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New approach to Electronic Band Gap filtering structures combining Microstrip and Dielectric Resonators

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***Abstract* — A novel design combining standard microstrip technology with single ring resonator and high dielectric constant resonator for design of low and band pass filtering electromagnetic band gap(EBG) structures, operating in the range from 1 to 20 GHz is presented in this paper. The design is based on a high dielectric constant resonator embedded in a microstrip structure substrate. The dielectric resonator is fabricated by using commercial high dielectric constant EPOXY paste in a process compatible with serigraphy and screen printing technology.**

Index Terms —resonators, passive microwave circuits, microstrip, dielectric resonators

I. INTRODUCTION

Filters have a wide range of applications such as wireless systems, radio frequency (RF), television and satellite broadcast, mobile communications, broadband microwave, millimeter-wave communication systems, radars and many other systems related to the information telecommunication, which makes them so interesting to develop novel technologies. Since micro-strip has a compact size, light weight, planar structure and is easy to integrate with other component, being much less expensive than traditional waveguide technology it is a very attractive technology to design of filters.

On the other hand, periodically loaded waveguide constitutes a well known method to synthesize band pass and low-pass filters in the microwave theory [1]-[2]. In this paper, it is proposed, a novel design combining standard micro-strip resonators with high dielectric constant resonators, for design of low-pass and band-pass filtering electromagnetic band gaps (EBG) structures, operating in the range from 1 to 20 GHz.

The basic cell of the EBG is composed by a standard micro-strip ring resonator and a Dielectric Resonator (DR) embedded in the microstrip PCB, in such a way that the micro-strip ring act as a feed structure for some of the DR resonant modes. Moreover, dielectric resonators have been widely studied and applied to the design of the microwave communication systems from the beginning of the activity in the field [3]. Although, an equivalent circuit model can be used to describe the basic behavior of the resonator structure, the complexity of the physical behavior (with multiple resonator modes) overwhelms the description supplied by any equivalent circuital model, being necessary a full 3D numerical analysis to optimize the final design. The first resonant frequency of the DR used in the proposed design is determined by the cylindrical geometry as well as the value of the dielectric permittivity of the resonator material. CREATIVE 122-06 pad-printable high dielectric constant epoxy paste, characterized by a value of ε_r=45 has been used in the design pointing out the possibility of using commercial dielectric pastes.

The fabrication process of such structure is compatible with screen printing, serigraphy and LTCC technologies [3].

The first resonant frequency of the DR used in the proposed design is determined by the cylindrical geometry as well as the value of the dielectric permittivity of the resonator material. The utilization of high dielectric constant films allows the miniaturization of both active and passive components reducing the losses [4]. The existence of surface modes in high dielectric constant thick layers has been reported by some of the authors in previous works [5]. DR resonant frequencies depend on of both geometrical and dielectric constant values; however, the more important parameter for the resonance frequency is the relative permittivity. The geometry of the proposed structure, consists in a 3 cells EBG each one formed by a cylindrical DR with 2 mm diameter and 1.27 mm height, and 1.3 mm width micro-strip ring resonator with an inner radius of 2.3 mm.

It can be shown that the impedance of a passive resonator can be obtained as a partial expansion of the generic impedance function displayed in (1) [6]- [7].

$$z(j\omega) = jX(\omega) = j\left[A_\infty \omega - \frac{A_0}{\omega} + \sum_{i=1}^{m} \frac{2 \cdot A_i \cdot \omega}{\omega_i^2 - \omega^2}\right] \quad (1)$$

According with the Foster synthesis [6], the equivalent circuit model (1) can be reproduced as an infinite series of LC parallel tanks with a series LC resonator.

The parameter values can be obtained by fitting measures obtaining a reasonable agreement between both.

II. THE FILTERING STRUCTURE

The electronic band gap has been used as an effective way to create microwave filters. In our case the structure is a microstrip periodically loaded with resonators that can be characterized as series LC branch. (Showed in Fig. 1)

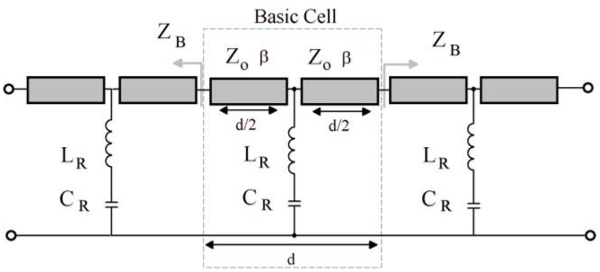

Fig. 1. EGB filter structure where the grey boxes represent the micro-strip host transmission line determined by the length of the basic cell d, the propagation constant β and the characteristic impedance Z_o, and the dielectric resonator is modeled by the series L_R-C_R branch

The microstrip host transmission line characteristic impedance Z_o and propagation constant β can be analytically evaluated from the dimensions of the microstrip line and the physical properties of the substrate which in our case is the 50 mil Rogers RO3010.
It can be shown that for a symmetrical passive structure, the dispersion equation is ruled by the equation (2) [1]

$$\cos(\beta d) = \cos\left(\frac{k_0 d}{2}\right) - \frac{\omega^2 L_R C_R - 1}{\omega C_R} sin\left(\frac{k_0 d}{2}\right) \qquad (2)$$

where β is the propagation constant of the periodic structure, k_0 is the propagation constant of the microstrip host line, d is the basic cell length and the lumped elements of the equivalent circuit model of the resonators are L_R and C_R. The confinement of the right hand of (2) between -1 and 1 will determine the transmission bands. In the presented case it corresponds to a low-band filtering structure with successive spurious bands.

III. FABRICATED PROCESS

The 50 mil Roger substrate used for the host micro-strip is characterized by a loss tangent δ=0.0022 and ε_r=10.2 at the operating frequencies.
Layers of the Creative 122-06 dielectric have been deposited until a thickness of the substrate has been achieved in the resonators. The structures have been in a conventional oven at 150ºC for one hour.
The dielectric paste used in the proposed structure and PCB embedded with DR is in the extreme of the Fig. 2, an illustrative example of a band pass filter that is embedded with DR and the response of the frequency is around 2.1 GHz

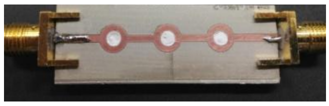

Fig. 2. Picture of the fabricated prototypes that was embedded with DR

IV. MEASUREMENTS AND DISCUSSION

The measurements of the fabricated prototype embedded with DR has been done using a Vectorial Analyzer and the results has been used to generate the two-port touchstone file format which has been used in ADS software to compare with equivalent circuit model of the structure.
As you can see in Fig .3 the measured response of the prototype clearly exhibits the EBG behavior.

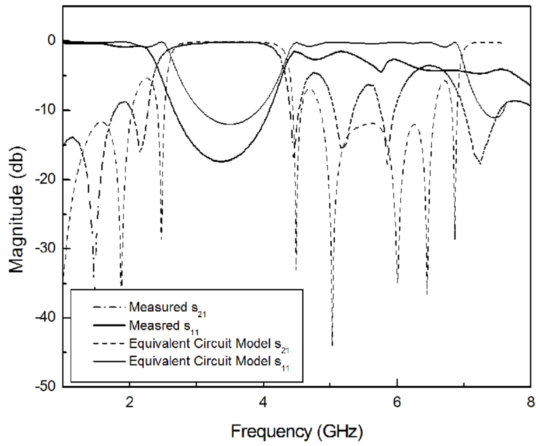

Fig. 3. Measured S-parameter for a band pass EBG fitted with the equivalent circuit model showed in Fig. 1.

The frequency responses are verified by simulation and measurement with good agreement. The simulation are achieved with the aid of Agilent-Empro 2012.09 software.

V. CONCLUSION

This paper shows the ability of the high dielectric constant resonators to be used as elements for the design passive elements in the range between 1 to 10 GHz bands. The resonator physical complex behavior requires the utilization of full 3D electromagnetic software in the design of devices based on these resonators. The proposed structure points out the possibility of using DR for the creation of EBGs. Further work is under development to improve the utilization of embedded DR as resonators in planar devices.

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