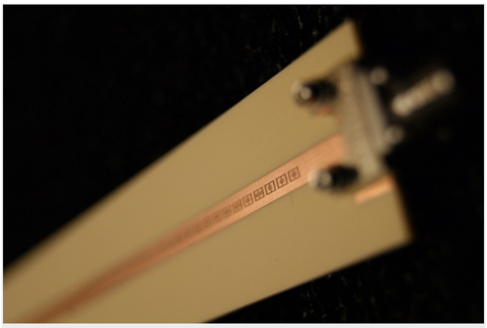
Camera shoots and compresses image in one go

Single-pixel microwave sensor could lower cost of airport scanners and radar systems.

Katherine Bourzac

23 January 2013



John Hunt, Duke ECE

Researchers have designed a camera that can capture microwave images using a single-pixel sensor and produce ready-compressed data. The system, described last week in *Science*[1], could be adapted for other wavelengths, such as those used in millimetre-wave scanners for airport security screening.

Today's cameras take images as 'raw' arrays of pixels, which can take up many megabytes of storage, and then use data-compression algorithms such as JPEG to store the image in a smaller file.

"Why collect that data in the first place?" asks John Hunt, an engineer at Duke University in Durham, North Carolina, and a co-author of the study. To design the new device, Hunt and his colleagues used an approach called compressive sensing.

The trick is figuring out what data to acquire, says Richard Baraniuk, an electrical and computer engineer at Rice University in Houston, Texas. "The data-points that matter will be different in a picture of the Eiffel Tower and a picture of your mother," he says.

But it is not possible for a device to 'know' what is important before the data are recorded. Compressive sensing works by sampling at random — eliminating the need to sift through data — and it still produces enough information to generate a good image.

In 2006, Baraniuk and his colleagues made the first optical camera that produced multi-pixel images with a single-pixel sensor. In that device, light is run through a system of micromirrors before reaching the sensor[2]. But longer, microwave wavelengths — for applications such as airport scanners — require a different approach, because there are no materials that can serve as micromirrors in that part of the spectrum.

For the latest study, the researchers turned to metamaterials — artificial structures patterned to interact with light in exotic ways. Whereas a conventional microwave radar system uses a moving dish antenna to collect microwaves reflecting off a moving object, the Duke system uses a stationary metamaterial aperture, a strip that guides microwaves to a single sensor.

Just as in a radar system, the device sends out waves that reflect off the moving object to be imaged. But here, the source sequentially sends out microwaves of different wavelengths. The returning waves are then collected by the metamaterial aperture.

As microwaves travel down the metamaterial strip, they interact with patterns etched along its surface. These patterns prevent light from travelling down the strip depending on the direction it's coming from, says Hunt. Because the directions the aperture receives light from are random for each frequency, says Hunt, the system provides the random sampling needed for compressive sensing. An algorithm compiles data from each wavelength to generate a complete image every 0.1 seconds.

Using their device, the researchers were able to record a video of a moving object's path in two dimensions. The group hopes to make a three-dimensional video system by using a metamaterial array rather than a strip.

Today's millimetre-wave airport scanners physically move an array of multiple sensors around a person. Hunt wants to build a less expensive imager that uses one detecting element and no moving parts. He says that the metamaterial aperture could also be used to simplify radar systems and infrared imaging.

Nature | doi:10.1038/nature.2013.12240

References

1. Hunt, J. *et al*. *Science* **339**, 310–313 (2013).
2. Wakin, M. B. *et al*. *IEEE Imag. Proc.* http://dx.doi.org/10.1109/ICIP.2006.312577 (2006).
3. Schurig, D. *et al*. *Science* **314**, 977–980 (2006).