# DETERMINATION OF THE RADAR CROSS SECTION OF STACKED CIRCULAR MICROSTRIP PATCHES

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## 1. INTRODUCTION

Although the standard configuration for a microstrip antenna is a single patch of conductor supported above a ground plane by a simple dielectric substrate, two patch radiators separated by different dielectric layers are sometimes stacked one above the other for obtaining increased bandwidth or dual-frequency operation [1,2,3].

As the radar cross-section (RCS) of a military platform is reduced by geometrical shaping and the use of composite radar absorbing materials, it becomes increasingly important to consider the RCS of antennas mounted on the structure since such scattering may give the most significant contribution to the overall RCS of a low-observable platform. Bearing in mind that microstrip antennas are very suitable for use on aircraft and aerospace vehicles owing to their light weight and conformability, in the last few years several researchers have focused on obtaining both theoretical and experimental results for the RCS of microstrip antennas [4]. In the current paper, the authors apply Galerkin's method in the Hankel transform domain (HTD) [5] to the determination of the RCS of stacked circular microstrip patches used for both increased bandwidth applications and dual-frequency applications. The numerical results obtained for the RCS of every pair of stacked circular patches are compared with those obtained when one of the two stacked patches is absent in order to see how the RCS of a single patch is affected by the presence of a second patch.

## 2. NUMERICAL PROCEDURE

Fig. 1 shows the side and top views of two stacked circular microstrip patches of radii $a_1$ and $a_2$. The patches are assumed to be aligned so that their centers are placed along the same line perpendicular to the ground plane (this line is taken to be the $z$ axis in Fig. 1). Both the circular metallic patches and the ground plane are assumed to be perfect electric conductors of negligible thickness. The patches are placed in a multilayered dielectric substrate, and the layers of the substrate are assumed to be of infinite extent along the $x$ and $y$ coordinates. Let us assume that a TEM plane wave travelling through the air incides on the resonant multilayered structure of Fig. 1. The incident plane

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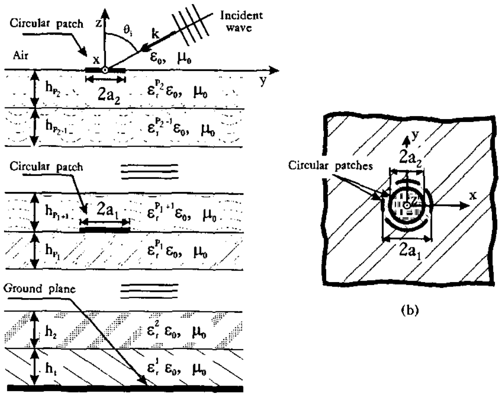

(a)

(b)

Fig.1. Side (a) and top (b) views of two stacked circular microstrip patches placed in a multilayered dielectric medium. A plane wave whose direction of propagation makes an angle $\theta_i$ with the $z$ axis incides on the stacked circular patches fom the air region existing above the upper circular patch.

wave will be both reflected by the multilayered substrate and scattered by the two metallic circular patches. If the total tangential electric field on every patch (sum of the electric fields of the incident wave, the reflected wave and the scattered wave) is obliged to be zero, a set of two electric field integral equations (EFIE's) for the current density on the patches is obtained. In order to solve these two EFIE's, in the current paper the authors have expressed the unknown current density on the patches, $j_i(\rho,\varphi)$ ($i$=1,2), as a Fourier series of the cylindrical $\varphi$ coordinate given by

$$\mathbf{j}_i(\rho,\varphi)=\sum_{m=-\infty}^{m=+\infty}\mathbf{j}_{mi}(\rho)e^{jm\varphi}=\sum_{m=-\infty}^{m=+\infty}(j_{mi,\rho}(\rho)\hat{\boldsymbol{\rho}}+j_{mi,\varphi}(\rho)\hat{\boldsymbol{\varphi}})e^{jm\varphi}\quad(i=1,2)\qquad(1)$$

Bearing in mind (1), the two original EFIE's have been written in the HTD in order to obtain an infinite set of decoupled pairs of equations for the Hankel transforms of the vector functions $j_{m1}(\rho)$ and $j_{m2}(\rho)$($m$=...,-2,-1,0,1,2,...) appearing in the modal decomposition of $j_1(\rho,\varphi)$ and $j_2(\rho,\varphi)$ respectively. Each decoupled pair of equations has been solved by applying Galerkin's method in the HTD as in [5]. Once the current density on the patches has been obtained, the far zone scattered electric field has been determined by applying the stationary phase method [5] in order to obtain the RCS of the patches.

## 3. RESULTS

In Fig. 2 the authors show results for the monostatic RCS of stacked circular patches of similar size ($a_2/a_1$=1.02) in a configuration intended for increased bandwidth applications. It can be noticed that the results obtained for the RCS of the stacked patches are in general very close to those obtained for the upper patch in the absence of the lower patch except for small frequency intervals placed in the vicinity of the resonant frequencies of the lower patch. Note that the RCS peaks corresponding to these resonances are very sharp. This is attributed to the high values of their quality factors, which can be explained by the low level of radiation emitted by the lower patch owing to the shielding effect exerted by the upper patch. In Fig. 3 results are presented for the RCS of stacked circular patches of different size ($a_2/a_1$=0.75) in a configuration intended for dual-frequency applications. It can be noticed that the frequency and magnitude of the first four RCS peaks of the stacked patches tend to coincide either with the RCS peaks of the lower patch in the absence of the upper patch or with the RCS peaks obtained for the upper patch when the lower patch is substituted by an infinite ground plane. However, this is not true any more for the fifth peak -placed roughly at 17.5 GHz- owing to the fact that in this latter case there seems to be an interference phenomenon between a resonance of the lower patch and a resonance of the upper patch.

## 4. CONCLUSION

Galerkin's method in the Hankel transform domain (HTD) is applied to the determination of the radar cross section (RCS) of stacked circular microstrip patches which can be used as either increased bandwidth microstrip antennas or dual-frequency microstrip antennas. The numerical results obtained show that the RCS values of a pair of stacked circular patches may be very different from those obtained for one patch in the absence of the other patch.

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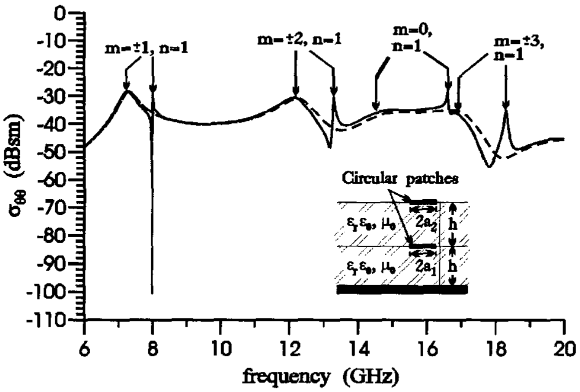

Fig. 2. Monostatic RCS of stacked circular microstrip patches for increased bandwidth applications ($a_1$=7.1 mm, $a_2$=7.25 mm, $h$=0.7874 mm, $\varepsilon_r$=2.2) versus frequency. The incident angle is $\theta_i$=63°. The results obtained for the RCS of the stacked patches (solid line) are compared wih those obtained for the upper patch in the absence of the lower patch (dashed line). The vertical arrows locate the resonant frequencies of the resonant modes of the stacked patches.

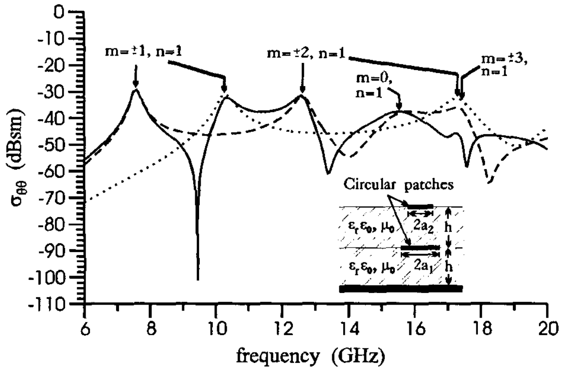

Fig. 3. Monostatic RCS of stacked circular microstrip patches for dual-frequency applications ($a_1$=7.1 mm, $a_2$=5.3 mm, $h$=0.7874 mm, $\varepsilon_r$= 2.2) versus frequency. The incident angle is $\theta_i$=63°. The results obtained for the RCS of the stacked patches (solid line) are compared wih those obtained for the lower patch in the absence of the upper patch (dashed line) and with those obtained for the upper patch when the lower patch is substituted by an infinite ground plane (dotted line). The vertical arrows locate the resonant frequencies of the resonant modes of the stacked patches.