Synthesis of Dielectric Resonator for Microwave Filter Designing

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Abstract

In this paper, synthesis of cylindrical dielectric resonators, for the design of transmission mode filters is presented. Dielectric constants of these resonators are calculated from the TE$_{01\delta}$ resonant mode of the DR using Hakki-Coleman method. Microwave band pass filter characteristics are studied by measuring the reflection and transmission characteristics of the dual mode HEM$_{11}$.

Introduction

Dielectric resonators are integrable and provide all the advantages of an integrated circuit in terms of space, weight, etc. and offer higher Q’s as well as better temperature stability over conventional wave guide resonators. Compact bandpass filters using dielectric resonators made of TiO$_2$ have been reported by Cohn [1]. Since then, the availability of high Q temperature compensated dielectric resonators has been advancing tremendously. The dielectric filter technology based on high-Q ceramic materials has been contributing to great size reduction of mobile telecommunication equipment, especially cellular handset and base station. Furthermore, it has great mass productivity and low cost. Significant development efforts have been spent and great progress has been achieved in DR filter technology since the end of 1960’s [2, 3, 4].

There are several possible operating modes for dielectric resonator filters. The list includes single transverse electric (TE) modes, single transverse magnetic (TM) modes, dual hybrid electromagnetic (HEM) modes, triple (TM) modes and triple TE modes. These modes have an impact on the filter size, unloaded Q and spurious performance. Two types of DR filters are the most commonly used. One is the single mode filter operating in the TE$_{01\delta}$ mode, providing low loss and good spurious free performance. Also an elliptic function response can be realized by this type of filter to further reduce the loss and the volume. The most preferred mode of operation when designing DR filter is TE$_{01\delta}$ mode [5, 6]. Other type is the dual mode filter, operating in the HE$_{11}$ mode, providing low loss, smaller volume and elliptic function realizations.

A filter employing the HEM$_{11\delta}$ mode, often which is a dual degenerate mode is analyzed in this paper.

DR- Synthesis Procedure

The DRs are synthesized from TiO$_2$ raw material powders with cylindrical pellet die, of suitable dimensions. High pressures are applied to densely pack the TiO$_2$ powder in the die. The DR pellets thus obtained are then sintered at a high temperature of 1200 °C for 4 hours. The sintered pucks are polished by grinding and smoothening. Cylindrical discs of different aspect ratios (height/diameter) are machined. The dielectric constants of these pellets are measured from the TE$_{01\delta}$ resonant mode excited in Hakki-Coleman measurement setup, as 69.5.

Filter Fabrication

The principal resonant mode is HEM$_{11\delta}$ and the aspect ratio of the resonator, (h/d) is chosen around 0.5 to avoid interference of spurious modes. The orientation of the DR can be either co-axial or transverse as discussed in [3]. The transverse orientation is preferred because in this configuration, DR can be tuned with screws concentric with resonators, so as to avoid spurious mode excitation. The simplest way to integrate the dielectric resonator into a microwave network is placing it on top of a microstrip transmission line. The lateral distance between the resonator and the microstrip conductor determines the amount of coupling between them. The coupling coefficient between the resonator and the transmission line is a function of the distance between the resonator and the line and is given by

$$K = \frac{S_{11}}{S_{21}}$$
Where \( S_{11} \) and \( S_{21} \) are the reflection and transmission coefficients respectively.

DR filters with microstrip line coupled to co-axial port have been developed as shown in the Figure 1 A rectangular cavity of dimension 82 x 82 x 25 mm is fabricated using aluminium metal.

![Diagram of DR filter](image1)

**Figure 1:** Top view of the proposed cavity.

SMA connectors were fixed on the adjacent sides to facilitate connection to the microstrip lines (of dimension 62 x 3 mm\(^2\)) etched on the substrate for the filter. An HP 8510 C network analyzer interfaced with a computer is used for measuring reflection and transmission coefficients (\( S_{22} \) and \( S_{21} \) respectively).

**Results**

Figure 2 shows the return loss (\( S_{22} \)) and transmission coefficient (\( S_{21} \)) of the empty cavity. Measurement has been carried out in the S-band (2-4GHz) of microwave frequencies. The \( S_{22} \) shows no resonance in the 2 to 4 GHz range for this cavity. A cylindrical dielectric resonator of dimensions, height = 6.54 mm and diameter = 19.8 mm is mounted on the stripline and it is positioned so as to get minimum reflection and maximum transmission. Figure 3 shows the characteristics of the dielectric loaded cavity. From the Figure 4 it is found that the first mode being HEM\(_{11\delta}\) of the filter is having a -3 dB bandwidth of 30 MHz centered around 2.38 GHz.

Volume reduction can be achieved by modifying the cavity structure in lieu of the \( Q_{unload} \) of the HEM\(_{11\delta}\) mode[7]. Tuning is possible by varying the height of the metal enclosure above the cavity. By bringing the metal enclosure close to the DR, the resonant frequency of TE\(_{01\delta}\) mode is modified to a new increased value and HEM\(_{11\delta}\) mode is lowered in frequency and becomes the fundamental mode. The reason for such behavior of the resonant frequency can be found in cavity perturbation theory namely when a metal wall of a resonant cavity is moved inwards, the resonant frequency will decrease if the stored energy of the displaced field is predominantly
electric. Otherwise, when the stored energy close to the metal wall is predominantly magnetic as is the case for a shielded TE_{01} dielectric resonator, the resonant frequency will increase when the wall moves inward. The dielectric resonator functions like a resonant cavity by confining the electromagnetic energy in the dielectric and its close vicinity by means of reflections at the dielectric air interface. In order to prevent losses due to radiations, the entire device is usually enclosed in a shielding box made of aluminium.

Conclusion

Band pass filter with dielectric resonator coupled to microstriplines enclosed by aluminium cavity is analyzed. Dielectric resonators are synthesized from TiO\textsubscript{2} for these filters. The reflection and transmission characteristics of the empty cavity and dielectric loaded cavity are studied for the HEM\textsubscript{11δ} dual mode. The filter is having a -3 dB bandwidth of 30 MHz centered around 2.38 GHz.

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