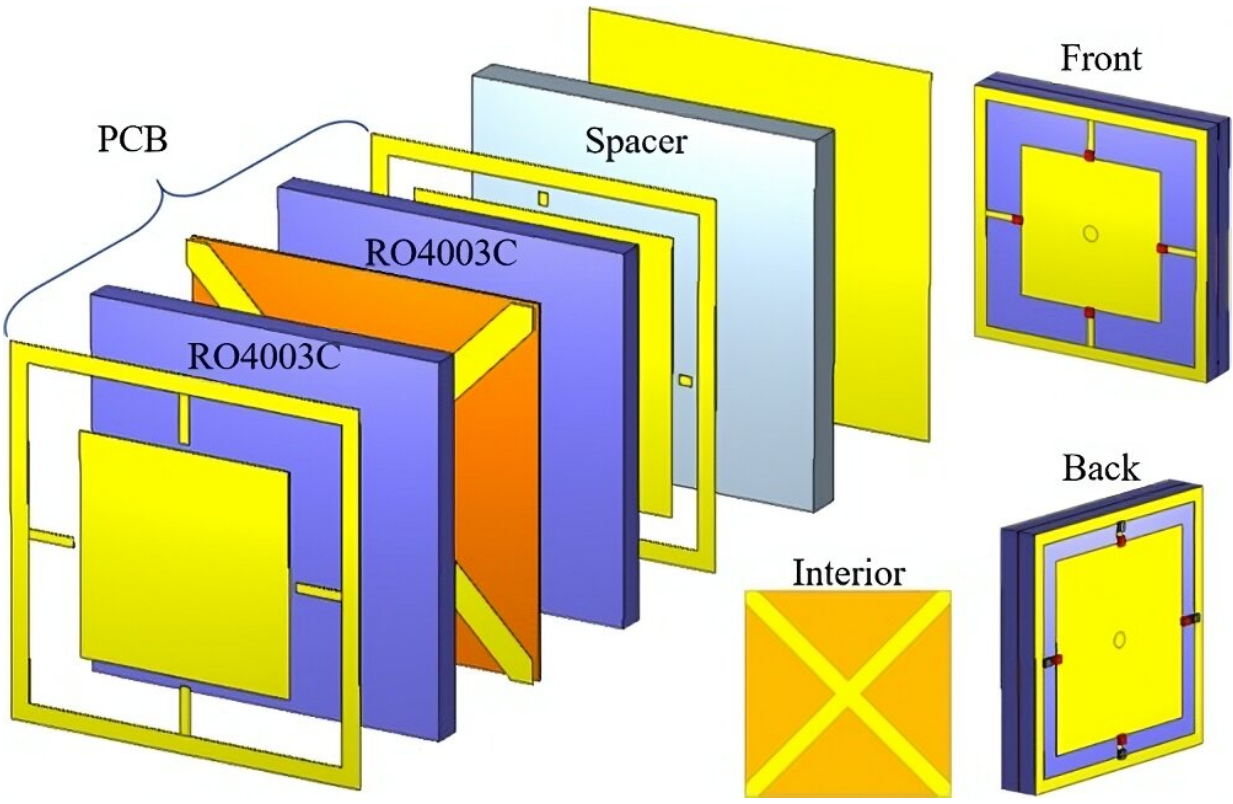


Breakthrough metasurface materials tech unleashes enhanced control for advanced telecommunications and beyond

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Dual-resonance unit cell with three copper layers on a printed circuit board and a backplane. The front and back of the unit cell are also shown, which, respectively, host a varactor and series varactor-resistor pair. Credit: *Physical Review Applied* (2023). DOI: 10.1103/PhysRevApplied.20.014004

Cities can be obstacle courses for communications signals. A radio signal must travel from a cell phone to a router to a cell tower, and onward to its recipient—all while bouncing between walls, buildings and other structures. When it hits an obstacle, the radio wave gets scattered, diminishing the signal. This in turn reduces the bandwidth. At the same time, the signal must compete with the bandwidth needs of numerous other devices in the area. All this reduces the amount of information the signal can communicate.

Newly developed small, lightweight [reflective surfaces](#) could revolutionize communications in crowded environments by providing unprecedented control over electromagnetic signals, like radio waves.

Historically, engineers have used repeaters—[electronic devices](#) that receive a signal and retransmit it—to help these communications signals cover longer distances and get around obstacles, but this technology is reaching its limits. Now, engineers are looking to modify the behavior of the communications signal itself. Enter reconfigurable intelligent surfaces (RIS).

RIS are programmable surface structures that can reflect, redirect and modulate [electromagnetic signals](#) to boost data rates and achieve other desirable behaviors. As this technology continues to develop at breakneck speeds, its promise has been lauded and anticipated—but its shortcomings have also been noticeable.

Researchers have long believed that metasurfaces—a type of material that uses patterning or microstructuring on a surface to influence the behavior of electromagnetic waves, like light and radio signals—would be the ideal technology to implement RIS. But efforts to date have been limited by undesirable characteristics of metasurfaces, including signal loss and the need to include a resonant material in the design.

But now, for the first time, technologists at the Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland, have developed a [metasurface](#) technology that resolves these challenges and augments the reflective behaviors of RIS. This clears the way for improved communications in crowded environments and promising advancements in telecommunications and [low-power](#) sensing applications. Their results have recently been published in the journal *Physical Review Applied*.

"This really shows promise for critical applications such as advanced communications, novel low power sensing and enabling operations in the most challenging environments," said Jeff Maranchi, who leads the research program area in APL's Research and Exploratory Development Department.

"The reconfigurable intelligent surfaces are another fantastic example of our team's ability to key in on the hardest technical challenges, design a new material, model and optimize the design using the latest sophisticated tools, build it, test it, and rapidly show strong potential."

Harnessing both magnitude and phase

Most metasurfaces change both the magnitude (or strength), and phase (or position in time), of an electromagnetic wave. But changing one usually changes the other.

"When you can separately control phase and magnitude, it gives you ultimate control over the reflection behaviors of the metasurface," said Tim Sleasman, a research scientist at APL and the lead author of the paper.

Controlling the magnitude and phase separately enables the metasurface to adapt the signal in many ways for situation-specific demands.

This capability has remained elusive until now.

The APL team closely studied the reflection behaviors of a two-layer metasurface, implementing a series of patch-like elements, control knobs, varactor diodes and resistors to exert more control over key parameters. Through this complex design, they created a dynamic cascaded metasurface that can separately control magnitude and phase, while fitting onto a small, cost-effective printed circuit board.

"As a signal passes through the metasurface, it interacts with each of the layers on the way in and as it's reflected out," Sleasman said. "These interactions are very complex. The layers essentially talk to one another and behave as though they know the others are there. As the signal passes through, each of the layers operates on it, creating the desired behavior."

The new material flattens the uneven signal loss that metasurfaces were previously known for, and includes two resonant materials to circumvent the shortcomings of using just one.

Not only does the resulting metasurface provide widely sought-after control over electromagnetic wave behavior, but it's incredibly small and lightweight. It could be possible to attach these printed circuit boards to surfaces around a city, for example, to boost the bandwidth of cell or Wi-Fi signals.

Reducing power requirements through reflection

Retransmitting a signal, as traditional repeaters do, requires a lot of power and a sophisticated piece of equipment like an antenna or even a phased array of multiple antennas, which takes up a significant amount of space.

The APL team's dynamic cascaded metasurfaces boost signals by reflecting them off their patterned surfaces instead. "You could run this technology off of a nine-volt battery or something like that," Sleasman said.

Other potential technology applications

The ability to control the magnitude and phase of electromagnetic waves independently has implications that extend far beyond telecommunications.

"While our focus has been on radio frequency applications, the concepts and techniques we have introduced hold value across a wide range of the electromagnetic spectrum," said David Shrekenhamer, who manages the Physics, Electronic Materials and Devices program at APL. "At higher frequencies, materials science like this effort becomes a crucial consideration."

Dynamic cascaded metasurfaces could also aid in creating smaller, more lightweight sensors that could collect and provide data while using very little power.

"You might have a sensor on a buoy in the ocean measuring salinity," said Sleasman. "You don't want to load this thing up with batteries and have it transmit actively. With one of these surfaces attached, you could fly over it with a helicopter and exfiltrate the data by pinging the metasurface, which would reflect the information back."

This capability could be useful in other operational scenarios when a constantly transmitting signal might prove undesirable, such as in a contested environment.

"We're very excited to see how much interest this technology has

generated, in both the commercial and government spaces," said Sleasman. "We plan to continue developing this concept for a wide array of applications."

More information: Timothy Sleasman et al, Dual-Resonance Dynamic Metasurface for Independent Magnitude and Phase Modulation, *Physical Review Applied* (2023). [DOI: 10.1103/PhysRevApplied.20.014004](https://doi.org/10.1103/PhysRevApplied.20.014004)

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