Coupling between Coplanar Waveguide and $TE_{01\delta}$ Mode Dielectric Resonator

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Abstracts **— This paper presents that coupling between a coplanar waveguide(CPW) and a $TE_{01\delta}$ 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 three 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 $TE_{01\delta}$ 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 pulished 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

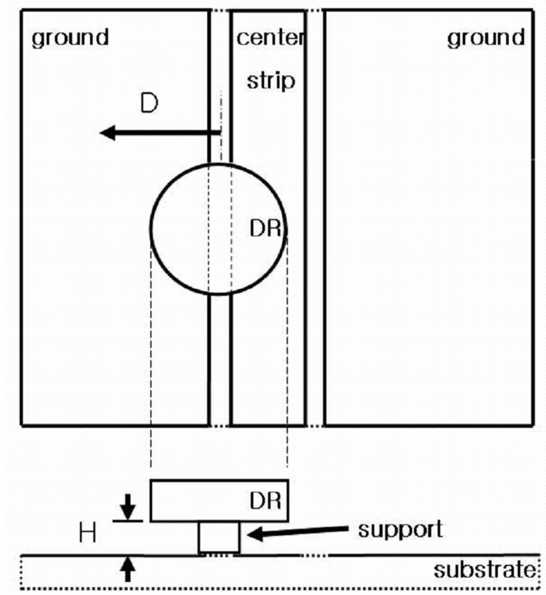

Fig. 1. Configuration of (a) a top and (b) a cross sectional view of coupling structure between a CPW and a $TE_{01\delta}$ mode DR.

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 $TE_{01\delta}$ mode DR as a parallel resonant structure in microstrip line environement.

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 $TE_{01\delta}$ 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.

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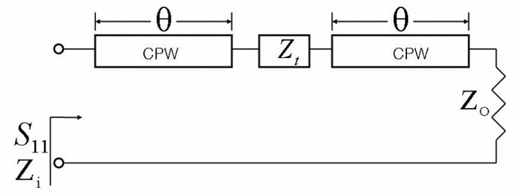

Fig. 2. Equivalent circuit for the coupling structure examined in this study.

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

II. STRUCTURE AND MODELING

If a cylindrical DR is placed on a slot of a CPW as shown in Fig. 1, the $TE_{01\delta}$ 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].

$$S_{11} = \frac{Z_t / Z_o}{2 + Z_t / Z_o} e^{-2j\theta} \quad (1)$$

$$S_{21} = \frac{2}{2 + Z_t / Z_o} e^{-2j\theta} \quad (2)$$

where θ is the electrical length of the CPW in Fig. 2. And, the input impedance

$$Z_i = \frac{Z_t}{1 + jX} \quad (3)$$

where

$$Z_t = \omega_O Q_O \frac{L_m^2}{L_r},$$

$$X = \frac{2\Delta\omega}{\omega_O} \quad \text{with} \quad \Delta\omega = \omega - \omega_O,$$

ω_O is a resonant frequency, Q_O unloaded quality factor, L_m mutual inductance, and L_r DR's inductance.

III. SIMULATION AND MESUREMENT

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_{21} 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 strucure on a CPW is proposed for sharper resonant characterisitcs. We measured $|S_{21}|$ characteristics of the DR coupling strucutre with a slit. The $|S_{21}|$ characteristics of the DR coupling strucutre with a slit is compared with the structure without a slit in Fig. 5.. The comparison demonstrates that the DR coupling strucutre with a slit has slightly sharper $|S_{21}|$ characteristics than those of the DR coupling strucutre without a slit.

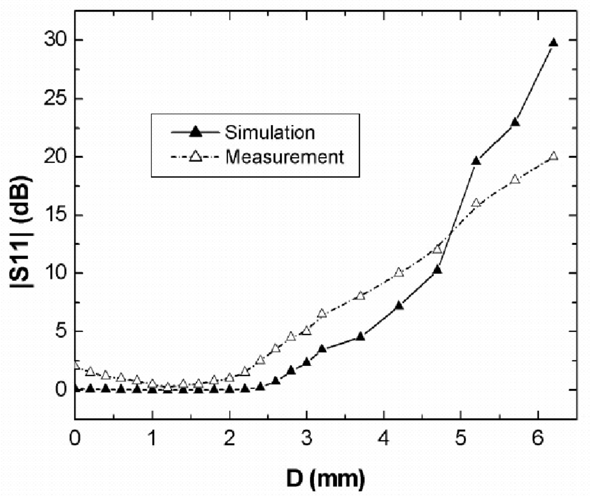

Fig. 3. Comparison of simulated and measured $|S_{11}|$ characteristics with respect to the variation of the distance D at H = 1 mm.

IV. CONCLUSION

Coupling characteristics between a CPW and a $TE_{01\delta}$ mode DR have been investigated in terms of S-parameters. Simulation and measurement results shows that a CPW coupled with the DR can be used for a parallel resonant element as the DR in microstrip line environement. Furtheremore, 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.

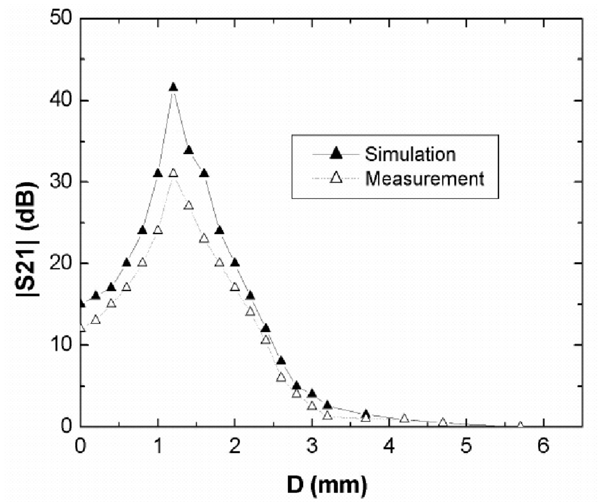

Fig. 4. Comparison of simulated and measured $|S_{21}|$ characteristics with respect to the variation of the distance D at H = 1 mm.

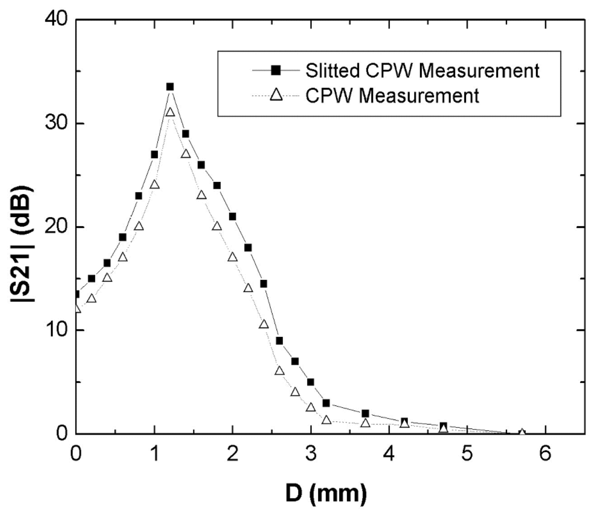

Fig. 5. Comparison of measured $|S_{21}|$ characteristics for the coupling structure with and without slit with respect to the variation of the distance D at H = 1 mm.

REFERENCES

[1] D. Kajfez and P. Guillon, Dielectric Resonators, Second Ed., Noble Publishing Co., pp. 379-430, 1998.

[2] S. J. Fiedziuszko and S. Holme, " Dielectric Resonators," IEEE Microwave Magazine, pp.51-60, Sept. 2001.

[3] P. Guillon and Y. Garault, "Coupling between a Microstrip Transmission Line and a Dielectric Resonator," 1976 IEEE MTT-S International, pp.200-202, June 1976.

[4] Y. Komatsu, Y. Murakami, "Coupling Coefficient between Microstrip Line and Dielectric Resonator," IEEE Transactions on Microwave Theory and Techniques," Vol. 83, No. 1, Pages:34 - 40. Jan 1983.

[5] P. Guillon, B. Byzery, and M. Chaubet, " Coupling Parameter between a Dielectric Resonator and a Microstripline," IEEE Trans. Microwave Tech., Vol. 33, No. 3, pp.222-226, Mar. 1985.

[6] X. P. Peng and K. A. Zaki, " Hybrid Mode Coupling of Dielectric Resonators to Microstrip Lines," 1990 IEEE MTT-S International, pp.395-398, June 1990.

[7] D. Kajfez and J. Guo, " Precision Measurement of Coupling between Microstrip and TE01 Mode Dielectric Resonators," Electronics Letters, Vol. 30, No.21, pp.1771-1772, Oct. 1994.

[8] K. Hosoya, T. Inoue, M. Funabashi, and K. Ohata, "Systematic Evaluation and Analysis for 60 GHz Dielectric Resonators Coupled to a Microstrip Line on a GaAs Substrate," IEEE Trans. Microwave Theory & Tech., Vol. 46, No. 4, pp. 352-358, April 1998.

[9] A. M. Ghuniem, A. Mitkees, and N. T. Messiha, "Analysis of End Coupling between Microstrip Line and Cylindrical Dielectric Resonator Using the FDTD Method," 21st National Radio Science Conference(NRSC2004), Proceedings of the Twenty First, pp.B23-1-8, March 2004.

[10] R. N. Simons, Coplanar Waveguide Circuits, Components, and Systems, Wiley Interscience, 2001.

[11] G. E. Ponchak, "Experimental Analysis of Reduced-sized Coplanar Waveguide Transmission Lines," 2003 IEEE MTT-S International, Vol. 2, pp.971 – 974, June 2003.

[12] V. S. Mottonen, "Wideband Coplanar Waveguide-to-Rectangular Waveguide Transition Using Fin-Line Taper," IEEE Microwave and Wireless Components Letters, Vol. 15 , No. 2 , pp. 119 – 121, Feb. 2005.

[13] B. Guillon, et al, " Design and Realization of High Q Millimeter-wave Structures through Micromaching Techniques," 1999 IEEE MTT-S International, Vol. 4, pp.1519 – 1522, June 1999.

[14] Y. Guo and K Luk, "Dual-Polarized Dielectric Resonator Antennas," IEEE Trans. Antennas and Propagation, Vol. 51, No. 5, pp.1120-1123, May 2003.

[15] Y. Guo and K. Luk, " On Improving Coupling between a Coplanar Waveguide Feed and a Dielectric Resonator Antennas," IEEE Trans. Antennas and Propagation, Vol. 51, No. 8, pp.2144-2146, Aug. 2003.

[16] R. N. Simons, and R. Q. Lee, "Planar Dielectric Resonator Stabilized HEMT Oscillator Integrated with/Aperture Coupled Patch Antenna," 1992 IEEE MTT-S International, pp.433-436, Vol. 1, 1-5 June 1992.

[17] G. Baumann, D. Hollmann, and R. Heilig, " A 29 GHz DRO in Coplanar Waveguide Configuration with an AlGaAs HEMT," Integrated Nonlinear Microwave and Millimeterwave Circuits, Third International Workshop, 5-7 Oct. 1994.

[18] H.C. Duran, U. Lott, H. Benedickter, and W. Bachtold, " A K-band DRO in Coplanar Layout with Dry and Wet Etched InP HEMTs," 1998 IEEE MTT-S International, Vol. 2, pp.861-863, June 1998.