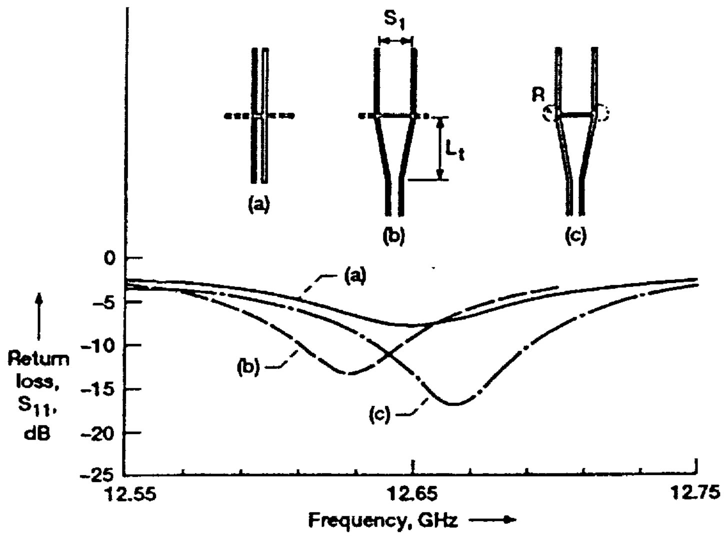

Fig. 3 Measured return losses vs. frequency for feed structures with: (a) a series gap and a rectangular slot, (b) an enlarged series gap and a rectangular slot, and (c) an enlarged series gap and a 'dumbbell' slot. (S_1=0.355 cm, L_t=0.711cm, and R=0.0843 cm)

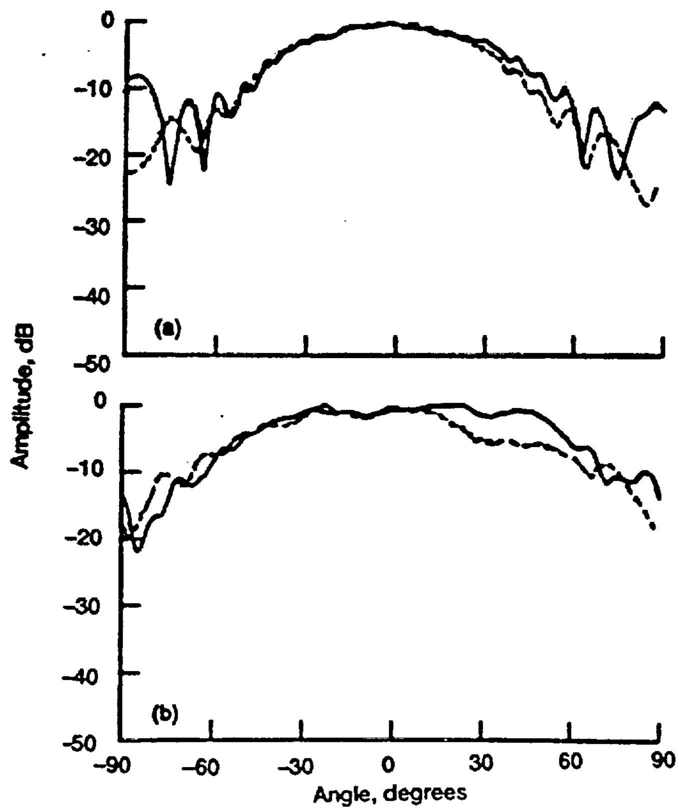

Fig. 4 Measured radiation patterns for the CPW fed patch antennas with (—) notch/slot and (---) gap/slot coupling: (a) H-plane and (b) E-plane.