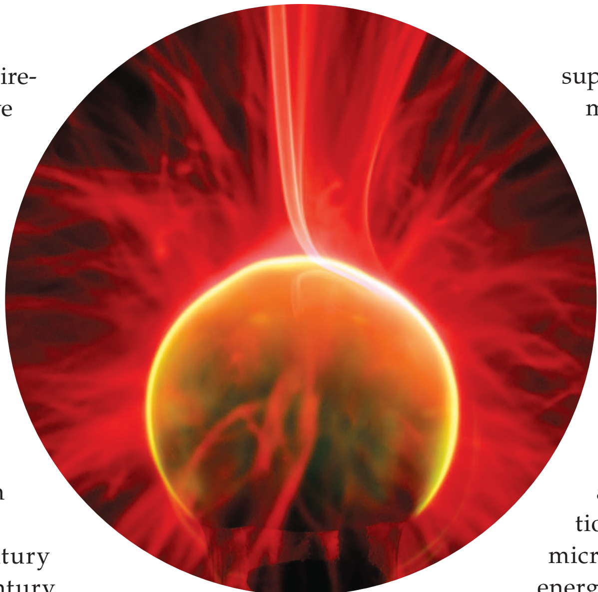
From the Guest Editors' Desk

Wireless Power Transmission—The Last Cut of Wires...

■ **Zhizhang (David) Chen, Shigeo Kawasaki, and Nuno Borges Carvalho**

When we consider wireless communications, we think of systems that communicate without wires. The communication in that case is made wirelessly. Nevertheless, all these systems developed so far have a certain moment in time where they are still connected by wires. This is when they need to recharge its batteries. Thus, wireless means communication wireless and not necessarily device or system wireless.

In the end of the 19th century and beginning of the 20th century Nicola Tesla predicted what is now known as wireless power transmission, which will become the last cut of wires in any wireless system. Actually, what is envisaged for the future is the possibility to send energy via air and thus all devices or systems could use electromagnetic energy to power them up in a clever and interesting way.



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Over the last couple of decades, we have made remarkable progress in the development of radio-frequency (RF) and microwave technologies. Traditionally, these technologies have been used for wireless telecommunication systems and sensor systems. However, as the third usage of the microwaves, it is found that microwave propagation achieves wireless power transmission. With a few initial experiments, wireless power supply using electromagnetic or microwave energy became a viable practical method for green wireless power generation, opening a new horizon of research and development. Applications to this technology spans from environmental sensors, medical appliances and sensors, home automation devices, and high-power systems such as electric cars, credit cards, and a multitude of other solutions. To this end, the RF and microwave energy transmission and energy harvesting technologies have evolved rapidly.

The wireless power transmission is generally categorized into three branches: the electromagnetic coupling, the magnetic resonance, and the microwave power transmission. Although they are distinguished by the energy transfer rate with respect to the distance between the transmitter and the receiver, the down-converted power is effectively used to operate low power consumption circuits. In this special issue of *IEEE Microwave Magazine* we will open a window on these devices and on how we can design circuits and systems that will cope with this futuristic vision and

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drive us to the final solution of truly wireless devices and systems. In this respect, we have combined a group of five articles that will takes us on a journey through long-range high-power to short-range low-power wireless transmission and from low RF to gigahertz transmission.

The article "Optimum Behavior," by Alírio Boaventura, Ana Collado, Nuno Borges Carvalho, and Apostolos Georgiadis, gives an insight on the modeling aspects for wireless power transmission circuits and presents some ideas to increase the range coverage of these systems.

The article written by Richard M. Dickson, "Power in the Sky," describes wireless power transmission (WPT) systems applications that span the spaces from the size of a room to those involving flying helicopters, airplanes, and airships, within continents, to intercontinental spans, Earth to low-earth-orbit (LEO) satellites, geostationary-earth-orbit (GEO) satellites, the Moon, and beyond. It discusses the requirements for a microwave beamer for powering high-altitude (up to 25 km) platforms such as airships or circling aircraft and considers various factors such as operating frequency, economic considerations, exclusion fly-zones, etc. Examples of requirements for airship beamers and circling drones are given along with tradeoffs associated with each beamer system. Beam safety considerations for ground personnel, aircraft and other flyers, and spacecraft are also presented.

In this special issue of *IEEE Microwave Magazine* we will open a window on how we can design microwave circuits and systems that will drive us to the final solution of truly wireless devices and systems.

The article titled "Rectifying Loose Coils," by Brian W. Flynn and Kyriaki Fotopoulou studies the commonly used coils for wireless power transmission and analyzes the effects of misalignment of the coils on power transfer efficiency for different coil geometries. A novel set of analytic expressions for the power transfer between two loosely coupled coils under different alignment conditions is presented. Extensive experimental work was carried out with large-scale model coils in the 2–10 MHz region of the spectrum to verify the accuracy of these expressions.

Zoya Popovic's article, "Cut the Cord," thoroughly studies the historical background and the main challenges of wireless power transmission in a very enthusiastic way. This article is a good lead-in to the one that follows, which is by Dr. Mingui Sun's research group.

"Batteries Not Included," by Qi Xu, Zhaolong Gao, Hao Wang, Jiping He, Zhi-Hong Mao, and Mingui Sun investigates a mat-based witricity system consisting of an array of driving coils, a transmitter mat with hexagonally packed resonators, a receiving resonator, and a load coil. The finite-element method was applied to compute the field distribution for nearly constant power delivery and for minimization of effects due to a moving receiver. Measurements were carried out with an implantable resonator and a novel structure. The results obtained in this article enable future design and optimization of wireless power delivery systems involving free-moving receivers, especially for people or animals implanted with electronic devices.

In our view, wireless power transmission is a part of the healthy development of our human society in making it sustainable by means of the green ecotechnology. This special issue is intended to promote the ideas and concepts in this direction and hopefully inspire more thoughts and activities along the line.