Finite Element Modelling of Liquid Crystal-Based Microwave Devices

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Liquid crystal (LC) substrates provide a convenient means to fabricate reconfigurable or tunable microwave devices. The large anisotropy shown by LC materials, of the order of 25% and higher, permits to obtain a wide range of tunability, which can be achieved by the application of external, low-frequency electric or magnetic fields. Device fabrication is inexpensive and the voltage and power requirements to operate them are very low.

The work described here consists of the finite element (FE) modelling of the liquid crystal behavior when electric fields are applied, necessary to find the permittivity distribution in the LC substrate, combined with the full modelling of the electromagnetic fields in the entire device. The LC substrate's permittivity is a full tensor that varies from point to point through the device, so commercial EM modelling packages are not suitable. The FE modelling of the LC substrate is based on a variational formulation for the Gibbs energy including the elastic and electric energies in the LC. The relation between electric and elastic behavior is highly nonlinear and the solution is achieved by iterations within a time-stepping approach. This results in the LC director distribution and from this, the permittivity distribution in the substrate can be found. This is mapped onto the (FE) mesh of the entire device and the electromagnetic field propagation is calculated using a full-field approach implemented with tangential FE elements, using perfect conductor walls, absorbing boundary conditions or boundary elements for radiating structures. The excitation field is provided by a modal analysis at a designated input port, based on the transverse electric field and also implemented with tangential FE elements.

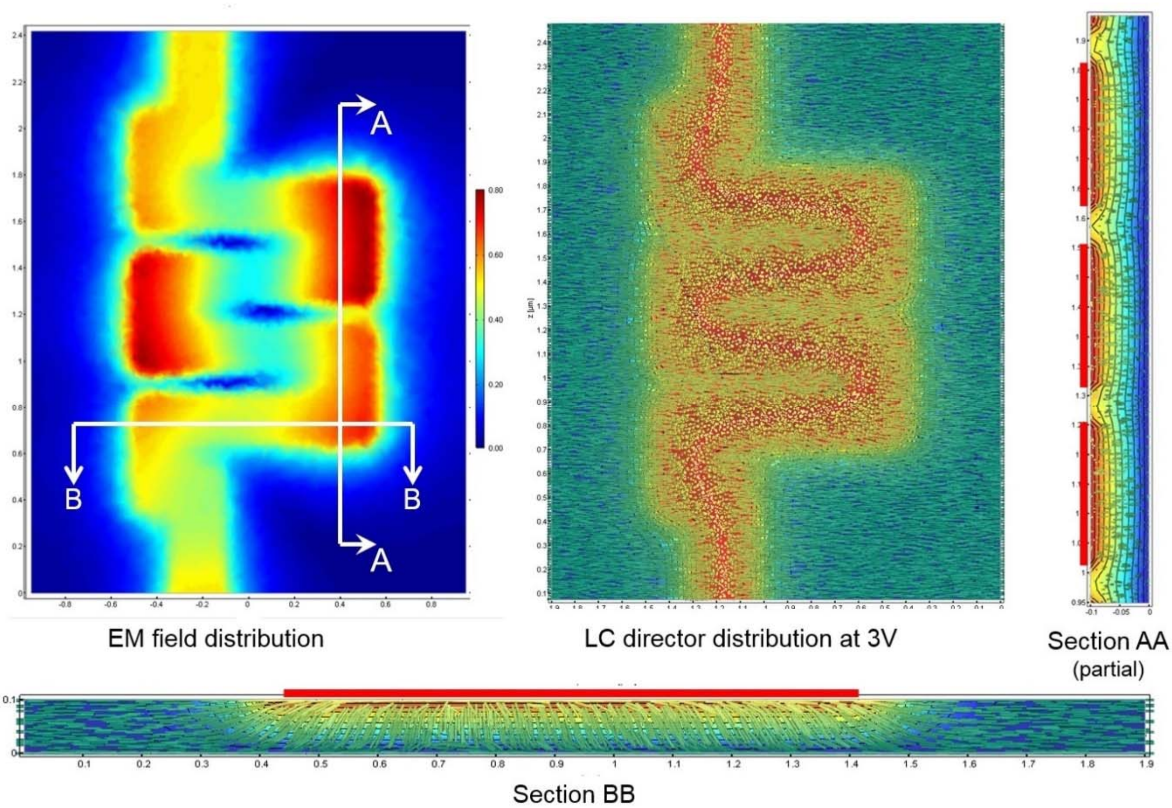

Fig. 1 Cross-section view of a meander-line phase shifter showing the electric field distribution (top left) and the LC director distribution (top middle, right and bottom).