Superabsorbers and Invisible Sensors

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The optimal properties of receiving antennas and sensors have been the subject of extensive debate for many years and there has been recent renewed interest in several fundamental questions on the constraints on absorbed and scattered power of an arbitrary receiving antenna. In general, an antenna designed to receive power in an efficient way is expected to produce large scattering, significantly perturbing the signal under measurement. Bach Andersen and Frandsen [J. Bach Andersen, A. Frandsen, *IEEE Trans. Antennas Propagat.* 53, 2843 (2005)] theoretically showed that there is in principle no limit to the ratio between scattered and absorbed powers, yet a methodology to design a minimum-scattering receiver with specific absorption ratio does not exist.

In recent years, there has been a substantial interest in devising methods to realize 'invisible' receivers/sensors. In principle the objective is to achieve a reasonable amount of absorption while maintaining the scattering as low as possible. Alù and Engheta [A. Alù, N. Engheta, *Phys. Rev. Lett.* 102, 233901 (2009)] proposed the application of plasmonic cloaks to absorbing particles, recently followed by an experimental verification by Fan *et al.* on a photodetector [P. Fan et al., *Nature Photonics* 6, 380 (2012)]. This phenomenon, based on scattering cancelation, requires to tune the antenna (absorber) load to align high absorption and low scattering at the same frequency. Although providing a handy solution for cloaking sensors, the technique is well applicable only to subwavelength structures and suffers of inherent limitations on the maximum achievable power. Recent efforts have been devoted to design optimal Huygens receivers that maximize the received power and are at the same time invisible in the backscattering direction (detectable from all other angles), as well as Green's matched antennas that decreases the scattering at the expense of reducing the absorbed power.

In this talk, we provide comprehensive theoretical limits on the ratio between absorbed and scattered powers in arbitrarily shaped receiving antennas and sensors of most general form, as well as a roadmap to design invisible sensors with strong absorption properties. We will discuss how strongly a sensor can interact with the electromagnetic wave without significantly perturbing it. Using the general Mie solution, we demonstrate that in principle there is no upper limit neither on the amount of absorption nor on the ratio between absorbed and scattered powers. Our studies interestingly indicate that the only parameter that may limit the efficiency of an absorber is its size, and we show that balanced non-resonant scattering modes are required to access the maximum attainable efficiency for a fixed amount of absorption and size of sensor. We show how plasmonic cloaking can be used specifically at small size limits to achieve the theoretical boundaries presented. Unlike previous studies on low-scattering absorbers, our theory also indicates a simple roadmap to design minimum-scattering sensors. To illustrate the application of our theory, we present the design of an optical sub-wavelength absorber with transverse cross-section smaller than $0.3\lambda_0$, an absorbed power equal to the one of a resonant dipole antenna, and a total scattering cross-section reduced by 8 folds. Our theory is applicable to broad frequency ranges from microwaves to the optical regime, of interest for many exciting applications from biomedical engineering and imaging to security and radar technology.