Analytical modeling of compound metallic reflection gratings

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The transmission and reflection of electromagnetic waves impinging on metallic surfaces with periodically distributed slits (diffraction gratings) have been the subject of thorough studies using numerical and experimental approaches. Of special interest are the properties of the so-called compound gratings, which are periodic arrays of slits whose unit cell contains several of them. The transmission properties of such diffraction gratings have been studied along the last few years both theoretically (D.C. Skigin and R.A. Depine, Phys. Rev. Lett., 95, 217402, 2005) and experimentally (A.P. Hibbins et al., Phys. Rev. Lett., 96, 257402, 2006; M. Navarro-Ca et al., App. Phys. Lett., 94, 091107, 2009). However, analytical models are very useful for design purposes and, moreover, they provide physical insight that is not obvious from numerical approaches. For compound transmission gratings, the authors of this contribution recently developed a circuit-model-based analytical approach (F. Medina, F. Mesa and D.C. Skigin, IEEE Trans. on Mic. Theory Tech., 58, 105-115, 2010) that captures the essential physics of these optical systems. Thus, compound transmission gratings are now well understood, and numerical or analytical design tools are available.

Other related structures of great interest are the reflection gratings with compound unit cells. In these structures the slits do not connect the two half spaces at both sides of the metal plate and only reflection operation is allowed. The theoretical analysis of this kind of gratings showing narrow band phase resonances was reported a few years ago (A.N. Fantino et al., Phys. Rev. E, 64, 016605, 2001; S.I. Grosz et al., Phys. Rev. E, 65, 056619, 2002). The theoretical predictions in those papers have recently been confirmed through experiments carried out in the millimiter wave range (M. Beruete et al., Opt. Express, 18, 23957-23964, 2010). The purpose of this contribution is to provide circuit-like analytical models that give simple and accurate explanation to the observed phenomenology for these structures. The models are based on the use of lossless/lossy transmission lines and lumped elements accounting for propagating and evanescent fields in the different regions of the periodic structure. Very accurate agreement with numerical and experimental data is achieved provided some restrictions on the dimensions of the slit widths are enforced. Qualitative explanation of the observed reflection spectra is simple using this model and the involved computational complexity is much smaller than that required by full-wave numerical approaches.