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Realization of dielectric loaded waveguide filter with substrate integrated waveguide technique based on incorporation of two substrates with different relative permittivity

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ABSTRACT

In this paper a new structure based on substrate integrated waveguide (SIW), called incorporated substrate integrated waveguide (ISIW), has been used to implement the dielectric loaded waveguide filter in planar structure. Conventional waveguide filter and dielectric loaded waveguide filter have been realized with SIW and ISIW technique, respectively. The use of ISIW structure has reduced the size of the filter, required precision in designing process and the cost of manufacturing process, at the cost of increasing the losses. Thus, while the size of filter and the cost of manufacturing process reduce significantly, there is no need to build the particular dielectric material as resonator and integration with other microstrip devices will be much easier too. Two different excitation mechanism have been considered to cancel the spurious response in the desired frequency band. The SIW and ISIW filters have been fabricated and fairly compared with waveguide filters. Advantages and disadvantages of ISIW structure have been scrutinized in detail. Good agreement between the simulated and measured frequency response of proposed filters has been shown.

1. Introduction

The H-plane waveguide filter with corrugated sections as direct coupled resonators [1,2] is the candidate for modelling of waveguide filters. One method of size reduction in the H-plane waveguide filters is the use of dielectric resonators [3–8]. Multiple instances of H-plane waveguide filters, loaded with circular dielectric posts, have been compared in [4] and the advantages of the dielectric use have been studied in detail. However, the preparation of particular dielectric material as resonator and its precise placement in the waveguide are the structural problems of this method.

On the other hand, the method that leads to a further reduction in size and easier integration with planar circuits is the use of the SIW technique. Over the past years, many studies have been performed to implement the waveguide filters with SIW technique [9–14]. Substrate Integrated Corrugated Waveguide (SICW) filter with microstrip excitation [11] and SIW H-Plane filter in a sandwich model with strip-line excitation [12] are the samples of them.

This study discusses how to realize the all-metallic *H*-plane waveguide filter and dielectric loaded *H*-plane waveguide filter [3–5] with the SIW technique. Also, differences in their realization with SIW structure have been carefully considered. The all-metallic *H*-plane waveguide filter is implemented with the SIW technique in accordance with [11]. The realization of dielectric loaded *H*-plane waveguide filter with the SIW technique is slightly different and has several structural problems, which are: providing of particular dielectric material with the required sizes and relative permittivity, incorrectness in the insertion of dielectric posts in the substrate, how to fix them to the dielectric substrate of the SIW, metallization of the top and bottom of the rods and also, electric continuity of them with the rest of the structure.

The incorporated substrate integrated waveguide (ISIW) structure has been used to mitigate these problems. According to Fig. 1, in ISIW structure cylindrical pieces of high permittivity dielectric substrate are incorporated in SIW structure and act as resonator. The structural properties of ISIW technique have been explained in Section 3. A full-wave simulation tool such as high frequency structure simulator is required in the design strategy and has been repeatedly used in order to find the optimal dimensions of the filter.

Providing of high relative permittivity substrate as resonator is easier than particular dielectric material and there is no need to metallization of its top and bottom. Also, the exact placement of the resonators in the SIW structure will be done easily and with high accuracy. However, due to substrate losses and inevitable air–gap between resonators and SIW structure, insertion and return losses will be

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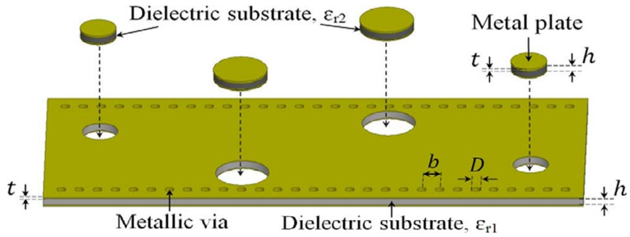

Fig. 1. Topology of incorporated substrate integrated waveguide (ISIW).

increased. The SIW and proposed ISIW filter have been fabricated with standard printed circuit board (PCB) process and fairly compared with all-metallic *H*-plane waveguide filter and dielectric loaded *H*-plane waveguide filter. Good agreement between the simulated and measured frequency response of proposed filters and conventional waveguide filters has been shown.

2. *H*-plane waveguide filters loaded with dielectric resonators

In [4] the all-metallic *H*-plane corrugated waveguide filter has been compared with *H*-plane dielectric-loaded waveguide filters. The space mapping technique with segmentation and hybrid optimization algorithms [15] have been used to design the all-metallic coupled cavities filter (Fig. 2(a)). The dielectric-loaded waveguide filter (Fig. 2(b)) has been designed using the strategy described in [16]. The space mapping with segmentation and hybridisation of optimisation techniques have been used in this strategy. Since in this case it is difficult to obtain a good starting point, as it is possible with all-metal filters, two optimisation levels with two different coarse simulators have been considered. The details of these structures and their simulation results by Ansoft HFSS software have been shown in Fig. 2 and Fig. 3, respectively.

According to what has been mentioned in [3,4] dielectric use increases power transmission capability and thermal stability and also reduces size of the filter, at the cost of increasing the losses. The CAD tool has been used to achieve a band-pass response centered at 11 GHz with 300 MHz band width and 20 dB return loss [3,4]. This frequency band is typical for spatial applications such as satellite communications. Standard WR-75 (9.525 mm × 19.05 mm) and ceramic material with relative permittivity of $\varepsilon_r = 24(1{-}j0.001)$ have been used as structure and resonator, respectively [4].

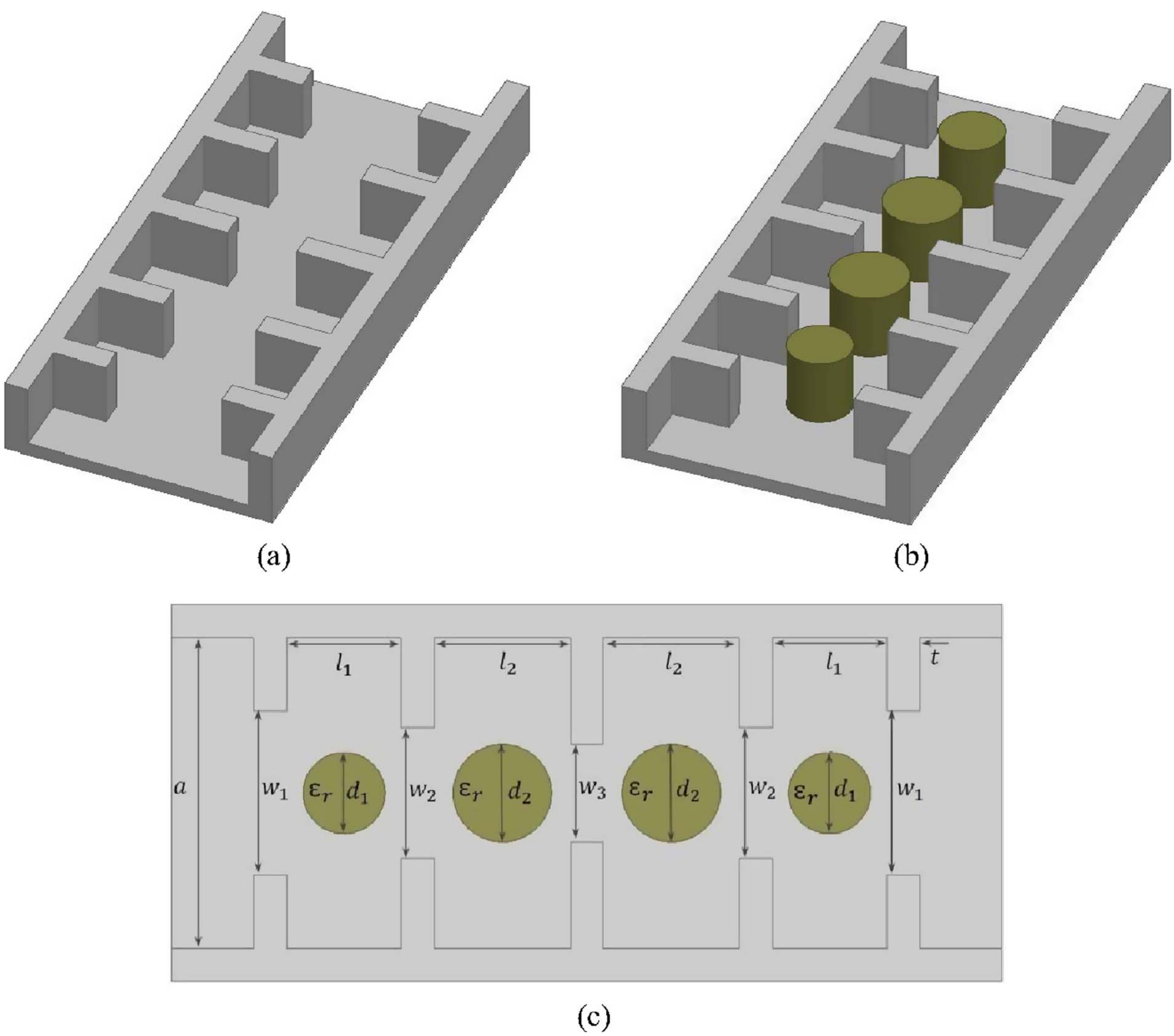

Fig. 2. Topologies and designed parameters of *H*-plane waveguide filters, studied in [4]. Unit: mm. (a) All-metallic waveguide filter. $l_1 = 15.68, l_2 = 17.605, w_1 = 10.52, w_2 = 7.098, w_3 = 6.52, a = 19.05, t = 2$ (b) Dielectric loaded waveguide filter. $l_1 = 6.98, l_2 = 8.28, w_1 = 13.37, w_2 = 6.286, w_3 = 6.1, d_1 = 4.222, d_2 = 4.344, a = 19.05, t = 2$ and $\varepsilon_r = 24(1{-}j0.001)$.