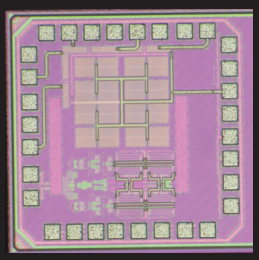
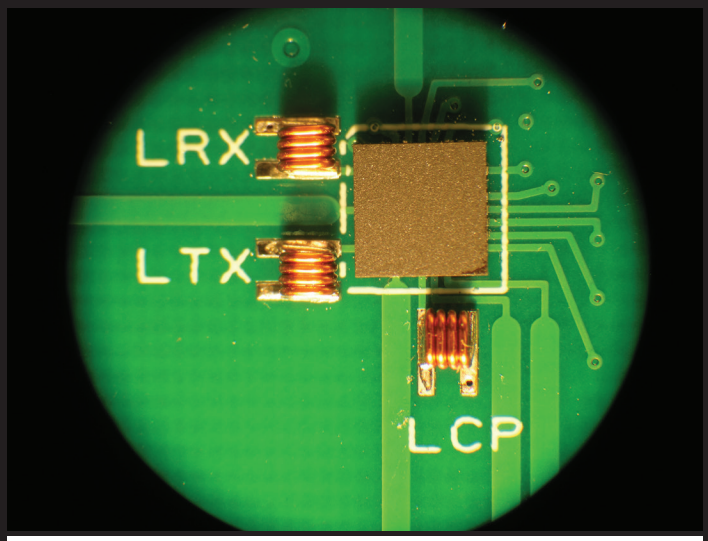
Novel miniaturized circulator opens way to doubling wireless capacity

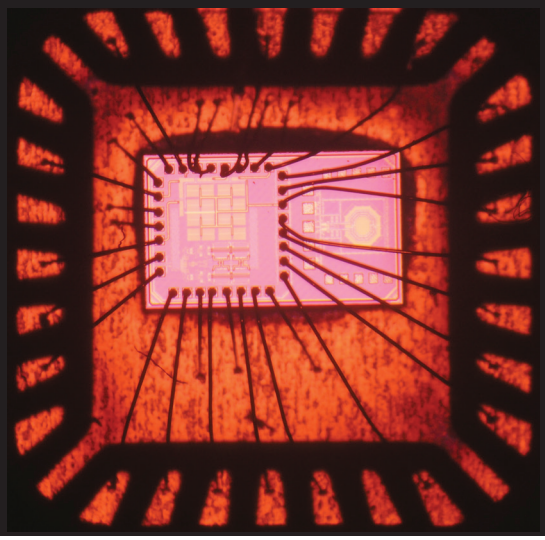


Take a scenic tour of a specialized and first-of-its-kind microelectronic component called a circulator. Among the advances it could lead to are a doubling of radiofrequency (RF) capacity for wireless communications and smaller, less expensive and more readily upgraded antenna arrays for radar, signals intelligence and other applications. Funded under DARPA's Arrays at Commercial Timescales (ACT) program, Columbia University electrical engineers Harish Krishnaswamy and Negar Reiskarimian describe their achievement in the April 15, 2016 issue of *Nature Communications*. For additional details about the work, please visit DARPA's web site at http://www.darpa.mil/news-events/2016-04-15.



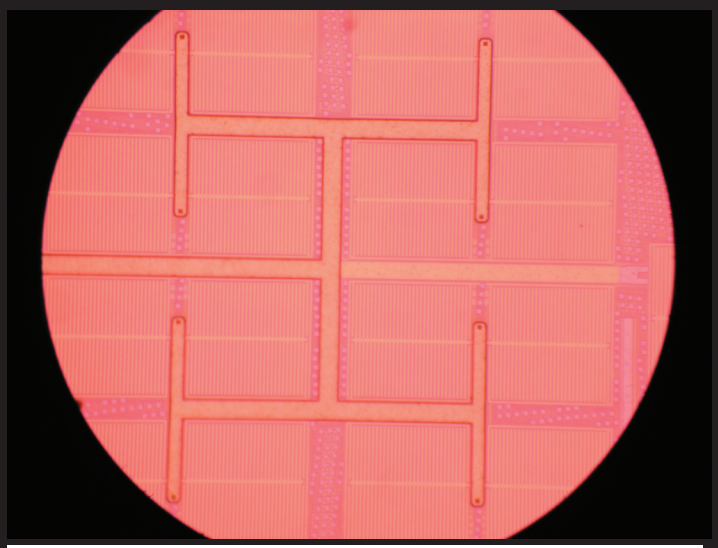
5mm x 5mm

Little Brown Box
In its brown plastic packaging, the new circulator component appears as just another unassuming electronic part soldered into a printed circuit board. The three sesame-seed-sized inductors are clues that the little box is working with radiofrequency signals. The inductors help miniaturize the "one-way highway" between the transmitter port, which is next to the single inductor, the antenna port between the paired inductors, and the receiver port at the twelve o'clock position of the image.



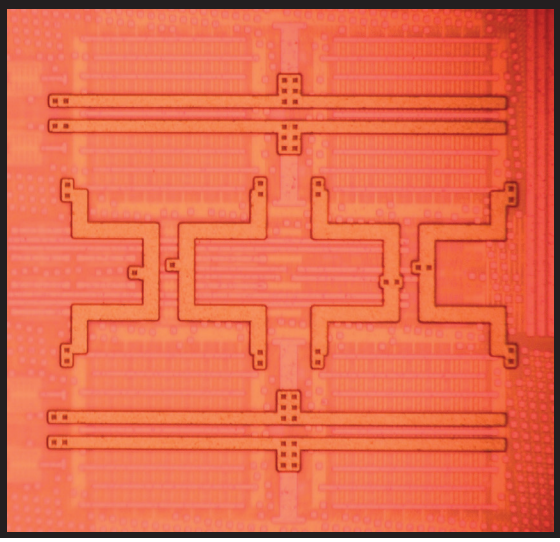
1.2mm x 2.6mm

Roundabout Circuitry
Hidden inside the chip package is the circulator die, which includes the capacitor-dominant circulator block (grid of 16 tiny squares) with high-precision clock circuitry nearby. The lavendar-colored close-up of the die at the top of the infographic showcases the sixteen circulator capacitors, each one just big enough to frame a dust speck. Below the capacitors is the "clock generation circuit," which orchestrates the capacitor activity so RF signals course in one direction through the circulator.



80um x 80um

In-Charge of the Charge
The square patches with light horizontal lines through them are individual capacitors, each about a hair's width by a hair's width. Their precisely timed and orchestrated activity is pivotal for ensuring one-way travel for RF signals in the circulator.



1mm x 0.4mm

Tickers and Tockers
Next to the circulator's capacitor bank is a clock-generation circuit. It consists of twin clock units that generate timing signals, which in turn drive the too-small-to-see transistors that control the circulator's capacitors. The collective action of the capacitors controls the phase of RF signals in the circulator so the signals can propagate in only one direction.