Breaking the Diffraction Limit in Wave Physics

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Recently, there has been a renewed research interest on breaking the diffraction limit in wave physics. The diffraction limit (or Rayleigh criterion) describes that we cannot inscribe a feature or see a feature smaller than half-wavelength of the exposing wave. In this talk, we will review and discuss two different experimental verifications to overcome the diffraction limit reported previously in two different regimes. In the acoustics regime, sub-wavelength focusing has been achieved using a time-reversal mirror and an acoustics sink (J. de Rosny and M. Fink, Physcial Review Letters, vol. 89, no. 12, pp. 124301-1 – 124301-4, 2002). In the above paper, the investigators presented an experiment where an ultrasonic source is time reversed and a focal spot size is achieved much less than the diffraction limit. The investigators brought up the possibility of focusing towards a sub-wavelength spot underlines the issue of the time reversal of a field containing evanescent waves. In the electromagnetics regime, we have experimentally demonstrated super-resolution imaging in nonlinear inverse scattering (F.-C. Chen and W. C. Chew, Applied Physics Letters, vol. 72, no. 23, pp. 1284-1287, 1998). The inverse scattering imaging experimental setup was based on a time-domain ultra-wideband microwave imaging radar system. The experimental data were processed with the distorted Born iterative method (DBIM), and showed that it could resolve features smaller than the half-wavelength dictated by the Rayleigh criterion for limited angle tomography. We have attributed the phenomenon to the multiple scattering effect within an inhomogeneous body. The high spatial frequency (high resolution) information of the object is usually contained in the evanescent waves when only single-scattering physics is considered. Multiple scattering converts evanescent waves into propagating waves and vice versa. Hence, in an inverse scattering experiment, even though an object has to be interrogated with a propagating wave, and that only scattered waves corresponding to propagating waves can be measured, the scattered waves contains high resolution information about the scatterer because of the evanescent-propagating waves conversion. Therefore, an inverse scattering method that can unravel the multiple scattering information can extract the high-resolution information on a scatterer. Note that DBIM can be regarded as an extended form of a time-reversal mirror. In this talk, we will re-examine the physics behind the nonlinear inverse scattering approach to achieve the super-resolution imaging.