Coupling between Coplanar Waveguide and TE_{01δ} Mode Dielectric Resonator

Jong Hyuk Kim and Ihn S. Kim

College of Electronics and Information, KyungHee University,
1 Seochon, Kihung, Yongin, Kyungki-do, 449-701, South Korea,
Tel : +82-31-201-2587, email : ihnkim@khu.ac.kr

Abstracts — This paper presents that coupling between a coplanar waveguide (CPW) and a TE_{01δ} mode DR (Dielectric Resonator) can be realized for a parallel resonant characteristic as a DR coupling structure in a microstrip line. It shows that different place of the DR on a CPW from that of the DR on a microstrip line is required. FEM simulation (HFSS) results in terms of S-parameters agree well with measurement results. Finally, a slit structure on a CPW is proposed for sharper resonant characteristics.

I. INTRODUCTION

Cylindrical dielectric resonators (DRs) have been considered as frequency selective elements in microwave circuits due to their simple structure, commercial availability, and easy tuning. So, the application of the DRs particularly in various microwave filters and oscillators has been increased in the last decades [1],[2] because of their high Q characteristic, low cost, small size, temperature stability, and compatibility with planar transmission media, such as microwave integrated circuits (MICs) and monolithic microwave integrated circuits (MMIC’s).

Coupling of a planar transmission medium to a cylindrical TE_{01δ} mode DR has been realized in mostly microstrip line structures for designing filters, oscillators, and other frequency selective circuits. The reason why microstrip structures have been exclusively adopted for the circuits may be that various coupling information between the DRs and microstrip lines for MIC and MMIC applications has been published in the literature [1]-[9] until quite recently and very well known.

In the last decade, however, the trend of (M)MIC planar circuit design has been slowly shifting from microstrip structure to CPW for the various advantages over the former [10]-[12]. Coupling information of the DR to various CPW configurations has been needed for CPW circuit designs. But, very limited number of research on this subject has been shown in the literature; a paper based on coupling of a CPW to a DR operating in whispering gallery mode was appeared in [13] and a couple of papers were published on coupling of CPWs to DR antennas[14],[15]. And even in CPW DRO (Dielectric Resonator Oscillator) circuits [16]-[18], coupling part of a DR to a microstrip line was used for frequency stabilization characteristic, instead of the consistent use of a CPW as a transmission medium.

No paper has been published on coupling information between a CPW and a TE_{01δ} mode DR as a parallel resonant structure in microstrip line environment.

This paper reports that a CPW coupled with the DR can be used to obtain a parallel resonant characteristic as in a microstrip line coupled with the DR and shows that a different location of the DR from that of the DR on a microstrip line is required for a CPW. A coupling property, in terms of S-parameters, between a CPW and a TE_{01δ} mode DR is investigated with HFSS (High Frequency Structure Simulator : Finite Element Method Commercial Tool) simulation and experiment. And the simulation results are compared with experimental results.

Fig. 1. Configuration of (a) a top and (b) a cross sectional view of coupling structure between a CPW and a TE_{01δ} mode DR.
Fig. 2.Equivalent circuit for the coupling structure examined in this study.

Finally, a slit structure on a CPW is proposed for sharper resonant characteristics

II. STRUCTURE AND MODELLING

If a cylindrical DR is placed on a slot of a CPW as shown in Fig. 1, the TE_{010} mode is excited. The transmission property is modified by the magnetic effect as in the structure of a microstrip line coupled with a DR. In order to model the transmission property, we consider the structure which has a top and a cross sectional views as shown in Fig. 1. The DR (DRD051U E022; Murata) is placed on either one of two slots between a center strip conductor and two ground planes in a CPW without ground plane where a wide center strip has been used for modeling. The DR has resonant frequency at 10 GHz. The structure is based on a substrate with dielectric constant of 2.52 and a thickness of 0.54 mm. The CPW has dimensions such as 3.8 mm for width of center strip and 0.182 mm slot width. The coupling property has been investigated by placing the DR on a special support above the CPW and by moving the DR away from the center of a slot of the CPW to the ground plane. The support is a dielectric material which has a dielectric constant of 2.2 and a height H. Note that coupling property is depending on the height.

The DR coupled with the CPW is identical to a parallel resonant circuit placed in series with the line as shown in Fig. 2. This circuit can be modeled in terms of S-parameters as the DR coupled with a microstrip line[5].

\[
S_{11} = \frac{Z_i/Z_o e^{-j\theta}}{2 + Z_i/Z_o} \\
S_{21} = \frac{2 e^{-j\theta}}{2 + Z_i/Z_o}
\]

where \( \theta \) is the electrical length of the CPW in Fig. 2. And, the input impedance

\[
Z_i = \frac{Z_o}{1 + jX}
\]

where

\[ Z_i = \omega_o Q_o \frac{L_i}{L_c} \]

\[ X = \frac{2\Delta\omega}{\omega_o} \] with \( \Delta\omega = \omega - \omega_o \).

\( \omega_o \) is a resonant frequency. \( Q_o \) unloaded quality factor, \( L_i \) mutual inductance, and \( L_c \) DR’s inductance.

III. SIMULATION AND MEASUREMENT

The structure has been simulated with HFSS and measured with Anritsu 37269C network analyzer at 10 GHz. The DR is placed on the center strip of the CPW. As a first step, the coupling property of the structure has been investigated, as the height H is increased. Secondly, coupling property is examined, as the distance D from the center strip is increased. The D is initially located at the center of the slot. An optimum height of the support was found at H = 1 mm. Then, \( S_{11} \) and \( S_{21} \) characteristics have been simulated and measured at H = 1 mm as the distance D is increased. These simulated and measured S-parameter characteristics are compared in Figs. 3 and 4.

The simulation results agree well with the measured results. For \( S_{11} \) characteristics in Fig. 3, there is a constant difference between the simulated and measured results. The reason why the difference exists may be that there is mismatch loss between the CPW and a coaxial connector in the test circuit. At D = 1.2 mm, we can observe that the lowest \( S_{21} \) and around 0 dB return loss characteristics are obtained. And, finally, a slit structure on a CPW is proposed for sharper resonant characteristics.

We measured \( |S_{11}| \) characteristics of the DR coupling structure with a slit. The \( |S_{11}| \) characteristics of the DR coupling structure with a slit is compared with the structure without a slit in Fig. 5. The comparison demonstrates that the DR coupling structure with a slit has slightly sharper \( |S_{11}| \) characteristics than those of the DR coupling structure without a slit.

Fig. 3. Comparison of simulated and measured \( |S_{11}| \) characteristics with respect to the variation of the distance D at H = 1 mm.
IV. CONCLUSION

Coupling characteristics between a CPW and a TE_{011} mode DR have been investigated in terms of S-parameters. Simulation and measurement results show that a CPW coupled with the DR can be used for a parallel resonant element as the DR in microstrip line environment. Furthermore, this study demonstrates that a DR coupled with CPW with a slit has slightly sharper \(|S_{21}|\) characteristics than the DR coupling structure without a slit.

![Graph showing comparison of simulated and measured \(|S_{21}|\) characteristics with respect to the variation of the distance D at H = 1 mm.](image1)

Fig. 4. Comparison of simulated and measured \(|S_{21}|\) characteristics with respect to the variation of the distance D at H = 1 mm.

![Graph showing comparison of measured \(|S_{21}|\) characteristics for the coupling structure with and without slit with respect to the variation of the distance D at H = 1 mm.](image2)

Fig. 5. Comparison of measured \(|S_{21}|\) characteristics for the coupling structure with and without slit with respect to the variation of the distance D at H = 1 mm.

REFERENCES
