Design and Evaluation of Liquid Crystal-Based Pixels for Millimeter and Sub-Millimeter Electrically Addressable Spatial Wave Modulators

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During the last decades, the Liquid Crystal (LC) technology has been widely used in the near infrared and visible regions of spectrum to develop tunable devices such as displays or spatial light modulators (SLM), which is the term used in photonic to describe an aperture antenna fed by an external source in reflection or transmission mode, known as reflectarray (RA) and transmitarray (TA) in microwaves. However, the use of the LC to implement tunable devices for millimeter and sub-millimeter waves is very recent. In the particular case of RAs/TAs, some efforts have been made in the last recent years to develop LC-pixels [1]-[3] or full antennas [2]-[3] up to 100 GHz. The main difference between both an LC-pixel in these frequencies and that one developed to operate in photonic applications lies in the use of resonators, which must be included in the pixels (cells) to achieve the appropriate phase-shift (Fig 1). The use of resonators makes the performance of the cells completely different for the critical electrical parameters, which also depends on the particular characteristics of the LC mixture used (dielectric anisotropy and loss tangent) at the operating frequency.

Figure 1. Different pixel architectures for LC-spatial wave modulators along the spectrum

In this contribution, the design of several LC-based TA and RA elements to operate from 0.1 to 100 THz will be shown, with the aim to analyze several key parameters of the pixels: phase-shift, absorption losses and switching times. GT3.23001 LC mixture, particularly designed by Merck for mm and sub-mm wave applications, is used for each pixel. As an example, Fig 1 shows the first LC-RA pixel designed to work at 1 THz, which exhibits the required cycle of 360°. The manufacturing processes to develop the different pixels and the ways to experimentally test them also depend on the frequency and will be analyzed in the paper as well. The existence of a frequency range within the infrared spectrum from which the resonators cannot be implemented with the current technological maturity will be discussed together with their potential technological solution in short/mid-term.

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