SHORT WAVE ASYMPTOTIC EXPANSIONS OF THE RYTOV APPROXIMATION

Ilyushin Yaroslaw and Kunitsyn V.E.
Moscow State University, Leninskie gory, Moscow, Russia, Russian Federation

Abstract:

Approximate techniques for solution of wave scattering problems play an important role in many practical applications, such as ionospheric tomography [1,2], remote sensing, non-destructive testing, medical diagnostics etc. Among all the objects being tested, the so-called smooth scattering media are widely represented in practice and therefore are of special interest. For the objects, large in comparison to the wavelength, various shortwave asymptotic techniques are widely used. Those include but not limited to such techniques as geometrical optics (GO), GO perturbation theory [3,4], Rytov approximation [3], some special techniques of quantum mechanics [5] and so on. Most of these methods commonly treat the scalar wave problems; however, they can be generalized to vector wave field formulation. On the other hand, many practically important vector wave scattering problems may be reduced to the scalar ones [1].In particular, Rytov approximate technique suggests the representation of complex field phase in the form of expansion into power series in some formal parameter, characterizing smoothness of the scattering object. Individual coefficients of this series obey the system of coupled equations. The solutions of these equations are expressed in terms of rapidly oscillating integrals. Making use of the known asymptotic techniques (stationary-phase approximation, the steepest descent method etc.), one can obtain the short wave asymptotic solutions of the wave scattering problem. In particular, leading asymptotics of the Rytov approximation is a well known \"phase-screen\" approximation, which is widely used in applied calculation. A huge number of practical results, obtained within this approximation, confirms its reliability. However, higher order asymptotics of this approximation are not so thoroughly studied. In particular, there is still not any evidence of convergence the formal series lying at the base of Rytov approximation. A formal algorithmic procedure for calculation of higher order asymptotic expansions has been proposed in [1]. Several first short wave asymptotic terms of Born and Rytov series are also calculated there for the particular case of plane sounding wave. In the present work, we obtain higher order asymptotic approximations of these series by the algorithm [1] for plane and spherical sounding wave and analyze them. The numerical tests of the obtained solutions on the wide class of model scatterers has been performed. The model scatterers were the spherically- symmetric potentials, for which the exact solutions may be obtained by means of the partial wave technique [2]. The characteristic parameters of model scatterers (the density and typical spatial scale) have been widely varied. In particular, a number of practically important cases, e.g. propagation of meter waves

through kilometer-scale ionospheric irregularities [1,2] have been thus considered. As a result of the investigation, the following conclusions may be formulated: the 1st short wave approximation of Rytov technique (the phase-screen approximation) is the most reliable and applicable. The higher order asymptotics do not make notable contribution to the solutions, except of very small and intensive scattering potentials. In these cases, when their contribution is significant, many asymptotic terms should be taken into account to get the correct results. It may mean that the diffractional and other effects, neglected in the phase- screen approximation, are not satisfactory described by a limited number of higher-order terms of short wave asymptotic series of Rytov solution. In fact, many those terms (or even infinite number, i.e. some subsequence of the series) may be required to describe these effects correctly and accurate enough.

[1] Kunitsyn V.E. Tereshchenko E.D. Ionospheric Tomography, Springer-Verlag, 2003.

[2] Ya.A. Ilyushin, V.E.Kunitsyn Reconstruction of projections of strongly scattering irregularities in ionosphere. Phystech Journal, 1996 V.2 N.3, P.61-69.

[3] Rytov S.M., Kravtsov Yu.A., Tatarskii V.I. Principles of Statistical Radiophysics Vol. 1, 2. Berlin: Springer-Verlag, 1987.

[4] Kravtsov Yu.A. Geometrical Optics of Inhomogeneous Media. Berlin, New York: Springer-Verlag, 1989.

[5] Schwinger J. On Gauge Invariance and Vacuum Polarization. Phys. Rev. 1951 V.82 P.664-679.