Novel folded SRR-loaded waveguide bandpass filters

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Novel Folded SRR-Loaded Waveguide Bandpass Filters

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Introduction

Modern wireless communication systems require low cost, mass producible and low dissipation loss microwave and millimetre-wave components such as filters, diplexers, multiplexers and antenna filters. As broadband communication systems are becoming popular, wide band operation becomes an important property for microwave components. The latest interest in implementation of broadband wireless communication systems is conditioned by the set of considerable advantages of such systems over its wired technology analogues. The wider applications demand fulfilment of the new requirements for the systems performance and parameters. This leads to the permanent necessity for the improvement of various components.

The steady growth in commercial interest in microwave and millimeter wave systems such as High data rate line of sight links (LOS), high data rate Wireless Personal Area Networks (WPAN), point to multipoint links, 24 GHz UWB Radar Sensors, and 77 GHz Automotive Radar has provided a significant challenge to conventional microwave circuits and their design methodologies. High performance narrow-band bandpass filters having a low insertion loss, compact size, wide stopband and a high selectivity are important for next-generation wireless and cellular communications, and broadband microwave communication systems. At present most filters at microwave and mm-wave frequencies are produced either in waveguide (air-filled metal pipe, dielectric-filled or micromachined air-filled) with high associated machining costs, image guide and non-radiative dielectric guide with high associated loss [1,2,3]) or using dielectric resonators although they are less compatible with modern MMIC technology, especially when one is concerned about convenient and efficient integration with active devices or using planar technologies (microstrip, suspended substrate stripline and coplanar waveguide) [4,5].

The microwave and mm-wave applications require wireless communication sub-systems in order to transform signals so that they reach the destination with the level, sufficient for proper reception. The high-performance filters are required for separating frequencies in diplexers and multiplexers. They should possess such important properties as low insertion loss and low distortion level along with their compact size realisation.

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Over the past few decades rectangular waveguides have been a sustainable solution used to design robust, low loss and high power circuits at microwave and millimeter-wave frequencies. In the filter structures, which are viable to meet requirements of the modern technology [6], reduction of the physical size has become one of the primary goals. Recently proposed concepts of left-handed medium (LHM) have become the subject of extensive investigations due their capability to provide novel unconventional properties to different propagation media [7]. This approach makes use of the left-handed medium created by a novel type of resonance elements, FSRRs in combination with the thin metal wireline [8]. These are printed on the dielectric slab, which is then inserted into the plane of symmetry of the rectangular waveguide. These structures are able to alter the electromagnetic boundary conditions of the surface and prohibit propagation of signal in a certain frequency band. Thus, the traditional miniaturization techniques, which commonly employ dielectric-filled waveguides with standard dimensions bound to the wavelength (λ), may be enhanced to achieve more compact high-performance waveguide components. In this research we make use of the left-handed properties imposed by the novel FSRRs in order to achieve miniaturization of rectangular waveguide filters.

This paper therefore proposes for replacement of the conventional section of rectangular waveguide E-plane filters with a FSRR filter structure, consists of a periodic cascade of metal septa. It maintains the low-cost and mass-producible characteristics of split-block metal insert E-plane technology.

FSRR-Loaded Waveguide Bandpass Filter

The proposed metamaterial based Folded SRR (FSRR) loaded waveguide filter is shown in Fig. 1. The proposed filter structure is constructed of the transmission line loaded in the metal-dielectric slab, which conveniently facilitates the FSRR filter with the metal septa. The FSRRs are presented on a single side of the dielectric block and is characterised by the following parameters. The dielectric which has relative dielectric permittivity of 2.2, thickness of 0.51 mm supports this FSRR filter with the metallisation thickness of 0.017 mm.

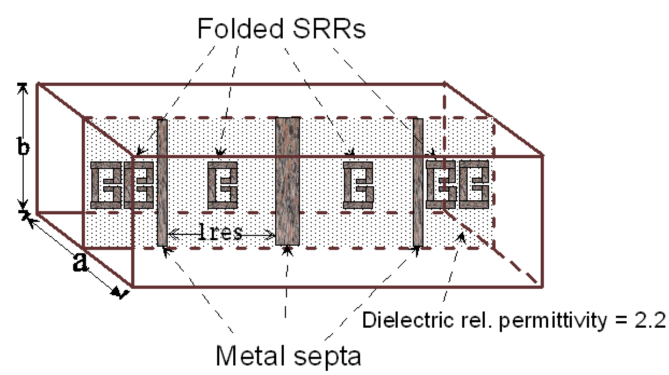

Fig. 1. Configuration of the proposed FSRR loaded bandpass filter

Standard rectangular waveguide of WG-16 (a = 22.86 mm, b = 10.16 mm) has been used as a housing to fit the 0.51 mm thick dielectric slab having total structure length of 51 mm and l_{res} of 14 mm. Simulated insertion and return losses of the proposed bandpass filter are shown in Fig. 2.

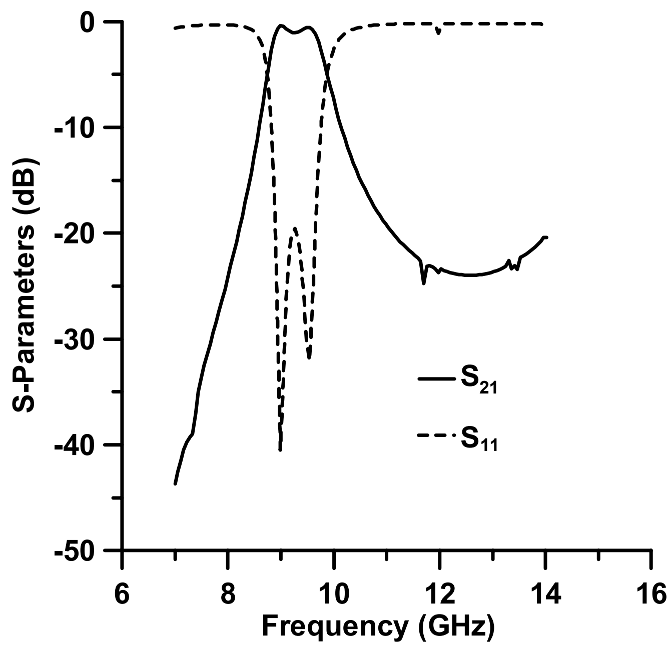

Fig. 2. Simulated Insertion and Return losses of the proposed FSRR-loaded bandpass filter

Parameters (mm)	
WG inner dimensions (WG16)	22.86* 10.16
Total structure length	51
Dielectric slab length	51
Dielectric thickness	0.51
Metal septa length	1.2, 3, 1.2
lres	12
Metallization thickness	0.0017
Distance between the two Folded SRRs on the side	1.28

Table I. Dimensions of the proposed FSRR-loaded bandpass filter

The electromagnetic analysis of the proposed metamaterial based FSRR filter structure is conveniently based on the finite element method (HFSS^{TM}) [9]. In order to derive a design procedure for the proposed type of the filter, the propagation characteristics of the slow wave, such as the guided wavelength or phase velocity need to be determined. These in turn are determined by geometrical parameters, namely the gaps and the lengths. The gaps can be chosen arbitrarily. The periodicity lengths, together with the chosen gaps will effectively determine the wavelength; this in turn should determine the length l_{res}. Dimensions of the proposed FSRR filter at 9.45GHz are given in Table I.

Conclusion

A novel class of E-Plane, low-cost, compact and metamaterial-based filter structure using FSRRs for microwave, millimeter wave applications has been proposed. The proposed FSRR-loaded waveguide bandpass filter has been designed and simulated at 9.45 GHz. The structure can be easily realized with a single metal insert within a rectangular waveguide. This kind of filters can be found in applications particularly in the mm-wave range circuits, e.g. in diplexers and multiplexers.

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