Guidelines for Student Reports

Sintesi Di Array Per Radioastronomia Basati Su ADS E Ottimizzatori Genetici

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Abstract

La radioastronomia è l'osservazione dei corpi celesti mediante la misura della loro emissione di onde radio. A causa della lunghezza d'onda molto più grande rispetto alla luce visibile, e la potenza molto ridotta delle sorgenti celesti, tale osservazione si basa sull'utilizzo di antenne di grandi dimensioni combinate per formare un'array. Inoltre, al fine di aumentare la dimensione efficace dell'array, tali sistemi si basano sull'analisi della correlazione dei segnali ricevuti. Al fine di massimizzare le prestazioni della schiera di antenne riducendone la ridondanza, i costi e la complessità, la progettazione di array per radioastronomia si basa sulla selezione ottimizzata delle posizioni degli elementi radianti. In questo ambito, il gruppo ELEDIA ha sviluppato metodologie di design analitiche basate su Almost Difference Sets in grado di garantire a-priori prestazioni elevate in termini di ridondanza e caratteristiche radianti dell'array risultante, e tempi di design estremamente contenuti anche nel caso di array di grandi dimensioni. Attualmente tali metodologie forniscono prestazioni soddisfacenti nel caso di geometrie lineari, ma non sono state ancora approfondite le loro prestazioni nel caso di array planari, sia in configurazione rettangolare che triangolare e derivate. A tal fine, la selezione dell'ADS (o dei differenti ADS) richiede l'utilizzo di una procedura ibrida, che includa un ottimizzatore genetico per la selezione, all'interno di un certo insieme di ADS a disposizione, delle sequenze che garantiscono le prestazioni migliori. Scopo dell'attività è perciò quello di progettare, simulare ed analizzare le prestazioni degli array per radioastronomia basati su ADS (selezionati da un GA) nel caso di geometrie planari, e di valutarne vantaggi e limitazioni in termini di Peak Sidelobe Level, copertura delle baselines, e risoluzione spaziale.

Reference Bibliography: Evolutionary Optimization [15]-[67]; Array Synthesis [1]-[14], [68]-[91]; Analytic Sequences [1]-[14].

[1] 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.
[2] 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.
[3] 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.
[4] 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.

[5] 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.
[6] 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.
[7] P. Rocca, "Large array thinning by means of deterministic binary sequences," IEEE Antennas Wireless Propag. Lett., vol. 10, pp. 334-337, 2011.
[8] 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.
[9] 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.
[10] G. Oliveri, P. Rocca, and A. Massa, "Interleaved linear arrays with difference sets," Electronics Letters, vol. 46, no. 5, pp. 323-324, Mar. 2010.
[11] 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.
[12] 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.
[13] 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.
[14] G. Oliveri, L. Lizzi, F. Robol, and A. Massa, "Polarization-agile ADS-interleaved planar arrays," PIER, in press, 2013.
[15] P. Rocca, M. Benedetti, M. Donelli, D. Franceschini, and A. Massa, "Evolutionary optimization as applied to inverse problems," Inverse Problems - 25 th Year Special Issue of Inverse Problems, Invited Topical Review, vol. 25, pp. 1-41, Dec. 2009.
[16] P. Rocca, G. Oliveri, and A. Massa, "Differential Evolution as applied to electromagnetics," IEEE Antennas Propag. Mag., vol. 53, no. 1, pp. 38-49, Feb. 2011.
[17] M. Donelli, D. Franceschini, P. Rocca, and A. Massa, "Three-dimensional microwave imaging problems solved through an efficient multi-scaling particle swarm optimization," IEEE Trans. Geosci. Remote Sensing, vol. 47, no. 5, pp. 1467-1481, May 2009.
[18] M. Benedetti, G. Franceschini, R. Azaro, and A. Massa, "A numerical assessment of the reconstruction effectiveness of the integrated GA-based multicrack strategy," IEEE Antennas Wireless Propag. Lett., vol. 6, pp. 271-274, 2007.
[19] G. Oliveri, M. Donelli, and A. Massa, "Genetically-designed arbitrary length almost difference sets," Electronics Letters, vol. 5, no. 23, pp. 1182-1183, Nov. 2009.
[20] 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.
[21] 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.
[22] 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.
[23] 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.

[24] F. Viani, M. Salucci, F. Robol, and A. Massa, "Multiband fractal Zigbee/WLAN antenna for ubiquitous wireless environments," Journal of Electromagnetic Waves and Applications, vol. 26, no. 11-12, pp. 1554-1562. 2012.
[25] F. Viani, M. Salucci, F. Robol, G. Oliveri, and A. Massa, "Design of a UHF RFID/GPS fractal antenna for logistics management," Journal of Electromagnetic Waves and Applications, vol. 26, pp. 480-492, 2012.
[26] L. Lizzi, R. Azaro, G. Oliveri, and A. Massa, "Multiband fractal antenna for wireless communication systems for emergency management," Journal of Electromagnetic Waves and Applications, vol. 26, no. 1, pp. 1-11, 2012.
[27] R. Azaro, E. Zeni, P. Rocca, and A. Massa, "Innovative design of a planar fractal-shaped GPS/GSM/Wi-Fi antenna," Microwave Opt. Technol. Lett., vol. 50, no. 3, pp. 825-829, Mar. 2008.
[28] R. Azaro, F. Viani, L. Lizzi, E. Zeni, and A. Massa, "A monopolar quad-band antenna based on a Hilbert self-affine pre-fractal geometry," IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 177-180, 2009.
[29] R. Azaro, L. Debiasi, E. Zeni, M. Benedetti, P. Rocca, and A. Massa, "A hybrid prefractal three-band antenna for multi-standard mobile wireless applications," IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 905-908, 2009.
[30] L. Lizzi and A. Massa, "Dual-band printed fractal monopole antenna for LTE applications," IEEE Antennas Wireless Propag. Lett., vol. 10, pp. 760-763, 2011.
[31] L. Lizzi and G. Oliveri, "Hybrid design of a fractal-shaped GSM/UMTS antenna," Journal of Electromagnetic Waves and Applications, vol. 24, no. 5/6, pp. 707-719, Mar. 2010.
[32] R. Azaro, E. Zeni, P. Rocca, and A. Massa, "Synthesis of a Galileo and Wi-Max three-band fractal-eroded patch antenna," IEEE Antennas Wireless Propag. Lett. , vol. 6, pp. 510-514, 2007.
[33] F. Viani, "Dual-band sierpinski pre-fractal antenna for 2.4GHz-WLAN and 800MHz-LTE wireless devices," Progress In Electromagnetics Research C, vol. 35, pp. 63-71, 2013.
[34] E. Zeni, R. Azaro, P. Rocca, and A. Massa, "Quad-band patch antenna for Galileo and Wi-Max services," Electronics Letters, vol. 43, no. 18, pp. 960-962, Aug. 2007.
[35] L. Lizzi, F. Viani, E. Zeni, and A. Massa, "A DVBH/GSM/UMTS planar antenna for multimode wireless devices," IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 616-619, 2009.
[36] L. Lizzi, F. Viani, R. Azaro, and A. Massa, "A PSO-driven spline-based shaping approach for ultra-wideband (UWB) antenna synthesis," IEEE Trans. Antennas Propag., vol. 56, no. 8, pp. 2613-2621, Aug. 2008.
[37] L. Lizzi, R. Azaro, G. Oliveri, and A. Massa, "Printed UWB antenna operating over multiple mobile wireless standards," IEEE Antennas Wireless Propag. Lett., vol. 10, pp. 1429-1432, 2011.
[38] L. Lizzi, F. Viani, R. Azaro, and A. Massa, "Design of a miniaturized planar antenna for FCC-UWB communication systems," Microwave Opt. Technol. Lett., vol. 50, no. 7, pp. 1975-1978, Jul. 2008.
[39] F. Viani, L. Lizzi, R. Azaro, and A. Massa, "A miniaturized UWB antenna for wireless dongle devices," IEEE Antennas Wireless Propag. Lett., vol. 7, pp. 714-717, 2008.
[40] F. Viani, L. Lizzi, R. Azaro, and A. Massa, "Spline-shaped ultra-wideband antenna operating in the ECC released frequency spectrum," Electronics Letters, vol. 44, no. 1, pp. 7-8, Jan. 2008.
[41] L. Lizzi, F. Viani, R. Azaro, and A. Massa, "Optimization of a spline-shaped UWB antenna by PSO," IEEE Antennas Wireless Propag. Lett., vol. 6, pp. 182-185, 2007.
[42] L. Lizzi, G. Oliveri, and A. Massa, "A time-domain approach to the synthesis of UWB antenna systems," Progress in Electromagnetic Research, vol. 122, pp. 557-575, 2012.

[43] L. Lizzi, G. Oliveri, and A. Massa, "Planar monopole UWB antenna with UNII1/UNII2 WLAN-band notched characteristics," Progress in Electromagnetic Research B, vol. 25, pp. 277-292, 2010.
[44] L. Lizzi, F. Viani, and A. Massa, "Dual-band spline-shaped PCB antenna for Wi-Fi applications," IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 616-619, 2009.
[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] 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.
[47] 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.
[48] 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.
[49] 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.
[50] 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.
[51] 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.
[52] 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.
[53] 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.
[54] 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.
[55] 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.
[56] 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.
[57] 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.
[58] 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.
[59] 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.

[60] 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.
[61] 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.
[62] 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.
[63] 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.
[64] 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.
[65] 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.
[66] 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.
[67] 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.
[68] 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.
[69] 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.
[70] 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.
[71] 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.
[72] 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.
[73] 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.
[74] 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.
[75] 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.
[76] 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.

[77] G. Oliveri, "Multi-beam antenna arrays with common sub-array layouts," IEEE Antennas Wireless Propag. Lett., vol. 9, pp. 1190-1193, 2010.
[78] 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.
[79] 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.
[80] 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.
[81] 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.
[82] 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.
[83] 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.
[84] 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).
[85] 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).
[86] 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).
[87] 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.
[88] 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.
[89] 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.
[90] 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
[91] 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.

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