Guidelines for Student Reports

Analysis of the impact of the vertex-to-edge distance on the resonant behavior of multi-band coplanar-fed Sierpinski Gasket fractal antennas

N. Anselmi

Abstract

Nowadays, a large number of electronic devices exploits multiple wireless standards. Moreover, the dimensions of such products (e.g., mobile handsets) are becoming smaller and smaller following the users needs and thanks to the progress of the modern integrating circuit technology. In this framework, it is usually necessary to integrate the RF-part (i.e., the whole set of wireless interfaces) in only one antenna.

Such a requirement becomes even more challenging when also a high degree of miniaturization is required. It has been demonstrated that fractal shapes are suitable solutions for both miniaturization and multi-band issues. These results are enabled by two important properties of fractal geometries: the space-filling capability and the self-similarity. The former refers to the ability of fractal curves to be very long occupying a compact physical space. The other indicates that small regions of the geometry are copies of the whole structure, but on a reduced scale, with an expected similar electromagnetic behavior at different frequencies. Moreover, it has been found that by perturbing a reference fractal shape (i.e., introducing some additional degrees of freedom), it is possible to tune the locations of non-harmonic resonance frequencies. The use of a Particle Swarm Optimizer (PSO) algorithm has been validated as an efficient (and clever) way to "tune" the antenna resonances by modifying its geometrical descriptors.

The project aim is to analyze the impact on radiation performances and impedance matching when modifying the distance between each vertex and the triangles edges of a coplanar-fed Sierpinski Gasket antenna (single and double fractal iteration). Moreover, the activity will introduce this parameter as part of the antenna optimized geometrical descriptors. The goal is to obtain two multi-band antennas, that can be used to accommodate the following wireless communications standards:

- 1 iteration model: LTE 2600 MHz, Wi-Max 3500 MHz
- 2 iteration model: UMTS 2100 MHz, LTE 2600 MHZ, Wi-Max 3500 MHz

Reference Bibliography: Evolutionary Optimization [13]-[53]; Evolutionary Optimization and Fractal Antennas [1]-[12].

[1] 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.

[2] 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.

[3] 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.
[4] 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.
[5] 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.
[6] 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.
[7] 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.
[8] 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.
[9] 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.
[10] 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.
[11] 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.
[12] 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.
[13] 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.
[14] 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.
[15] 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.
[16] 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.
[17] 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.
[18] 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.
[19] 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.
[20] 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.

[21] 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.
[22] 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.
[23] 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.
[24] 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.
[25] 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.
[26] 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.
[27] 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.
[28] 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.
[29] 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.
[30] 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.
[31] 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.
[32] 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.
[33] 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.
[34] 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.
[35] 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.
[36] 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.
[37] 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.
[38] 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.

[39] 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.
[40] 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.
[41] 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.
[42] 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.
[43] 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.
[44] 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.
[45] 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.
[46] 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.
[47] 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.
[48] 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.
[49] 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.
[50] 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.
[51] 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.
[52] 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.
[53] 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.

This report is submitted in partial fulfillment of the degree of the course "ACM".
Supervisors: Prof. Andrea Massa, Dr. Fabrizio Robol, Dr. Federico Viani.