TABLE I

	Gain		Bandwidth		Beamwidth		
N	Theory	Experiment	3 dB	1 dB	E	H	Sidelobes
4	14.5 dB	13.5 dB	1.5 GHz	550 MHz	35°	37°	−8 dB
8	17.7 dB	17 dB	1.5 GHz	700 MHz	32°	16°	−9 dB
16	21 dB	20.3 dB	1.5 GHz	600 MHz	15°	15°	−12 dB
64	27 dB	24.3 dB	1.4 GHz	650 MHz	8°	8°	−12 dB

This formula may be used to find the element width so the radiation resistance will be 200 Ω. It should be noted that the integrand for P_R is the radiation pattern of a single element. The radiation pattern for an array will be given by the product of this integrand by the array factor. This was used in the computer simulation to find the optimum distance between elements.

The same expression with a different current distribution was also used to estimate the radiation loss from the feed network in the array.

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REFERENCES

[1] R. J. Mailloux, J. F. McIlvenna, and N. P. Kernweis, "Microstrip array technology," *IEEE Trans. Antennas Propagat.*, vol. AP-29, no. 1, pp. 25–37, Jan. 1981.

[2] J. Ashkenazy, P. Perlmutter, S. Shtrikman, and D. Treves in *Proc. First Mediterranean Electrotech. Conf.*, IEEE Melecon '81, Tel Aviv, Israel, Antennas 4.3.1.

[3] N. K. Uzunoglu, N. G. Alexopoulus, and J. G. Fikioris, "Radiation properties of microstrip dipoles," *IEEE Trans. Antennas Propagat.*, vol. AP-27, no. 6, pp. 853–858, Nov. 1979.

On Some Broad-Band Microstrip Resonators

D. R. PODDAR, J. S. CHATTERJEE, AND S. K. CHOWDHURY

Abstract—**The variation of voltage standing-wave ratio (VSWR) with frequency for microstrip antennas on stepped and wedge-shaped dielectric-substrates is measured for a band of frequencies, and is compared with those of an equivalent rectangular microstrip resonator. The results indicate a considerable improvement in bandwidth.**

INTRODUCTION

Microstrip resonators of rectangular, circular, and other shapes have been investigated in many works [1]-[5] because of their various advantages, such as ease of fabrication and compatibility with solid-state microwave devices. The main drawback of microstrip resonators is their narrow bandwidth. Various attempts have been made to improve the bandwidth of microstrip resonators like using parasites [6] and increasing the thickness of substrates [7] by various planar and multilayered structures [8]. The present work is concerned with the measurement of the (1:2) voltage standing-wave ratio (VSWR) bandwidth of some microstrip resonators on stepped and wedgeshaped dielectric-substrates. These measurements indicate that the fractional bandwidth in percentage obtainable by these structures ranges from 25 percent, whereas the bandwidth of microstrip antennas reported so far by others is less than 20 percent.

EXPERIMENTAL RESULTS

The antennas are shown in Fig. 1. All the relevant dimensions in terms of guide wavelength are indicated in Fig. 1. The microstrip patches were etched on perspex dielectric substrates. The

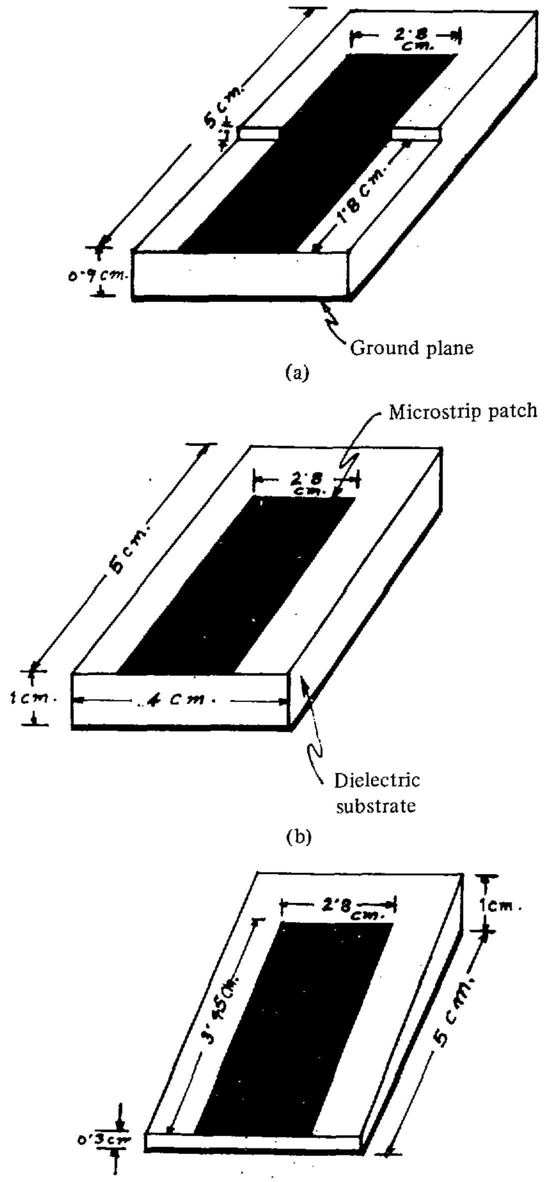

Fig. 1. Proposed microstrip structures. (a) Stepped microstrip resonator. (b) Rectangular microstrip resonator. (c) Wedge-shaped microstrip resonator.

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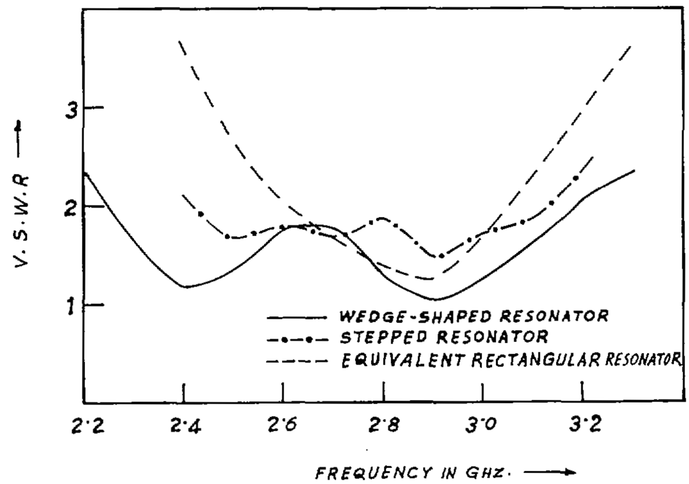

Fig. 2. VSWR versus frequency plot.

VSWR versus frequency plots of the resonators shown in Fig. 1 are given in Fig. 2. The (1:2) VSWR bandwidth of the microstrip resonator on a wedge-shaped dielectric is 28 percent and that on a stepped dielectric is 25 percent, whereas the bandwidth is 13 percent for an equivalent rectangular resonator. The maximum height for all the resonators was 0.01 m. This indicates that there is considerable improvement of bandwidth over that of a similar rectangular microstrip resonator. It may be mentioned that the feed point was in the same position for all the resonators.

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REFERENCES

[1] R. E. Munson, "Conformal microstrip antennas and microstrip phased arrays," *IEEE Trans. Antennas Propagat.*, vol. AP-22, no. 1, pp. 74–77, Jan. 1974.
[2] J. Q. Howell, "Microstrip antennas," *IEEE Trans. Antennas Propagat.*, vol. AP-23, pp. 90–93, Jan. 1975.
[3] J. Watkins, "Circular resonant structures in microstrip," *Electron. Lett.*, vol. 5, no. 21, pp. 524–525, Oct. 1969.
[4] A. G. Derneryd, "A theorectical investigation of the rectangular microstrip antenna," *IEEE Trans. Antennas Propagat.*, vol. AP-26, pp. 532–535, July 1978.
[5] Y. T. Lo *et al.*, "Theory and experiment on microstrip antennas," *IEEE Trans. Antennas Propagat*, vol. AP-27, no. 2, pp. 137–145, Mar. 1979.
[6] C. Wood, "Improved bandwidth of microstrip antennas using parasitic elements," *Proc. Inst. Elec. Eng. H, Microwaves, Opt. Acoust.*, vol. 127, pp. 231–234, Aug. 1980.
[7] A. G. Derneryd *et al.*, "Broad-band microstrip antenna element and array," *IEEE Trans. Antennas Propagat.*, vol. AP-29, no. 1, pp. 140–141, Jan. 1981.
[8] P. S. Hall *et al.*, "Wide bandwidth microstrip antennas for circuit integration," *Electron. Lett.*, vol. 15, no. 15, pp. 458–459, July 19, 1979.
[9] J. R. James *et al.*, "Design of microstrip antenna feeds, Part I: Estimation of radiation loss and design implications," *Proc. Inst. Elec. Eng. H, Microwaves, Opt. Acoust.*, vol. 128, Feb. 1981, pp. 19–25.

Cylindrical-Rectangular Microstrip Antenna

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Abstract—**Resonant frequencies f_r of a cylindrical-rectangular microstrip antenna are theoretically calculated. Comparison is made to f_r for a planar rectangular patch antenna, including the simplest planar patch modes having no field variation normal to the patch surface. The validity of using planar antenna patches to characterize microstrip antennas is examined.**

INTRODUCTION

In many applications pertaining to satellites, missiles, spacecraft, and aircraft, conformal microstrip antenna patches are used. Microstrip antenna patches are placed above what may be characterized as a conducting plane with a dielectric substrate separating the patch from the conducting plane [1]. However, often this plane surface is either distorted or the antenna elements are intentionally placed on a curved surface. Thus to determine the correct modal field solution to the electromagnetic cavity problem, which can be used to find the radiation field solution, this curvature should be taken into account. Here this is done for a rectangular patch on a cylindrical surface. The assumption that the conducting patch and the conducting cylinder (ground surface) act as electric walls, and that the open cavity ends act as magnetic walls is applied to the analysis for obtaining the fields and associated modal resonant frequencies [4]. This assumption should be particularly valid when using these fields for determining the radiation pattern for the limiting case of thin cavities ($h \ll a$) which are utilized for most microstrip antenna applications. All of the analysis for simplicity also assumes that the permittivity ϵ and permeability μ are constant (homogeneous medium filling cavity) and real (no dielectric losses).

The eigenvalue equations for resonant frequencies f_r are numerically solved and examined over a range of dielectric substrate thicknesses h. These resonant frequencies f_{rC} for the curved cylindrical-rectangular antenna, representing a distortion of a planar rectangular microstrip antenna, are compared to resonant frequencies f_{rR} of the planar patch antenna in order to assess the validity of the commonly used assumption that conformally mounted microstrip antennas may be treated as planar. The results demonstrate that this assumption is *good* for h that is small compared to the surface curvature a, and that it is *excellent* when considering excitation of the antenna with no spatial field variation normal to the surface.

THEORY

The geometry of the cavity is shown in Fig. 1 where Fig. 1(a) is a perspective drawing of a conducting patch on a cylindrical surface, Fig. 1(b) is a cross section through the patch and normal to the z-axis, and Fig. 1(c) shows the cavity isolated by itself in cross section. The conducting patch and grounded cylindrical surface are treated as electric walls and the magnetic walls of the cavity are defined by dropping perpendiculars from the patch

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