Resonances of Closed Modes in Thin Arrays of Complex Particles

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Abstract

Controlling the reflection and/or the transmission properties of surfaces is an important problem of applied electromagnetics. For various microwave applications, there is a need to use active material layers with thicknesses extremely small in comparison to the wavelength. The introduction of resonant particles could be an interesting solution to this problem. A material layer with high quality factor and a thickness very small in comparison to the wavelength appear to be two contradictory requirements. Actually, very thin open structures can not have inner resonant volumes, furthermore the resonant inclusions are strongly coupled with free space. Consequently their resonance quality factors are low. Nevertheless there are still opportunities to produce thin structures with high quality frequency resonances by optimizing the field excitation and reducing the coupling between resonant inclusions and free space. These opportunities are provided by the resonance regime of the so-called *closed modes*.

As an example of very thin structure with *large resonance volume*, let us consider one-periodic planar grating of very thin narrow metal strips. Strips are placed in the grating so that their planes are rectangular to the grating plane. Strip width is much smaller than the wavelength. If a normal incident plane wave is polarized orthogonal to the strips, the reflection coefficient is null for all frequencies. Let us now incline strip planes with regard to the grating plane. There is now an interaction between the incident wave and the grating. If the wavelength is close to the grating period but a little smaller, a sharp resonance of full reflection occurs. The reason of this resonant reflection is the appearance of a standing wave along the grating plane. The field of standing wave occupy a large volume and it is weakly coupled with the field of incident wave. If the strip width decreases, the quality factor of the resonance rises.

Very sharp resonances in the reflection from infinitely thin doubly-periodic *multi-element* FSS can appear due to the resonant properties of strip particles of the periodic cell. The existence of *Multi-particles* in the array's cell is essential to the existence of high quality resonance of closed modes. For example, let us consider a doubly-periodic two-element array. Each cell of the array contains two C-shaped strip particles placed opposite one to other as one can see on the symbol $\subset\!\!\supset$. C-shaped elements are placed in the cell in a non-symmetric way, so that the left split between them is a little different from the right split. If a normal incident wave is polarized in the direction of the arrow $\uparrow$ $\subset\!\!\supset$, a sharp resonance reflection appears. It is the resonance of a closed mode because equal and opposite directed currents on the two elements of the complex particle radiate little in free space.