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A forward scattering sum rule of periodic metamaterials is investigated. The sum rule relates the total extincted power over a bandwidth to the static polarizability of a scatterer. This shows that the all spectrum interaction between the electromagnetic field and an object is bounded by the sum of the electric and magnetic polarizability,γ. The sum rule was first introduced for dielectric spheroids by Purcell [1] and it was generalized to arbitrary objects in [2, 3].

The forward scattering sum rule, $\frac{1}{\pi^2}\int_0^\infty \sigma_{\text{ext}}(\lambda)\,\mathrm{d}\lambda = \gamma$, where σ_{ext} denotes the extinction cross section and λ the wavelength in free space, is derived using the optical theorem. This version of optical theorem is used to show that $\sigma_{\text{ext}} = \operatorname{Im} h(k)$, where k is the wavenumber in free space, $h(k) = \mathrm{i}2(1 - T(k))A$ is a Herglotz function [4], A denotes the cross section area of the unit cell and T the co-polarized part of the lowest order transmission coefficient. Using the analytic properties of Herglotz function, the low-frequency asymptotic expansion of $h(k)$ is used to derive the forward scattering sum rule for an arbitrary periodic structure [4, 5].

A parallel plate waveguide measurement setup is used to verify the forward scattering sum rule for a set of Split Ring Resonators (SRR). Two TEM horn antennas are placed inside the parallel plate waveguide as to be the transmitter and the receiver. They operate over the frequency range $[1 - 20]\,\mathrm{GHz}$ and generate a plane wave front at a close distance from the antennas. The measurement results are in good agreement with simulations and confirm the sum rule.

References

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