Rectangular waveguide resonators in planar form for filter applications.

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RECTANGULAR WAVEGUIDE RESONATORS IN PLANAR FORM FOR FILTER APPLICATIONS

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Abstract – This paper observes microwave waveguide resonators in planar form and proposes design for obtaining low-cost devices in planar form that are suitable for mass fabrication. Periodic resonators at 3.6 GHz are designed and simulated using this technique, which represents advantages of this technology, resulting the reduced size, cost and compactness of these components, while maintaining easy fabrication process. This is achieved due to the configuration that holds both the microstrip and the rectangular waveguide interconnected by a simple taper on the same substrate.

I. INTRODUCTION

The increasing introduction of microwave and millimeter-wave applications in communication systems has created new challenges for different technologies in design of passive devices. The demand for low-profile, lightweight and high-performance circuits of compact design is growing rapidly. High-Q resonators are required in microwave and millimeter-wave applications such as LANs and point-to-point communications.

Classical waveguide theory can still be used in order to meet the modern requirements of component parts for communication systems. Rectangular waveguide filters are well-known to be of highly-rated performance due to higher resonator Q values [1]; however their difficulty in integration and high cost makes them improbable for utilization in low-cost high volume applications. This can be solved by implementing design technique where rectangular waveguide is integrated with planar circuits on the same substrate. Moreover, introduction of a dielectric substrate results in significant size reduction without considerably diminishing its performance [2], [3].

In this paper, the conventional rectangular waveguide is modified to implement the dielectric substrate and to achieve planar structure of resonators and filters for microwave and millimeter-wave applications. Within the substrate the sidewalls can be realized either using metallized posts (metallic vias), metallized groove or paste sidewalls. The ground plane at the bottom and the tapered microstrip line on top both provide the metallic walls effect for the structure.

II. RECTANGULAR WAVEGUIDE RESONATORS IN PLANAR FORM

Fig.1 shows the structure of a $\lambda/2$ TEM-mode planar-rectangular dielectric waveguide resonator. The dielectric material has the following properties: dielectric constant ε_r = 2.2 and thickness h = 1.52 mm. The substrate is Rogers RT/Duroid 5880, cladding with copper and a dielectric loss tangent of 0.0007, according to manufacturer data sheet.

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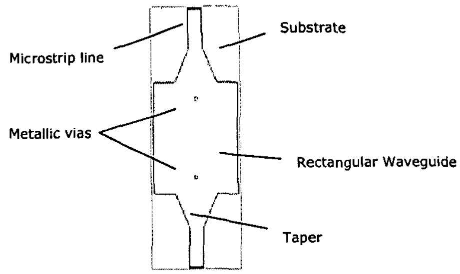

Fig. 1. Configuration of a waveguide resonator in planar form

The resonant frequency (f) of the dominant mode of λ/2 TEM-mode planar waveguide resonators can be calculated using the following relation:

$$f = \frac{c}{2 \cdot l \sqrt{\varepsilon_{eff}}}$$

where c is the velocity of light in free space, l is length of the resonator along the direction of propagation and ε_{eff} is the effective dielectric constant, which is defined as

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10h}{w}\right)^{-1/2}$$

where ε_r is the relative permittivity of the dielectric material, h is the thickness and w is the width of the resonator.

The modal energy transformation from waveguide, supporting the TE10 mode, to microstrip and vice versa is performed by tapers acting as mode converters on input and output ports of the structure. The integrated microstrip with a rectangular waveguide structure preserves the guided wave properties of the corresponding conventional rectangular waveguide with equivalent width. This allows for the analysis and design of these structures using the well-known techniques for a conventional waveguide [4].

The structure integrates the resonator, microstrip and taper on the same substrate. The discontinuity of resonator is presented by metallic holes [5], [6], transversely inserted inside the waveguide.

The resonator is constructed on a 1.52 mm thick dielectric substrate with $\varepsilon_r = 2.2$. The waveguide has a width $w = 30$ mm and length 40 mm. Both metallic cylinder holes are 0.7 mm in diameter and of 1.52 mm height. The length of the resonator l is 28 mm, which is chosen to be approximately half the guide wavelength (λg / 2).

Simulated and experimental results of the proposed resonator are shown on Fig.2 and Fig.3.

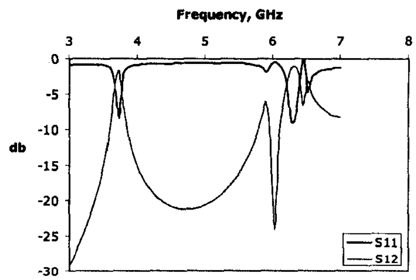

Fig. 2. Simulated response of the rectangular waveguide resonator in planar form

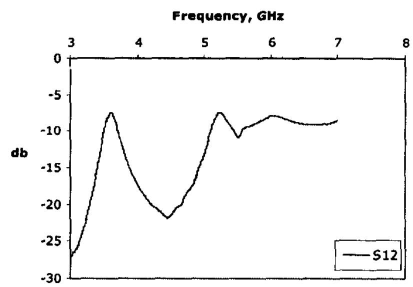

Fig. 3. Experimental response of the rectangular waveguide resonator in planar form

III. APPLICATIÒN

To verify the feasibility of the proposed structure, the two resonator filter was simulated. E-plane bandpass filter, designed with its center frequency at 5.15 GHz and bandwidth of 300 MHz integrating rectangular waveguide and the planar circuit on MIC technology is with the response presented at Fig.5.

The three-dimensional (3-D) EM simulator package HFSS [7] was used for simulation of presented structures.

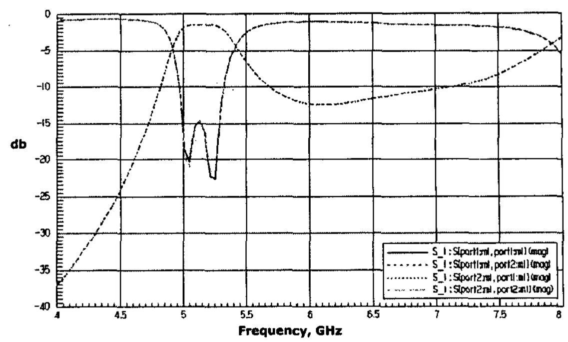

Fig. 4. Simulated response of the two resonator filter

IV. CONCLUSION

To meet the modern requirements for wireless communication devices, we have designed the low-cost, small-sized and suitable for mass fabrication passive structures integrating rectangular waveguide and planar circuits on the same substrate. Resonators structure design concepts have been investigated and obtained. The rectangular waveguide planar resonator has been simulated and measured. The feasibility of the proposed structure has been shown by simulated two resonator bandpass filter.

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