

# Wireless Without Batteries: Radio Communications with Low-Powered, Energy-Harvesting Integrated Circuits

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Tutorial

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**Abstract**

Recent innovations in energy-harvesting, low-power electronics, backscatter communications, and RFID now indicate the possibility of wireless communications at UHF and microwave frequencies with devices that have little or no on-board power supply. In this tutorial, we outline new techniques that dramatically extend both the range and the potential data rate of these types of communications links using multiple antennas, new and bizarre forms of modulation, unconventional radio elements. These techniques will soon allow the exchange of low data rates over surprisingly far distances (hundreds of meters for purely passive devices), with profound implications in the world of sensors, radio location, and consumer electronic devices.

This tutorial will demonstrate how simple, energy-scavenging integrated circuits can be used to conduct radio communications with small, battery-less devices. By harvesting energy from incident RF waves or other hybrid sources, we demonstrate unique forms and techniques for wireless communications. We will discuss first-principles operation of these low-powered communications links, with real-life case studies that include the Intel WISP platform as well as 5.8 GHz high-voltage sensors for realizing "Smart Grid" applications. The tutorial is targeted for a bachelor-level communications engineer and is an excellent introduction to the emerging field of microwave energy-harvesting radios and wireless sensors.

**Gregory D. Durgin** joined the faculty of Georgia Tech's School of Electrical and Computer Engineering in Fall 2003 where he now serves as associate professor of electromagnetics. He received the BSEE (96), MSEE (98), and PhD (00) degrees from Virginia Polytechnic Institute and State University. In 2001 he was awarded the Japanese Society for the Promotion of Science (JSPS) Post-doctoral Fellowship and spent one year as a visiting researcher with Morinaga Laboratory at Osaka University. In 1998 he received the Stephen O. Rice prize (with coauthors Theodore S. Rappaport and Hao Xu) for best original journal article in the IEEE Transactions on Communications. Prof. Durgin also authored Space-Time Wireless Channels, the first textbook in the field of space-time channel modeling. Prof. Durgin founded the Propagation Group (<http://www.propagation.gatech.edu>) at Georgia Tech, a research group that studies radiolocation, channel sounding, backscatter radio, RFID, and applied electromagnetics. He is a frequent consultant to industry, having advised more than 12 multinational corporations on wireless technology. He is a winner of the National Science Foundation CAREER award as well as numerous teaching awards, including the Class of 1940 Howard Ector Outstanding Classroom Teacher Award at Georgia Tech (2007).

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