STATISTICAL ELECTROMAGNETIC PROPAGATION AND SCATTERING IN RANDOM MEDIA AND ROUGH SURFACES

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During the past century, major advances have been made in statistical electromagnetic theory and applications in imaging and remote sensing of objects in geophysical and biological media, medical optics, ultrasound imaging, object detection, characterization of composite materials, and wireless communications. This paper discusses several areas of research starting with historical highlights and covering some of the most recent developments.

Troposcatter and ionospheric turbulence scattering have been studied for many decades. In astrophysics, considerable research has been conducted on the effects of interstellar turbulence on radio, microwave and optical observations including broadening of pulsar pulses. The earth's atmospheric effects on optical scintillations and the coherence length are key elements in adaptive optics. The ionospheric effects on SAR, particularly at low microwave frequencies, are significant for FOPEN applications. The enhanced RCS due to turbulence is an unexpected multiple scattering effect. Similar studies on the wave fluctuations have been conducted for seismic coda waves.

In the atmosphere and geophysical media, multiple scattering effects are important in microwave and millimeter wave propagation in rain and snow, and the optical propagation in fog is highly diffused, particularly at blue-green wavelengths. In biological media, tissue optics and ultrasound are important tools for imaging and detecting inhomogeneities. Transport theory or radiative transfer theory has been extensively used to determine propagation and scattering in geophysical media, vegetation and snow, and the diffusion theory and photon density waves have been used extensively in tissue optics. The recent discovery of coherent backscattering has been recognized as the weak Anderson localization and created considerable excitement. Further studies of multiple scattering, such as the memory

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effect, are expected in object detection and imaging and in wireless technology.

Rough surface scattering research dates back to the early Rayleigh-Rice studies, and the conventional perturbation and Kirchhoff theories have been known for many years. However, recent interest in LGA (low grazing angle) scattering has spurred intensive studies on various new numerical techniques. In addition, new studies have been reported on the Sommerfeld dipole problem for rough surfaces, enhanced backscattering by high-slope surfaces, imaging and detection of objects close to the rough surface, stochastic Green's functions, and passive remote sensing.

For the past century, great progress has been made in understanding multiple scattering phenomena in random media and rough surfaces, and applications to many practical problems include object detection in clutter environment, imaging, communications, radar and lidar, SAR, biological imaging, and wireless propagation. Also, the multiple scattering studies for random media are one of the most challenging theoretical problems today and have benefited greatly from many studies in quantum electrodynamics and astrophysics including Feynman diagrams, Wigner distributions, Anderson localization, and Dyson and Bethe-Salpeter equations. Thus the field of waves in random media continues to challenge theoreticians and mathematicians as well as engineers in the new millennium.