DIPARTIMENTO DI INGEGNERIA
CORSO DI DOTTORATO IN INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE -
PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING - 34TH CYCLE

Title of the research activity:	Reconfigurable Networks for MIMO and 5G **RN4M&5G**
State of the Art:	With the emergence of paradigms such as Internet of Things, Networked Society, and 5G, the number of devices connected to the Internet has thoroughly increased and an explosion is foreseen for the next few years. A tremendous need for bandwidth has pushed communication systems toward millimeter-waves, and more efficient protocols, such as OFDM, have been implemented [1]-[3]. However, although very helpful, such techniques are not sufficient to avoid interference among the many coexisting systems and to provide throughput performance satisfactory for real time applications. As a consequence, research is focusing on reconfigurable systems based on spatial diversity. According to this technique, multiple communications can occur at the same time and frequency by keeping physical channels separate. Basically, transmitter and receiver should aim to each other, and this can be achieved designing antennas with a narrow beam-width, or, in other words, adopting antenna arrays. Such solutions are electrically large, but, as the adopting frequencies are migrating toward millimeter-waves, the physical dimensions of the systems are still compatible with common applications. As transmitters and receivers can change position over time, a high level of re-configurability is required as well. Electronic scanning with phased arrays is quite an interesting approach, although many issue still need to be addressed, such as power consumption, need for improved isolation between radiating elements and need for increased number of steerable directions [4],[5]. Some solutions are currently under study, regarding both different antenna arrangements and, most of all, different feeding networks. Among the most well-known beam-forming networks, Butler matrix is probably the most studied and well-known [6]-[8]. Butler matrix is a passive NxN network, used to provide beam steering by selecting the relevant input port. The input power is equally divided among the output ports with a constant progressive phase difference among adjacent output ports, the latter difference depending on the selected input port. The output ports are connected to the radiating elements (usually arranged to form a linear array) and on the basis of the selected input ports N beams can be obtained, distributed, however, over less than 180° in the azimuthal plane. Spatial scanning can be achieved at the expense of arranging multiple Butler matrices in 3D configurations [7]. It usually ends up in cumbersome architectures. Ultimately, a vast area of research does exist in order to optimize the overall efficiency of such antenna systems (including feeding networks [11]) in view of massive MIMO

	evolution for 5G applications.
Short description and objectives of the research activity:	This PhD project aims at fostering the progress of reconfigurable antenna arrays to fulfill the emerging requirements posed by the expected 5G communications. Although the 5G standards are not established yet, some directions of evolution can be clearly envisaged [3]. The proposed research project will focus on circuital design and RF aspects of the upcoming telecommunications systems. The design of 5G antenna systems can be partly borrowed from other more mature scenarios, such as aerospace, where similar requirements of beam-forming flexibility were already addressed. On the other hand, performance, in terms of beam-width reconfigurability, steering ability, speed of commutation and so forth, has to be improved, while addressing additional operational constraints that ranges from harsh environment operation to environmental compatibility, from easiness of installation, to low esthetic impact. These requirements will be targeted, as a whole, by merging the most advanced architectures for reconfigurable antennas, likely inherited by the aerospace field, with the most recent technologies and materials pulled, in the last years, by the booming IoT eco-system. Among them, the adoption of flexible and ecofriendly materials as well as the use of additive manufacturing technologies are considered of paramount importance. The specific objective of the activity is the realization of antenna system prototypes at a Technology Readiness Level around 5 (validation in a pertinent field) including antenna elements, beam forming networks and control unit. To this purposed, an intense preliminary phase, approximately quantifiable in six months will be devoted to three propaedeutic activities: 1) recover the SoA of beam-forming techniques and technologies. 2) investigate the 5G expectations concerning antenna systems, by focusing on those applications exhibiting the best compromise between feasibility and potential impact. 3) practice with the most important instruments to develop the targeted systems, namely: EM numerical simulators, RF CAD suits, Lab facilities and equipment for prototype manufacturing and testing. After that, some demonstrators will be targeted according to the common scientific methodology that, in this specific case, is actuated by conceiving the preliminary block diagram of the systems, then breaking it down in subsystems, likely antenna arrays, flexible beam-forming networks and control units, till the level of single components (antenna elements, passive and active sub-circuits and so forth). Elements will be designed, prototyped and validated, after that they will be assembled and validated with an increasing level of aggregation and in case of validation failure, the loop will be restarted from the proper point. This core phase is tailored to last about two years, in order to allow for final demonstrator realization and thesis writing approximately in the last six months. In terms of outcomes, it is reasonably foreseeable that results beyond the state of the art can be achieved both in the area of antennas and propagation as well as in the area of RF electronics and systems. Accordingly to this, at least two papers per each field can be published to high impact reviews in the respective fields. Beyond that, an

	intense activity, testifying more specific solutions for limited problems can be imagined to be published at the most relevant international conferences in the field (MTT International Microwave Symposium, IEEE- Antennas and propagation symposium, European Microwave Conference, European Conference on Antennas and Propagation and so on). The activity will be synergic to the development of the approved EST4IoT (Electronic and Sensor Technology for IoT) laboratory in the sense that, on the one hand the experimental activity will be carried out in the lab, on the other hand the experience gain though the research process will contribute to address the development of the EST4IoT lab by invluding targeted technologies.
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