Extended Unitarity for S-matrix and Electromagnetic Radiation Transfer in Dielectric Random Media with Effects of Near Fields and Opposite Wave Streams' Interference

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The phenomenological radiative transfer theory is derived from the theory of wave multiple scattering in random media at neglecting the repeated scattering of a monochromatic wave by just the same inhomogeneity— so-called single-group approximation, together with the far-field approximation for fields scattered by inhomogeneities [1]. The best-known effect of the multi-group scattering events is the coherent backscattering enhancement (weak localization) caused by the contribution of so-called cyclical (maximally crossed) diagrams [2]. This effect gives a correction to the transfer equation for backward scattering cone, with cone width being of the order of the wavelength over the extinction length [3]. Despite the achivements of the weak localization theory, there is a problem to conform the contribution of the maximally crossed diagrams into multiple scattering of waves to the energy conservation law.

In this report we present an original and perhaps unexpected resolution to the stated problem using a physical idea that the weak localization phenomenon should be coupled with the evanescent waves in a random medium. Technically our approach is based on the modern development of the wave multiple scattering theory in terms of Sommerfeld-Weyl angular-spectrum decomposition of wave amplitudes, transfer relations [4], extended unitarity for 2×2 block S-scattering matrix and effect of energy emission from an evanescent wave [5]. In result we derive a transfer equation for 2×2 block coherence matrix of angular-spectrum amplitudes of waves inside a 3D random medium slab. The diagonal blocks of the coherence matrix describe the autocoherence peculiarities of waves going forward or backward with respect to an embedding parameter into the medium slab but the off-dioganal blocks present the cross-coherence of the opposite going waves. The derived transfer equation possesses a specific energy invariant (pseudo-trace of the coherence matrix), in respect of the embedding parameter, that conforms its solution to the energy coservation law, the energy transformation between propagating and evanescent waves being taken into account. We evaluate with the aid of this transfer equation a relative contribution of evanescent waves into the coherent backscattering of waves; the influence of evanescent waves on coherent backscattering cone width and on reducing of the random medium depth where the coherent backscattering is actually formed; a specific dependence of the evanescent waves' effect on the shape of a random medium inhomogeneity.

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