Frequency Diverse Arrays (FDA) for Focused and Range-Angle Dependent Beampatterns: A Compressive Sensing Approach

Said E. El-Khamy, Life Fellow IEEE, and Magdy Abdelhay

Dept. of Electrical Engineering, Faculty of Engineering,

Alexandria University, Alexandria 21544, Egypt.

Email: elkhamy@ieee.org

Phased antenna arrays (PAA) achieve enhanced performance and have enhanced capabilities. They are used to generate directive and narrow beams, as well as the synthesis of arbitrary radiation patterns. PAA also provide other interesting features such as electronic beam scanning, redundancy, and diversity. Interference rejection is an essential task in many PAA applications, such as radar, cognitive radio, and satellite communications. Interference signals are suppressed by producing nulls in the PAA pattern in the directions of the interfering signals.

One drawback of PAA is that while they offer angle-dependent beampatterns, their patterns are constant in all ranges, for a given direction. On the other hand, Frequency Diverse Arrays (FDA) provide range-angle-dependent beampatterns. This can be used to concentrate the transmitted energy in a particular range-angle area, and hence provides the ability to suppress the range-dependent interferences. The range-angle-dependent beampattern in FDA is accomplished by applying small frequency increments between successive array elements.

Utilizing linearly increasing frequency increments generates a coupled S-shaped range-angle beampattern, which is periodic in range, angle, and time. Focused and decoupled beampattern synthesis can be achieved by optimizing the frequency increments using evolutionary optimization techniques. On the other hand, non-linear frequency increments between the elements provide a non-periodic and decoupled beampattern. Results of using logarithmically increasing frequency offsets as well as square and cubic frequency offsets are presented.

Compressive Sensing (CS) is a relatively new paradigm within which data acquisition and data processing are combined. CS allows data to be compressed when sampled by capitalizing on the sparsity existing in many common signals. By doing this, it offers an efficient way to minimize the frequency of measurements required for the perfect signal recovery. CS has attracted a lot of attention in recent years, with thousands of scientific papers and applications emerging in fields such as direction of arrival estimation, image processing, computational electromagnetics and many more. The application of compressive sensing to the target localization in both the range and the angle domains by FDA is of great interest and is investigated in this presentation for different array structures with classical and some other new frequency increment schemes such as random frequency increments.

Multi-carrier FDA, where each antenna element transmits multiple logarithmically increasing frequencies are also discussed. Utilizing multi-carrier FDA provides higher degrees of freedom that can be exploited to generate focused dot-shaped range-angle beampattern. Convex optimization is used to find the optimum set of weights that are needed to focus the pattern into a specific range-angle location. Also, by formalizing the problem as a sparse recovery problem, it is possible to use CS framework to achieve a thinned FDA array, i.e., an array that uses a reduced number of elements while satisfying the same pattern constraints.

Biography of Prof. Said E. El-Khamy

Said E. El-Khamy (*Life Fellow*, *IEEE*) received the B.Sc. (Hons.) and M.Sc. degrees from Alexandria University, Alexandria, Egypt, in 1965 and 1967, respectively, and the Ph.D. degree from the University of Massachusetts, Amherst, USA, in 1971. He has been a Teaching Staff with the Department of Electrical Engineering, Faculty of Engineering, Alexandria University, since 1972, and was appointed as a Full-Time Professor in 1982 and the Chairman of the Department of Electrical Engineering from 2000 to 2003, where he is currently an Emeritus Professor. His current research areas of interest include wireless multimedia communications, wave propagation, smart antenna arrays, modern signal processing techniques, image processing, and security and watermarking techniques. He has authored or coauthored about 400 scientific articles in national and international conferences and journals. He took part in the organization of many local and international conferences, including the yearly series of NRSC (URSI) conference series from 1990 to 2019, ISCC'95, ISCC'97, ISSPIT'2000, MELECON'2002, and IEEE GCIoT'2019. He took part in many IEEE Region eight activities and URSI general assemblies. Prof. El-Khamy has earned many national and international research awards among which are the R. W. P. King Best Paper Award of the Antennas and Propagation Society of the IEEE in 1980, the Egypt's State Engineering Encouraging Research Award for two times in 1980 and 1989, respectively; Abdel-Hamid Schoman–Kingdom of Jordan award for Engineering Research in 1982, the State Scientific Excellence Award in Engineering Sciences in 2002, Alexandria University Appreciation Award of Engineering Sciences in 2003; State Appreciation Award of Engineering Sciences for 2004 and as the IEEE Region 8 Volunteer Award in 2010. In 2016, he was honored by Egypt's National Radio Science Committee of URSI and was selected as the Radio Science recognized figure of the year. In 2016, he was announced to be The Distinct Scientist of Alexandria University, in Engineering Sciences. Prof. El-Khamy has been a Fellow Member of the IEEE since 1999 and has been an IEEE Life Fellow member since 2010. He is also a Fellow of the Electromagnetic Academy. He is the founder and the Past President of the IEEE Alexandria/Egypt Subsection and the past President of Egypt's National Radio Science Committee of URSI. (Based on document published on 18 January 2021).