Reconfigurable Antenna Systems for the Next Generation Devices Based on 4G/5G Standard

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ABSTRACT

This article is devoted to showing the applications of innovative reconfigurable antenna systems suitable for the next generation 4G/5G devices. Microwave antenna technology can be very useful for next generation devices based on 4G/5G standards. Next generation tablets and smartphones based on 4G/5G standards will require high bandwidth and high velocity channels with respect to conventional devices. This work tries to present a complete overview of possible applications of advanced antenna technologies for 4G/5G devices and systems. Methodologies, such as phased and fully adaptive arrays, multiple-input and multiple-output (MIMO) antennas based on compact Rotman lenses or Butler matrices, development of innovative reconfigurable antennas based on reconfigurable parasitic structures or new materials such as graphene, and unconventional modulation techniques have been investigated in this work. The work ends with some conclusions and considerations related to ideas for future works.

KEYWORDS

Array Control Algorithms, Evolutionary Algorithms, Fully Adaptive Array, Graphene Antennas, Microstrip Antennas, Phased Arrays, Reconfigurable Parasitic Elements Based Antennas, Rotman Lens Antenna, Smart Antennas, Unconventional Modulation Techniques

INTRODUCTION

In the last years modern mobile telecommunications systems such as mobile smart phones, tablets offer multimedia applications and different services including high resolution video that require high bandwidth, velocity and stability in spite of the limited dimensions of the devices. In particular, the next generation 4G/5G standard offer, in addition to usual voice and other services of standard 3G systems, ultra-broadband internet connection, IP telephony, mobile web access, gaming services and other interesting multimedia application (such as high definition television). In such a framework the design of a suitable radiating system could play a key role in the design of these devices. In particular, antenna systems for the new 4G/5G devices must be light, cheap and able to keep the devices performances to very high levels. In such scenario the use of antenna systems able to adapt their radiation properties to complex scenarios are of fundamental importance. The most known reconfigurable antennas are antenna arrays with fully adaptive properties (Bernhard & Roach, 2016; Jakovljevic et al., 2017; Mailoux, Massa, Oliveri, & Rocca, 2017; Cao, Hussain & Majid, 2015; Donelli, Lommi, Massa, & Sacchi, 2003; Caorsi De Natale, Donelli, Lommi, & Massa, 2004; Caorsi, De Natale, Donelli, Franceschini, & Massa, 2004; De Natale, Donelli, Lommi, Massa, & Sacchi, 2004; Caorsi, De Natale, Donelli, Massa, & Pastorino, 2004; Azaro, De Natale, Donelli & Massa, 2006; De

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Natale, Donelli, & Sacchi 2007; De Natale, Donelli, D’Orazio, Fedrizzi, & Sacchi, 2007; Donelli, D’Orazio, Louveaux, Sacchi & Vandendorpe, 2011) simplified version which work only on the phase of each element, the phased arrays. These antenna systems in the past clearly demonstrated their effectiveness to dramatically improve the performances of a telecommunication system in particular if they are combined with suitable reconfigurable digital back end processing unit. Phased and fully adaptive antenna arrays, are commonly used in several applicative civil as well as military scenarios such as airport surveillance, missile detection and tracking. Unfortunately phased and fully adaptive arrays are unfortunately too much complex, expensive and bulky to be used for commercial portable devices such as mobile phone, and tablets. Attempts to reach high degrees of miniaturization and multi-bands behavior have been reached considering pre-fractal geometries antennas in microstrip technology as in (Azaro, De Natale, Donelli, Massa, & Zeni, 2006; Azaro, Boato, Donelli, Massa, & Zeni, 2006; Azaro, Donelli, Franceschini, Massa, & Zeni, 2006; Sing, & Singhal, 2017; Li, & Wang, 2017; Harbaji, Zahed, Habboub et al., 2017; Azaro, Donelli, De Natale, Massa, & Zeni, 2006; Azaro, Boato, Donelli, Massa, & Zeni, 2006; Azaro, Donelli, Franceschini, Massa, & Zeni, 2006), where low cost multiband antennas has been used with success for UMTS, GPS and WI-FI practical applications. The main drawback of such kind of antenna system is their low impedance, the difficulty to fulfill the frequency bands requirements, and the fabrication problems due to mechanical constraints. To strongly reduce the cost of commercial devices the use of switched beam antennas is generally adopted instead of phased or fully adaptive arrays. Recently a new kind of reconfigurable parasitic antennas, able to electronically select different configurations of the radiation pattern (Azaro, Donelli, Fimognari, & Massa, 2007; Donelli, Lizzi, Massa, Oliveri, Pagnolato, & Viani, 2010; Donelli, & Febvre, 2012; Donelli, Massa, Oliveri, Rocca, & Viani, 2013; Peterson, Rausch & Wiebach, 1997), have been successfully adopted for different practical applications, such as WI-FI systems (Donelli, & Febvre, 2012), wireless sensor networks applications (Azaro, Donelli, Fimognari, & Massa, 2007) and sum-difference radars (Donelli, Massa, Oliveri, Rocca, & Viani, 2013). Such kinds of antennas offer a good compromise between the fully adaptive arrays and the switched beam solution. In this work the advantages of this antenna technology based on parasitic reconfigurable antennas will be discussed. Another class of antennas that could strongly improve the performances of 4G/5G systems, are MIMO antennas based on butler matrix (Butler & Lowe, 1961; Fragola, Orefice, & Pirola, 2001; DuFort, 1985; Chang, Chu, Li, & Lin, 2004) or Rotman lenses (Peterson, Rausch, & Wiebach, 1997; Fuchs, & Nüßler, 1999; Musa & Smith, 1989; Hansen, 1991; Lenzing, Luebbers, & Penney, 2005; Albarano, Lenzing, Luebbers, & Penney, 2006; Mano, & Sato, 1984; Leonakis 1986; Gatti, Marcaccioli, Sbarra & Sorrentino, 2007). Both Rotman lenses and butler matrix feeding networks permit to obtain simple and cheap radiating systems with good performances. In particular feeding networks based on Rotman lenses permit to fabricate radiating structures without lumped elements commonly used to implements phase shifters and attenuators. The discovered of new materials such as graphene opened new horizons in the field of antenna design. In particular graphene has recently attracted a great interest in many antenna practical applications, ranging from microwave to terahertz (Bachmatuk, Rummel, Schaffel, & Warner, 2012; Carrasco, Carrier & Tamagnone, 2013; Hanson, 2008; Novoselov, Geim, Morozov et al., 2005; Carrier, Gomez-Diaz, & Mosig, 2013). Graphene presents unique band structure that could bring significant benefits in the field of antenna-technology such as extreme miniaturization, tuning of the electric characteristics, and good mechanical properties. Compared to conventional materials, such as copper or silver, commonly adopted for the synthesis of antennas, graphene presents important advantages. The most important advantages of graphene are its tunability, which can be easily obtained with an applied external electric or magnetic bias field. Recent research demonstrated that use of graphene for the development of standard antennas at microwave frequencies, such as patch antenna or dipoles, offers no substantial advantages with respect to metallic antennas, but it permits the development of reconfigurable feeding networks particularly interesting for the fabrication of smart arrays. Another way to improve the performance and in particular the data rate exchange for communication systems on the hardware side is the introduction of advanced
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