A 29.3-GHz Cavity-Enclosed Aperture-Coupled Circular-Patch Antenna for Microwave Circuit Integration

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Abstract—**A circular-patch antenna fed by an aperture coupled microstrip line has been demonstrated at 29.3 GHz. The patch was enclosed by a cavity to reduce surface-wave interactions in an array environment and to improve heat dissipation when using active devices. The antenna exhibited a 2:1 input VSWR bandwidth of 12% from 27.52 to 30.95 GHz.**

I. Introduction

At low frequencies, microstrip patch antennas can be efficiently fed by a coaxial probe or microstrip line [1]–[5]. At millimeter-wave frequencies, the patch size becomes very small and the size of the probe or microstrip line is comparable to the patch. In this case, the performance of the antenna is severely affected by radiation and the discontinuity at the feedpoint. Furthermore, the reliability and the reproducibility of the probe feed method is poor due to the drilling and soldering procedure required.

Pozar proposed an aperture coupled microstrip antenna feeding scheme [6], [7] for a rectangular patch antenna. The method provides good isolation between the antenna and its associated microwave circuits. Since the aperture is hidden behind the patch and the microwave circuits are on the other side of the ground plane, spurious radiation is minimized. Another advantage of this circuit is in the separate optimization of the antenna and microwave circuitry.

This letter reports, for the first time, a 29.3 GHz circular patch antenna fed by an aperture coupled microstrip line. The patch demonstrated a 12% bandwidth from 27.52 to 30.95 GHz. The patch is enclosed by a cavity that is as thick as the antenna substrate and comes close to the radiating edges of a patch. This configuration improves the heat dissipation when using active devices and reduces surface-wave interactions in an array environment by isolating each antenna element.

II. Design Description

Fig. 1 shows the circuit and feed configuration. The aperture was etched on the ground plane of the feedline substrate to avoid machining. This procedure greatly improves the reproducibility and reduces the cost. The aperture coupled patch also allows individual optimization of the microstrip stub length (ΔL, ϵ_{r2}, h_2) and slot aperture (W_s, L_s) separate from the patch antenna (D, ϵ_{r1}, h_1). The antenna was designed on a substrate of a low dielectric constant (RT-Duroid 5870) to improve radiation efficiency. The microstrip feedline was on a substrate of a high dielectric constant (RT-Duroid 6010.5) for easy integration with GaAs monolithic circuits. The dimensions of key parameters are given in Table I.

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III. Performance

The input reflection coefficient was measured using an HP-8510B network analyzer. The element exhibited a 2:1 VSWR bandwidth of 12% from 27.52 to 30.95 GHz shown in Fig. 2. The *H*-plane pattern at 29.3 GHz is shown in Fig. 3. The patterns displayed a wide beamwidth and a cross-polarization below 15 dB. The *E*-plane patterns (Fig. 4) indicated a gain level of 5 dBi at 27.84, 28.57, 29.30, and 30.03 GHz. There was a dip at boresite primarily due to edge diffraction from the small test fixture and the proximity of the step used to house the OS-50 connector. The cross-polarization was consistently 15 dB below the maximum in the *E*-plane measurement. The front-to-back ratio was consistently $\geq$ 15 dB at 29.3 GHz.

The cavity enclosure was designed to reduce the surface wave interactions among elements in an array environment as well as improve heat dissipation from active elements. The enclosure has little effect on input impedance of the patch antenna. However, edge diffraction from the enclosure does increase the cross-polarization level 1 to 2 dB.

IV. Conclusion

A 29.3-GHz circular-patch antenna fed by an aperture coupled microstrip line has been demonstrated. The antenna has reasonable gain and bandwidth, and low cross-polarization and back-radiation. The antenna should have applications in conformal phased arrays at millimeter-wave frequencies.

V. Acknowledgment

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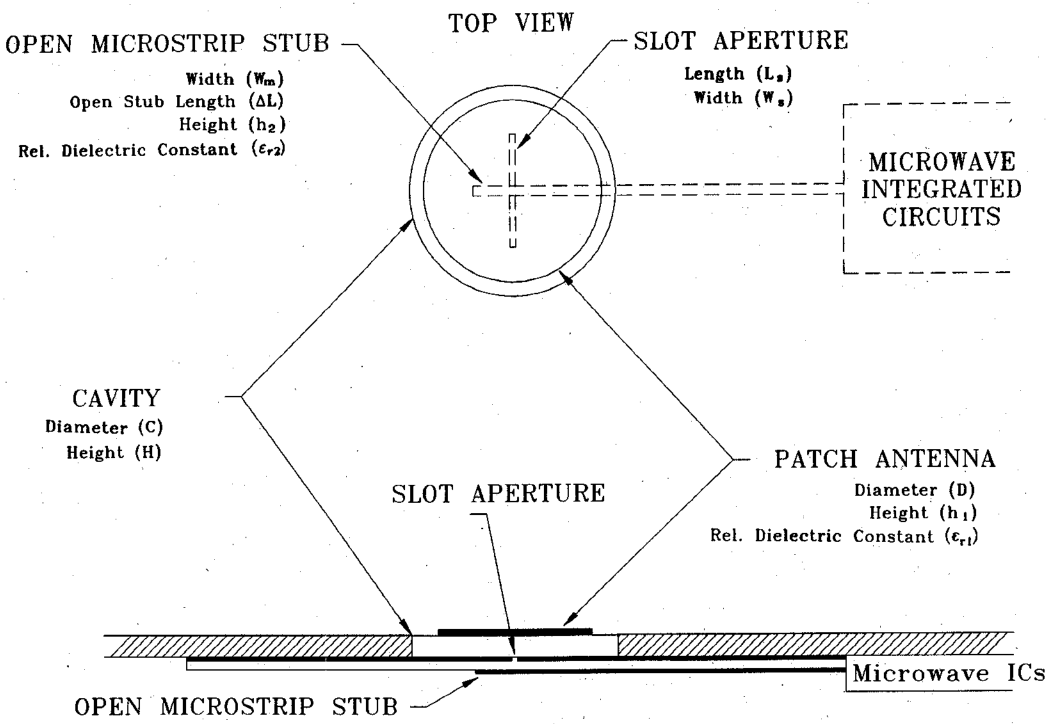

Fig. 1. Circuit configuration.

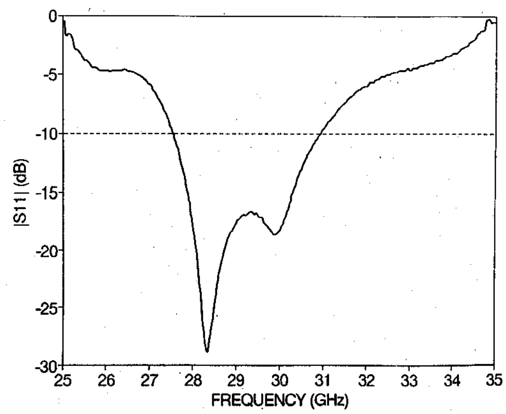

Fig. 2. Input $|S_{11}|$ measurement.

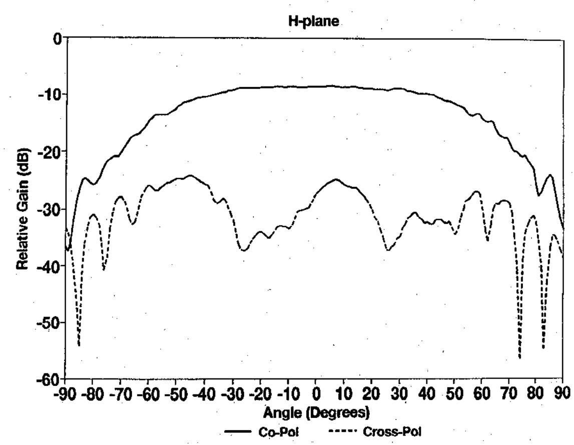

Fig. 3. *H*-plane pattern at 29.3 GHz.

TABLE 1
KEY PARAMETERS OF THE APERTURE COUPLED PATCH ANTENNA

Antenna Substrate	Feedline Substrate
$\epsilon_{r1} = 2.3$	$\epsilon_{r2} = 10.5$
$h_1 = 0.762$ mm	$h_2 = 0.254$ mm
$D = 3.350$ mm	
Cavity Dimensions	*Microstrip Stub*
$C = 4.500$ mm	$W_m = 0.230$ mm
$H = 0.762$ mm	$\Delta L = 0.830$ mm
Slot Aperture	
$W_s = 0.300$ mm	
$L_s = 1.800$ mm	

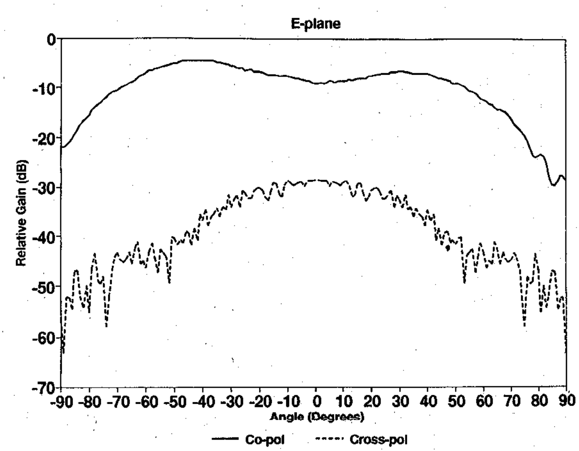

Fig. 4. *E*-plane pattern at 29.3 GHz.

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