Tailored flexible illusion coatings hide objects from detection

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Developing the cloak of invisibility would be wonderful, but sometimes simply making an object appear to be something else will do the trick, according to Penn State electrical engineers.

"Previous attempts at cloaking using a single metasurface layer were restricted to very small-sized objects," said Zhi Hao Jiang, postdoctoral fellow in electrical engineering, Penn State. "Also, the act of cloaking would prevent an enclosed antenna or sensor from communicating with the outside world."

Jiang and Douglas H. Werner, John L. and Genevieve H. McCain Chair Professor of Electrical Engineering, developed a metamaterial coating with a negligible thickness that allows coated objects to function normally while appearing as something other than what they really are, or even completely disappearing. They report their research in *Advanced Functional Materials*.

The researchers employ what they call "illusion coatings," coatings made up of a thin flexible substrate with copper patterns designed to create the desired result. They can take a practical size metal antenna or sensor, coat it with the patterned film and when the device is probed by a radio frequency source, the scattering signature of the enclosed object will appear to be that of a prescribed dielectric material like silicon or Teflon. Conversely, with the proper pattern, they can coat a dielectric and it will scatter electromagnetic waves the same as if it were a metal object.

"The demonstrated illusion/cloaking coating is a lightweight two-dimensional metasurface, not a bulky three-dimensional metasurface," said Werner.

The researchers take the object they want cloaked and surround it with a spacer, either air or foam. They then apply the ultrathin layer of dielectric with copper patterning designed for the wavelengths they wish to cloak. In this way, antennae and sensors could be made invisible or deceptive to remote inspection.

Another application of this material would be to protect objects from other emitting objects nearby while still allowing electromagnetic communication between them. This was not possible with the conventional transformation optics-based cloaking method because the cloaking mechanism electromagnetically blocked the cloaked object from the outside, but this new coating allows the object surrounded to continue working while being protected. In an array of antennae, for example, interference from the nearby antennas can be suppressed.

The metasurface coating consists of a series of copper, geometric patterns placed on a flexible substrate using standard lithographic methods currently used to create printed circuit boards. Each illusion coating must be designed for the specific application, but the designs are optimized mathematically. This method of manufacture is low cost and well established.

Another advantage of this method is that it works not only for direct hits by radio frequency waves incident normally on the coated object, but also continues to operate properly within a 20 degree field of view, making it a better angle-tolerant shield than previous attempts that employed bulky metamaterials. Currently, the metasurface coatings only work on narrow bands of the spectrum for any application, but can be adapted to work in other bands of the electromagnetic spectrum

including the visible spectrum.

"We haven't tried expanding the bandwidth yet," said Werner. "But the theory suggests that it should be possible and it will probably require multiple layers with different patterns to do that."

Illusion coatings could be used for things other than hiding. They could enhance the way radio frequency ID tags work or could redistribute energy in different, controlled patterns making things more visible rather than less visible. The materials shielding ability can also be used to protect any type of equipment from stray or intentional electromagnetic interference.

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