Radar advance: Acoustic time delay device could reduce size and cost of phased array systems

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Georgia Tech Research Institute (GTRI) research engineers Kyle Davis and Ryan Westafer, with professor William Hunt of the School of Electrical and Computer Engineering (l-r), examine a 3-inch-diameter silicon wafer on which they have fabricated thousands of bulk acoustic-wave devices capable of delaying electromagnetic waves. The computer monitor in the background shows a microscope view of the type of device they are patenting. Credit: Gary Meek

(Phys.org) —Radar systems today depend increasingly on phased-array antennas, an advanced design in which extensive grids of solid state components direct signal beams electronically. Phased array technology is replacing traditional electro-mechanical radar antennas – the familiar rotating dish that goes back many decades – because stationary solid state electronics are faster, more precise and more reliable than moving mechanical parts.

Yet phased array antennas, which require bulky supporting electronics, can be as large as older systems. To address this issue, a research team from the Georgia Institute of Technology has developed a novel device – the ultra-compact passive true time delay. This component could help reduce the size, complexity, power requirements and cost of phased array designs, and may have applications in other defense and communication areas as well.

The patent-pending ultra-compact device takes advantage of the difference in speed between light and sound, explained Ryan Westafer, a Georgia Tech Research Institute (GTRI) research engineer who is leading the effort. The ultra-compact device uses acoustic technology to produce a type of signal delay that's essential to phased-array performance; existing phased-array antennas use cumbersome electrical technology to create this type of signal delay.

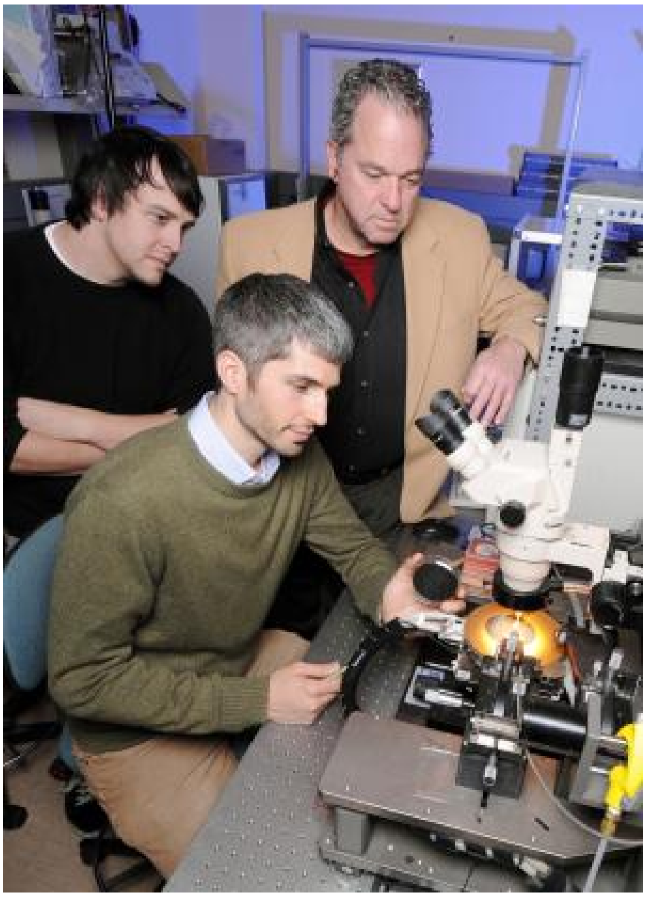
"Most true time delay equipment currently uses long, meandering electromagnetic delay lines – comparable to coaxial cable – that take up a lot of space," Westafer said. "In addition, there are some time delay designs that utilize photonic technology, but they currently have size and functionality drawbacks as well."

The ultra-compact delay device uses acoustic delay lines that are embedded entirely within thin film materials. The component can be made thousands of times smaller than an electrical delay-line design, Westafer said, and it can be readily integrated on top of semiconductor substrates commonly used in radar systems.

A Critical Delay

In a phased array radar system, true time delays are necessary to assure proper performance of the many signal beam producing elements that make up the array. As the elements scan back and forth electronically at extremely high speeds, their timing requires extremely fine coordination.

"The individual antenna elements of a phased array appear to scan together, but in fact each element's signal has to leave up to a few nanoseconds later than its neighbor or the steered beam will be spoiled," explained Kyle Davis, a GTRI research engineer who is a team member. "These delays need to march down each element in the array in succession for a steered beam to be produced. Without correct time delays, the signals will be degraded by a periodic interference pattern and the location of the target will be unclear."



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Traditional phased array systems use one foot of electrical delay line for each nanosecond of delay. By contrast, the Georgia Tech team's time-delay design consists of a thin-film acoustic component that's a mere 40 microns square. The tiny device can be readily integrated into the silicon substrate of a radar component, yet it provides the same delay as many feet of cable.

This size reduction is possible because of a simple fact of physics – sound traveling through the air moves about 100,000 times more slowly than light. As a result, when an electromagnetic wave such as a radar signal becomes an acoustic wave, it slows down dramatically. In the case of the ultra-compact passive true time delay component, the acoustic area of the component furnishes a multi-nanosecond delay in the space of a few microns.

"Microwave acoustic delay lines actually date back to 1959, but our ultra-compact delay's small size represents a significant advance that should allow microwave acoustic delay lines to be manufactured and integrated much more readily," explained William Hunt, a professor in the Georgia Tech School of Electrical and Computer Engineering. "And it's worth noting that this innovative work took place as the result of both strong student participation and very effective collaboration across several Georgia Tech units."

Acoustic Wave Conversion

A phased array radar using the Georgia Tech time delay component could operate like this: An electromagnetic wave is transmitted through an electrical line to the compact time delay device. Then, within the delay device, a piezoelectric transducer converts electromagnetic waves to acoustic waves, and over the distance of a few microns the waves are slowed by several orders of magnitude.

Once the required delay is achieved, the acoustic waves are transduced back to electromagnetic waves, delivered into another electrical line and transmitted by an antenna. A similar but reverse sequence takes place when the radar beam bounces back from its target and is received by the antenna.

In addition to Westafer, Davis and Hunt, the Georgia Tech development team includes GTRI principal research engineers Jeff Hallman and Jim Maloney; GTRI research engineer Brent Tillery and GTRI research associate Chris Ward; School of Electrical and Computer Engineering student Stephen Mihalko, and GTRI student assistant Jonathan Perez.

To date, the Georgia Tech team has successfully demonstrated that the current version of the ultra-compact passive true time delay can handle radar signals at 100 percent bandwidth while delivering a 10 nanosecond delay. The team is presently addressing technical issues such as signal loss, and near-term plans call for the demonstration of an improved device design and the delivery of initial packaged devices to customers.

Provided by Georgia Institute of Technology
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