Abstract

Antennas able to concentrate the radiated power in a very narrow angular region, i.e. antennas with high gain, are required in several applications such as radar or communication systems. This feature could be achieved using aperture antennas or arrays of small radiating elements. An aperture antenna consists in a metallic, passive curved reflector on which the field radiated by a feed impinges and is re-radiated. The profile of the reflector, that in the easiest version is parabolic, could be adjusted depending on the desired shape of the antenna radiation pattern. If a scanning of the main beam is required, instead of a single feed a cluster of feed could be used. Despite their wide use in many applications, recently their drawbacks, and in particular the fact they are bulky, heavy and they require a complex mechanism for their deploying, limit their use in modern communication systems. Arrays consist in an ensemble of equal and equi-oriented “small” radiating elements, characterized by poor gain. Properly arranging a suitable number of such antennas to form a linear or a planar array is however possible to design a high-gain antenna, that could radiate a shaped beam or could be reconfigurable. Moreover, the surface where the radiating elements are located could be conformed to a curved stand. The main drawback of an array is related to the fact that it requires a complex feed network to excite all its elements; in most cases this is also the main responsible for the losses in the entire antenna.

Another solution is represented by printed Reflectarrays (RAs) that try to overcome both limitations of conventional reflector and array antennas, still keeping their advantages. Reflectarrays are conventionally flat, passive arrays, where the resonant behavior of the array elements (patches with or without phasing lines, dipoles, slots, etc.) allows a phase shaping of the incident beam, thus replacing the curvature of a conventional reflector. The low profile of a RA with respect to a conventional reflector, and the absence of a feeding network as for arrays, makes the RAs potentially well suited for a wide range of both space and terrestrial applications.

These same good features are shared by Transmitarray (TA) antennas with the difference that they essentially behave a a lens (in fact, they are also named planar lenses), in which the field radiated by the feed is focalized in a desired direction. Also in this case the lack of curvature is balanced properly adjusting one of more degree of freedom of each unit-cell in which the TA surface is divided. With respect to reflectarrays, they present the advantage to not suffer from the feed blockage.

In the most recent years, new scenarios arise, where applications as those for 5G communication systems, small satellites, satcom on the move or radar for automotive or surveillance push the need of new technologies for the antenna system, with enhanced performances. The used frequency band move from microwaves to millimeter waves, and in most of the cases, a wideband or multi-bands have to be covered; furthermore, in several applications, multi-beam or beam scanning capabilities are required. In addition to these radiating features, the antenna has also to possibly have a low profile, a reduced visual impact, to be easily deployable if mounted on board of a satellite and finally to have a low cost. The activities carried on during the PhD fit in this framework, since they have been mainly focused on the introduction of innovative configurations of reflectarrays and transmitarrays, with enhanced features, and on the development of ad-hoc techniques for their design. Most of the proposed solutions work at millimeter waves (Ka band); for some of them a prototype has been realized and experimentally characterized.

For what concerns reflectarrays, the focus has been on the study of configurations that could be easily integrated in the surface where they have to be mounted. A first solution that has been investigated consists in a RA in which the reflector is no longer planar but it can be fit on non-planar surfaces, as the fuselage of an aircraft or the wall of a (contemporary) building. The effects of several types of curvature on the antenna radiating features have been numerical analyzed, while at a later stage the attention has been concentrated on a convex configuration, were the reflector has been supposed to be bent to a cylinder, since it seemed it was the most interesting from the application point of view. The experimental characterization of a prototype, design ed at 30 GHz, prove the antenna feasibility, but also pointed out that optimizations had to be carried out to improve its radiation properties. In view of this, two different solutions have been considered, the first based on the use of multi-resonant patches as re-radiating elements, the other, more innovative, consisting in the design of a proper, non-conventional feed, that has been manufactured with a 3D printer technique: once substituted to the original, traditional feed it has allowed a noticeable increase of the antenna performances, in particular of the bandwidth and of the efficiency. A related, even if quite different problem that has been faced, has been that of the design of a scanning beam planar reflectarray for direct to home (DTH) applications. The use of a reflectarray with mechanical beam steering, as the one proposed, is completely new with respect to the conventionally adopted antennas that are mainly parabolic reflectors or in few case phase arrays, and it presents the advantage to have a very low visual impact. The RA has been designed to mimic the behavior of a quasi-spherical reflector, still keeping a size comparable with that of a parabola. As a proof of these concepts, two prototypes, with different re-radiating elements, have been manufactured and measured.

The concept of conformal antenna has been then extended to transmitarray, with the aim to study possible configurations to be used as base antenna for 5G communication systems. Initially several unit-cells have been analyzed, with particular attention to their sensitivity to the direction of arrival of the incident field. Then, the possibility to design a multi-beam passive TA has been considered; two different techniques has been compared, one consisting in designing a bifocal transmitarray, the other based on the use of a global optimization approach.

The adopted algorithms are the Social Network Optimization (SNO) and the M_QC_{10}-BBO, an enhanced version of the Biogegraphy Based Optimization (BBO): before their use for the design of multi-beam or scanning beam RA/TA, their performances, evaluated in terms of goodness of the provided solution, of speed of convergence and reliability, have been studied by their application to other antenna problems. In particular, the SNO has been applied to the optimization of a shaped beam reflectarray.