Stacked Slot-Coupled Printed Antenna

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***Abstract*—An aperture-coupled microstrip stacked patch antenna is studied with the goal of obtaining wide bandwidth, low cross-polarization and weak parasitic radiation from the feeding aperture for applications in printed phased array antennas.**

I. Introduction

APERTURE coupling to printed antennas [1] has many advantages over other classical feeding techniques (probe feeds, edge-feeds). Recently, it has been shown [2], [3] that the poor bandwidth of this type of antenna can be increased by coupling the resonant patch to the slot near its resonance. In this case, although the bandwidth is increased drastically, this technique induces a quite high back radiation level, due to the proximity of the resonance of the slot that radiates on both sides of the ground plane. This phenomena can be a serious drawback for applications in integrated phased array antennas, causing the malfunction of associated devices due to electromagnetic compatibility problems. In order to alleviate this problem, stacked patches (Fig. 1) were used to achieve the bandwidth. In this case, the resonance of the slot is chosen to be as far as possible from the operating band of the antenna (Fig. 2) so that its radiation level will be small.

II. Method of Analysis

The analysis of the structure was based on the solution of field integral equations solved in the spectral domain by the method of moments. The reciprocity method [4], which avoids calculation of the microstrip line currents, was used to simplify the analysis. Evaluating the various reaction integrals required the calculation of the exact Green's functions of the structure. The resonant currents on the patches were expanded in a set of entire domain basis functions, while the electric field in the nonresonant slot was well described by a single piecewise sinusoidal basis function. For convergence, five expansion modes were required on each of the patches.

III. Simulations and Results

An antenna of this type was designed for operation in C band. It was found convenient to use air dielectric between the patches, the thickness H2 being then achieved by spacers. The dimensions are given below with respect to the notation of Fig. 1: H3 = 1.54 mm; Er3 = 2.2; Tgd3 = 0.001; Wx2 = Wy2 = 18 mm; H2 = 4.6 mm; Er2 = 1.0; Tgd2 = 0.0; Wx1 = Wy1 = 15 mm; H1 = 1.54 mm; Er1 = 2.2; Tgd1

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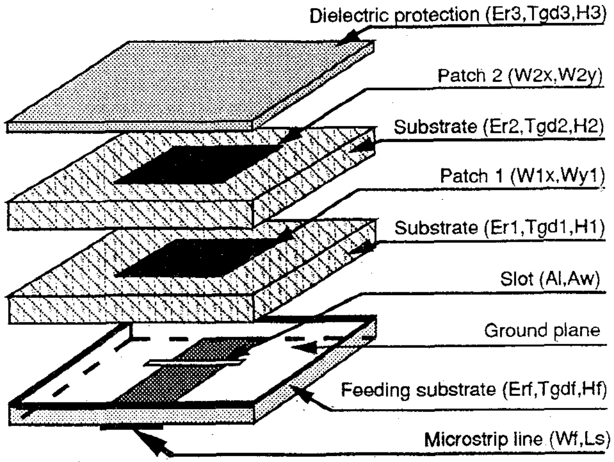

Fig. 1. Stacked patches aperture coupled to a microstrip line.

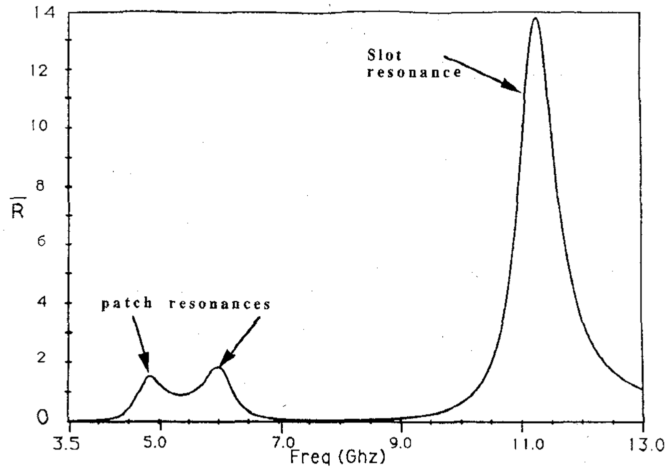

Fig. 2. Resonant frequencies of the three resonators.

= 0.001; Al = 13.5 mm; Aw = 0.8 mm; Erf = 2.2; Hf = 0.762; Tgdf = 0.001; Wf = 2.32 mm; Ls = 9.0 mm.

Where the Tgdi represents the loss tangent of the different dielectric substrates. The comparison between the theoretical and measured impedance loci (Fig. 3), taken at the slot reference plane, shows a good correlation for the useful bandwidth of the antenna. However, a sensitive difference is observed outside of this bandwidth that can be attributed to a combination of different effects including the error in the calculation of the reference plane (propagation constant in the microstrip line), the insufficient description of the field in the slot outside of the operating band of the antenna, the tolerances in the fabrication, the effect of the connector, and the losses in the feeding line. A 25% bandwidth (4.6–6.0 GHz) with VSWR less than 1.6 was achieved. This was quantitatively consistent with the calculated results within a 4% shift in the frequency response.

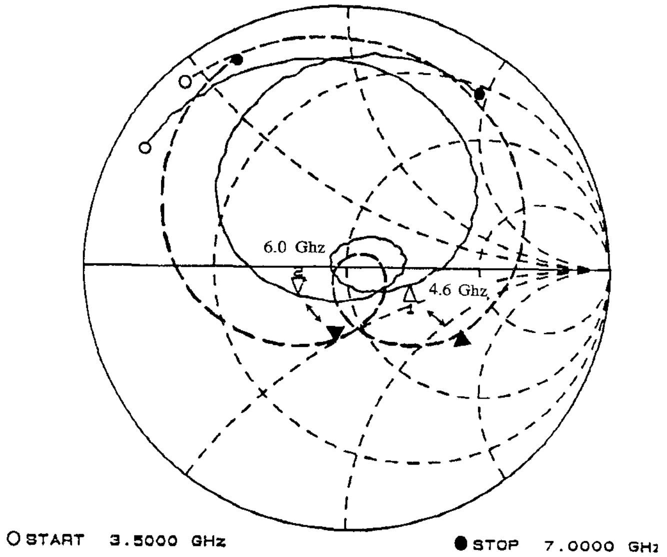

Fig. 3. C band antenna impedance locus at the slot reference plane (- - - Theoretical; —— Measured).

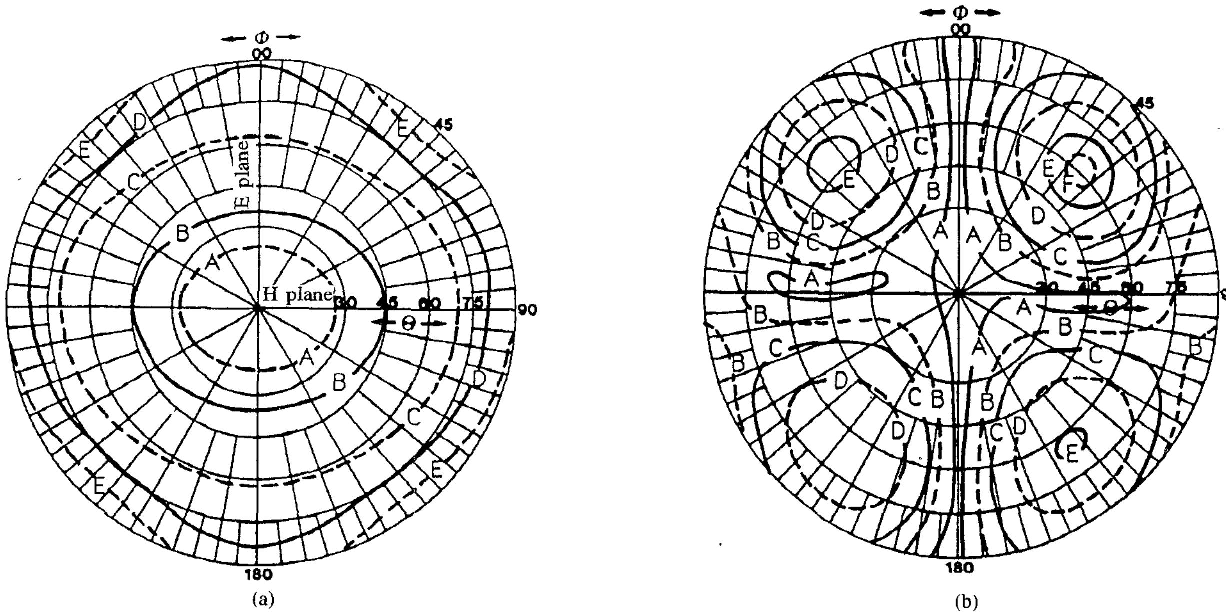

Fig. 4. (a) Measured copolarized contour plot at 5.25 GHz ($\Theta = 0°–90°$; $\Phi = 0°–360°$) A = −1 dB; B = −3 dB; C = −10 dB; D = −15 dB; E = −20 dB. (b) Measured crosspolarized contour plot at 5.25 GHz ($\Theta = 0°–90°$; $\Phi = 0°–360°$) A = −40 dB; B = −30 dB; C = −26 dB; D = −22 dB; E = −19 dB; F = −18 dB.

Figs. 4(a) and 4(b) show the experimental front radiation pattern of this antenna at midband, where the influence of the finite ground plane has been removed by a near field measurement technique [5]. Some remarks can be made in comparison to the single patch wideband structure [3]. 1) The copolarized component (Fig. 4(a)) is in this case more isotropic (directivity between 7.6 and 9.0 dB over the bandwidth). This effect is related to the lower inter-resonator distance necessary to achieve an equivalent bandwidth. 2) The crosspolarized component (Fig. 4(b)) is very low near broadside (< 40 dB), but seems to be less symmetric (maximum of this component ranging from −22– −18 dB in the diagonal planes ($\Phi = 45°$ and $\Phi = 135°$) and the curve B (Cross_pol = −30 dB) is not symmetric with respect to the H plane). This is probably due to the misalignment of the resonators when assembling the substrate layers. It should be pointed out that even though this effect had only a small influence on the impedance characteristics, it might have a more significant influence on the polarization purity of the antenna when used at millimeter wave frequencies.

Lastly, the theoretical radiation pattern of the antenna is presented (Fig. 5) for the E and H planes and at the upper frequency of the antenna. This representation gives a worst case theoretical back to front ratio of about −18 dB for this antenna. This ratio was found to be −21 dB at the lower frequency of the band. These results are consistent with the

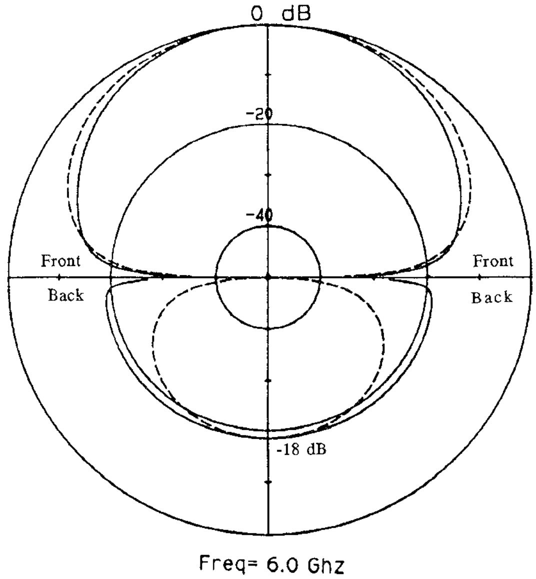

Fig. 5. Front and back theoretical radiation patterns at the upper frequency (6 GHz) (E plane ——; H plane - - -).

measurements which ranged from −21 to −17 dB over the band. This more complicated structure presents a good improvement over the configuration of [3] which has a back to front ratio ranging from −13 to −11 dB over the band when measured with the same set-up. It must be noted that there is a trade-off between bandwidth and back radiation, and that this latter criterion can be optimized below −20 dB over the entire bandwidth, at the expense of a narrower bandwidth.

IV. Conclusion

A stacked patch aperture coupled microstrip was presented. The comparison of the calculated and measured impedance loci of C band antenna shows good agreement. This structure is more flexible and allows a better design of both bandwidth and back radiation criteria than the former single-patch wideband structure. The cross-polarization level of the stacked patch configuration is lower than that of the single patch, but more sensitive to eventual misalignment of the resonators. This type of antenna should be useful as an element in arrays requiring wideband, high polarization purity and electromagnetic compatibility with associated devices.

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