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A Millimeter-Wave Cavity-Backed Suspended Substrate Stripline Antenna

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A MILLIMETER-WAVE CAVITY-BACKED SUSPENDED SUBSTRATE STRIPLINE ANTENNA

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I. INTRODUCTION

Future generation satellite communication systems in near-Earth orbit will operate at frequencies in the higher mm-wave frequency bands. These satellite systems require low-profile, high gain, light weight and low cost antennas for communications to and from Earth as well as for inter-satellite links (ISL). At higher mm-wave frequencies, the conductor loss of conventional microstrip line is high (ref. 1) and consequently the feed network loss of patch antenna arrays is also high. The high loss lowers the array efficiency (refs. 2 and 3), and in addition lowers the G/T ratio in a receiving array. Recently a radial line slot antenna array has been demonstrated to have high gain and efficiency at 60 GHz (ref. 4). In this paper, the design, fabrication and characterization of a V-Band (50-75 GHz), cavity backed, circular aperture antenna with suspended substrate stripline (SSS) feed is presented.

II. SUSPENDED SUBSTRATE STRIPLINE FEED

The basic suspended substrate stripline (SSS) configuration is shown in figure 1. The SSS consists of a strip conductor of width W and thickness t printed on a dielectric substrate of thickness d and permittivity ε_r. The substrate is suspended inside a grooved metal channel of width a and height b. The SSS has several advantages: First, the attenuation is lower compared to conventional microstrip (ref. 1). Second, the effective dielectric constant is close to that of free space and hence the circuit size is large. Third, the dominant mode is a quasi-TEM mode hence dispersion is low. The disadvantage of SSS is that very low values of characteristic impedance cannot be realized. This is because the dimension a of the channel is chosen such that the waveguide modes are cut off and therefore the maximum width of the strip W is limited. To excite the array elements in equal amplitude and phase a SSS corporate feed with T-junctions and quarter wave transformers is constructed.

III. ANTENNA ELEMENT DESIGN

A cavity backed circular aperture antenna with SSS feed is shown in figure 2. The antenna element (ref. 5) consists of a thin dielectric substrate of thickness d supported between two cylindrical waveguides of axial height h_1 and h_2. The lower waveguide is terminated in a short circuit so as to form a cavity. The radius r of the waveguide is chosen such that the dominant TE_{11} mode propagate but the next higher order TM_{01} mode is cut off. The TE_{11} mode is excited by extending the strip conductor of the SSS through an opening (a×b) in the wall thus forming a probe of width W_1 and length L_1. The probe impedance is matched to the SSS impedance by proper choice of W_1, L_1 and the cavity height h_2. The antenna radiates with a linear polarization along the y direction. A N×N planar array can be constructed by arranging the elements on a square lattice and exciting them with a SSS corporate feed.

IV. SUSPENDED SUBSTRATE STRIPLINE TO WAVEGUIDE TRANSITION

A SSS to rectangular waveguide transition is constructed to couple power to the array. The transition consists of a E-plane probe of length L_2 and width W_2. The probe is coupled to the SSS strip conductor by a taper of length L_3. Characterization of the transition is done by measuring the insertion loss and return loss of two of them in a back-to-back arrangement. Figures 3(a) and 3(b) show a schematic and a photograph of two back-to-back transitions respectively. Figures 4(a) and 4(b) show the measured insertion loss and return loss respectively. The insertion loss is less than 1 dB and the return loss less than −10.0 dB over large part of the frequency range. Typical dimensions of the antenna and the feed are presented in table I.

V. MEASURED ANTENNA CHARACTERISTICS

The element design is validated initially by characterizing the circular aperture which has a TE_{11} mode excitation. The measured E- and H-plane radiation pattern of the circular aperture at 50.5 GHz is shown in figure 5. The beamwidth in the E- and H-plane are 63° and 50° respectively. The measured gain is about 10 dB. The measured cross polarization is below 30 dB. A 2×2 array is being fabricated and its performance will be presented at the Symposium.

VI. CONCLUSIONS

The design of a V-Band 4×4 cavity backed circular aperture array with SSS feed for potential satcom applications is presented. The measured radiation patterns of a single circular aperture shows excellent characteristics.

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TABLE I.—TYPICAL DIMENSIONS FOR THE ANTENNA AND FEED

Suspended substrate stripline
a = 0.074 in.
b = 0.037 in.
c = 0.09 in.
d = 0.005 in.
ε_r = 2.2
t = 17.0 µm
Circular aperture antenna and probe feed
r = 0.0705 in.
h_1 = 0.25 in.
h_2 = 0.1 in.
W_1 = 0.0175 in.
L_1 = 0.06 in.
Rectangular waveguide-to-suspended substrate stripline transition
W = 0.04 in.
W_2 = 0.0175 in.
L_2 = 0.025 in.
L_3 = 0.066 in.

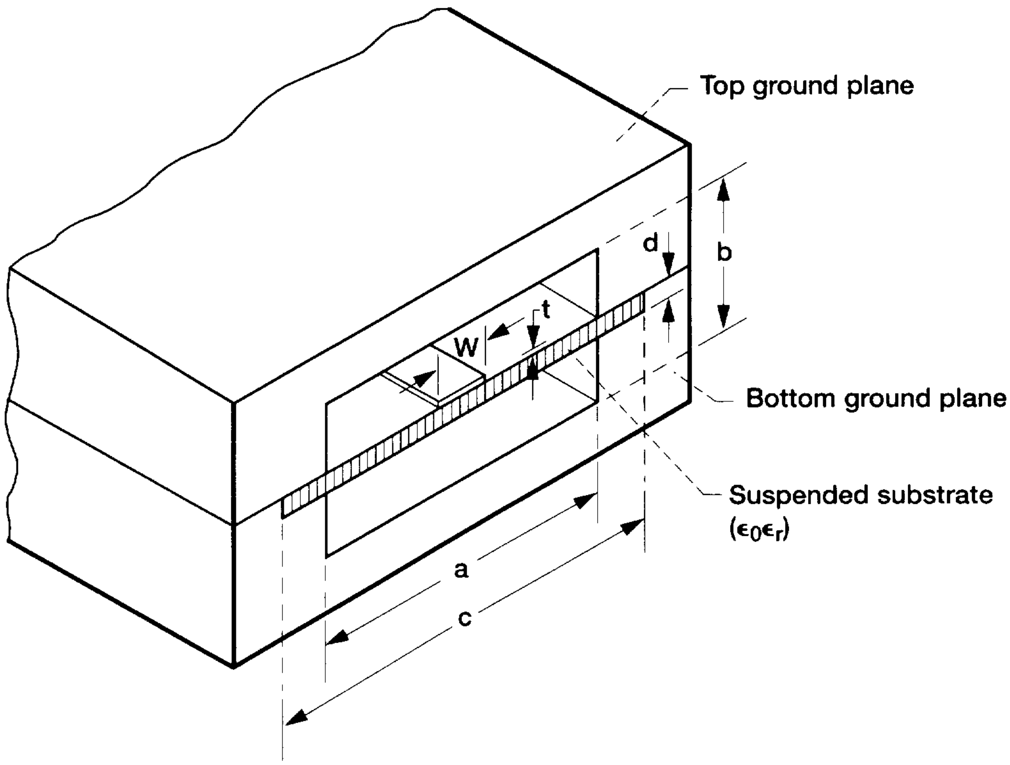

Figure 1.—Cross section of suspended substrate stripline.

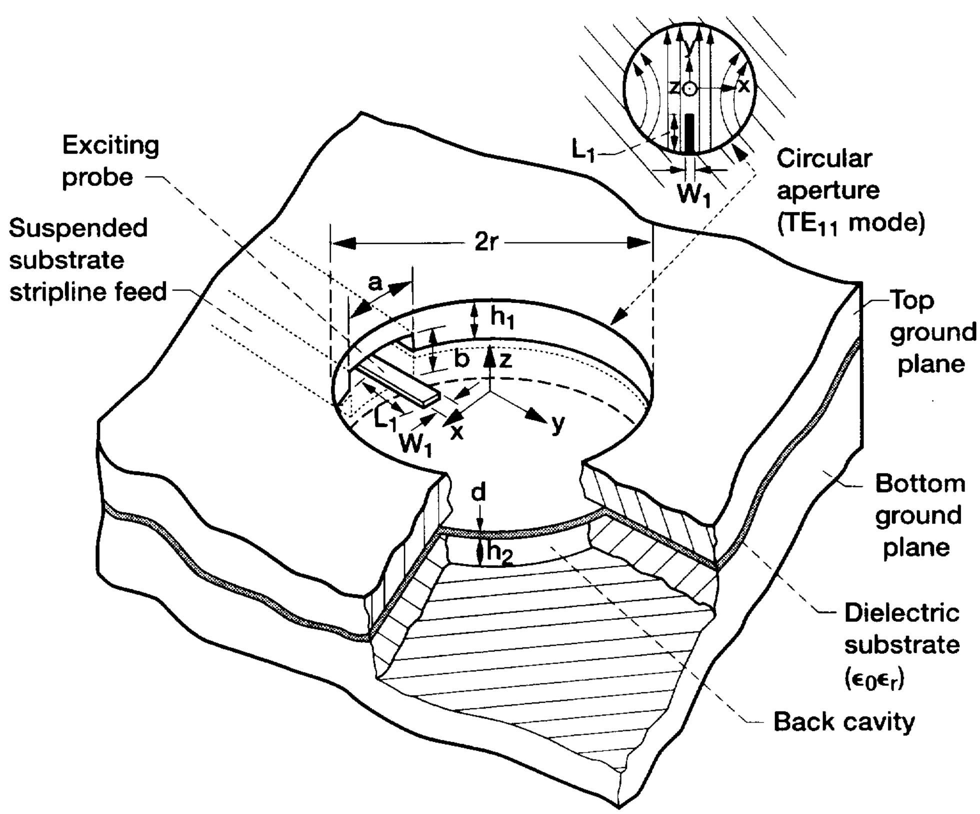

Figure 2.—Cavity backed circular aperture antenna with suspended substrate stripline probe feed.

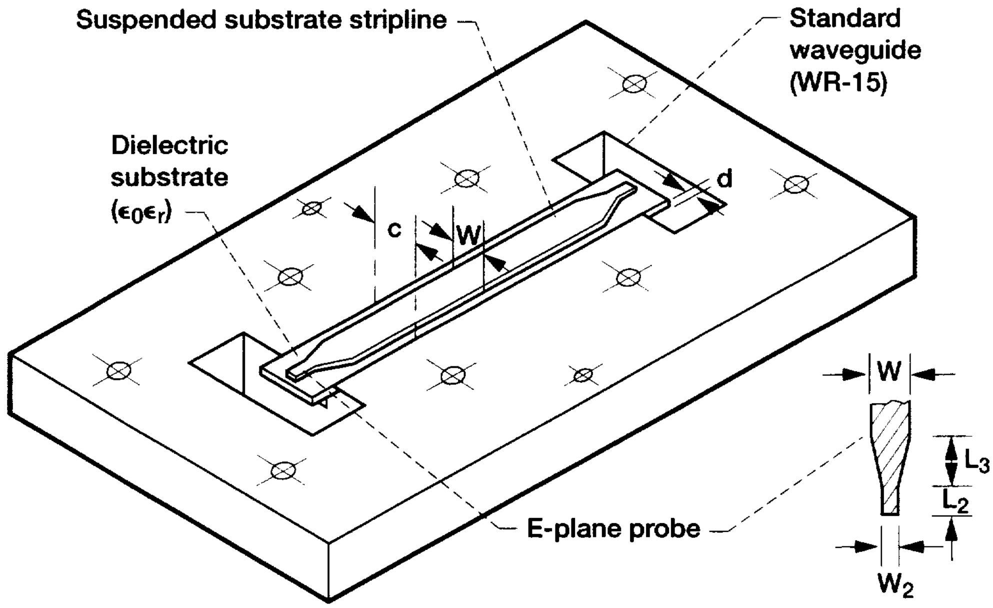

Figure 3.—(a) Back-to-back rectangular waveguide to suspended substrate stripline transition with top cover removed.

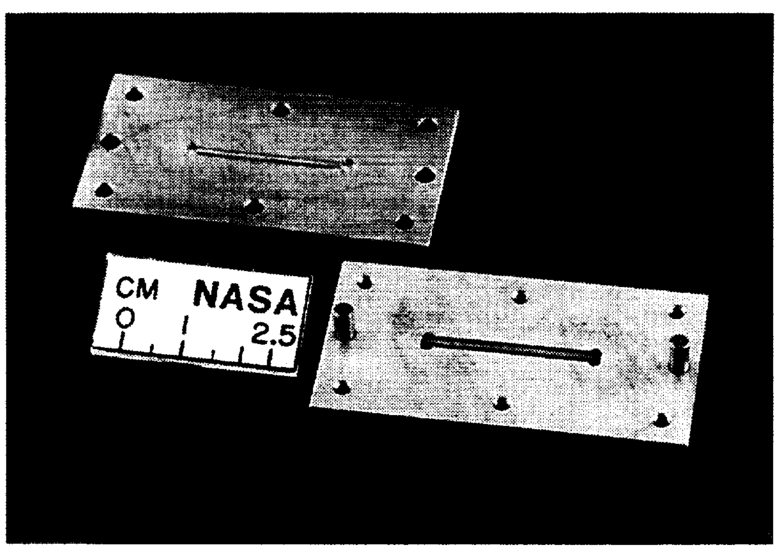

Figure 3.—(b) Photograph of two back-to-back rectangular waveguide to suspended substrate stripline transition.

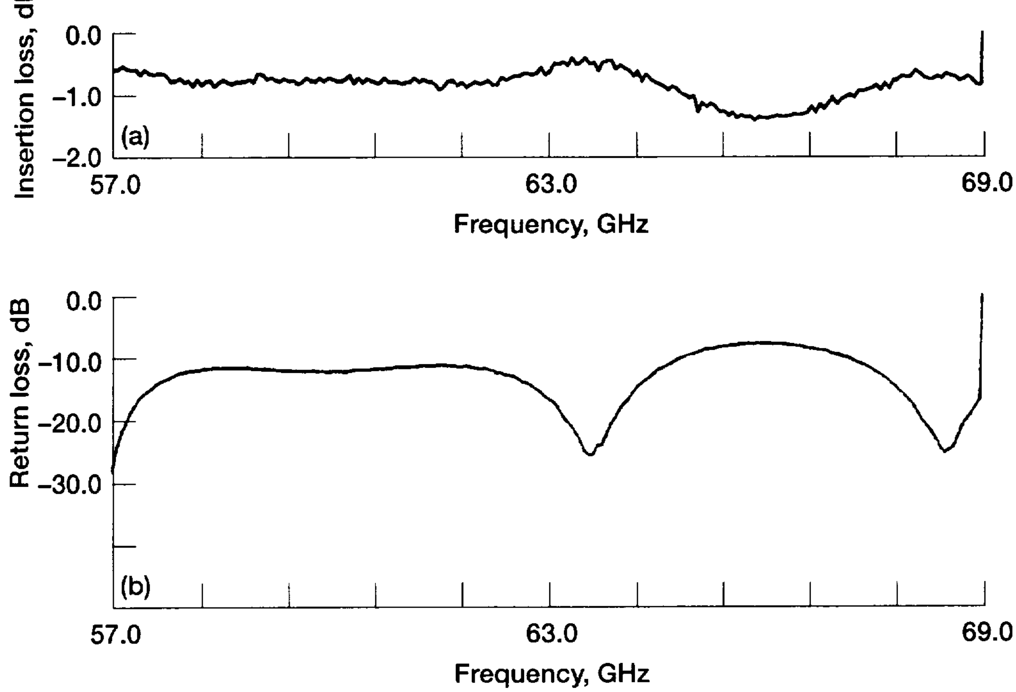

Figure 4.—Measured characteristics of the two back-to-back transitions. (a) Insertion loss. (b) Return loss.

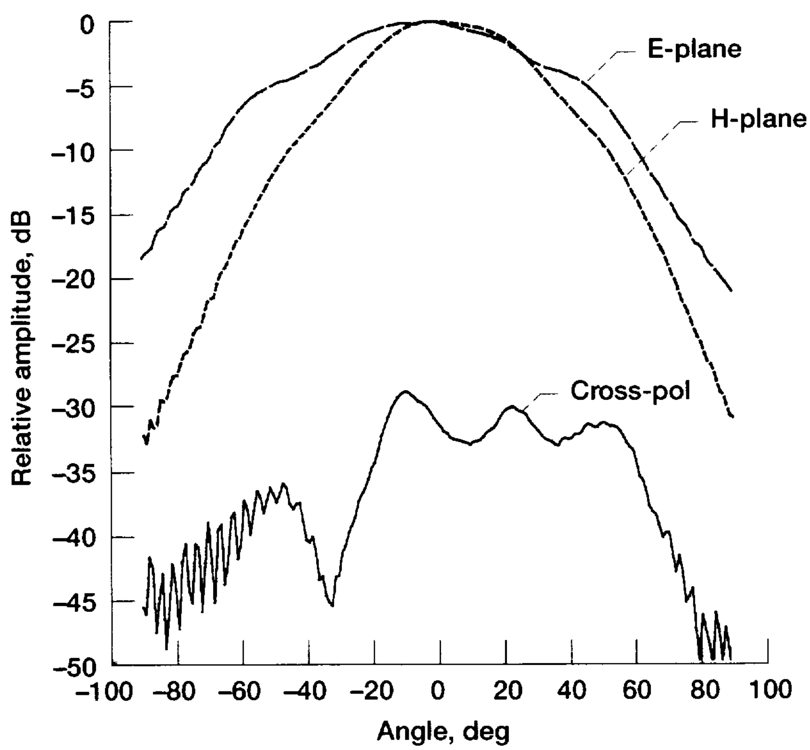

Figure 5.—Measured E- and H-plane radiation patterns and cross polarization at 50.5 GHz.

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14. SUBJECT TERMS

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