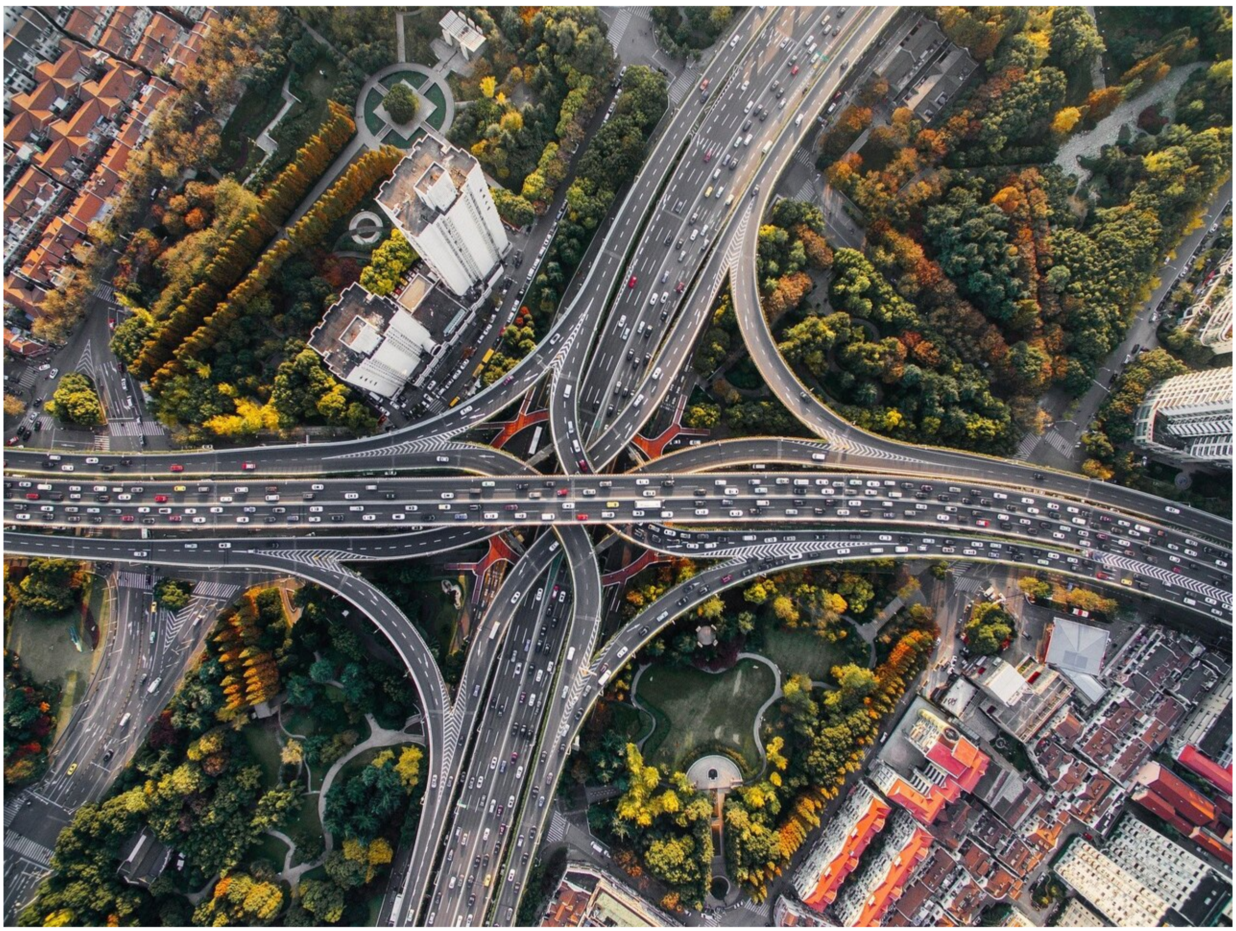
Microwaves improve imaging systems, hasten infrastructure evaluation

September 2 2021, by Monique Clement



Credit: Pixabay/CC0 Public Domain

Microwaves do more than just heat up your leftovers. These invisible waves of electromagnetic radiation can also be used in a variety of imaging applications.

From observing the Earth's climate and surface topography to screening baggage at airports, microwaves can help us see things that may be hidden. That is because different frequencies of microwaves can penetrate objects that would normally block our vision in the visible light spectrum—such as clouds or the outer layer of a suitcase.

However, the limitations of microwave imaging are the unfavorable size, weight, power consumption and cost of the systems. These factors limit their use to applications such as bulky scanners at airports or large satellites in orbit.

Mohammadreza Imani, an assistant professor of electrical engineering in the Ira A. Fulton Schools of Engineering at Arizona State University, is looking to overcome these challenges by making microwave imaging systems more portable and accessible.

His research focuses on one particular area of opportunity for microwave imaging: using metamaterials—engineered combinations of elements that have unique patterns or structures not found in nature—to simplify microwave imaging hardware and make it easier to generate images.

Imani shares how to improve microwave imaging using metamaterials and how this new way of "seeing" can help inspect buildings, aid in search and rescue efforts, speed up airport security and even assist in our own home improvement projects.

Question: What is the big challenge with microwave imaging systems that you're addressing?

The complexity of current imaging systems comes from multiple factors. A crucial one is the antenna hardware.

Think of a security screening system at an airport. This system has a mechanical arm equipped with many antennas that scan around the person. Though it can capture fantastic images, it is expensive, bulky and slow.

Metamaterials offer a simple way to get several measurements of a particular scene of interest. In essence, they can alleviate the need for mechanical movement or using very large antenna arrays.

Metamaterials consist of many inclusions, or encapsulated compounds in the material's structure, that resonate when an electromagnetic wave interacts with them. Their resonance response determines the patterns generated.

By designing metamaterial structures that exhibit specific resonance responses as a function of frequency or electronic signals, we can generate diverse patterns that interrogate the scene of interest and obtain several measurements of the scene.

In this manner, we can replace multiple antennas with a single one that is fashioned with metamaterial structures. When we reduce the number of antennas and mechanical motion, we can make imaging systems faster and simpler.

Question: How else do metamaterials address microwave imaging challenges?

We can leverage metamaterials' dynamic and diverse interactions with a scene to obtain enough measurements to form an image even at a single frequency. Other imaging systems use several frequencies over a wide bandwidth.

Bandwidth, or the range of electromagnetic frequencies used, is usually a huge bottleneck in microwave imaging. Many devices operate in microwaves—ranging from microwave ovens to reconnaissance radars. When using a large bandwidth for microwave imaging, we increase the chances of interfering with other devices. Wide bandwidth also usually increases the complexity and cost of the devices. Further, in the case of imaging through surfaces, using wideband electromagnetic waves can cause image distortion.

Using a single frequency, or a very narrow bandwidth, solves the problems associated with wide bandwidth, which is where my research comes into play. Reconfigurable metamaterials provide a simple means to realize imaging systems that use a single frequency.

Question: What is innovative about your approach to developing imaging technology?

The innovation at the heart of using metamaterials to obtain diverse measurements comes from the application of computational imaging. In this framework, computational post-processing is used to retrieve the desired image instead of relying solely on hardware components.

This change of roles has immense benefits in terms of imaging speed and hardware complexity, and it allows us to use unconventional hardware such as metamaterials.

Question: Can you "see" through walls with this technology?

Seeing through layers has always been a fascinating idea in science fiction. However, that is not quite what is possible when we use microwave imaging to see through opaque layers. The resulting images may not easily be interpretable by the human eye but the measurements they produce carry a lot of information.

The images obtained using microwave imaging can be used to examine structural integrity, detect structural damages, such as water leaks and cracks; locate items of interest, such as pipes or studs; or find and count the number of humans beyond walls, for example, in rescue operations. You can also use microwave imaging to inspect packages or backpacks, for example, to detect concealed threats.

Question: How can microwave imaging technology be used to ensure infrastructure is safe?

Microwave imaging enables nondestructive and usually noncontact evaluation and monitoring of different layers of infrastructure.

It can even provide information about optically invisible layers. For example, it can detect cracks that may be invisible to the eye or provide information about a crack's depth. If we can make a microwave imaging system more easily deployable and portable, it can be used in a range of applications, like examining building integrity and aiding restoration and repair projects.

Question: How can it be used in search and rescue operations?

Microwaves are reflected by the human body, but they go through most other optically opaque layers, such as buildings and fabric. That means a microwave imaging device can in principle locate a person by "looking through" walls or wreckage in disasters such as earthquakes, building collapses or fires. To bring these potentials to widespread use, we need to improve the speed and size of microwave imaging systems, as well as associated image processing techniques.

Question: How else could this imaging technology improve people's lives?

If we can speed up data acquisition, we can eliminate the need for the stop-and-go process used currently at airports. Microwave imaging can be used in crowded places like stadiums, train stations, schools, hospitals and more as a simple and fast security screening device. As passengers pass through a corridor, the microwave imaging system can detect suspicious objects. Keep in mind that microwave imaging can also see through backpacks and luggage. Fast and affordable microwave imaging may thus detect potential threats concealed in backpacks in crowded areas, without requiring everyone to take them off.

On a domestic basis, a fast and deployable microwave imaging system can be used in DIY projects, repairs, inspections or just for fun. When starting a DIY home improvement project, or doing an inspection of a house, one wants to know about the material behind walls, roofs or ceilings. For example, has the insulation settled down? Is there water leakage? Is there a pipe or wire behind the wall I am about to drill into? An affordable microwave camera can provide the answers to such problems.

One can also just use the microwave camera for fun applications, such as checking how your foot fits within a shoe or discovering the contents of your gifts before opening them.

Provided by Arizona State University