PhD position @ ISAE-SUPAERO

Microwave Invisibility Using Plasma Discharge

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Summary: The ability to make an object stealthy, or even invisible, is a crucial issue for today's defense systems. From a practical point of view, this consists in significantly reducing its electromagnetic, thermal, and acoustic signature, and thus preventing its detection and identification by ground or on-board systems. In the field of microwaves, we seek mainly to hide different objects (planes, missiles, ...), or parts of objects, to radar systems. These systems can be mono- or multi-static. To improve the stealth, we modify the shape of the object to distribute the diffracted energy [1]. By using absorbing materials or coatings, it is also possible to act effectively on the reflected power by reducing it [2]. However, if these techniques can improve the stealth of an object, they do not lead to its almost total invisibility.

Recently, research in the field of metamaterials has allowed the development of original solutions leading to the invisibility of canonical objects (cylinders, spheres, ...) [3-7]. Some metamaterials have indeed exotic properties such as a negative dielectric permittivity and magnetic permeability, and therefore a refractive index potentially negative too. By combining these properties and transformation optics, it has been shown by Pendry et al. that we can make an object totally invisible in the microwave field [3,4]. In this particular case, a strongly anisotropic and inhomogeneous metamaterial is created in order to distort the space, usually isotropic. Invisibility is thus obtained by bending the incident electromagnetic wave and completely isolating the object.

Another approach, simpler to implement, has been proposed by Alù et al. in 2005 [5]. The Scattering Cancellation Technique (SCT) consists in combining the initial object (a dielectric sphere in [5]) with a material producing a dipole moment of the same intensity but of opposite sign. The plasmonic cloack, resulting from the bilayer structure, thus cancels the diffracted far-field. Contrary to the Pendry et al. approach, the material needed for cloacking remains isotropic and homogeneous with only a low positive or negative dielectric permittivity, which greatly facilitates its implementation. Experimental verification of the potentialities of this method has mainly been carried out using metamaterials in the microwave field [6,7].

In the proposed work, we are interested in substituting the metamaterial by an ionized gas, also known as plasma, to obtain invisibility. Indeed, plasma inherently has a dielectric permittivity weakly positive, or negative, in the range of microwaves. The main objective of this thesis is to take advantage of the dielectric properties of the plasma to make invisible objects at microwave frequencies.

Recently, innovative work has been undertaken in the field of plasma / microwave interactions. They were conducted in the framework of a partnership between GRE (Groupe de Recherche en Electromagnétisme) and GREPHE (Groupe de Recherche Energétique, Plasma, Hors Equilibre) groups of LAPLACE (LAboratoire PLAsma et Conversion d'Energie) and DEOS (Département Electronique Optronique Signal) of the ISAE (Institut Supérieur de l'Aéronautique et de l'Espace). The obtained results suggest the possibility of experimentally demonstrating the contribution of plasmas for the invisibility at microwave frequencies.

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