Fano type resonance in Wood anomalies

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Abstract

Resonant scattering from periodic gratings has been the subject of extensive investigations [1]. The scattering coefficients of any periodic grating are characterized by resonant features, the most remarkable being the manifestations of so-called Wood's anomalies [2,3]. In recent papers [4,5], studies of the polarization properties in spectral transmittance of a nanohole array grating have been reported. The observations have been interpreted in terms of Fano-type resonnances resulting from the coexistence of the two Wood's anomalies (in [4], the Fano shape is interpretd in terms of the coherent interference between a discrete and a continuum of states). We present a study based on modal analysis to quantitatively predict the transmission spectrum of an array, accounting for the polarisation (p- or s- polarisations) and on the grating material. It is shown that the equivalent admittance of the grating can be determined in the weak scattering approximation, by integration of a Riccatti type equation governing this admittance. Then, following Oliner and Hessel [3], we propose analytical expressions of the reflexion coefficients for each interference order (of each mode in terms of modal analysis), that account for the shape and for the composition of the grating. Comparison with direct numerical calculations reveals the accuracy of our prediction (Fig. 1). It is shown that the occurence of Fano shape in the reflectance only occurs under certain circumstances, (for s-polarized wave, see Fig. 1, and corresponding electric field on Fig. 2, 3). This is due to the fact that the first Wood anomaly (often referred as the Rayleigh Wood anomaly) always occurs at the cut off frequencies producing the extinction of all the propagative modes while the second -resonant- Wood anomaly does not happen for all gratings (essentially, this is dependent on the wave polarization and on the grating material).

References

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Figures

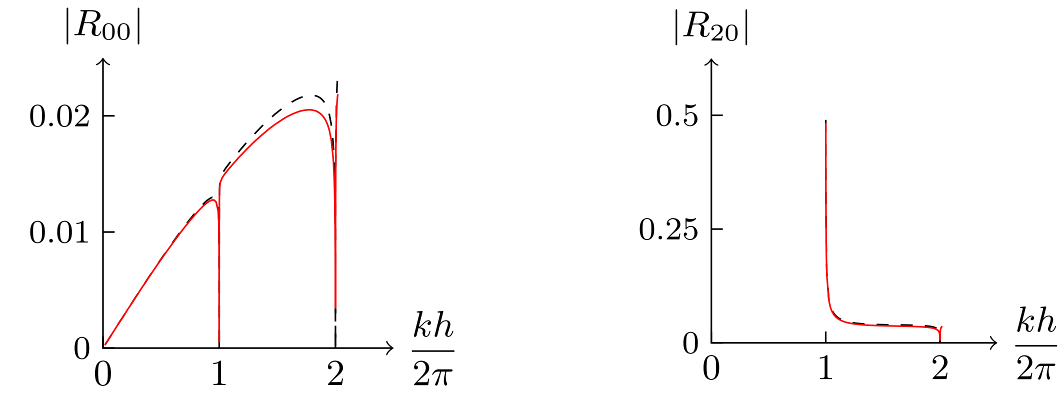

Fig. 1: Example of reflectance of the mode 0 and mode 2 of a grating with subwavelenght hole arrays as a function of the frequency of the incident (plane) wave, case of s-polarized (non magnetic grating material with permittivity e_0 smaller than the host medium, e_0/e=0.5). h denotes the grating period.
Plain red lines: full wave calculations, dotted black lines: analytical prediction.

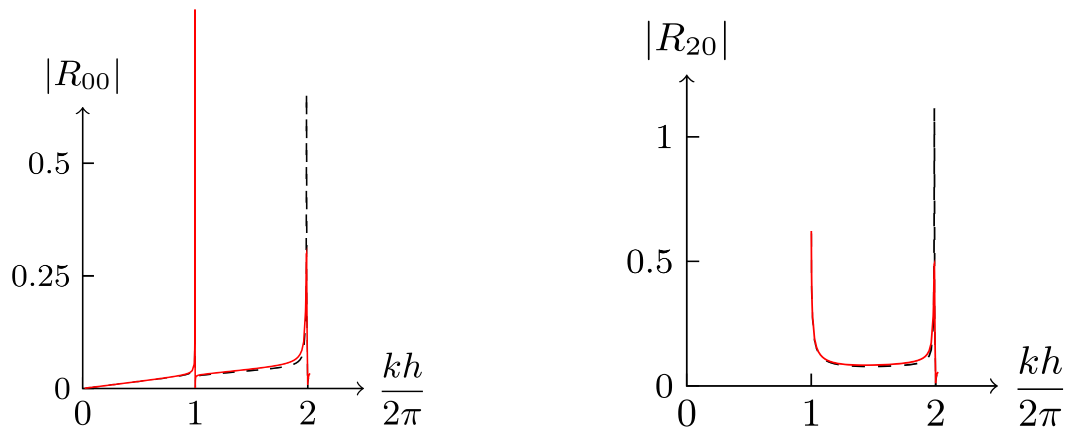

Fig. 2: Same representation for a grating material having a permittivity e_0 higher than the host medium (e_0/e=2).

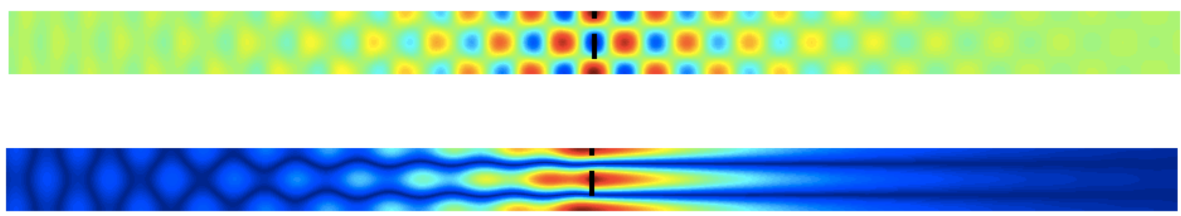

Fig. 3: Spatial distribution of the E-field at frequency k=0.998 2p (in norm), just bellow the first cut off (represented on a unit vertical cell). Dotted line indicate the position of the grating.
Top: in the case of Fig. 1. The scattered field is composed of evanescent modes. The transmission is perfect.
Bottom: in the case of Fig. 2. The scattered near field is composed of the grazing mode. The reflexion is perfect.

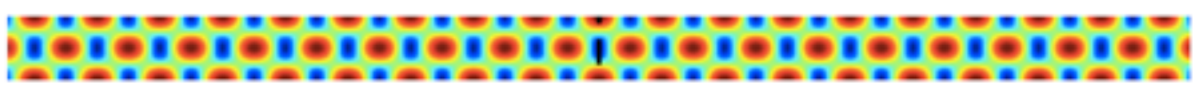

Fig. 4: Spatial distribution of the E-field at frequency k=1.0001 2p (in norm), just above the first cut off (represented on a unit vertical cell). The scattered field is composed of the grazing mode only, propagative at that frequency. The pattern is the same in the cases of Figs. 1 and 2.