Techniques Of Electromagnetic Cloaking

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***Abstract*— How to conceal objects from electromagnetic radiation has been a hot research topic. Radar is an object detection system that uses Radio waves to determine the range , angle, or velocity. A radar transmit radio waves or microwaves that reflect from any object in their path. A receive radar is typically the same system as transmit radar, receives and processes these reflected wave to determine properties of object. Different organizations are working onto hide object from the radar in outer space. Any confidential object can be taken through space without being detected by the enemies. This calls for necessity of devising new method to conceal an object electromagnetically.**

I. INTRODUCTION

The first electromagnetic cloaking device was produced in 2006, using gradient-index metamaterials. This has led to the burgeoning field of transformation optics (and now transformation acoustics), where the propagation of waves is precisely manipulated by controlling the behavior of the material through which the light (sound) is travelling.

One of the ways to cloak an object by manipulating the electromagnetic waves around is to cover the object with an anisotropic and inhomogeneous object(called a cloak) that bends the incident wave which essentially hides the object concerned. This comes at a great cost though. The electrical and magnetic characteristics, such as permittivity and permeability, of such a cloak approach extremes. The preceding method belongs to a category known as transformation optics and one of the drawbacks of transformation optics is its vulnerability to pulses because no cloak till date has responded well to a pulse. This combined with the ideal electromagnetic parameters required for a cloak along with the electrical losses in the thick shells of the cloak makes use of such a material a non-viable option and thus a need to come up with something else.

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II. VARIOUS TECHNIQUES

Some of the various techniques being practiced worldwide are discussed below.

A. *Cloaking objects at a distance*

Different with traditional cloak which deflects light around the core of the cloak to make the object inside invisible, our cloak guides the light to penetrate the core of the cloak but without striking some region of the cloak shell - the so called folded region. The purpose of the proposed cloak is to disguise the true information of the object, e.g. the position, the size, etc, and further mislead the observer and avoid being detected. Different from the conventional cloak which excludes the light from the central region, this cloak squeezes the bulk of incident light into a narrow beam that penetrates the core but without touching some regions of the outer layer.

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The cloak can enhance the scattering from the obstacle so that it seems to be produced by a much larger scatterer, or move the scattered field as if the object is moved from its original position. Such kind of cloak can be implemented by isotropic negative index materials with the magnitude of the spatially varying refractive index larger than one everywhere. Under this condition, concealment can be achieved with artificially structured negative-index media (NIM) like phonic crystal or sub-wavelength dielectric resonator.

The total field distribution when a conductive sphere with radius 1.5 cm is located at point A in the folded region is shown in Fig. 2(b), while Fig .2(c) displays the case when a conductive sphere with radius 6 cm is placed at point B in free space. By comparison, we find that the field distributions in the two cases are identical, indicating that an observers outside will see a bigger scatterer (with a size magnification of 4 in this case) which has been shifted from its original position and could not find out its real position, therefore, the volume and position information of the object will be disguised to mislead the observer. In order to understand this phenomenon from physical perspective we consider the case when a plane wave is incident upon the spherical concealing device in the free space, as shown in Fig.2 (d) ,the wave has penetrated into the core, making some energy circulating in the folded region without introducing any scattering, which is because that the whole system will store energy from the incident wave before the steady state is reached Therefore, the scattering shift and magnification phenomena here are also formed in time harmonic state, which is similar to the imaging of perfect lens.

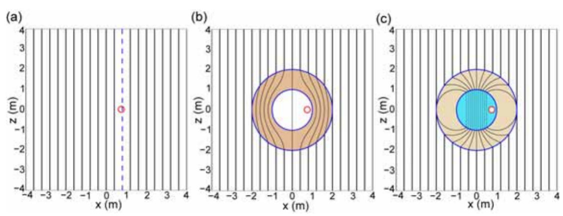

FIG 1:(a) Ray trajectories in the absence of the concealing device. The blue dashed line indicates that the scatterer can be detected by the incident ray. (b) The path of the rays when the scatterer is placed in an ideal transformation cloak proposed by J. Pendry. No lights can enter into the center of the shell. (c) The path of the rays when the scatterer is located at the hidden region of the coating. The lights have been smoothly bent around this region.

B. *Ordinary Spatial Cloaking*

Waves and the host material in which they propagate have a symbiotic relationship: both act on each other. A simple spatial cloak relies on fine tuning the properties of the propagation medium in order to direct the flow smoothly around an object, like water flowing past a rock in a stream, but without reflection, or without creating turbulence. Another analogy is that of a flow of cars passing a symmetrical traffic island - the cars are temporarily diverted, but can later reassemble themselves into a smooth flow that holds no information about whether the traffic island was small or large, or whether flowers or a large advertising billboard might have been planted on it.

Although both analogies given above have an implied direction (that of the water flow, or of the road orientation), cloaks are often designed so as to be isotropic, i.e. to work equally well for all orientations. However, they do not need to be so general, and might only work in two dimensions, as in the original electromagnetic demonstration, or only from one side, as for the so-called carpet cloak.

Spatial cloaks have other characteristics: whatever they contain can (in principle) be kept invisible forever, since an object inside the cloak may simply remain there. Signals emitted by the objects inside the cloak that are not absorbed can likewise be trapped forever by its internal structure. If a spatial cloak could be turned off and on again at will, the objects inside would then appear and disappear accordingly.

C. *Space-time cloaking (Event cloaking)*

The Event Cloak is a means of manipulating electromagnetic radiation in space and time in such a way that a certain collection of happenings, or events, is concealed from distant observers. Conceptually, a safecracker can enter a scene, steal the cash and exit, whilst a surveillance camera records the safe door locked and undisturbed all the time. The concept utilizes the science of metamaterials in which light can be made to behave in ways that are not found in naturally occurring materials.

The Event Cloak works by designing a medium in which different parts of the light illuminating a certain region can be either slowed down or sped up. A leading portion of the light is speeded up so that it arrives before the events occur, whilst a trailing part is slowed down and arrives too late. After their occurrence, the light is reformed by slowing down the leading part and speeding up the trailing part. The distant observer therefore only sees a continuous illumination, whilst the events that occurred during the dark period of the cloak's operation remain undetected.

The concept can be related to traffic flowing along a highway: at a certain point some cars are speeded up, whilst the ones behind are slowed down. The result is a temporary gap in the traffic allowing a pedestrian to cross. After this, the process can be reversed so that the traffic resumes its continuous flow without a gap. Regarding the cars as light particles (photons), the act of the pedestrian crossing the road is never suspected by the observer down the highway, who sees an uninterrupted and unperturbed flow of cars.

For absolute concealment, the events must be non-radiating. If they do emit light during their occurrence (e.g. by fluorescence), then this light is received by the distant observer as a single flash.

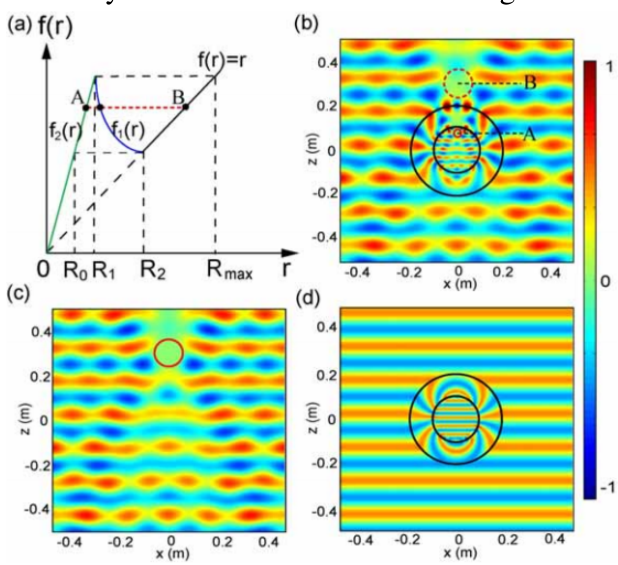

FIG 2: (a) Schematic figure of the functions f(r) which is non-monotonic. The inner media (0 ¡ r¡ R) is RHM, while the media in the coating (R1 2¡ r ¡ R) is LHM. The fold (R0 ¡ r ¡ R2) indicates the hidden region. (b) Field distribution of the same plane wave incident upon the coating when a conductive sphere with radius 1.5 cm is placed at the position A in the hidden region of coating. (c) Field distribution of this plane wave incident upon a conductive sphere with radius 6 cm placed at the position B in free space. (d) Field distribution of an Ex polarized plane wave incident upon the coating when there are no scatterers inside the coating.

Applications of the Event Cloak include the possibility to achieve 'interrupt-without-interrupt' in data channels that converge at a node. A primary calculation can be temporarily suspended to process priority information from another channel. Afterwards the suspended channel can be resumed in such a way as to appear as though it was never interrupted. The idea of the Event Cloak was first proposed theoretically by a team of researchers from Imperial College London (UK) in 2010, and published in the Journal of Optics. An experimental demonstration of the basic concept using nonlinear optical technology has been presented in a preprint on the Cornell physics arXiv. This uses time lenses to slow down and speed up the light, and thereby improves on the original proposal from McCall which instead relied on the nonlinear refractive index of optical fibres. The experiment claims a cloaked time interval of about 10 picoseconds, but that extension into the nanosecond and microsecond regimes should be possible.

D. *Plasmonic cover*

The plasmonic cover, mentioned alongside metamaterial covers (see plasmonic metamaterials), theoretically utilizes plasmonic resonance effects to reduce the total scattering cross section of spherical and cylindrical objects. These are lossless metamaterial covers near their plasma resonance which could possibly induce a dramatic drop in the scattering cross section, making these objects nearly invisible or transparent to an outside observer. Low loss, even no-loss, passive covers might be utilized that do not require high dissipation, but rely on a completely different mechanism.

Materials with either negative or low value constitutive parameters, are required for this effect. Certain metals near their plasma frequency, or metamaterials with negative parameters could fill this need. For example, several noble metals achieve this requirement because of their electrical permittivity at the infra-red or visible wavelengths with relatively low loss.

Currently only microscopically small objects could possibly appear transparent. These materials are further described as a homogeneous, isotropic, metamaterial covers near plasma frequency dramatically reducing the fields scattered by a given object. Furthermore, These do not require any absorptive process, any anisotropy or inhomogeneity, and nor any interference cancellation.

The "classical theory" of metamaterial covers works with light of only one specific frequency. A new research, of Kort-Kamp et al, who won the prize School on Nonlinear Optics and Nanophotonics of 2013, shows that is possible to tune the metamaterial to different light frequencies.

E. Tunneling light transmission cloak

As implied in the nomenclature, this is a type of light transmission. Transmission of light (EM radiation) through an object such as metallic film occurs with an assist of tunnelling between resonating inclusions. This effect can be created by embedding a periodic configuration of dielectrics in a metal, for example.

By creating and observing transmission peaks interactions between the dielectrics and interference effects cause mixing and splitting of resonances. With an effective permittivity close to unity, the results can be used to propose a method for turning the resulting materials invisible.

III. Conclusion

In 2007 cloaking with metamaterials is reviewed and deficienies are presented. At the same time, theoretical solutions are presented that could improve the capability to cloak objects.Later in 2007, a mathematical improvement in the cylindrical shielding to produce an electromagnetic "wormhole", is analyzed in three dimensions.Electromagnetic wormholes, as an optical device (not gravitational) are derived from cloaking theories has potential applications for advancing some current technology.

Other advances may be realized with an acoustic superlens. In addition, acoustic metamaterials have realized negative refraction for sound waves. Possible advances could be enhanced ultrasound scans, sharpening sonic medical scans, seismic maps with more detail, and buildings no longer susceptible to earthquakes. Underground imaging may be improved with finer details. The acoustic superlens, acousitc cloaking, and acoustic metamaterials translates into novel applications for focusing, or steering, sonic waves.

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