Guest Editorial for the Special Issue on Innovative Phased Array Antennas Based on Non-Regular Lattices and Overlapped Subarrays

TODAY there is a growing demand for large aperture antennas exhibiting increased capabilities (in terms of flexibility, reconfigurability, frequency bandwidth, and field of view) and reduced cost and complexity. Organizing a large array into overlapped subarrays or adopting a non regular lattice represent two effective strategies to achieve high performance while minimizing the number of controls for a limited field of view or wide band array.

The reduction of the number of controls in phased arrays antennas is in line with the notion of sparsity and compressive sensing namely the idea that the essential information contained in a signal can be represented with a small number of significant components. This notion, widespread in signal processing and data analysis, starts to be exploited successfully also for antenna design and optimization. The possibility of departing from the standard Nyquist sampling of the antenna aperture may be a key enabling factor to significantly reduce the cost of advanced phased arrays.

Arrays using non- regular lattices are a valid alternative to periodic arrays because they are able to generate an equivalent tapering by adjusting the element positions They also allow reducing the number of elements, and increasing the DC to RF overall efficiency of the antenna. Dividing a large array into overlapped sub-arrays (i.e., with a radiating antenna element contributing to more than one sub-array) permits increasing the extension of a sub-array, with improved angular filtering performances, while keeping the same or an increased inter-subarray distance. Because the number of subarrays is reduced compared to the total number of elements populating the whole array, a comparable reduction in the number of control elements is achieved and the overall antenna complexity may be reduced with respect to a conventional design.

In recent years there has been a renewed interest in phased arrays based on non regular lattices or overlapped subarrays for different types of applications ranging from spaceborne to ground antennas, from civil to military systems. The objective of this special issue consists in providing an overview of the current state-of-the-art in this field, highlighting the latest developments and innovations, and proposing new applications, solutions and challenges for the future.

The main topics considered are:

- sparse and thinned arrays;
- overlapped and interlaced subarrays;
- beamforming and multibeam excitation of irregular arrays;
- fabrication and signal distribution networks for large arrays;
- overlapped and non-regular conformal arrays;
- synthesis using irregular and overlapped subarrays.

This Special Issue achieved most of its goals. Most of the papers selected are in the area of array antennas based on non-regular lattices. We thank all authors who submitted their work for consideration in this special issue and regret that many could not be accepted. Papers were selected based on detailed peer review and relevance to the topic.

Papers are grouped into two main categories: 1) array antennas based on non-regular lattices and 2) array antennas organized in overlapped subarrays.

Group 1: Array Antennas Based on Non-Regular Lattices: The first group includes 21 papers. The invited paper written by A. Ishimaru opens the Special Issue. In this paper the design procedure for sparse arrays based on Poisson Sum formula, presented by the author in two seminal papers published in the 1960s, is revisited and new applications on circular arrays, active impedance and arrays on a curved surface are presented.

The paper by W. Keizer presents two new hybrid density taper methods for designing thinned planar arrays. One method applies a modified version of the iterative Fourier transform method to find the elements distribution to satisfy a prescribed low sidelobe level. In the second method the elements are distributed in a uniform random way. The paper by X.K. Wang *et al.* presents a modified iterative Fourier technique (MIFT) for the synthesis of large thinned planar arrays that can generate a pattern with a reduced sidelobe level (SLL). This technique is based on the iterative Fourier technique (IFT), and a variable filling factor introduced to avoid the local minima in the optimization.

In the paper by J. Koh *et al.* the far field pattern from a non-uniformly spaced antenna array is computed using an unevenly spaced antenna array through a least squares method. The method originally developed for spectral estimation for a non-uniformly spaced finite data set is applied for the analysis of the far field pattern from unevenly spaced antennas. D. Ludick *et al.* present an efficient method-of-moments based domain decomposition technique for analyzing large sparse arrays. The procedure is based on a perturbation technique where mutual coupling between array elements is considered in the active impedance matrix offering a significant saving in both runtime and memory usage.

Circular sparse arrays generating Taylor-like patterns are considered in the paper by A.A. Salas-Sánchez *et al.* A first method based on the optimization of the ring radii permits achieving a good approximation of the desired pattern while a second method guarantees a faster implementation but presents some limitations in the spacing between the rings. A method

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for the synthesis of large sparse arrays combining global and local optimizations is proposed in the paper by T. Clavier *et al.* It is based on the separation between the aperture-type and non-coherent parts of the array factor. Design constraints are included and the sidelobes level is reduced via a new type of flexible averaging cost function.

The synthesis of sparse arrays for satellite applications is presented in the paper by O.M. Bucci *et al.* After determining geometrical constraints induced from the steerability requirement, the proposed methods allow the synthesis of the optimal radiating feed and of the array layout in such a way to guarantee the required side lobe level for every steered beam. The two papers proposed by P. Angeletti *et al.* describe a deterministic algorithm based on simple analytical expressions for designing linear and planar sparse arrays where positions and dimensions of the radiating elements are jointly optimized and exploited. The proposed solution permits optimization of aperture efficiency subject to directivity limits. The accuracy of the method is guaranteed by the fact that the achieved directivity differs from the target value, associated to a continuous reference aperture distribution, by a quantity asymptotically equal to the filling factor of a planar array organized in concentric rings populated by circular apertures.

An alternating projection algorithm for power synthesis of reconfigurable arrays is proposed in the paper by G. Buttazzoni *et al.* The design method is suitable for conformal and sparse arrays and permits generating different radiation patterns just modifying the phase tapering. Constraints on excitation levels and near field may be imposed. In the paper by J. Araque Quijano *et al.* an alternating projection algorithm for the synthesis of planar arrays with arbitrary pattern requirements is proposed with constraints on the excitation coefficients. Differently from synthesis procedures based on the Array Factor only, the proposed array synthesis includes the element pattern.

In the paper coauthored by P. Gorman *et al.* the covariance matrix adaption evolutionary strategy is applied to the design of ultra-wideband aperiodic arrays using spiral radiating elements. In order to improve the axial ratio and the sidelobe level, the rotation of the spiral elements is implemented obtaining significant improvements. In the paper by A. Elmakadema *et al.* array antennas with a high number of elements and operating over a broad frequency range is examined. A method to easily optimize the array geometry for different applications is proposed with particular application to the square kilometer array (SKA) operating in the frequency band (70–450 MHz).

The design of sparse conformal arrays is carried out through a versatile multi-task Bayesian compressive sensing strategy in the paper coauthored by G. Oliveri *et al.* The problem of determining the sparsest excitation set (locations and weights) satisfying a reference pattern and some user-defined geometrical constraints is formulated in a probabilistic way. An optimization technique for the design of printed reflectarrays using elements with irregular orientation and position is presented in the paper by M. Zhou *et al.*. The algorithm exploits the local periodicity and a minimax optimization. The accuracy has been verified by comparisons with full wave method of moments and measured results.

J. Krieger *et al.* present sparse arrays for coherent imaging of sparse but unknown scenes. An efficient pattern design procedure using the co-array analysis is proposed. Moreover, robust and efficient algorithms implementing the associated array processing comprising scene support recovery, image and failures reconstruction are described. A sparse array for imaging systems for personnel security screening is presented in the paper by B. Gonzalez-Valdes *et al.*. The optimization procedure combined with compressive sensing techniques allows to drastically reduce the number of sensors, reducing system complexity and cost. Sample measurements support the simulations.

The paper by M.C. Vigano *et al.* presents a sparse phased array, with 1-bit phase controls, for low-cost mobile terminal antennas suitable for linear-polarized satellite communication systems. Preliminary measurements demonstrate the applicability of the design procedure which guarantees significant reduction in complexity and cost. In the paper by S.W. Qu *et al.* low-cost phased arrays exploiting the multiport property are presented. A three-element subarray is proposed with one patch antenna used as an active element and the other two as parasitic patches. Good agreement between simulations and measurements demonstrate the accuracy of the design procedure. In the paper by X. Ziyuan *et al.* the synthesis of sum and difference patterns for monopulse radar systems is proposed. A clustering method is presented to solve the array synthesis with an improved approach to synthesize low sidelobe patterns. Simulations validate the effectiveness and potentiality of the proposed methods.

Group 2: Array Antennas Organized in Overlapped Subarrays: This group of the Special Issue includes 5 papers related to arrays organized in overlapped subarrays. Two papers are new contributions to the theory of multiple beam antennas, and these are included in the section because of the application of multiple beam systems to the process of forming completely overlapping subarrays.

The paper by P. Angeletti presents a general theory of multiple beam arrays and establishes necessary and sufficient conditions for achieving realizable lossless beamforming networks and phase steering vectors. The paper by S. Skobelev proposes a general approach to the determination of geometrical parameters required for the radiation of specified orthogonal beam clusters from planar arrays. The goal of the paper is to present a systematic approach to determine optimal geometric parameters of a planar array capable of forming a specified number of orthogonal beams and their specified directions in space.

There are two papers in the section that present optimized numerical approaches to the design of arrays of overlapped subarrays. The first, by D. Petrolati *et al.*, presents a lossless beamforming network architecture for the design of limited-field-of-view arrays of overlapped subarrays, enabling the tradeoff of control devices at element and subarray levels. A paper by H. Krichene *et al.* addresses the pattern evaluation for large arrays with variable subarray overlapping over wide bandwidths. The need for fast pattern evaluation with arrays having random errors is necessary to perform iterative optimization in order to conduct Monte Carlo analysis. The simulation enables insertion of errors at elements, phase shifters, time delay devices and network errors in addition to element positional errors. The paper by Blanko *et al.* presents a study of the use of dielectric superlayers as Fabry Perot cavities for the purpose of suppressing grating lobes in an array of widely spaced elements. The paper focuses on the relationship between the dielectric permittivity on the mutual coupling within the array, and draws conclusions about grating lobe level, impedance match and directivity for arrays with a single superstrate layer.

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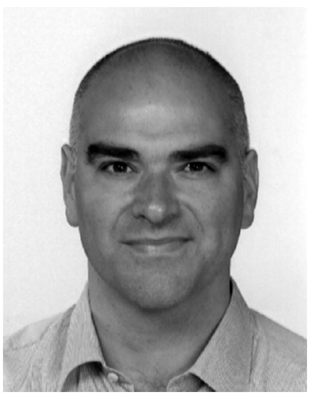
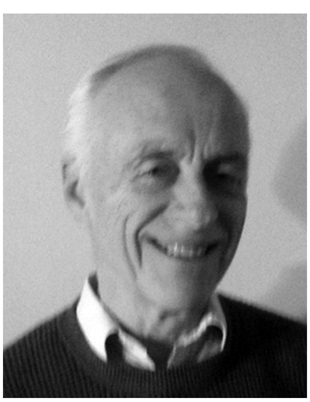
GIOVANNI TOSO, *Guest Editor*
European Space Agency
The Netherlands

ROBERT MAILLOUX, *Guest Editor*
Arcon Corporation
Waltham, MA 02451 USA



Giovanni Toso (S'93–M'00–SM'07) received the Laurea degree (*summa cum laude*) and the Ph.D. in electrical engineering from the University of Florence, Florence, Italy, in 1992 and 1995, respectively.

In 1996, he was Visiting Scientist at the Laboratoire d'Optique Electromagnétique, University of Aix-Marseille III, Marseille, France. From 1997 to 1999, he was a Postdoctoral student at the University of Florence. In 1999, he was a Visiting Scientist at the University of California, Los Angeles (UCLA). In the same year he received a scholarship from Thales Alenia Space (Rome, Italy) and was appointed Researcher in the Radioastronomy Observatory of the Italian National Council of Researches (CNR). Since 2000, he is with the Antenna and Submillimeter Section, European Space and Technology Centre, European Space Agency, ESA ESTEC, Noordwijk, The Netherlands. He has been initiating and contributing to several R&D activities on satellite antennas based on arrays, reflectarrays, constrained lenses and reflectors. He has coauthored more than 50 technical papers published in peer reviewed professional journals, more than 200 papers published in international conference proceedings, and more than 10 international patents. In 2009, he was coeditor of the Special Issue on Active Antennas for Satellite Applications in the *International Journal of Antennas and Propagation*. He is an Associate Editor of the IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION.



Robert Mailloux (LF'04) received the BS degree in electrical engineering from Northeastern University, Boston, MA, USA, in 1961 and the S.M. and Ph.D. degrees from t Harvard University, Cambridge MA, USA.

He is a retired Senior Scientist at the Sensors Directorate, Air Force Research Laboratory, and has served as the Chief of the Antennas and Components Division, Rome Laboratory and as a Physicist at the Air Force Cambridge Research Laboratory. He is the author or coauthor of numerous journal articles, book chapters, 13 patents and the books *Phased Array Handbook*, *Electronically Scanned Arrays* and is co-editor of the book *History of Wireless.* He now consults in the area of periodic structures and antenna arrays.

Dr. Mailloux is a member of Tau Beta Pi, Eta Kappa Nu, Sigma Xi, Commission B of the International Scientific Radio Union, and is a Life Fellow of the IEEE. He was President of the Antennas and Propagation Society in 1983, and in 1992 he received the IEEE Harry Diamond Memorial Award. He received two IEEE AP-S Honorable Mention Best Paper Awards, the IEEE Third Millennium Medal and the AP-S Distinguished Technical Achievement Award. He has received four Air Force Research Laboratory "Best Paper" awards, the "Engineer of the Year" award, and is an AFRL Fellow. He has been a distinguished Lecturer for the Antenna and Propagation Society and is currently chairman of the AP-S/IEEE Press Liaison Committee.