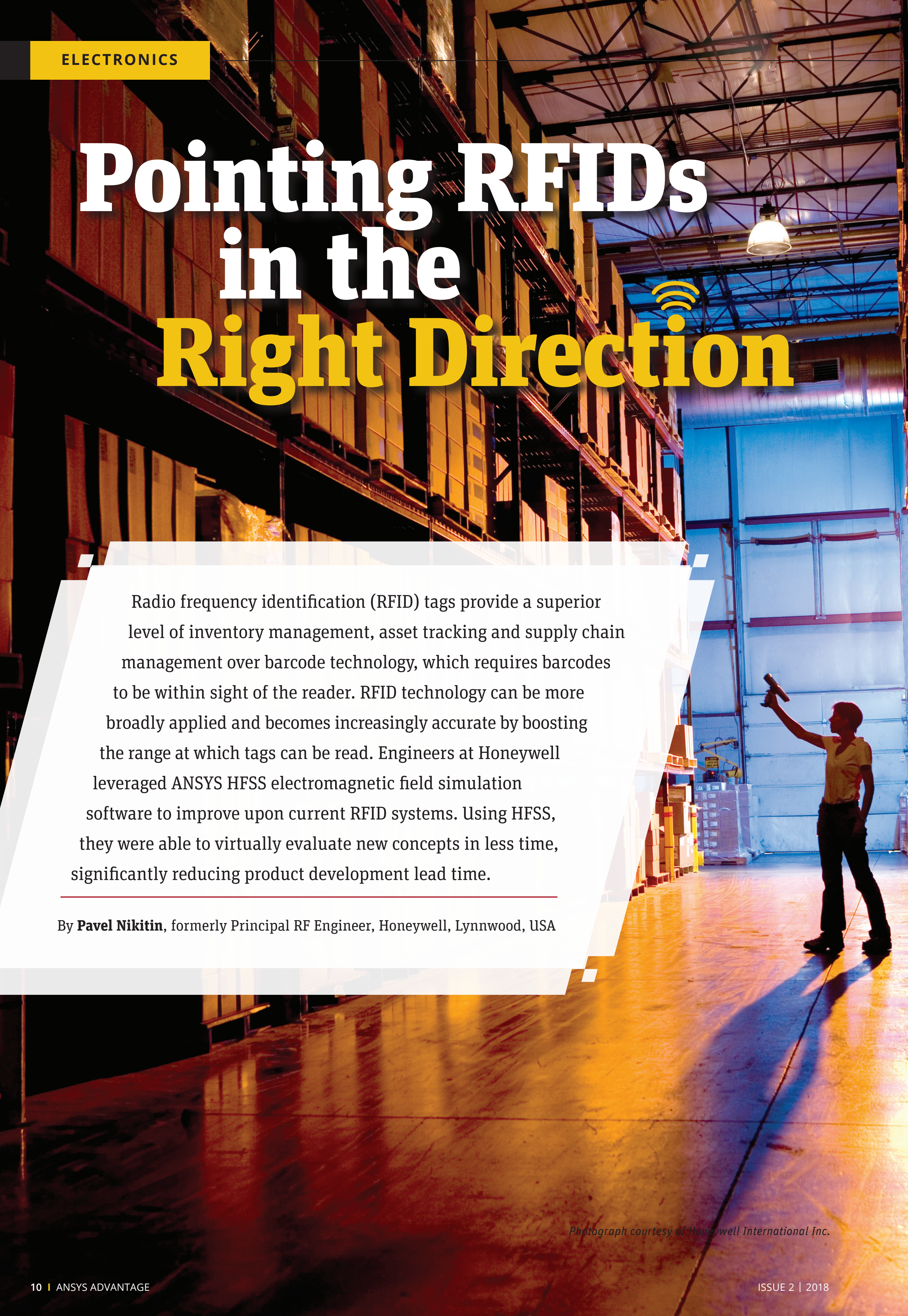
Pointing RFIDs in the Right Direction



Radio frequency identification (RFID) tags provide a superior level of inventory management, asset tracking and supply chain management over barcode technology, which requires barcodes to be within sight of the reader. RFID technology can be more broadly applied and becomes increasingly accurate by boosting the range at which tags can be read. Engineers at Honeywell leveraged ANSYS HFSS electromagnetic field simulation software to improve upon current RFID systems. Using HFSS, they were able to virtually evaluate new concepts in less time, significantly reducing product development lead time.

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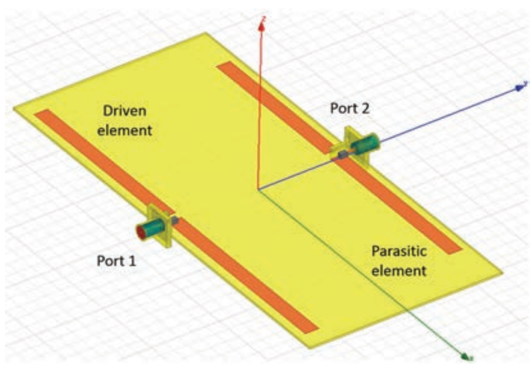
Photograph courtesy of Honeywell International Inc.

Radio-frequency identification (RFID) uses electromagnetic fields to automatically identify and track tags attached to objects. RFID tags are used in supply chain management in many industries to, for example, automate tracking of pharmaceuticals from the production plant to the pharmacy shelves. Accurate tracking reduces inventory levels and prevents counterfeiting. It is a growing and evolving market. RFID technology today extends beyond pure identification and now encompasses intelligent devices and systems with sensing, networking, security, and localization capabilities, and applications ranging from healthcare technology to vehicle identification.

Unlike barcode technology, an RFID tag does not require the tag to be in the line of sight of the reader. Barcodes must be aligned with an optical reader to properly capture the information, whereas RFID tags backscatter data to the reader using RF waves. Improving RFID systems is one of many areas of research at Honeywell, which invents and manufactures technologies that address some of the world's most critical challenges around energy, safety, security, productivity and global urbanization. The company is one of the top 100 global innovators as determined by Clarivate Analytics, based on an analysis of patent volume, patent–grant success rates, global reach and invention influence.



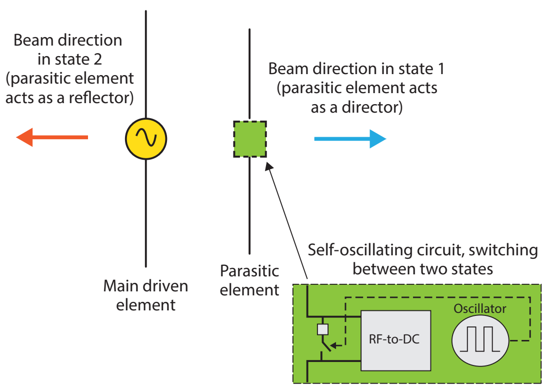
ANSYS HFSS model of antenna design

RFID tags are almost always passive (powered only by RF) to reduce their cost and increase their lifespan. Passive RFID tags harvest power from the electromagnetic waves produced by the RFID tag reader. The lack of an internal power source limits the range at which tags can be read. This can be a concern in some applications, such as in larger warehouses. One approach to increasing the range at which passive RFID tags can be read is to employ a reconfigurable antenna that concentrates all the wireless power generated by the reader in a single direction that changes as the reader scans its environment for tags. This approach was, before now, complex and costly because today's reconfigurable antennas require a network of control and power lines, and associated circuitry, which substantially increases the cost and complexity of the antenna. Honeywell proposed powering these switches by harvesting wireless energy from the antenna itself and controlling the switches through the wireless signal, substantially reducing the cost of making the antenna directional.

Engineers developed a proof of concept for this approach using ANSYS HFSS electromagnetic field simulation software, which allowed them to iterate through the design concepts in only a few minutes each. Honeywell believes this technology has potential and has filed several patents on it. A paper on this topic was selected as the best paper at the 11th Annual International IEEE 2017 Conference on RFID.

The Basic Approach

Honeywell's proof-of-concept design consists of a two-element planar Yagi array with a main driven element and a parasitic element. A self-oscillating RF-powered switching circuit periodically switches between two complex impedance values to turn the parasitic element into either a director or a reflector, based on the effect of the reactive load on the antenna parasitic element. This concentrates the power of the antenna in either one direction or the other. Engineers wanted to harvest enough power from a 20 dBm RF source to change the direction of the antenna



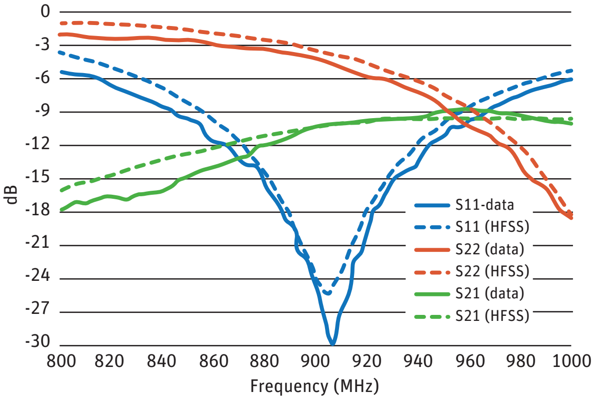
Schematic of new reconfigurable antenna design

"Engineers developed a proof of concept for this approach using ANSYS HFSS electromagnetic field simulation software to evaluate new concepts in only a few minutes."

Photograph courtesy of Honeywell International Inc.

by 180 degrees each time the circuit switches between the two states. They designed a discrete multistage RF-to-DC power harvesting circuit, like those used in many RFID tag front ends, feeding a simple oscillator. The circuit oscillates and modulates its RF input port, in the same way that an RFID tag integrated circuit (IC) modulates its antenna port. The circuit was designed so that when it is driven with a 10 dBm unmodulated RF signal at 900 MHz, it oscillates with a frequency of approximately 0.5 Hz, spending about 1 second in each switched state. This is long enough for the reader to read most of the tags in the beam's current direction before it is redirected.

Honeywell engineers built the switching circuit on a breadboard. They measured the impedance values of the circuit at 900 MHz at several different power levels as inputs for their antenna design. The main design parameters that affect the performance of the antenna are the length of the director, length of the reflector and spacing between the two elements. Without simulation, engineers would have used the build-and-test method, prototyping the antenna using copper traces on 30-mil FR4 substrate, and then connecting the switching circuit to the antenna and measuring the overall performance under load. This would have taken about an hour per iteration. Not enough time was available to pursue this project using this approach.



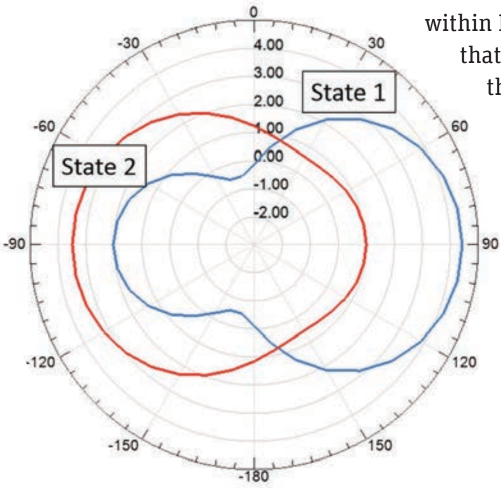
Measured and simulated S-parameters of the final design match up well.

Using Simulation to Drive the Design Process

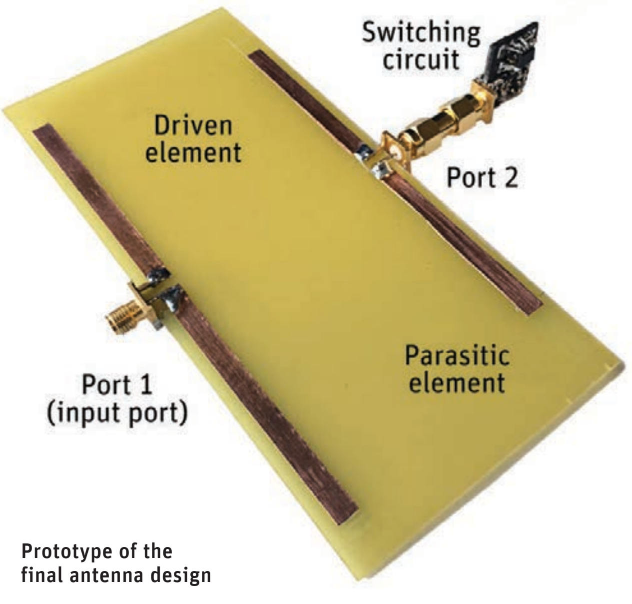
Instead, Honeywell engineers used ANSYS HFSS to drive the antenna design. The initial antenna design was modeled in HFSS using one driven element and one parasitic element. Both elements are 5-mm-wide planar copper traces, spaced 60 mm apart on a 30-mil FR4 substrate with a dielectric permittivity of 4.4. Port 1 is the input port of the antenna, and Port 2 connects to the switching circuit. The antenna was designed to operate at 900 MHz. Engineers used the coaxial connector model from the HFSS library for the two coaxial connectors.

These connectors are standardized except for the base that attaches to the circuit board. Engineers measured the width of the connector and length of the pins and modified the model to match the physical connectors.

Engineers first simulated 10 different initial designs to evaluate the effects of spacing between the two antenna elements. They selected a spacing that provides about a 4 dBi directional gain in each state. Next, they used the parametric analysis capability within HFSS to run 100 different cases that explored every combination of the 10 different lengths for each antenna element. This process was then repeated for several different impedance values of the loading circuit, available from measurements using different RF input power. Engineers configured HFSS to run through these designs without user intervention and calculated their radiation pattern and S-parameters. They examined the results and selected the best designs for further exploration. The simulation predicted that the best design would deliver a radiation pattern that concentrated the vast majority of the power of the antenna alternately into two states that had little overlap yet covered 360 degrees.



Simulated antenna radiation pattern with radial axis representing realized gain at 900 MHz in YZ plane



Prototype of the final antenna design

Simulation Predictions Match Physical Measurements

Next, engineers built a physical prototype of the antenna and compared its performance to the model. The simulated S-parameters were in good agreement with experimental measurements. Engineers also verified the switching beam behavior of the antenna by constructing a simple experimental test setup. An RF signal generator transmitted a 20 dBm 900 MHz signal into the antenna. During the switching cycle, the received RF power for maximum gain beam direction (state 1) changed by approximately 3 dB, matching the simulated radiation patterns. The full radiation pattern was then measured using a more complex setup described in the reference.

Honeywell has filed patents and is considering licensing this technology to outside interests. The device can be built as a research project; all necessary information is in the referenced IEEE paper.

Wirelessly powered reconfigurable antennas have the potential to increase the range of RFID readers at a relatively low cost. This new approach does not require adding power or control lines to operate the switching circuit, so it can easily be retrofitted to existing RFID readers that transmit sufficient power. This concept may pave the way to building other reconfigurable electronic components such as filters and amplifiers.

Antenna Design and Placement
ansys.com/antenna-design-placement

Reference

Nikitin, P. Self-reconfigurable RFID Reader Antenna, *2017 IEEE International Conference on RFID (RFID), Phoenix, AZ.* **2017**. pp. 88–95.