

# The Optical Response of Rectangular Metallic Gratings and Metal/Dielectric Multilayers

*Submitted by*

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# Abstract

**T**HE ABILITY OF periodic surface variations to influence and control the electromagnetic response of interfaces and structures has been recognised for many years. Concurrently with these investigations, it has been found that individual particles and wires support interesting electromagnetic resonances. It has also long been established that multi-layer structures of planar interfaces may also result in interesting electromagnetic responses. Multi-layer structures of alternating dielectrics have been shown to produce periodic transmission resonances, however, if one of the dielectrics is replaced with a thin metallic film, it has recently been demonstrated that wide band-pass regions are formed in the electromagnetic response of the structure.

The work presented in this thesis can be considered to be separated into two distinct, but related, areas. One of the areas involves the analysis of wire grid arrays. It is demonstrated that, like the case of deep surface relief perturbations, the waveguide modes in the slits can be considered as the evolution of surface modes on shallow surface relief perturbations. The perturbation effects of the slits on the surface modes and the effect of their excitation on optically thick and thin wires are also investigated. Finally, a new electromagnetic resonance is presented on both 1-dimensional and 2-dimensional wire grid arrays. It is shown that this is closely related to the localised surface modes that have been shown to occur on individual particles and wires. However, the resonance presented is shown to be subtly different from these modes, which typically result in a transmission and reflection extinction, because the planar geometry of the wires and the periodicity result in a reflection enhancement, even when the wires are optically thin.

The second area of this work may be separated into two distinct sub-sections.

The first section examines the electromagnetic response of dielectric/metal multi-layer stacks. These are confirmed to exhibit a periodic series of broad band-pass regions, with the spectral location of these regions being dependent only on the unit cell, not the full extent of the structures. The location of each band-edge of these regions are then demonstrated to be a result of the matching of boundary conditions between standing waves in the cavities having either a *cos* or a *sin* standing wave function, and the evanescent fields inside the metal layers having either a *sinh* or a *cosh* field distribution.

The second section examines the electromagnetic response of continuous surface relief gratings, with a rectangular cross-section, whose ridges are very thin. It is shown that vertical standing waves form, similar to the cavity waveguide modes, except with the fields coupled through the wires not across the grooves. These are then shown to reach a finite limit frequency as the grating height tends to infinity. Thus, the resonances have evolved into a different mode beyond a certain grating amplitude. This mode is shown to be equivalent to the band-pass region described in multi-layer metal/dielectric stacks. However, scattering and periodicity considerations require that only the low frequency band-edge can be coupled to at normal incidence, while only the high frequency band-edge may be coupled to at grazing incidence.

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