LARGE BANDWIDTH STACKED PRINTED ANTENNAS

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ABSTRACT

The authors present the theoretical analysis and measured results of two coaxially fed multilayer multipatch microstrip antennas. These antennas are made up of two centered patches separated by an air gap, and covered with a dielectric protective coating. The bandwidth obtained for a VSWR $\leq$ 1.5 is 12% in the L band and 38% in the X band.

INTRODUCTION

To increase the bandwidth of microstrip antennas, it is possible to take advantage of coupling between stacked patches (figure 1) [1].

Analysis of these structures is based on a reaction integral equation solved in the spectral domain [2]. The unknown variables in the resulting equations are the patch surface currents.

THEORETICAL ANALYSIS

The dielectrics and ground plane are assumed infinite, and the problem reduces to that of a stratified structure. The fields are computed in the spectral domain using the Fourier transform:

$$F(\alpha,\beta) = 1/\lambda_0^2 \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\, \exp\,[jK_0(\alpha x + \beta y)]\, dx\, dy$$

$\lambda = 2\pi / K_0$: wavelength in vacuum.

The unknown surface currents Js_1 and Js_2 on patches 1 and 2 respectively generate fields whose normal components Ez and Hz are first computed from the Helmholtz equations and continuity relationships at the interfaces. Tangent field components are then deduced in the transformed domain by the following relations:

$$Ex\,(\alpha,\beta,z) = -j[\alpha\, dEz/dz - j\beta\omega\mu Hz]/[K_0(\alpha^2 + \beta^2)]$$

$$Ey\,(\alpha,\beta,z) = -j[\beta\, dEz/dz - j\alpha\omega\mu Hz]/[K_0(\alpha^2 + \beta^2)]$$

The feed current J^{exc} generates its own field which is to be added to that caused by the currents Js_1 and Js_2. This field is described by a current density on the surface of the cylinder formed by the core of the coaxial feed going through the first substrate. The reaction theorem [3] allows us to write the integral equation:

$$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} Js_1\, E^{test}\, d\alpha\, d\beta + \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} Js_2\, E^{test}\, d\alpha\, d\beta = -\int_0^{H_1} [\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} J^{exc}\, E^{test}\, d\alpha\, d\beta]\, dz$$

E^{test} represents the field caused by test current J^{test} on one of the two patches. The unknown currents Js_1 and Js_2 are computed using Galerkin's method of moments. They are then expanded as basis functions Jn:

$$Js = \sum_n In.Jn$$

Since the patches are rectangular, sinusoidal functions (Fourier series) are used as test and basis functions.

A system of linear equations is thus obtained, enabling computation of the unknowns In by substituting into the integral equation as many test currents as there are unknowns:

$$[Z]\,[I] = [V]$$

Zij is the reaction on basis current j caused by test current i. [I] is the matrix of unknown coefficients In. Vi is the reaction on the feed current caused by test current i.

Once these currents are determined, the antenna's main characteristics such as its input impedance [4] and radiation pattern can be computed.

RESULTS

Theoretical analysis led to the determination of square-patch geometries for two different three-layer antennas [5] (figure 2), one X-band and one L-band. Only the lower patch is fed coaxially. The patches are centered, to ensure structural symmetry and to facilitate the subsequent achievement of circular polarization. The thickness of the air gap between the two patches can be varied in order to control coupling between them. This structure is also self-protected.

For the L-band, the two stacked patches are mounted on a polypropylene substrate, 1.6 mm thick ($\varepsilon_r = 2.25$; $\tan \delta = 0.001$). The feed is located along the diagonal of the lower patch. Figure 3 indicates the VSWR as a function of frequency. A 12% bandwidth is obtained (from 1.52 to 1.72 GHz) for a VSWR of less than 1.5. Figures 4 and 5 show the radiation patterns at 1.58 GHz, in the E and H planes. On-axis crosspolarization remains low throughout the bandwidth defined by measurement of the input impedance.

For the X-band antenna, a duroid substrate was used ($\varepsilon_r = 2.25$; $\tan \delta = 0.0008$). Substrate thicknesses were 1.53 mm (H_1) and 3.09 mm (H_3) for the lower and upper patches, respectively. The feed was located on the median of the lower patch. The bandwidths obtained for various VSWR values are as follows (figure 6):

* 35% (from 10.12 to 14.41 GHz) for a VSWR < 1.3
* 38% (from 9.925 to 14.61 GHz) for a VSWR < 1.5
* 46% (from 9.425 to 15.08 GHz) for a VSWR < 2.

The radiation patterns were measured over the 9.5 - 14.5 GHz band. An extremely low crosspolar level was obtained throughout this band in the E plane. H plane crosspolarization was higher (figures 7 and 8; E and H planes at 12 GHz).

Lastly, gain measurements showed this latter to be stable throughout the bandwidth defined by the measured input impedance.

CONCLUSION

The proposed structure leads to microstrip antennas featuring large bandwidths. In the L band, crosspolarization remains low throughout the bandwidth defined by the measured input impedance, but in the X band, it is slightly higher. The radiation patterns could conceivably be improved in this band by using a slotted feed in the ground plane [5]. Gain is satisfactory and remains stable throughout the bandwidth.

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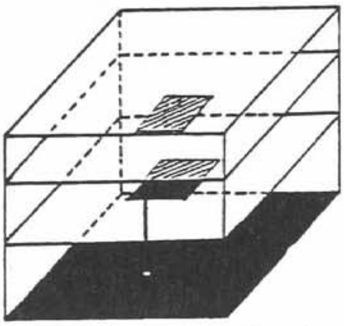

Fig. 1

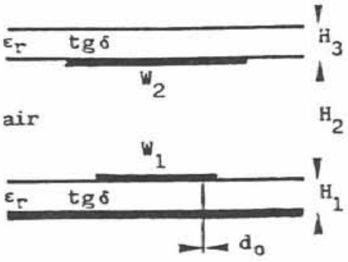

Fig. 2

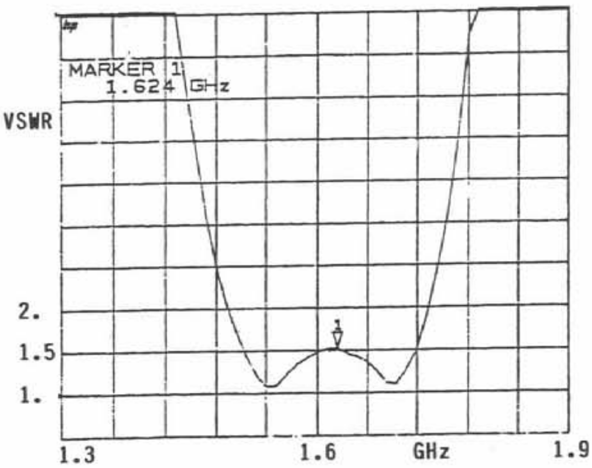

Fig. 3

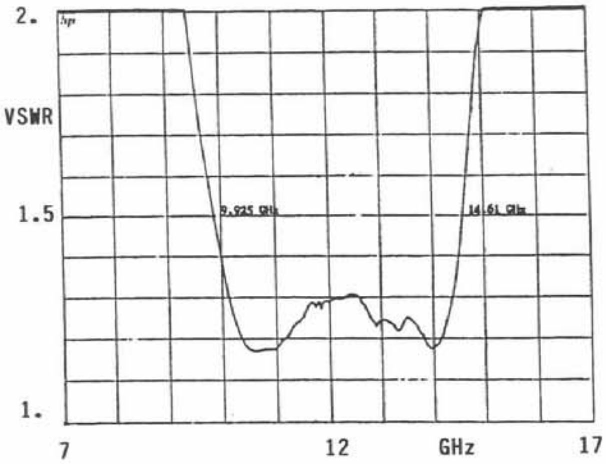

Fig. 6

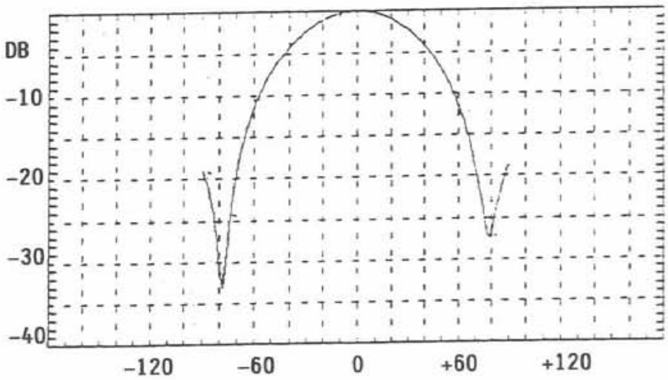

Fig. 4

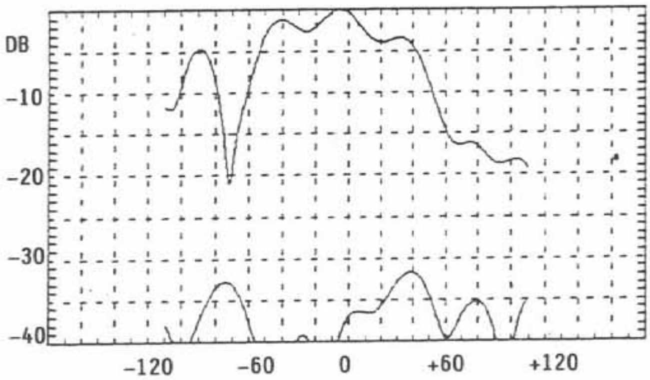

Fig. 7

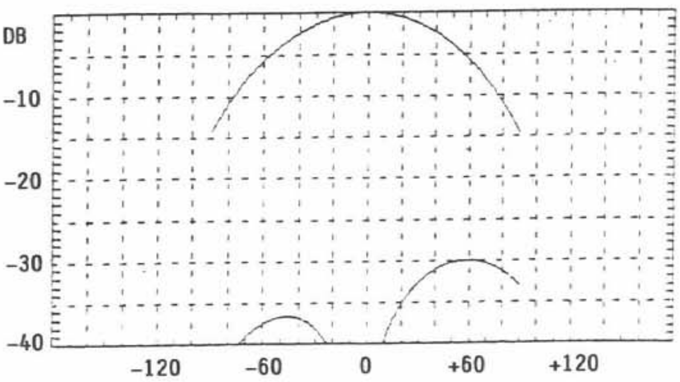

Fig. 5

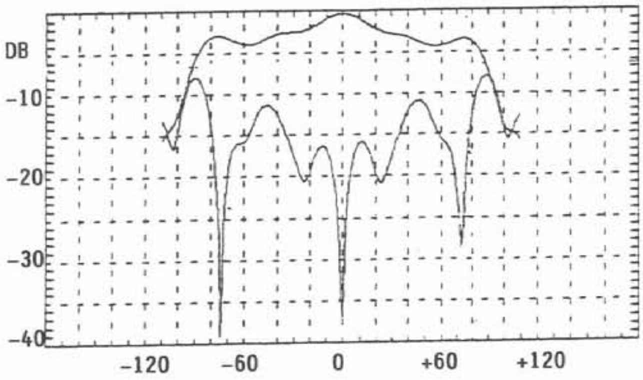

Fig. 8