From the Guest Editors' Desk

Medical Applications of RF and Microwaves—Therapy and Safety

■ **J.-C. Chiao and Dietmar Kissinger**

The focus sections of this and the May issue of *IEEE Microwave Magazine* are dedicated to the research activities in the IEEE Microwave Theory and Techniques Society (MTT-S) Technical Committee, Biological Effect and Medical Applications of Radio Frequency (RF) and Microwaves, MTT-10. Specifically, this issue focuses on RF and microwave technologies in therapeutic applications and the safety issues of using millimeter waves. The May issue will focus on medical sensing, monitoring, and diagnostics. These focus issues are organized to provide an overview of the ongoing research and development of microwave technologies in the quickly growing biomedical fields. Although we only cover a small portion of the landscape, we hope that these overviews can give the readers a high-level general picture of the state-of-the-art activities and inspire new thoughts and ideas in microwave and RF engineers and researchers for innovation in the near future.

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Health care is a top global problem both socially and economically. The rising costs of medical and senior care have an impact on everyone everywhere. The productivity and stability of human society are dependent on the outcomes and the factors in health care. The National Academy of Engineering has defined health care as one of the grand challenges for engineering. While there are many different aspects of engineering, efforts to improve quality of care, create new medicines, or increase efficiencies of health care, RF technologies and electromagnetics certainly play critical roles in this grand challenge. It is quite clear that wireless communication, which delivers electronic health records and provides customers quick access to caregivers' service, and magnetic resonance imaging (MRI), which enables a noninvasive view of the brain and the body to analyze functions and problems, have made phenomenal changes in our lives. Hence, it is expected that new technologies utilizing wireless power transfer through the body; electromagnetic waves for probing organs, tissues, cells, and biochemicals in the body; focused microwave powers for surgeries or stimulation of tissues; microwave and functional MRI techniques for noninvasive diagnostic tools; radar to monitor human external and internal activities; and body networking communication to empower patients to manage their own health are emerging as new exciting potential solutions. These technologies proposed for new diagnostic and treatment methods aim to reduce costs by resolving shortcomings in the existing systems.

Conventionally, RF and microwave systems are designed for homogeneous, linear, and isotropic media, and, often, the environments for wave propagation do not change. However, the anatomical, physiological, and biochemical variations in human bodies present tremendous challenges to designers. The challenges are compounded with realistic issues such as lack of simulation and experimental models; delayed, unquantifiable, or unmeasureable effects from biological systems; lack of standards and existing clinical practice and protocols; clinical constraints in implementation; and difficulty conducting experiments. The gap of communication or common language between engineers and clinicians remains a barrier in making desirable fast progress toward practical applications. In this issue, we aim to provide engineering professionals with some insights into the practical requirements and encountered constraints in medical applications. Hopefully, the disclosure will make the readers rethink existing RF, microwave, and millimeter-wave systems for futuristic uses in health-care applications.

In this issue, three main topics are presented: using microwaves for surgery and treatment of tissues, using wireless communication and power transfer for implants, and the safety considerations of millimeter-wave communication.

In "A New Wave in Electrosurgery," Hancock et al. review experimental and commercially available systems that use RF and microwave energy for therapeutic and surgical applications. In particular, electrosurgical systems utilizing both low and high frequencies to achieve better overall results are introduced in terms of antenna and mechanical designs and delivery methods for desired effects on tissues. Prototypes and experiments on tissues show potential for future use in minimally invasive natural orifice transluminal endoscopic surgery and peroral endoscopic myotomy procedures, which in general can reduce pain, chance of infection, and recovery time for patients.

In "Don't Sweat It," Johnson and Steve Kim review using microwave ablation on sweat glands to treat axillary (underarm) hyperhidrosis, a condition of excessive sweating. The current treatment methods and energy-based ablation modalities are discussed. The theory, system design, preclinical experiments, and clinical trial results are presented, giving readers insight into what it takes to bring a concept of utilizing microwave power to the realization of a commercial product for treating a clinical condition. This article also assesses challenges in commercialization and product features in a clinical setting.

In "Too Much Pressure," Kawoos et al. review a wireless intracranial pressure monitoring method in the treatment of traumatic brain injuries. The elevation of intracranial pressure due to head injuries or diseases often leads to fatality or long-term disability. The current methods are bulky and inefficient. On the contrary, wireless signal transduction utilizing miniature microelectromechanical systems pressure sensors provides continuous monitoring of brain pressure in situ without bulky wires restricting patients. This article discusses the implantable antenna designs suitable for integration with the sensor and circuitry while operating properly with its small size in the brain. Design and fabrication material considerations, simulation, and models are presented. In vivo experiments, including surgical procedures and the injury model and the device performance demonstrate the feasibility of such a wireless implant in ambulatory conditions. Besides the technical contents, this article shows engineers a complete cycle of problem solving from system-level parameter considerations to practical challenges with in vivo tests.

In "Body Electric," Rao and Chiao review wireless power transfer techniques to provide energy for batteryless or rechargeable-battery-based medical implants. In particular, this article focuses on energy-harvesting techniques for traveling endoscopic sensors through the gastrointestinal tract and a gastrostimulator that moves inside the stomach. Due to the motion of the devices and higher power requirement to provide energy into the stomach tissues to activate gastric slow waves, wireless power transfer faces realistic challenges in achieving high power transfer efficiency while keeping the antenna and overall device form factor sufficiently small for swallowing. The consideration for misalignment between the implant coil and the powering coil worn by the patient as well as an optimization strategy for inductive coupling coil designs are presented. This article demonstrates a method of using equivalent circuits and calculated mutual inductance from the measured open- and short-circuit coil impedances to achieve better efficiency in wireless power transfer without excessive electromagnetic energy exposure to the body. A similar method can be applied to many different types of implants and can help to shrink implant sizes by both miniaturizing the antenna dimensions and reducing the battery capacity or even eliminating the battery.

In "Safe for Generations to Come," Wu et al. present a review of potential biological effects caused by nonionizing millimeter-wave radiation on the human body. This article focuses on the potential safety requirements for emerging millimeter-wave technologies in the next-generation, fifth-generation mobile communication networks. This article serves as a bridge to the May issue, in which microwaves and millimeter waves are utilized in sensing and monitoring as the electromagnetic energy will directly interact with the human body or tissues. In this article, a detailed discussion of safety considerations beyond simple power density is presented, considering more complex environments in the human body. Special attention is given to the eyes and skin since they receive most of the radiation in communication applications. A summary of studies on millimeter-wave effects at the cellular and molecular levels illustrates that there is still more to explore to understand the biological effects, short or long term, of high-frequency nonionizing electromagnetic waves. With the fast growth of millimeter-wave applications in communication, sensing, and stimulation, it is important to gain the knowledge in the near future.

The multidisciplinary nature and broad scopes of research topics in the Biological Effect and Medical Applications of RF and Microwaves MTT-10 committee are illustrated in this special issue of *IEEE Microwave Magazine*. These five articles review the scientific and engineering potentials offered by utilizing RF and microwave technologies in medical applications. We believe that the efforts will have long-lasting effects on our society. We would like to thank Alfred Riddle, the editor-in-chief, and Sharri Shaw for administrating the review processes and making the final decisions on these articles. We heartily thank the authors and reviewers for their significant contribution.