Tunable THz band-pass filter

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Abstract

In this paper we present a design of tunable band-pass filter for THz frequency. The filter consists of several layers of conducting wire grids separated by a layer of metal strips. The structure is filled with nematic liquid crystal providing tunability of the filter frequency response.

1. Introduction

THz science and technology is widely investigated for last decade. A great interest in THz is provided by possibility of their applications in space, earth research and meteorology, security , medicine, telecommunications, imaging and sensing [1-2]. New compact sources and detectors of THz power are now possible to realize, but there is still a lack of devices for controlling THz radiation. Recently a new class of electromagnetic metamaterials have been introduced to design devices for manipulating THz radiation. Design of THz switches, modulators and phase shifters has been reported in variety of papers [3-4]. In this paper we consider a tunable band-pass filter based on crossed wires infiltrated with liquid crystal.

2. Filter design

The basis of the structure considered is a set of crossed wire layers (Fig 1a). This type of inductive grid exhibits a narrow transmission behavior near the frequency where the period of the structure coincides with the wavelength of the incident electromagnetic wave. Because of mutual coupling of the closely positioned grid layers, the higher number of layers, the higher is number of transmission maximums in the operating frequency (Fig 1b).

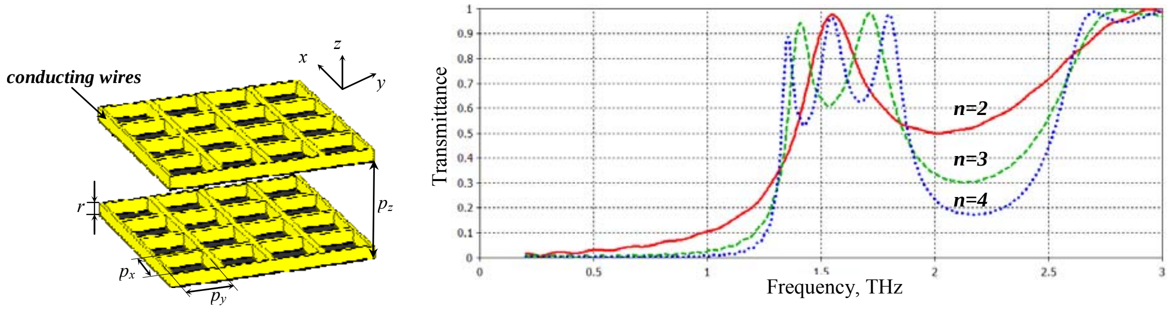

Fig. 1: (a) layers of the crossed wires forming wire medium, (b) the transmission coefficient for the wire medium consisting of $n = 1$, $n = 2$, and $n = 3$ numbers of crossed wires layers.

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The filter structure is shown in Fig. 2. The distance between the adjacent wires is equal to the period $p_x = p_y = p_z = p$ and is equal to several tenth of micrometers for THz operating frequencies. The bottom layer of the wires is placed on a dielectric low-loss substrate (Fig. 2). In order to design a pass-band THz filter, the geometry parameters are optimized to give an isolated, narrow pass band. To provide this, the filter design is completed with metal strips which are placed on the dielectric low-loss superstrate between the wire medium planes. The strips provide increasing the slope parameter of the transmittance curve and higher attenuation above the operating frequency (Fig. 3). Therefore adding the strips leads to a higher selectivity of the filter. To provide 2D isotropy, these metal constituents are formed as crosses designed as two orthogonal metallic strips.

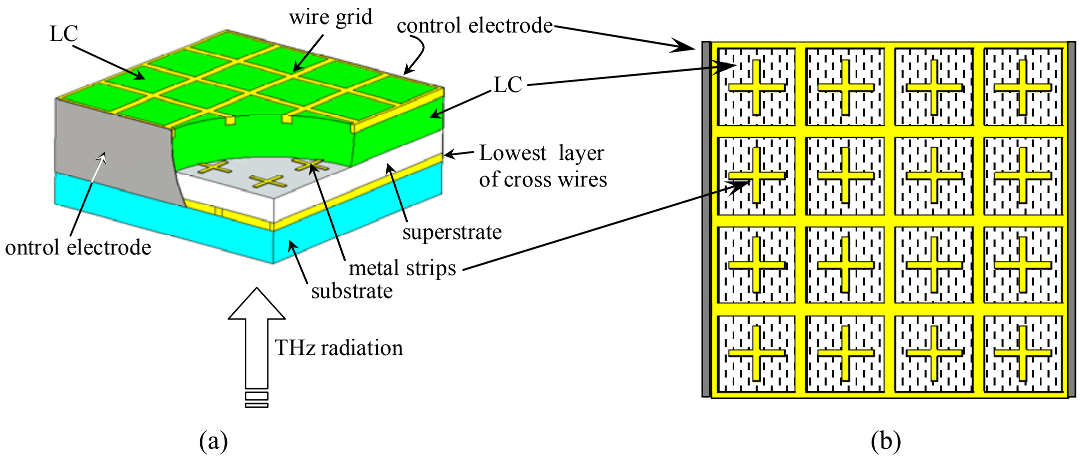

Fig. 2: (a) 3D view and (b) top view of the pass-band filter design.

The tunability of the filter is provided by the nematic liquid crystal (LC) filling the space between the top layer of the cross wires and the crossed strip superstrate (see Fig. 2). The LC layer provides a tunability of the structure by applying biasing voltage. To perform the rotation of nematic liquid crystal molecules and change the permittivity of the liquid crystal two control electrodes are placed on the both sides of the structure. The LC with birefringence of $\Delta n = 0.3$ can be used in the structure. The LC permittivity at THz is supposed to be changed from 2 to 3, depending on the voltage applied to the side electrodes.

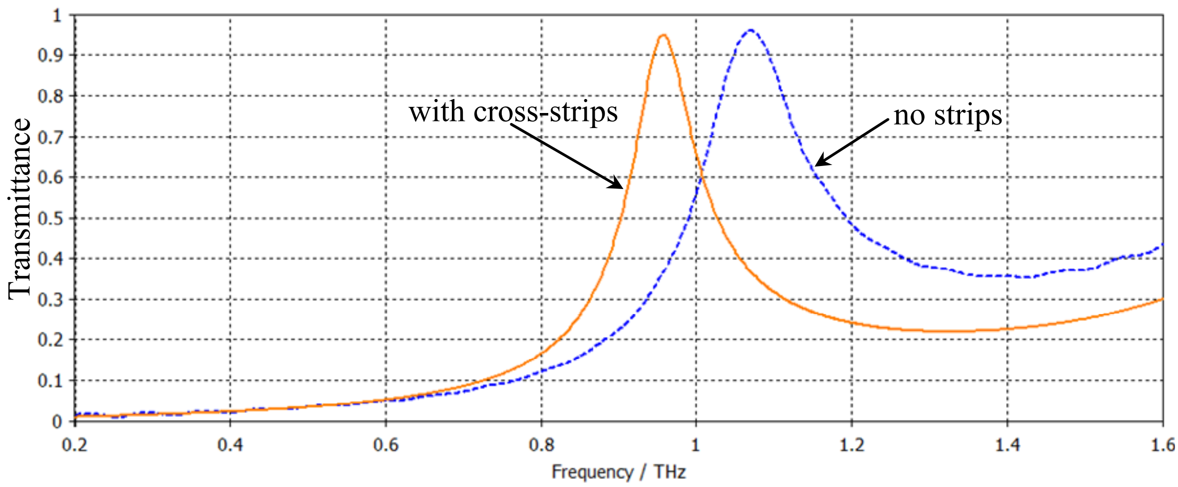

Fig. 3: Transmission coefficient for the filter with and without conducting strips.

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Transmission characteristic can be pre-tuned by changing parameters of the structure. Central frequency, transmitssion coefficient and the pass-band width depend on the period of the structure and the wire radius.

The tuning range about 13% is shown in Fig. 4. The permittivity of the liquid crystal is changed from $\varepsilon_{LC} = 2$ to $\varepsilon_{LC} = 3$.

Finally the higher number of wires and strip layers can be used to perform a narrower pass-band near the operating frequency.

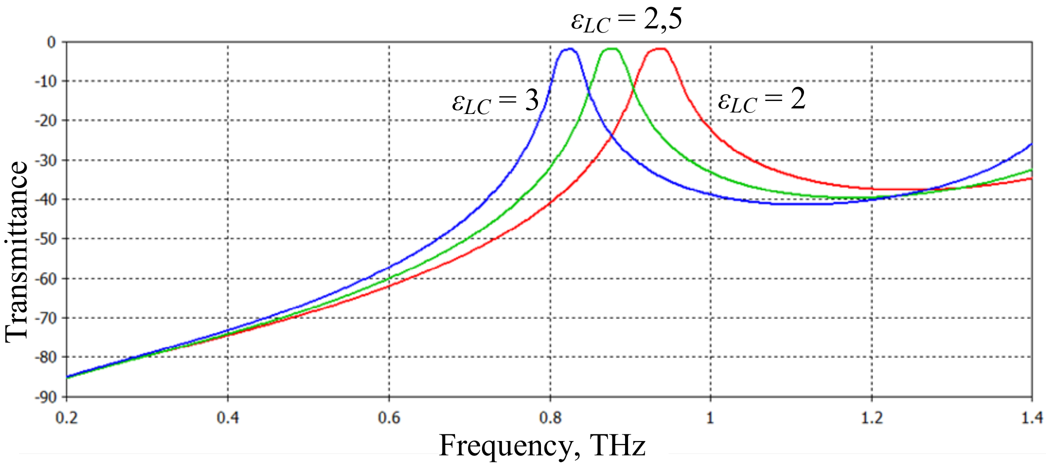

Fig. 4. Transmission coefficient in dB for a filter with different values of the liquid crystal permittivity.

4. Conclusion

Design of the THz band-pass filter has been presented. Simulation results reveal a band-pass behaviour of the filter. Adding liquid crystal to the structure design provides effective tunability of the filter. The central frequency of the pass band is assigned to be tuned with the tuning range of 10-20%. The structure of the tunable MTM can be also used for switching and amplitude modulation of THz electromagnetic radiation.

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