Guidelines for Student Reports

Sparse array synthesis for wireless power transmission

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Abstract

The implementation of solar power plants Orbital is one of the new technology options for clean energy on a large scale and with very low environmental risks. The key advantage that this type of plants can provide compared to traditional solar power plants is linked to the fact that it can receive uninterrupted sunlight (they are in geostationary orbit), and that the intensity of solar radiation received in orbit is much higher than one received on the ground (as they do not suffer due to the absorption from the atmosphere). The performance of these systems, however, poses many technological challenges in terms of collecting energy, weight and size of the system to be put in orbit, size of the collection system of the radiation on the ground, and the cost of energy produced. In fact, these plants require solar energy transmission from space to earth through a thin beam of microwave radiation, which must be conveyed to the ground in a very low (a few square kilometers) than at present for Information transmission system by satellite (which has footprint of several hundred kilometers). For this reason, the realization of a solar power is vital to the antenna system for energy transmission from the satellite, placed in geostationary orbit (GEO), the central post to the earth. Given the size of the antennas involved (several hundred meter aperture), using arrays of radiator (antenna arrays) is the only choice for the realization of such systems. To save weight, cost and consumption of such antennas, the use of sparse architectures (e.g. methods for reducing the number of elements while maintaining the radiant properties of the array) is essential. The choice of method in this case should focus in particular the efficiency of the technique of sparsening, given the very large antennas at hand.
Consequently, the objective of the activity is to assess a methodology for designing large arrays for applications in energy transmission by satellite. More in detail, the sparsening of linear arrays of different size and with arbitrary pattern shapes will be considered through the Bayesian Compressive Sampling approach.

Reference Bibliography: Compressive Sensing [1]-[5], [14]-[23]; Array Synthesis [1]-[5], [24]-[83]; Wireless Power Transmission [6]-[13].

[1] G. Oliveri and A. Massa, "Bayesian compressive sampling for pattern synthesis with maximally sparse non-uniform linear arrays," IEEE Trans. Antennas Propag., vol. 59, no. 2, pp. 467-481, Feb. 2011.
[2] G. Oliveri, M. Carlin, and A. Massa, "Complex-weight sparse linear array synthesis by Bayesian Compressive Sampling," IEEE Trans. Antennas Propag., vol. 60, no. 5, pp. 2309-2326, May 2012.
[3] G. Oliveri, P. Rocca, and A. Massa, "Reliable Diagnosis of Large Linear Arrays - A Bayesian Compressive Sensing Approach," IEEE Trans. Antennas Propag., vol. 60, no. 10, pp. 4627-4636, Oct. 2012.

[4] F. Viani, G. Oliveri, and A. Massa, "Compressive sensing pattern matching techniques for synthesizing planar sparse arrays" IEEE Trans. Antennas Propag., in press. doi:10.1109/TAP.2013.2267195
[5] G. Oliveri, E. T. Bekele, F. Robol, and A. Massa, "Sparsening conformal arrays through a versatile BCS-based method," IEEE Trans. Antennas Propag., in press, 2013.
[6] A. Massa, G. Oliveri, F. Viani, and P. Rocca, "Array designs for long-distance wireless power transmission - State-of-the-art and innovative solutions," Proceedings of the IEEE - Special Issue on "Wireless Power Technology, Transmission and Applications," vol. 101, no. 6, pp. 1464-1481, June 2013.
[7] G. Oliveri, L. Poli, and A. Massa, "Maximum efficiency beam synthesis of radiating planar arrays for wireless power transmission," IEEE Trans. Antennas Propag., pp. 2490-2499, vol. 61, no. 5, May 2013.
[8] G. Franceschetti, P. Rocca, F. Robol, and A. Massa, "Design and optimization of efficient rectenna systems for space solar power applications," International Conference on Electromagnetics and Advanced Applications (ICEAA 2012) - Invited paper, Session title: "Wireless power transmission", Cape Town, South Africa, Sep. 2-7, 2012.
[9] G. Franceschetti, P. Rocca, F. Robol, and A. Massa, "Innovative rectenna design for space solar power systems," IEEE MTT-S International Microwave Workshop Series on "Innovative Wireless Power Transmission: Technologies, Systems, and Applications" (IMWS-IWPT2012), Kyoto, Japan, pp. 151-153, May 10-11, 2012.
[10] G. Oliveri, P. Rocca, F. Viani, F. Robol, and Andrea Massa, "Latest advances and innovative solutions in antenna array synthesis for microwave wireless power transmission," IEEE MTT-S International Microwave Workshop Series on "Innovative Wireless Power Transmission: Technologies, Systems, and Applications" (IMWS-IWPT2012), Kyoto, Japan, pp. 71-73, May 10-11, 2012.
[11] G. Oliveri, P. Rocca, and A. Massa, "Array antenna architectures for solar power satellites and wireless power transmission," XXX URSI General Assembly and Scientific Symposium of International Union of Radio Science (URSI GASS 2011) - Invited paper, Session title: "Solar power satellites and wireless power transmission", Istanbul, Turkey, Aug. 13-20, 2011.
[12] G. Franceschetti, A. Massa, and P. Rocca, "Innovative antenna systems for efficient microwave power collection," IEEE MTT-S International Microwave Workshop Series on "Innovative Wireless Power Transmission: Technologies, Systems, and Applications" (IMWS-IWPT2011), Uji (Kyoto), Japan, pp. 275-278, May 12-13, 2011 (Invited paper).
[13] P. Rocca, G. Oliveri, and A. Massa, "Innovative array designs for wireless power transmission," IEEE MTT-S International Microwave Workshop Series on "Innovative Wireless Power Transmission: Technologies, Systems, and Applications" (IMWS-IWPT2011), Uji (Kyoto), Japan, pp. 279-282, May 12-13, 2011 (Invited paper).
[14] L. Poli, G. Oliveri, and A. Massa, "Imaging sparse metallic cylinders through a Local Shape Function Bayesian Compressive Sensing approach," Journal of Optical Society of America A, vol. 30, no. 6, pp. 1261-1272, 2013.
[15] F. Viani, L. Poli, G. Oliveri, F. Robol, and A. Massa, "Sparse scatterers imaging through approximated multitask compressive sensing strategies," Microwave Opt. Technol. Lett., vol. 55, no. 7, pp. 1553-1558, Jul. 2013.
[16] L. Poli, G. Oliveri, P. Rocca, and A. Massa, "Bayesian compressive sensing approaches for the reconstruction of two-dimensional sparse scatterers under TE illumination," IEEE Trans. Geosci. Remote Sensing, vol. 51, no. 5, pp. 2920-2936, May. 2013.

[17] L. Poli, G. Oliveri, and A. Massa, "Microwave imaging within the first-order Born approximation by means of the contrast-field Bayesian compressive sensing," IEEE Trans. Antennas Propag., vol. 60, no. 6, pp. 2865-2879, Jun. 2012.
[18] G. Oliveri, P. Rocca, and A. Massa, "A bayesian compressive sampling-based inversion for imaging sparse scatterers," IEEE Trans. Geosci. Remote Sensing, vol. 49, no. 10, pp. 3993-4006, Oct. 2011.
[19] G. Oliveri, L. Poli, P. Rocca, and A. Massa, "Bayesian compressive optical imaging within the Rytov approximation," Optics Letters, vol. 37, no. 10, pp. 1760-1762, 2012.
[20] L. Poli, G. Oliveri, F. Viani, and A. Massa, "MT-BCS-based microwave imaging approach through minimum-norm current expansion," IEEE Trans. Antennas Propag., in press. doi:10.1109/TAP.2013.2265254
[21] M. Carlin, P. Rocca, G. Oliveri, F. Viani, and A. Massa, "Directions-of-Arrival Estimation through Bayesian Compressive Sensing strategies," IEEE Trans. Antennas Propag., in press.
[22] M. Carlin, P. Rocca, "A Bayesian compressive sensing strategy for direction-of-arrival estimation," 6th European Conference on Antennas Propag. (EuCAP 2012), Prague, Czech Republic, pp. 1508-1509, 26-30 Mar. 2012.
[23] M. Carlin, P. Rocca, G. Oliveri, and A. Massa, "Bayesian compressive sensing as applied to directions-of-arrival estimation in planar arrays," Journal of Electrical and Computer Engineering, Special Issue on "Advances in Radar Technologies," in press.
[24] P. Rocca, L. Manica, and A. Massa, "An improved excitation matching method based on an ant colony optimization for suboptimal-free clustering in sum-difference compromise synthesis," IEEE Trans. Antennas Propag., vol. 57, no. 8, pp. 2297-2306, Aug. 2009.
[25] P. Rocca, L. Manica, and A. Massa, "Ant colony based hybrid approach for optimal compromise sum-difference patterns synthesis," Microwave Opt. Technol. Lett., vol. 52, no. 1, pp. 128-132, Jan. 2010.
[26] P. Rocca, L. Manica, and A. Massa, "Hybrid approach for sub-arrayed monopulse antenna synthesis," Electronics Letters, vol. 44, no. 2, pp. 75-76, Jan. 2008.
[27] P. Rocca, L. Manica, F. Stringari, and A. Massa, "Ant colony optimization for tree-searching based synthesis of monopulse array antenna," Electronics Letters, vol. 44, no. 13, pp. 783-785, Jun. 19, 2008.
[28] L. Poli, P. Rocca, G. Oliveri, and A. Massa, "Adaptive nulling in time-modulated linear arrays with minimum power losses," IET Microwaves, Antennas & Propagation, vol. 5, no. 2, pp. 157-166, 2011.
[29] P. Rocca, L. Poli, G. Oliveri, and A. Massa, "Adaptive nulling in time-varying scenarios through time-modulated linear arrays," IEEE Antennas Wireless Propag. Lett., vol. 11, pp. 101-104, 2012.
[30] M. Benedetti, G. Oliveri, P. Rocca, and A. Massa, "A fully-adaptive smart antenna prototype: ideal model and experimental validation in complex interference scenarios," Progress in Electromagnetic Research, PIER 96, pp. 173-191, 2009.
[31] M. Benedetti, R. Azaro, and A. Massa, "Memory enhanced PSO-based optimization approach for smart antennas control in complex interference scenarios," IEEE Trans. Antennas Propag., vol. 56, no. 7, pp. 1939-1947, Jul. 2008.
[32] M. Benedetti, R. Azaro, and A. Massa, "Experimental validation of a fully-adaptive smart antenna prototype," Electronics Letters, vol. 44, no. 11, pp. 661-662, May 2008.
[33] R. Azaro, L. Ioriatti, M. Martinelli, M. Benedetti, and A. Massa, "An experimental realization of a fully-adaptive smart antenna," Microwave Opt. Technol. Lett., vol. 50, no. 6, pp. 1715-1716, Jun. 2008.

[34] M. Donelli, R. Azaro, L. Fimognari, and A. Massa, "A planar electronically reconfigurable Wi-Fi band antenna based on a parasitic microstrip structure," IEEE Antennas Wireless Propag. Lett., vol. 6, pp. 623-626, 2007.
[35] M. Benedetti, R. Azaro, D. Franceschini, and A. Massa, "PSO-based real-time control of planar uniform circular arrays," IEEE Antennas Wireless Propag. Lett., vol. 5, pp. 545-548, 2006.
[36] F. Viani, L. Lizzi, M. Donelli, D. Pregnolato, G. Oliveri, and A. Massa, "Exploitation of smart antennas in wireless sensor networks," Journal of Electromagnetic Waves and Applications, vol. 24, no. 5/6, pp. 993-1003, 2010.
[37] E. T. Bekele, L. Poli, M. D'Urso, P. Rocca, and A. Massa, "Pulse-shaping strategy for time modulated arrays - Analysis and design," IEEE Trans. Antennas Propag., in press.
[38] P. Rocca, L. Poli, G. Oliveri, and A. Massa, "A multi-stage approach for the synthesis of sub-arrayed time modulated linear arrays," IEEE Trans. Antennas Propag., vol. 59, no. 9, pp. 3246-3254, Sep. 2011.
[39] L. Poli, P. Rocca, G. Oliveri, and A. Massa, "Harmonic beamforming in time-modulated linear arrays," IEEE Trans. Antennas Propag., vol. 59, no. 7, pp. 2538-2545, Jul. 2011.
[40] L. Poli, P. Rocca, L. Manica, and A. Massa, "Handling sideband radiations in time-modulated arrays through particle swarm optimization," IEEE Trans. Antennas Propag., vol. 58, no. 4, pp. 1408-1411, Apr. 2010.
[41] P. Rocca, L. Poli, G. Oliveri, and A. Massa, "Adaptive nulling in time-varying scenarios through time-modulated linear arrays," IEEE Antennas Wireless Propag. Lett., vol. 11, pp. 101-104, 2012.
[42] P. Rocca, L. Poli, and A. Massa, "Instantaneous directivity optimization in time-modulated array receivers," IET Microwaves, Antennas & Propagation, vol. 6, no. 14, pp. 1590-1597, Nov. 2012.
[43] P. Rocca, L. Poli, L. Manica, and A. Massa, "Synthesis of monopulse time-modulated planar arrays with controlled sideband radiation," IET Radar, Sonar & Navigation, vol. 6, no. 6, pp. 432-442, 2012.
[44] L. Poli, P. Rocca, and A. Massa, "Sideband radiation reduction exploiting pattern multiplication in directive time-modulated linear arrays," IET Microwaves, Antennas & Propagation, vol. 6, no. 2, pp. 214-222, 2012.
[45] L. Poli, P. Rocca, G. Oliveri, and A. Massa, "Adaptive nulling in time-modulated linear arrays with minimum power losses," IET Microwaves, Antennas & Propagation, vol. 5, no. 2, pp. 157-166, 2011.
[46] L. Poli, P. Rocca, L. Manica, and A. Massa, "Time modulated planar arrays - Analysis and optimization of the sideband radiations," IET Microwaves, Antennas & Propagation, vol. 4, no. 9, pp. 1165-1171, 2010.
[47] L. Poli, P. Rocca, L. Manica, and A. Massa, "Pattern synthesis in time-modulated linear arrays through pulse shifting," IET Microwaves, Antennas & Propagation, vol. 4, no. 9, pp. 1157-1164, 2010.
[48] P. Rocca, L. Poli, G. Oliveri, and A. Massa, "Synthesis of time-modulated planar arrays with controlled harmonic radiations," Journal of Electromagnetic Waves and Applications, vol. 24, no. 5/6, pp. 827-838, 2010.
[49] L. Manica, P. Rocca, L. Poli, and A. Massa, "Almost time-independent performance in time-modulated linear arrays," IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 843-846, 2009.
[50] P. Rocca, L. Manica, L. Poli, and A. Massa, "Synthesis of compromise sum-difference arrays through time-modulation," IET Radar, Sonar & Navigation, vol. 3, no. 6, pp. 630-637, 2009.

[51] P. Rocca, L. Manica, R. Azaro, and A. Massa, "A hybrid approach for the synthesis of sub-arrayed monopulse linear arrays," IEEE Trans. Antennas Propag. , vol. 57, no. 1, pp. 280-283, Jan. 2009.
[52] L. Manica, P. Rocca, M. Benedetti, and A. Massa, "A fast graph-searching algorithm enabling the efficient synthesis of sub-arrayed planar monopulse antennas," IEEE Trans. Antennas Propag., vol. 57, no. 3, pp. 652-664, Mar. 2009.
[53] P. Rocca, L. Manica, A. Martini, and A. Massa, "Compromise sum-difference optimization through the iterative contiguous partition method," IET Microwaves, Antennas & Propagation, vol. 3, no. 2, pp. 348-361, 2009.
[54] L. Manica, P. Rocca, and A. Massa, "An excitation matching procedure for sub-arrayed monopulse arrays with maximum directivity," IET Radar, Sonar & Navigation, vol. 3, no. 1, pp. 42-48, Feb. 2009.
[55] L. Manica, P. Rocca, A. Martini, and A. Massa, "An innovative approach based on a tree-searching algorithm for the optimal matching of independently optimum sum and difference excitations," IEEE Trans. Antennas Propag., vol. 56, no. 1, pp. 58-66, Jan. 2008.
[56] P. Rocca, L. Manica, and A. Massa, "Synthesis of monopulse antennas through the iterative contiguous partition method," Electronics Letters, vol. 43, no. 16, pp. 854-856, Aug. 2007.
[57] P. Rocca, L. Manica, A. Martini, and A. Massa, "Synthesis of large monopulse linear arrays through a tree-based optimal excitations matching," IEEE Antennas Wireless Propag. Lett., vol. 7, pp. 436-439, 2007.
[58] P. Rocca, L. Manica, and A. Massa, "An effective excitation matching method for the synthesis of optimal compromises between sum and difference patterns in planar arrays," Progress in Electromagnetic Research B, vol. 3, pp. 115-130, 2008.
[59] P. Rocca, L. Manica, and A. Massa, "Directivity optimization in planar sub-arrayed monopulse antenna," Progress in Electromagnetic Research L, vol. 4, pp. 1-7, 2008.
[60] G. Oliveri, "Multi-beam antenna arrays with common sub-array layouts," IEEE Antennas Wireless Propag. Lett., vol. 9, pp. 1190-1193, 2010.
[61] P. Rocca, R. Haupt, and A. Massa, "Sidelobe reduction through element phase control in sub-arrayed array antennas," IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 437-440, 2009.
[62] P. Rocca, L. Manica, M. Pastorino, and A. Massa, "Boresight slope optimization of sub-arrayed linear arrays through the contiguous partition method," IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 253-257, 2008.
[63] L. Manica, P. Rocca, G. Oliveri, and A. Massa, "Synthesis of multi-beam sub-arrayed antennas through an excitation matching strategy," IEEE Trans. Antennas Propag., vol. 59, no. 2, pp. 482-492, Feb. 2011.
[64] L. Manica, P. Rocca, and A. Massa, "Design of subarrayed linear and planar array antennas with SLL control based on an excitation matching approach," IEEE Trans. Antennas Propag., vol. 57, no. 6, pp. 1684-1691, Jun. 2009.
[65] P. Rocca, R. L. Haupt, and A. Massa, "Interference suppression in uniform linear array through a dynamic thinning strategy," IEEE Trans. Antennas Propag., vol. 59, no. 12, pp. 4525-4533, Dec. 2011.
[66] P. Rocca, L. Manica, N. Anselmi, and A. Massa, "Analysis of the pattern tolerances in linear arrays with arbitrary amplitude errors," IEEE Antennas Wireless Propag. Lett., vol. 12, pp. 639-642, 2013.
[67] L. Manica, P. Rocca, N. Anselmi, and A. Massa, "On the synthesis of reliable linear arrays through interval arithmetic," IEEE International Symposium on Antennas Propag. (APS/URSI 2013), Orlando, Florida, USA, Jul. 7-12, 2013 (accepted).

[68] L. Manica, P. Rocca, G. Oliveri, and A. Massa, "Designing radiating systems through interval analysis tools," IEEE International Symposium on Antennas Propag. (APS/URSI 2013), Orlando, Florida, USA, Jul. 7-12, 2013 (accepted).
[69] M. Carlin, N. Anselmi, L. Manica, P. Rocca, and A. Massa, "Exploiting interval arithmetic for predicting real arrays performances - The linear case," IEEE International Symposium on Antennas Propag. (APS/URSI 2013), Orlando, Florida, USA, Jul. 7-12, 2013 (accepted).
[70] G. Oliveri, L. Manica, and A. Massa, "ADS-Based guidelines for thinned planar arrays," IEEE Trans. Antennas Propag., vol. 58, no. 6, pp. 1935-1948, Jun. 2010.
[71] G. Oliveri and A. Massa, "ADS-based array design for 2D and 3D ultrasound imaging," IEEE Trans. Ultrasonics, Ferroelectrics, and Frequency Control, vol. 57, no. 7, pp. 1568-1582, Jul. 2010.
[72] G. Oliveri and A. Massa, "GA-Enhanced ADS-based approach for array thinning," IET Microwaves, Antennas & Propagation, vol. 5, no. 3, pp. 305-315, 2011.
[73] G. Oliveri, F. Caramanica, C. Fontanari, and A. Massa, "Rectangular thinned arrays based on McFarland difference sets," IEEE Trans. Antennas Propag., vol. 59, no. 5, pp. 1546-1552, May 2011.
[74] G. Oliveri, F. Caramanica, and A. Massa, "Hybrid ADS-based techniques for radio astronomy array design," IEEE Trans. Antennas Propag. - Special Issue on "Antennas for Next Generation Radio Telescopes," vol. 59, no. 6, pp. 1817-1827, Jun. 2011.
[75] M. Carlin, G. Oliveri, and A. Massa, "On the robustness to element failures of linear ADS-thinned arrays," IEEE Trans. Antennas Propag., vol. 59, no. 12, pp. 4849-4853, Dec. 2011.
[76] P. Rocca, "Large array thinning by means of deterministic binary sequences," IEEE Antennas Wireless Propag. Lett., vol. 10, pp. 334-337, 2011.
[77] P. Rocca, R. L. Haupt, and A. Massa, "Interference suppression in uniform linear array through a dynamic thinning strategy," IEEE Trans. Antennas Propag., vol. 59, no. 12, pp. 4525-4533, Dec. 2011.
[78] G. Oliveri and A. Massa, "Fully-interleaved linear arrays with predictable sidelobes based on almost difference sets," IET Radar, Sonar & Navigation, vol. 4, no. 5, pp. 649-661, 2010.
[79] G. Oliveri, P. Rocca, and A. Massa, "Interleaved linear arrays with difference sets," Electronics Letters, vol. 46, no. 5, pp. 323-324, Mar. 2010.
[80] G. Oliveri, L. Manica, and A. Massa, "On the impact of mutual coupling effects on the PSL performances of ADS thinned arrays," Progress in Electromagnetic Research, PIER B, vol. 17, pp. 293-308, 2009.
[81] G. Oliveri, M. Donelli, and A. Massa, "Linear array thinning exploiting almost difference sets," IEEE Trans. Antennas Propag., vol. 57, no. 12, pp. 3800-3812, Dec. 2009.
[82] G. Oliveri, F. Caramanica, M. D. Migliore, and A. Massa, "Synthesis of non-uniform MIMO arrays through combinatorial sets," IEEE Antennas Wireless Propag. Lett., vol. 11, pp. 728-731, 2012.
[83] G. Oliveri, L. Lizzi, F. Robol, and A. Massa, "Polarization-agile ADS-interleaved planar arrays," PIER, in press, 2013.

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