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Connected Array Loaded with Artificial Dielectric Layers

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A Planar Wideband Wide-Scan Phased Array: Connected Array Loaded with Artificial Dielectric Layers

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***Abstract*—We present a novel concept for wideband, wide-scan phased array applications. The array is composed by connected-slot elements loaded with artificial dielectric superstrates. The proposed solution consists of a single multi-layer planar printed circuit board (PCB) and does not require the typically employed vertical arrangement of multiple PCBs. This offers advantages in terms of complexity of the assembly and cost of the array. We developed an analytical method for the prediction of the array performance, in terms of active input impedance. This method allows to estimate the relevant parameters of the array with a negligible computational cost. A design example with a bandwidth exceeding one octave (VSWR<2 from 6.5 to 14.3) and scanning up to 50 degrees for all azimuth planes is presented.**

I. Introduction

Wideband, wide-scan phased arrays are of great interest for present and future applications in multi-function radars and broadband satellite communication. Several recent efforts have been made in the development of wideband and wide-scan arrays that could maintain simultaneously low cross-polarization and good matching efficiency for all pointing directions within the scan range [1]-[4]. These arrays consist of a set of vertically arranged printed circuit boards (PCBs) arranged in a three-dimensional structure. The vertical PCBs are often needed to realize long transmission lines that transfer the signal from the antenna elements to connectors or electronic components below the backing reflector, which is typically located at about a quarter wavelength distance from the array plane. A similar PCB arrangement is used for tapered slot antenna arrays [5], [6].

More recent designs have been proposed, with the goal of realizing a planar implementation of this type of arrays, reducing the cost and the assembly complexity [7], [8]. Following the same path, we propose in this work a planar solution for wideband, wide-scan phased arrays. We combine the connected array concept with artificial dielectric layers (ADLs). For design of the total structure (array loaded with ADLs) we used an in-house developed analysis tool, which is based on closed-form expressions and thus resorts to minimal computational resources. A realistic feed structure is also proposed, which consists of a microstrip line connected to a coaxial feed. Such a solution does not require balanced-to-unbalanced (balun) transitions, which often limit the achievable bandwidth. The proposed structure achieves in simulations more than an octave bandwidth (6.5 to 14.3 GHz) for single polarization, within a scanning volume of 50 degrees in all azimuth planes. Similar performance can be achieved also for dual-polarized designs.

II. Antenna Concept

Connected arrays consist of an array of either slots or dipoles which are electrically connected [9]. They have the advantage of being broadband and, at the same time, they exhibit low cross polarization. Practically the bandwidth of a connected array is limited by the distance from the backing reflector, which is needed to ensure unidirectional radiation. A connected array of slots in presence of a backing reflector is depicted in Fig. 1, with the relative geometrical parameters. Here, we propose to load these arrays with ADL superstrates.

ADLs consist of a cascade of layers, each composed by periodic electrically small metal patches, included in a dielectric host medium to enhance its equivalent relative permittivity (Fig. 2). The factor by which the permittivity of a medium is increased depends on the physical dimensions of the metallic patches and the inter-layer distance [10], [11]. Loading the array with a single or multiple ADL slabs allows to significantly reduce the distance between the array and the backing reflector, enabling the implementation of the feed by means of PCB via hole technology.

As an example, Fig. 3(a) shows a unit cell of the connected array loaded with a 3-slab ADL superstrate. The ADL slab is characterized by a high effective relative permittivity, thus increasing the radiation towards the positive z-direction. Consequently, the array 'feels' less the presence of the backing reflector, which can be located closer to it without strongly degrading the impedance matching properties. Simulating a structure like the one in Fig. 3(a) requires heavy computational resources. Therefore, an analytical tool was developed to estimate the performance of the connected array of slots loaded with ADL. The formulation exploits and combines the analytical spectral solutions of connected arrays [12] and ADLs [10], [11].

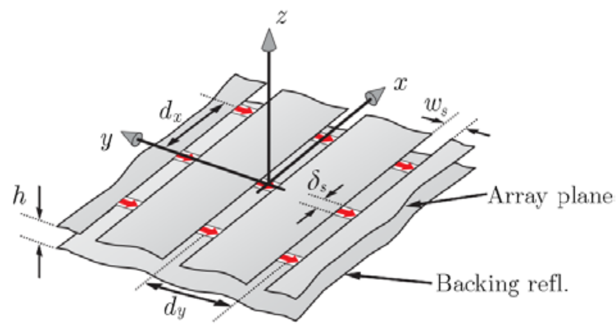

Fig. 1. Connected array of slots in the presence of a backing reflector.

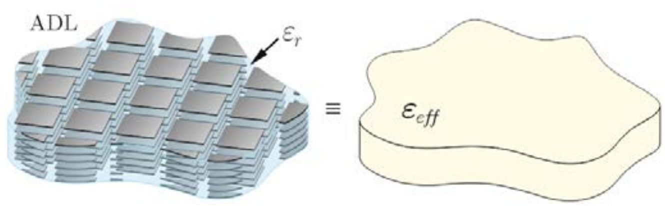

Fig. 2. A planar ADL slab hosted by a homogeneous dielectric to realize an equivalent anisotropic medium.

Based on this concept, a design example is shown in this paper, for a single-polarized array. Simulated results are presented to investigate the effectiveness of the proposed array concept, targeting the frequency range of one octave, from 7 to 14 GHz, and scanning up to 50 degrees in all azimuth planes. A possible implementation of the feed structure and is also carried out, but not shown here for the sake of brevity.

The active reflection coefficient of the array is shown in Fig. 2(b), for broadside and scanning to 50 degrees in E- and in the H-plane. The VSWR is less than 2 over more than one octave bandwidth. A good comparison is obtained with the commercial solver CST [13] for all the scanning angles. However, with our analytical tool, calculation of the active input impedance, for 15 frequency points and 3 scan angles, can be completed in 0.2 seconds, while it requires about 180 minutes with CST, on the same computer.

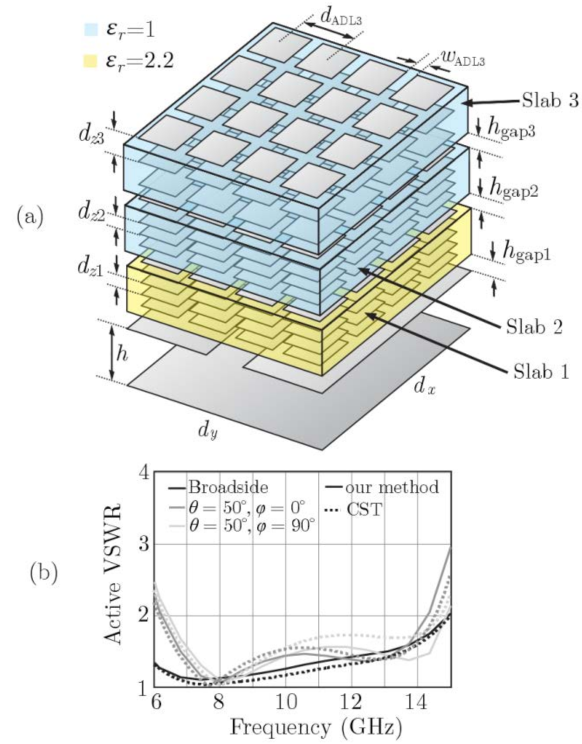

Fig 2. (a) A unit cell of the connected array radiating in the presence of multi-layer ADL stack and (b) active VSWR for broadside and scanning to 50 degrees in E- and H- plane.

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