Compact multilayer SRR-loaded integrated waveguide filters on liquid crystal polymer substrate

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Introduction

World wireless communications show tremendous growth during last 10-15 years. Higher and higher frequency ranges are utilized for either civil or military purposes. Development of new compact, cheap components with low losses for Ka-, V- and W-bands is strongly required from the point of satisfaction fast increasing industrial needs.

One of relatively new approaches to achieve cheapness and compactness of microwave components is utilization of substrate integrated waveguides (SIWG), which are very convenient for field transmission at high frequencies, for instance, mm-waves [1]. Moreover, SIWGs are highly applicable for mass production using well developed modern IC-technologies [2].

Usual substrates like LTCC, RT/Duroid or FR4 are unable to provide required loss properties at Ka and higher frequency ranges. In order to satisfy the demand of low losses application of LCP (liquid crystal polymer) is rather preferred because of its much lower dielectric tangent loss [3]. Another important feature for designers is that LCP also allows fabricating multilayer structures [4].

Several structures built upon rectangular waveguides containing metamaterials were studied in [5-8]. However, works dedicated to the combination of SIWG and metamaterials are still rare. In this paper we would like to present a microwave filter based on SIWG designed for fabrication using multilayer LCP substrate with utilization of split ring resonators.

Proposed Waveguide Filter Structure

Proposed waveguide filter is designed using the idea presented in [9], where a conventional rectangular waveguide was filled with several sections of E-plane resonators loaded with SRRs, situated in the plane of symmetry of the waveguide. Realization of such an approach for SIWG provides a significant challenge to designers from the point of construction. Each ring of the SRR must be implemented as a 3D object contrary to planar rings in original design. A view of the 3D substrate integrated SRR is presented in Fig. 1. A ring of the SRR requires at least two dielectric layers and consists of two parallel strips connected with a

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metallic via post. Rings are rotated in opposite direction thus forming an analog of conventional stacked SRR.

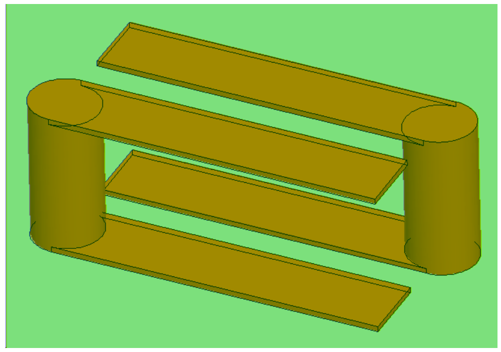

Fig. 1. View of the integrated SRR.

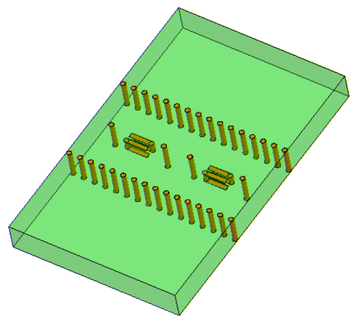

Fig. 2. View of the whole 2-sections SIWG-filter.

The configuration of the whole filter is shown in Fig. 2. It consists of two sections of combined E-plane resonator and SRR located inside the SIWG organized as two rectangular ground planes connected with metallic via posts which form side walls of the waveguide. E-plane resonators are made with metallic via posts, situated in the symmetry plane of the waveguide, connecting top and bottom ground planes and passing all three dielectric layers. LCP with relative permittivity $\varepsilon = 3.0$ and $\tan\delta = 0.002$ was chosen as a substrate from the reasons of good performance at high frequencies. The sections are separated by the gap which usually is less than section's dimension. The structure was parameterized precisely and simulated with HFSS™ software.

In Fig. 3 the magnitude of S-parameters of the 2-sections filter is presented. Main dimensions of the filter are following: height of the waveguide Hwg = 1.524 mm (3 layers of LCP, each 0.508 mm high), width of the waveguide Wwg = 5.08 mm, strip width W = 0.254 mm, space between two rings of the SRR S = 0.127 mm, diameter of via connector Dvia = 0.508 mm, length of the E-plane resonator Leres = 2.54 mm, length of the gap between sections Lgap = 1.27 mm, length of the SRR Lsrr = 1.2 mm. Total length of the structure is L = 11.62 mm. Such a filter shows good frequency selectivity at the range between 27.3 and 29.4 GHz, i.e. about 28 GHz. Let us compare this frequency response with the response of the same 2-sections filter from which the SRRs were removed. Fig. 4 shows S-parameters of the filter without SRRs. Comparing two graphs, one can see that pass band in Fig. 3 is drifted to the lower frequencies relatively to the graph in Fig. 4. Also in Fig. 3 a zero lower the cutoff frequency is formed by the SRRs. It makes lower slope of the filter's frequency response sharper. Unfortunately, due to the little Q-factor of the integrated SRRs this zero is not expressed well. Design of the configuration of integrated SRR with high Q-factor is essential for such type of filters.

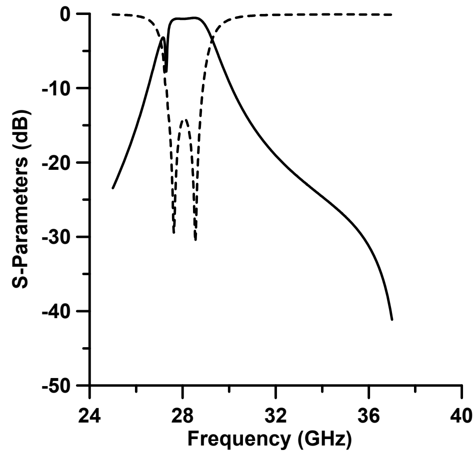

Fig. 3. S-parameters of the proposed waveguide filter with SRRs.

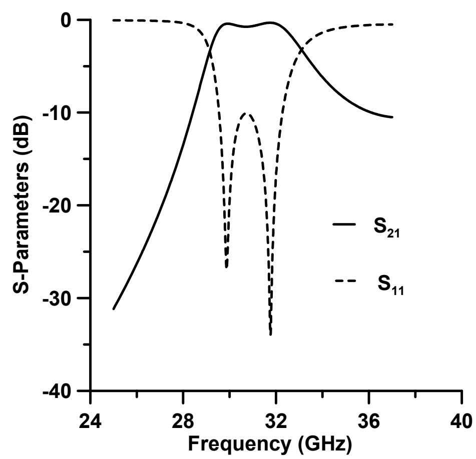

Fig. 4. S-parameters of the waveguide filter without SRRs.

Conclusion

Compact bandpass filters based on rectangular substrate integrated waveguides and split ring resonators for implementation in multilayer LCP technology were proposed. Filter which included two sections of E-resonator and SRR was tuned up to central frequency of about 28 GHz and bandwidth of about 2 GHz.

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