High dielectric ring resonators for designing passive filter

Bahareh Moradi ^{1*} , Joan Garcia ¹

¹ Autònoma University of Barcelona, Department of Electrical Engineering, Barcelona, Spain

* Correspondence: baharch.morandi83@gmail.com; Scopus ID: 55795876700

Abstract: In this paper, the utilization of high dielectric constant resonator as a passive element for design of filter in the range of Ku band is investigated. The design is based on a new kind of dielectric resonator fabricated with a commercial high dielectric constant EPOXY paste. The design is based on a microstrip line periodically loaded with a new kind of dielectric resonator fabricated with a commercial high dielectric constant Epoxy paste compatible with serigraphy and screen printing technology.

Keywords: Dielectric resonator, passive filter, microstrip.

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1. Introduction

Dielectric resonators (DRs) are widely used in microwave component where weight and volume savings are of two major requirements. The potential of dielectric resonator for microwave applications such as oscillators [1], slow wave structures [2] and band-pass and band-stop filters [3] became clear in the early 1960's. One of their attractions was their ease of integration in microstrip circuits [4]. During this period, the research concentrated in the modelling of the DR (usually of cylindrical shape) which resulted in the characterization of the different modes of resonances and the drawing of the first mode charts.

Recently, materials having a dielectric constant between 30 and 40 with benefit temperature stability and low dielectric losses have become available. Most of the current works

dedicated to the characterization of dielectric materials comprise complex manufacturing and measurement setups as in [5] in which the experimental setup is based on coupled coils and microstrip split ring resonator (SRR). For the applications of DRs in microwave filters, it is necessary to study the coupling between dielectric resonators.

In this work, first the analysis of single resonator based on epoxy paste commercial dielectric constant is investigated and then periodically loaded dielectric resonators on microstrip is studied.

DR is made of high dielectric constant epoxy paste with a relative dielectric permittivity of 45, loss tangent ($\tan\delta=0.008$) and temperature coefficient $Tf\sim 50\text{ ppm}/\pm C$. The quality factor Q

has been found to be 125. For an isolated short cylindrical dielectric resonator shown in Fig 1(a), the resonance mode with the lowest resonance frequency is the TE_{01δ} mode.

According to the electric and magnetic field distribution shown in Figs. 1(b) and (c), the resonator behaves like a magnetic dipole in TE_{01δ} mode. Since the electric and magnetic dipole moments can be envisioned as the alphabet for making metamaterials (MTMs) [6], the resonator is expected to be a magnetic MTM in the TE_{01δ} mode. Although the geometrical form of a dielectric resonator is extremely simple, an exact solution of the Maxwell equations is considerably more difficult than for hollow metal cavities. For this reason, the exact resonant frequency of a certain resonant mode, such as TE_{01δ} mode, can only be computed by rather complicated numerical procedures. For an approximate estimation of the resonant frequency of the isolated dielectric resonator, the resonant frequency of the TE_{nm1} mode is reported in [7]. One of the main applications of dielectric resonators is in dielectric-loaded cavity filters. In the design of certain type of these filters [8-9], the relationship between coupling coefficients and dielectric spacing should be known.

Figure 1. (a) An isolated short cylindrical dielectric resonator and (b) Electric field distribution (c) Magnetic field distribution in meridian plane for TE_{01δ} mode.

On the other hand, the approximate impedance of a passive resonator can be obtained

2. Materials and Methods

The used substrate for the host line is a 25 mil thickness Rogers RO3010 with a $\epsilon_r=10.2$ and a loss tangent $\delta=0.0022$ at the operating frequencies. Several layers of the Creative 122-06 dielectric have been deposited by means of in home fabricated masks until a thickness of 0.6 mm have been achieved in the resonators. The structures have

as a partial expansion of the generic impedance function displayed in (1) [10].

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

Also, for a passive structure, the dispersion equation is ruled by the equation (2) [11]

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

The basic cell design corresponds to a non-attenuated propagating wave with $\cos \beta d = \cos \theta - b/2 \sin \theta$ definition is depicted in Fig. 2, where $\theta = kd$, and k is the propagation constant of the unloaded line and “b” is a shunt susceptance. The confinement of the right hand of (2) between -1 and 1 which determine the transmission bands. Since, periodically loaded waveguide constitutes a well-known method for synthesize filters in the microwave theory, in next step periodically DRs is considered for filtering. The equivalent circuit model of microstrip line loaded with periodically DRs is illustrated in Fig. 2.

Figure 2. Equivalent circuit model of periodically loaded DRs on microstrip line.

Where the grey boxes represent the microstrip host transmission line determined by the length of the basic cell d , the propagation constant β and the characteristic impedance Z_0 , and the dielectric resonator is modelled by the series LR-CR branch.

been cured in a conventional oven at 150°C for one hour.

Figure 3(a) shows the fabricated device. The measurements of the fabricated prototype have been done by using a Vectorial Analyzer as can be observed in figure 3(b) the proposed equivalent circuit model offers an excellent fit of the measurements for $L_R=0.25$ nH and $C_R=0.07$ pF.

The proposed structure points out the possibility of using DRs for the creation of filtering and it needs to development to improve the utilization of them as resonators in planar devices.

To improvement of the high rejection level, one approach is use of path between input and output ports and the signals are enforced to cancel each other at the output port by proper adjustment of amplitudes and phases. In this case, by modifying the configuration of the prototype by surrounding DRs with microstrip ring resonator, band pass could be improved. The utilization of microstrip ring resonator and embedded DRs as resonators in planar devices is shown in figure 4. By drilling an array of circle via-slot patterns in a substrate as shown in figure 4(a), waveguide dielectric channel can be created. Layers of the epoxy have been deposited until a thickness of the substrate has been achieved in the resonators as shown in figure 4(b).

3. Results and Discussion

As shown in figure 4(c) the coefficient S_{11} that shows the reflection loss from 2.75 GHz to 4.6 GHz bands and the parameter S_{21} , the insertion loss, is less than -20dB. It also presents a flat response in the pass-band. As can be observed in figure 4(c), there is an excellent agreement

Figure 3. (a) Picture of the fabricated microstrip line loaded with periodically DRs. (b) Measured S-parameter for a 3 stage DRs fitted with the equivalent circuit model showed in Fig. 2.

between simulation, equivalent circuit model and measurement.

As can be observed in figure 4(c), there is an excellent agreement between simulation, equivalent circuit model and measurement.

Figure 4. Picture of the fabricated prototypes (a) Before embedded with DR (b) After embedded with DR. (c) Comparison of simulated, measurement and equivalent circuit model when DRs are embedded in microstrip.

4. Conclusions

This paper shows the ability of the thick film high dielectric constant resonators to be

used as passive elements for the design passive filters in the range of Ku band. The resonator

physical complex behavior leads to the utilization of full 3D electromagnetic software to the design of devices based on these resonators. Also, the proposed circuit models based on the coupling coefficient lets to

establishing a clear relation between the equivalent circuit model and the layout physical dimensions and, therefore establishing a link between the filter specifications and the layout physical dimensions.

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Conflicts of Interest

The authors declare no conflict of interest.

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