Impact of Scan Blindness for Metadome covered Wide-Scanning Array

A. Benini[(1)], E. Martini[(1)], S. Monni[(2)], F. Silvestri[(2)], E. Gandini[(2)], G. Gerini[(2)], G. Toso[(3)], S. Maci[(1)]
(1) University of Siena, Siena, Italy
(2) TNO, The Netherlands
(3) ESA/ESTEC, Noordwijk, The Netherlands

Nowadays, having a fully electronic beam-scanning within a reduced angular range (e.g. ± 30-40°) does not imply severe technical problems, while larger scanning ranges can be problematic. Nonetheless, scanning over ± 70° may be required in many applications, as for instance in aircraft-satellite communications and in some radar antennas. The technique presented here is a good way to reuse already available low-performance scanning arrays to obtain high-performance scanning arrays. It is based on a phase-gradient metasurface (MTS) dome combined with a pre-distortion of amplitude and phase of the array excitation. It also allows to mitigate scan blindness problems.

The scan blindness is a well-known phenomenon that occurs in large phased array antennas and it corresponds to a strong mismatch of the active impedance when the scan reaches a certain angle related to the periodicity of the elements. This phenomenon has two different main causes, both due to the periodic nature of the geometry and to the linear phasing. Recently, metamaterial based solutions were proposed (P.R. Ulibarri *et al.* "Experimental demonstration of metamaterials application for mitigating scan blindness in phased array antennas," EPJ Applied Metamaterials Vol 3, n. 9, 2016).), however, the theoretically needed material parameters can only be obtained in a limited bandwidth. Placing a properly designed dielectric dome over a phased array is an interesting method to improve the scanning performance, since it does not suffer of bandwidth limitation. The main drawback of such solution is, besides the weight, the overall height of the structure.

The idea we pursue here is to improve the scan range and to minimize the overall size consists in using a curved dome constituted by a "phase-gradient" (PG) MTS (N. Yu *et al.*, "Light propagation with phase discontinuities: generalized laws of reflection and refraction." Science, vol. 334, no. 6054, pp. 333–7, Oct. 2011). This terminology refers to the fact that a ray is deflected by an angle which is proportional to the transverse gradient of the phase discontinuity introduced by the MTS. Although the concept behind PG-MTS is similar to the one of transmit-arrays, the low-thickness of the MTS and the possibility to homogenize the field-discontinuity conditions has demonstrated to give additional engineering possibilities (N. Yu, P. Genevet, *et al*., "Flat Optics: Controlling wavefronts with optical antenna metasurfaces," IEEE Journal of Selected Topics in Quantum Electronics, vol. 19, no.3, pp. 4700423, 2013) and to allow for simple synthesis processes. It is seen that a single printed layer for realizing a MTS cannot provide a perfect matching of a plane wave with a phase shift that varies over a range of 360°. Instead, the introduction of three strictly coupled MTS layers, whose total thickness is still electrically thin, can provide perfect matching and full-angle phase discontinuity over a controllable bandwidth, since the elements may be chosen to be sub-resonant.

Based on the above concepts, we will present a simple design procedure to extend the scan range of arrays by using a curved metadome and a pre-distortion of amplitude and phase on the array elements. The practical implementation of subwavelength elements synthesizing a certain homogenized MTS boundary condition is still a not completely solved issue, and may require massive optimization. Fast progresses on this subject are however taking place. Following these results, we assume here the possibility to implement a perfectly matched, curved, MTS dome in order to improve the scan range in slot line arrays and we establish a univocally defined design procedure for increasing the grating-lobe free scan range. The considered slot arrays are schematizations of connected arrays (A. Neto, J.J. Lee, "Ultrawide band properties of Long Slot Array" IEEE Trans. Antennas Propagat., vol. 54, 2, pp. 534-543, June 2005). We end-up with a process that requires a non-linear modification on the array phase and amplitude. We show how this modification creates a change of active input impedance with respect to the one of the phased array without covering, thus, increasing the scan blindness-free scan range.