Effective Medium Theory for Finite Size Aggregates

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We propose an effective medium theory for random aggregates of small spherical particles which accounts for the finite size of the embedding volume. The technique is based on the identification of the successive orders of the Born series within a finite volume for the coherent field and the effective field. Although the convergence of the Born series requires a finite volume, the effective constants which are derived through this identification are shown to admit a large scale limit. With this approach we recover successively, and in a simple manner, some classical homogenization formulas: the Maxwell- Garnett (MG) mixing rule, the Effective Field Approximation, and a correction to the Quasi-crystalline Approximation (QCA) which takes into account the finiteness of the medium. The last formula will be referred to as Finite-Size Quasi-crystalline Approximation (FS-QCA). In the light of this approach, we re-examine the validity of the MG mixing rule. We show that in certain configurations MG can be accurate even at high density of scatterers or in presence of strong multiple scattering, and we give numerical evidence for this. We then discuss QCA and FS-QCA and their relationship to MG. We show that FS-QCA coincides with the usual low-frequency QCA in the limit of large volumes, while bringing substantial improvements when the dimension of the embedding medium is of the order of the probing wavelength. An application to composite spheres is proposed.