Losses Estimation in Liquid-Crystal-Based Reconfigurable Slotted Metasurfaces

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Liquid Crystals (LCs) can be considered a promising material with various applications at microwave/millimeter waves. Since their very early introduction (F. Reinitzer, Wien. Monat. Für Chem., 9, 421–441, 1888), they were investigated and classified in detail by different research communities, both by physicists and engineers. Indeed, LCs behave as common crystals only between a lower and upper critical temperatures, depending on the chemical properties of the different compounds used to design them. Undoubtedly, so-called *nematics* are the most widely used in engineering applications, thanks to their very simple rod-type structure that allows for an easy electronic control. From the macroscopic electromagnetic viewpoint, *nematics* can be described as uniaxial anisotropic media.

Although considerable efforts have been made to optimize LCs at optical frequencies, e.g. for designing high-performance and low-power displays (H. Kawamoto, Proc. of IEEE, 90, 4, 460–500, 2002) or for polarization control, their application at microwave and millimeter wave frequencies is a less mature field. In these frequency ranges, up to now LCs were mainly used for the design of reconfigurable phase-shifters or for other microwave devices (P. Yaghmaee, O. H. Karabey, et al., Intern. Journ. Anten. Propag., 2013). On the other hand, only few attempts have been done to realize LC-based reconfigurable antennas (A. Gaebler, A. Moessinger, et al., Intern. Journ. Anten. Propag., 2009).

It has been shown (S. C. Pavone, E. Martini, et al., sub. to IEEE Trans. Anten. Propag., 2016) that LCs can be profitably used as an electronically-tunable substrate supporting the propagation of surface waves (SWs). Indeed, by properly biasing the LC substrate, the average orientation of *nematics* can be controlled, thus allowing the electrical permittivity modulation and, hence, the tuning of SW propagation constant. In addition, by topping the LC substrate with an inductive metasurface, this effect can be significantly enhanced. Therefore, if the slotted metasurface is designed in such a way to periodically modulate its surface reactance, the surface wave wavenumber modulation allows control of the pointing angle of the $n = -1$ Floquet mode.

An important issue when one deals with LCs for the design of reconfigurable antennas is the rigorous estimation of losses both in the conductors and in the LC substrates. In particular, by considering that tunable LC layers are usually very thin (i.e., in the order of hundred microns), conductor losses are not negligible, and thus have to be taken into account.

In this paper, we propose a technique for losses estimation of a grounded layer of LCs loaded by a slotted metasurface. Such analysis will be applied to the design of a novel class of reconfigurable metasurface antennas.