Wormholes on Earth?

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According to a group of mathematicians, it may be possible to create devices with internal tunnels that are invisible to detection by electromagnetic waves—wormholes, in a sense. The group discusses the idea in a paper published in the October 29 online edition of *Physical Review Letters*.

The scientists say that by custom designing the values of two parameters that describe electromagnetic (EM) materials, the electrical permittivity and magnetic permeability, around and inside a cylinder, a novel optical device could be produced. Essentially, most of the device would be invisible to detection by external EM radiation of a certain frequency, with only the ends of the cylinder being visible and accessible to the EM waves.

“The chosen values for the permittivity and permeability would cause the coating to manipulate EM waves in a way that is not seen in nature,” explained University of Rochester mathematician Allan Greenleaf, one of the paper's authors, to *PhysOrg.com*.

Permittivity is a measure of a material's readiness to become electrically polarized in response to an applied electric field (how well it “permits” the field). Permeability describes how magnetized a material becomes when a magnetic field is applied. Modern EM materials known as metamaterials allow theoretical designs, such as a wormhole, to be physically constructed, at least in principle.

Greenleaf and his colleagues, Yaroslav Kurylev of University College in

London, Matti Lassas of the Helsinki University of Technology, and Gunther Uhlmann of the University of Washington, use the word "wormhole" in more of a mathematical sense than physical. That is, the devices would act as wormholes from the viewpoint of Maxwell's equations, the four fundamental equations that describe the relationship between electric fields, magnetic fields, electric charge, and electric current.

For any other frequencies than those for which the permittivity and permeability were designed, the tunnel region would look roughly like a solid cylinder. But for the right frequencies, says Greenleaf, "the tunnel has the effect of changing the topology of space. The electromagnetic waves behave as though they are propagating through a space to which a handle has been attached, in the same way that ants crawling on the door of your refrigerator have two ways to get from one end of the handle to the other: by traveling over the handle or on the flat surface underneath."

That is, any object within the tunnel is only visible to EM waves that enter at one of the tunnel's ends. Conversely, any EM waves emitted by an object in the tunnel can only leave through one of the ends. However, Greenleaf says that it's important to note that the shape of space has not actually been changed, as does happen for Einstein-Rosen wormholes in general relativity.

This effect could have interesting applications. For example, a magnetic dipole (such as a bar magnet) placed near one of the ends would, at the other end, appear to approximate a magnetic monopole, a theoretical particle with only one magnetic pole, i.e. that has magnetic charge. True magnetic monopoles have never been discovered, and the work by Greenleaf and his colleagues does not claim otherwise.

The scientists propose other possible applications, such as in magnetic resonance imaging (MRI), where a wormhole device could be used to

allow doctors to operate on a patient while simultaneously imaging the patient. Doctors could insert metal surgical tools into the tunnel area without disturbing the MRI machine's magnetic field.

Another example is an optical computer, where active components could be placed inside wormholes such as to not interact with each other and cause malfunctions.

Metamaterials for invisibility, while still in the very early stages of development, are already being researched. Last year, scientists from Duke University created a device that renders a copper disc invisible to observation by microwaves.

Citation: Allan Greenleaf, Yaroslav Kurylev, Matti Lassas, and Gunther Uhlmann "Electromagnetic Wormholes and Virtual Magnetic Monopoles from Metamaterials" *Phys. Rev. Lett.* 99, 183901 (2007)