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:	Radio Frequency Systems for Wireless Power and Data Transfer **RFS4WPDT**
State of the Art:	In the last decade the transfer of energy by using electromagnetic waves as a vector, has been experiencing a kind of palingenesis. The art of wireless power transfer (WPT) in fact begun at the very end of the XIX century (1899)[1] and the artist was Nikola Tesla. Since that time a part the noir history of the Marconi's "death ray" [2], only some isolated wailings ([3] as the most meaningful example) have been proposed till the avalanche has been triggered by the historical contribution from MIT [4]. At that point, close to the and of the first decade of the third millennium, a big wave originated and growing industrial and societal needs along with the development of new technologies, opened the gates of the scientists' phantasy. WPT has been evolving in many directions: radiative as well as non radiative, magnetic or electric, capacitive or inductive, long range or short range, resonant coil based or non resonant coil based, and so forth. Many applications have been then considered as potential beneficiaries of this evolution. Among them it is worth recalling consumer appliances battery charge, electric vehicles power supplying, long range ground to ground energy transfer, power supply of disposable electronics (the so called energy shower), and last but not list satellite applications such as power supply of cluster satellites in a master slave configuration and also the visionary application of scavenging solar energy from the space by means of solar powered satellites (SPS) to transfer it to the Earth by means of suitable microwave beacons and large area receiving ground stations. On the transfer information side, needless to recover the history of telecommunication; however, since the first telegraph (Morse 1844), to the telephone fight between Meucci and Bell in the fifties of the XIX century, to the Marconi's radio across the XIX and XX centuries, till the booming of modern wireless communications; transfer of information took place exploiting several media, the most relevant being: air, optic fiber and wires. It is a matter of fact that there are several analogies in these two histories. Focusing on the media aspects, since the beginning energy traveled on copper cores (grid) while other kinds of metal cores were being used to transfer information (telegraph and telephone till Ethernet cables). These two ways, never met before the recent advent of powerline communication [qui ci vuole], however. Powerline technology, in fact, enabled the exploitation of the existing grid to transfer wirely not only energy but also information, with a great impact on applications such as domotics, industrial and domestic appliances control and so on. Nowadays a new opportunity, enabled by the development of WPT

	technologies comes up: why don't we exploit wireless power link to transfer both energy and information? At present only a very few contributions faced this problem of simultaneous wireless transfer of energy and information (commonly known as Wireless Power and Data Transfer – WPDT). This approach is actually at this infancy and a huge territory for high impact research is in front of us.
Short description and objectives of the research activity:	This project has the primary aim at boosting the WPDT technologies and making its enormous potential more real. In order for that, the following activity, tailored for a PhD program is conceived. In the first six months a deep investigation about the state of the art of the two separate technologies: WPT and Powerline, will be carried out. This phase is finalized of course to understand the technological foundations, and mostly to pinpoint the specific implications that must be accounted for to concurrently develop them towards the targeted final WPDT. In this phase, part of the effort will be devoted to analyze the potential market, mostly from the point of view of their mid-term expectations. This activity is considered here of paramount importance to select soon an area of application able to motivate a real demonstrator at technology readiness level (TRL) close to 5 that should be seen as the final outcome of the activity and thus should inspire it. Moreover, this phase will be also devoted to understand and practice with the most important designing tools, mainly numerical electromagnetic simulators as well as RF microwave CAD suits. These instruments, in fact, will be mandatory in the core following phase, i.e. the development of some solutions of high industrial/societal impact from TRL-1 to TRL-5. The activity in this phase will be carried on according to the commonly adopted scientific approach consisting of iterating the formulation of solutions at system level, the breakdown of the conceived systems in subsystems, the implementation of each subsystem still iterating theoretical formulations carried on by means of CAD with experimental validations and than back by aggregating partial outcomes to pursue the targeted demonstrators. Along this way, some criticisms can be already envisaged, most likely laying in the interface between the two technologies. In particular we foresee that the definition of the power electronics to separate the low frequency power signal from the information carriers in order to optimize them for transmission, and the dual subsystem to recombine data and energy on the same line will be critical. In order to mitigate this criticism, particular emphasis will be given also to the system analysis in terms of frequency spectrum, bandwidth of the wireless components (including in primis antennas, but also filters, diplexers, and similar stuff…) so that the first guess designs be as close as possible to a solution easily implementable for first validations. Overall, this activity is tailored to the PhD program, not only in terms of duration, but also in terms of compliance with the outcome expectations. To this regard, it is worth reporting that at least one high impact journal contribution will follow up the most of the relevant subsystems that, correctly environmented and motivated, constitute by themselves a step forward of high interest for the scientific community. The same considerations apply to partial evolution of the systems consisting on the assembly of subsets of subsystems (just to give a very coarse example: the transmitter and the receiver, separately considered).

	Several contributions to the most credited international conferences (for instance: IEEE-International microwave symposium as a generalist one for RF technologies, and IEEE- Wireless Power Transfer Conference as a more topical one for specific advancements) are expected to report incremental yet significant evolutions as well the solution of specific problems. 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 it will be carried in the lab, on the other hand it will contribute to address the development of the EST4IoT lab to include the targeted technologies.
Bibliography:	[1] Tesla 1899 [2] http://article.sciencepublishinggroup.com /html/10.11648.j.history.20160401.11.html [3] W.C. Brown, J.R. Mims and N.I. Heeman, 'An Experimental Microwave-Powered Helicopter', Proceedings IRECON, 1965, pp. 225-235 [4]Aristeidis Karalis a,*, J.D. Joannopoulos b, Marin Soljac˘ic´, "Efficient wireless non-radiative mid-range energy transfer", Annals of Physics 323 (2008) 34–48
Scientific coordinator (s)	Paolo Mezzanotte Valentina Palazzi
Contact (s)	Paolo.mezzanotte@unipg.it