Comparison Between End and Edge Coupling of Dielectric Resonator Coupled with Microstrip Lines

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ABSTRACT

In this paper, a comparison between two methods of coupling, end coupling and edge coupling, between microstrip line and cylindrical dielectric resonator (CDR) in a microwave integrated-circuit (MIC) environment is presented. The dielectric resonator is coupled to both open-circuited and short-circuited microstrip lines. The analysis is performed using the finite-difference time-domain (FDTD) method. It was shown that the end coupling configuration excites the hybrid electromagnetic modes (HEM_{mnp}) with respect to the axis of rotation of the resonator. The edge coupling configuration also excites these modes at almost the same resonant frequencies in addition to the axis symmetric mode $TE_{01\delta}$. The comparison between end coupling and edge coupling configurations shows that the edge coupling has better values for insertion loss when the ends of the microstrip lines are open-circuited, whereas the end coupling offers better mode separation and sharper resonance curves when the ends of the microstrip lines are short-circuited.

INTRODUCTION

Microwave resonators are important components in microwave communication circuits. They create filter and select frequencies in oscillators, amplifiers, and tuners. Conventional microwave resonators made by metallic waveguides are heavy in weight, large in size, and costly to manufacture. They do not allow for an easy integration with monolithic integrated circuits. A more recent advance in miniaturization of microwave circuits has been the appearance of the low-loss temperature-stable dielectric resonators. Dielectric resonators are mainly designed to replace resonant cavities in microwave circuits. Recent developments have revived interest in dielectric resonator applications for a wide variety of microwave circuit configurations and subsystems [1,2].

In a previous paper [3], we have studied in details the end coupling between microstrip line and cylindrical dielectric resonator (CDR) in a microwave integrated-circuit (MIC) environment using the finite-difference time-domain (FDTD) method. Numerical results of the insertion loss characteristic have been obtained. Distributions of the electromagnetic fields of the hybrid modes excited in the resonator have been drawn, in the frequency range of interest, to assign an appropriate name and set of mode indices. The effect of the separation distance between the end of the microstrip line and the dielectric resonator on the loaded quality factor, as well as the coupling coefficient between them is also studied. The aim of this paper is to compare between a CDR end coupled and edge coupled with microstrip line. The CDR coupled to both open-circuited and short-circuited microstrip lines, and their insertion loss characteristics are studied.

FORMULATION OF THE PROBLEM

The configuration of the end coupling between a microstrip line and a CDR is illustrated in Fig. 1(a). The characteristic impedance of the microstrip lines is 50 Ω. The diameter and height of the CDR are 5 mm, and 1.7 mm, respectively. The DR used in this study is made of zirconate ceramics, which has a dielectric constant, ε_r, of 38.8 and a dielectric quality factor, Q_d, of 37500 at 10 GHz [4]. The substrate has a dielectric constant, ε_s, of 9.5 and a thickness of 0.85 mm. The separation distance between each end of the microstrip line and the CDR is symmetrical and denoted by S.

When a DR is end coupled with a microstrip line, this structure works as a band-pass filter (BPF) just like a structure consisting of a waveguide and a transmission-type cavity [3]. As shown in Fig. 1(a), the mechanism of coupling between the input and output microstrip lines and the resonator is based on the end coupling. Referring to Fig. 1(b), also this structure works as a BPF but the mechanism of coupling is based on the edge coupling. The separation distance between the edge of the input and output microstrip lines and the CDR is also denoted by S.

The problem is solved using the finite-difference time-domain (FDTD) method. The perfectly matched layer (PML) boundary condition has been used as a means to truncate the FDTD lattice. In modeling the curved surface of a CDR, a conformal FDTD technique is used [5].

NUMERICAL RESULTS

End Coupling

For the end coupling configuration, the variation of the insertion loss with frequency for S=1.06 mm for both short-circuited and open-circuited end of the input and output microstrip lines is shown in Fig. 2. Since the hybrid modes have been found to be excited and coupled to the microstrip lines through the magnetic field action [3], consequently, short-circuiting the end of the microstrip lines increases (maximizes) the magnetic coupling since the magnetic field is maximum at the short circuit. Therefore, the insertion loss values obtained in this case are improved, as clearly shown in Fig. 2.

On the other hand, if the end of the microstrip lines is open-circuited, this end acts as a magnetic wall and hence the electric field is maximum there. In this case, the coupling is not strong as in the first case (short-circuited end). This is clearly observed from the resulting insertion loss characteristics in the two cases.

From the insertion loss characteristics, it can be seen that five modes are excited in the DR in the frequency range from 0 to 20 GHz. There are also many higher order modes at frequencies above 20 GHz. However, we intend to cover the frequency range of operation used in microstrip circuits, up to 20 GHz. The five resonances occur at resonant frequency of about 8.050, 12.275, 15.825, 16.700, and 19.175 GHz, respectively. These modes are the hybrid electromagnetic modes $HEM_{11\delta}$, $HEM_{21\delta}$, $HEM_{31\delta}$, $HEM_{21,1+\delta}$, and $HEM_{41\delta}$, respectively [3]. In addition, there is another mode excited at the resonant frequency of about 12.825 GHz in case of open-circuited microstrip lines. This mode is the hybrid electromagnetic mode $HEM_{11,1+\delta}$.

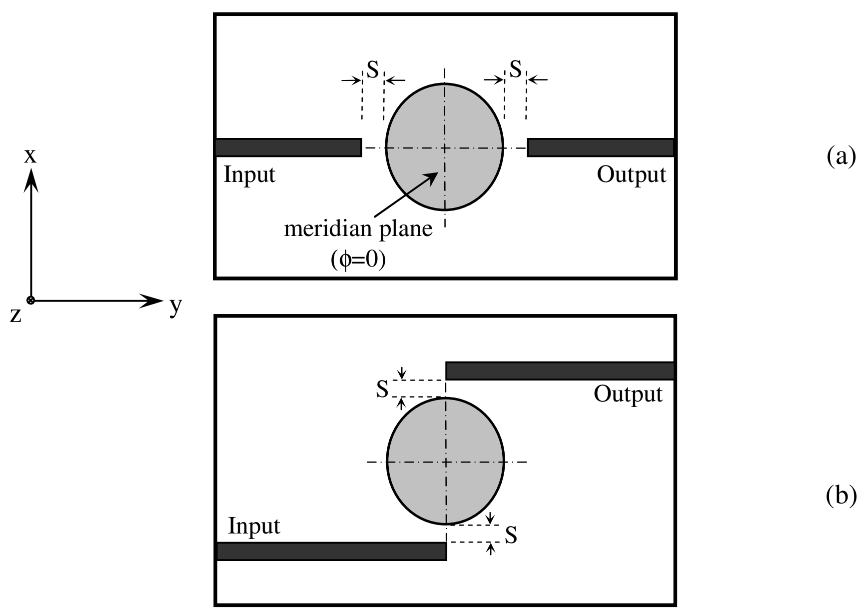

Fig. 1. Top view of the configuration of the (a) end coupling, (b) edge coupling between microstrip line and CDR in a MIC environment

Edge Coupling

For the edge coupling configuration, the variation of the insertion loss with frequency for S=1.06 mm for both open-circuited and short-circuited end of the input and output microstrip lines is also shown in Fig. 2. It can be observed that the values of the insertion loss are much better in case of open-circuited microstrip lines. This is in contrast to those of the end coupling, in which the short-circuited microstrip lines give low insertion loss values.

On the other hand, if theses characteristics are compared with that of the end coupling, it is clearly observed that there is another mode excited at resonant frequency of about 13.7 GHz (this mode is not excited in the end coupling case) which has the lowest insertion loss value among all of the excited modes in case of the open-circuited microstrip lines. This mode is the axis symmetric mode $TE_{01\delta}$. This mode is not observed in the case of end coupling because of the even symmetry which may be represented by a magnetic wall in one of the meridian planes.

As explained in [4], one method by which the ϕ-independent TE mode, $TE_{01\delta}$, can be excited is to place the resonator besides the microstrip line and hence it is magnetically excited. As expected, this situation is verified here in case of the edge coupling shown in Fig. 1(b) where the magnetic field of the microstrip line can link with those of the resonator.

COMPARISON BETWEEN END COUPLING AND EDGE COUPLING

When a pure sine wave is used as an input signal at each of the resonant frequencies of all modes excited in the two configurations mentioned above, the field distributions of the corresponding mode can be observed, and hence it can be identified. All modes that are excited in each case of coupling for short-, and open-circuited microstrip lines are summarized in Table 1.

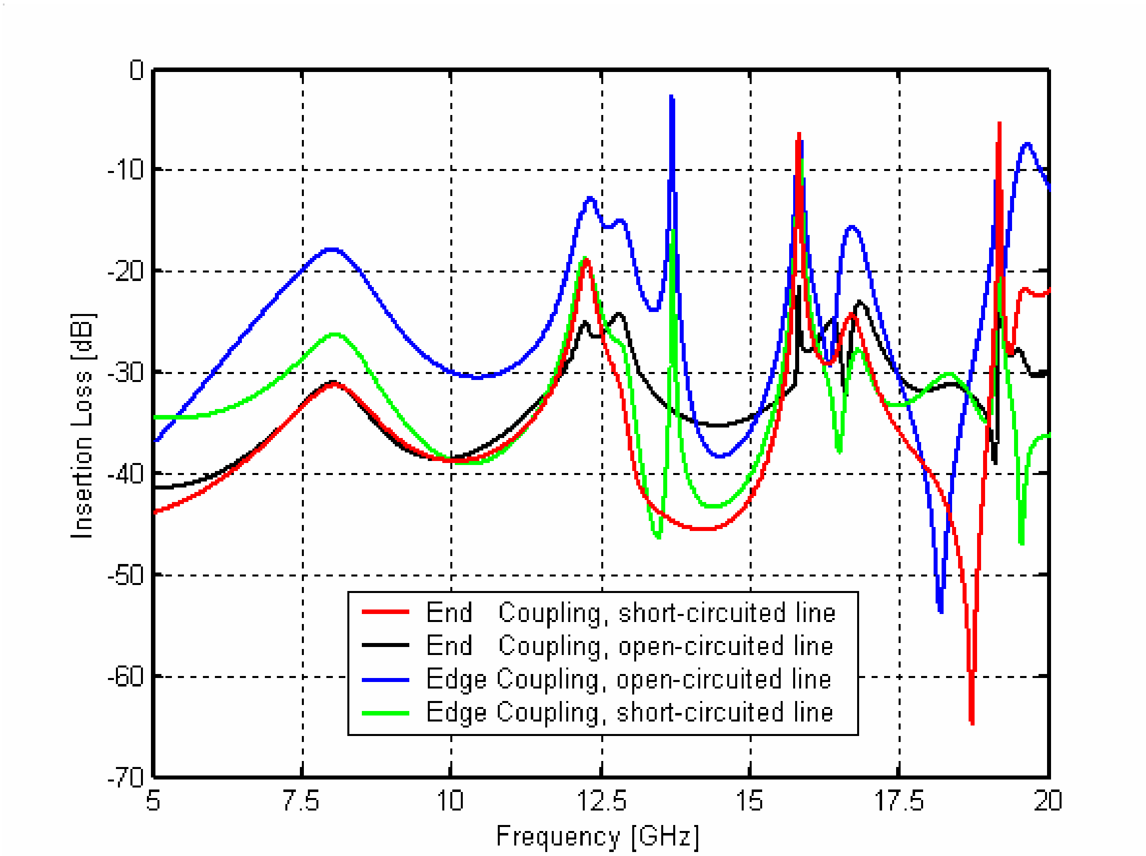

Fig. 2. A comparison of the insertion loss characteristic of the end coupling with both short-circuited and open-circuited microstrip lines with that of the edge coupling

Table 1 The resonant frequency in GHz for the excited modes in case of end and edge coupling

Coupling Type / Mode	End	End	Edge	Edge
	S.C*	O.C**	S.C	O.C
$HEM_{11\delta}$	8.050	8.050	8.025	8.025
$HEM_{21\delta}$	12.275	12.275	12.325	12.325
$HEM_{11,1+\delta}$	---	12.825	---	12.825
$TE_{01\delta}$	---	---	13.700	13.700
$HEM_{31\delta}$	15.825	15.825	15.850	15.850
$HEM_{21,1+\delta}$	16.700	16.850	16.725	16.725
$HEM_{41\delta}$	19.175	19.175	19.175	19.175

* Short circuited microstrip lines, ** Open circuited microstrip lines, --- Not excited.

Referring to Fig. 2, it can be shown that the two characteristics of the short-circuited end lines almost give the same insertion loss values as well as quality factors for the $HEM_{21\delta}$, $HEM_{31\delta}$, and $HEM_{41\delta}$ modes except that the end coupling offers mode separation better than that of the edge coupling. This is because of the presence of another excited mode in the later case, that is the $TE_{01\delta}$ mode. But in the case of open-circuited microstrip lines, it is clearly observed that the edge coupling gives much better characteristics. Therefore, if the CDR is end-coupled with the microstrip lines, the microstrip lines should be short-circuited, and if it is edge-coupled, they should be open-circuited. In this case, the end coupling offers better mode separation as well as sharper resonance curves than that of the edge coupling. Therefore, this configuration of coupling introduces generally better characteristic. But if the $TE_{01\delta}$ mode is the desired mode of operation, the edge coupling configuration is the suitable one. Moreover, the end coupling configuration shown in Fig. 1(a) is more compact than the edge coupling one shown in Fig. 1(b) which leads to a much smaller computational domain and hence the time consuming is shorter.

CONCLUSIONS

In this work, the coupling between dielectric resonators and microstrip lines is studied using the FDTD method. A comparison between end and edge coupling is made. It was found that the end coupling excites hybrid modes only unlike the edge coupling that excites the axis symmetric mode in addition to the hybrid modes. It was also found that short-circuiting the microstrip lines improves the end coupling in contrast with the edge coupling which is improved when the ends of the lines are left open. The edge coupling has better values for insertion loss whereas end coupling has better mode separation and sharper resonances. Furthermore, the end coupling configuration is more compact and occupies less area on the microstrip circuit than the edge coupling one.

REFERENCES

[1] J.K.Plourde and C-Li.Ren, "Application of dielectric resonators in microwave components," *IEEE Trans. Microwave Theory Tech.*, vol. 29, pp. 754-770, August 1981.
[2] R.R.Bonetti and A.E.Atia, "Analysis of microstrip circuits coupled to dielectric resonators," *IEEE Trans. Microwave Theory Tech.*, pp. 1333-1337, December 1981.
[3] A. M. Ghuniem, A. A. Mitkees, and N. T. Messiha, "Excitation of the hybrid electromagnetic modes of cylindrical dielectric resonator," *4th International Conference on Electrical Engineering (ICEEG2004)*, MTC, Cairo, Egypt, AW4, pp. 1-12, Nov. 23-25, 2004.
[4] D. Kajfez and P. Guillon, *Dielectric Resonators*, Norwood, MA: Artech House, 1986.
[5] S. Dey and R. Mittra, "A conformal finite-difference time-domain technique for modeling cylindrical dielectric resonator," *IEEE Trans. Microwave Theory Tech.*, vol. 47, pp. 1737-1739, Sept. 1999.