Statistical Electromagnetic Theories and Applications: A review of recent advances

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Statistical Electromagnetic Theories have been developed over many years and applied to a wide range of practical problems in remote sensing of geophysical media, biological media, medical optics, ultrasound imaging and object detection and communication in clutter. This paper gives a review of recent developments in applications of statistical wave theories. The super resolution of images occurs in random media due to the multiple scattering and the increase of apparent aperture size of the transmitter. Another interesting effect is that the scattered wave from multiple scattering remembers the direction of the incident wave and strong correlations can be observed under certain conditions. This is called the "Memory Effect". Recent study shows that under certain conditions, the angular and frequency correlations of the scattered wave can be enhanced or reduced and this effect can be used to reduce the clutter from the rough surface. It is also noted that the coherence in multiple scattering causes the increase of radar cross sections in turbulence due to the interference between the forward and backward waves, called the "double passage effect". This is related to the Anderson localization and the coherent backscattering.

It is possible to make use of 'Transformation Electromagnetics' to transform wave propagation in 'free space over the rough surface' to the 'random medium over the flat surface'. This is used for low grazing angle (LGA) scattering, which is important in imaging objects located close to the rough surface such as the ocean when the transmitter is also close to the surface, because the incident wave and the rough surface interfere and affect the image resolution. Communication problems are often handled by using certain statistical assumptions. It is possible, however, that we can make use of our knowledge of the mutual coherence function based on the random media model including the medium characteristics such as turbulence and scattering characteristic of the particles, rather than assumptions. Thus, wave propagation and signal processing can be integrated. It is also possible that Time Reversal imaging can include the mutual coherence function to obtain imaging through the use of random medium characteristics. This includes time reversal MUSIC, modified beam former and SAR used for imaging in a random medium. Imaging of tissues can include the use of photon density waves and tissue ultrasound.

Fundamental questions of radiative transfer in relation to power conservation and reciprocity need to be examined to show the limitations of radiative transfer theory. It should be noted that some effects indicated above are outside the radiative transfer theory, requiring new formulations. The Statistical Electromagnetic Theories are among the most challenging theoretical as well as practical problems and continue to challenge theoreticians as well as engineers.