DIELECTRIC RESONATOR $HE_{11\,\delta+1}$ MODE COUPLING TO A SHIELDED MICROSTRIP LINE.

A.P.S. KHANNA
GIGA INSTRUMENTATION
Immeuble Atlas - Av. Baltique
Z.A. Courtaboeuf Les Ulis
91941 FRANCE.
(now with Frequency Sources, Inc., Lanham, MD 20706)

and Y. GARAULT - M. GUEDIRA
Lab. Electronique des Microondes - L.A. n° 356 du CNRS
123, rue Albert Thomas 87060 LIMOGES Cedex
- FRANCE -.

Abstract :

A configuration is presented to effectively couple a dielectric resonator to a microstrip line using the $HE_{11\delta+1}$ mode. For this mode, the resonator acts as a magnetic dipole perpendicular to the resonator axis. The $f_0\,Q_0$ product is improved by about 50 % compared to $TE_{01\delta}$ mode.

Introduction :

Recent developments of the stable dielectric resonators has generated a lot of interest in their use in the active and passive MIC circuits (I). In the past the attention has been mainly directed towards the applications of $TE_{01\delta}$ mode in the microwave integrated circuits which is considered fundamental. The higher order and hybrid modes have either low quality factors or are difficult to couple to a microstrip line in the commonly used configuration. The $HE_{11\delta+1}$ mode is known to have a resonant frequency higher than that of $TE_{01\delta}$ mode for certain diameter/height ratios of the dielectric resonator . The configuration presented here allows the effective coupling of the $HE_{11\delta+1}$ mode which has an increased resonant frequency as well as unloaded quality factor as compared to that of the commonly used $TE_{01\delta}$ mode configuration. Experimental results of the $HE_{11\delta+1}$ mode coupling to a shielded microstrip line, are presented and compared to $TE_{01\delta}$ mode at C and X band.

For millimetric wave applications the reduced size of the $TE_{01\delta}$ mode dielectric resonator creates coupling problems. The $HE_{11\delta+1}$ mode, with a more practical size for coupling and a higher quality factor, is expected to offer a practical solution.

$HE_{11\delta+1}$ mode coupling : $(0 < \delta < 1)$

Field patterns of the open dielectric resonator $HE_{11\delta+1}$ mode is presented in fig.I. Here $HE_{11\delta+1}$ designates the hybrid resonant mode for which the resonator acts as a deformed magnetic dipole perpendicular to the cylindrical axis. In the same way $HE_{11\delta}$ will designate the resonant hybrid mode for which the resonator acts as a deformed electric dipole perpendicular to resonator axis. The resemblance of the $HE_{11\delta+1}$ field patterns to that of a magnetic dipole suggest the possibility of the magnetic coupling of this mode.
Fig. 2a shows the commonly used $TE_{01\delta}$ mode and the proposed $HE_{11\delta+1}$ mode magnetic coupling to a shielded microstrip line (fig. 2b and 2c).

Fiedziuszko recently {2} presented the calculations of resonant frequency for the shielded $HE_{11\delta}$ **mode.** In the limiting case where the shield coincides with dielectric resonator walls, we obtain a metalised D.R. In this case, the $HE_{11\delta+1}$ mode will degenerate in a TE_{112} mode and the $HE_{11\delta}$ in a TE_{111} mode. This is consistent with the increase of resonant frequency when the shield is brought nearer to the D.R. as confirmed by calculations using the same shielded configuration as in {2}.This theoretical situation with metallic walls nearer D.R. is not far from the experimental one where the resonator is placed on a shielded substrate with it axis parallel to the substrate plane(fig.2b, 2c).Presently such an experimental configuration cannot be rigourously treated theoretically except by means of 3D finite elements.

The equivalent circuit of the $HE_{11\delta+1}$ mode resembles that of $TE_{01\delta}$ mode (fig.3) with the coupling coefficient β defined as {3} :

$$\beta = \frac{S_{110}}{S_{210}} = \frac{S_{110}}{I-S_{110}} = \frac{I-S_{210}}{S_{210}}$$

where S_{110} and S_{210} represent the reflection and transmission coefficients at the resonant frequency in the symmetry plane of the dielectric resonator. Under fixed shielding conditions, β is a function of the distance between the resonator and the line.

In the proposed configuration, the $TE_{01\delta}$ mode is not excited due to the axial orientation of the resonator. We think that the increased unloaded quality factor is due to inherent higher stored energy in the $HE_{11\delta+1}$ mode as well as due to the fact that with respect to the $TE_{01\delta}$ mode configuration, the largest part of the resonator is farther from the substrate ground plane.

The $HE_{11\delta+1}$ mode can equally well be excited by rotating the dielectric resonator around its vertical axis (fig.2c), providing, thus, an additional control parameter for adjusting the magnitude and phase of the reflection and transmission coefficient.

Simultaneous coupling of the $HE_{11\delta+1}$ mode with two microstrip lines in the short circuit plane results in a passband filter with a higher selectivity than that achieved with $TE_{01\delta}$ mode.

Experimental Observations :

Figure 4 presents the typical transmission and reflection coefficient of the microstrip coupled dielectric resonator $HE_{11\delta+1}$ mode (fig.3) for different values of the distance between the microstrip line and the resonator. This shows that coupling coefficients as high as 10 can be obtained for $HE_{11\delta+1}$ mode.

Table I shows the $TE_{01\delta}$ and $HE_{11\delta+1}$ mode resonant frequencies as well as the unloaded quality factors determined from the transmission coefficient measurements {3} . Using the configurations shown in Fig.2(a) and 2(b).

Figure 5 presents the increase in the $f_0\ Q_0$ product of $HE_{11\delta+1}$ mode compared to $TE_{01\delta}$ mode for the same dielectric resonator. It can be noted that for the commonly used dielectric resonators ($2 < D/H < 3$) the f_0Q_0 product of $HE_{11\delta+1}$ mode is about 50 % higher than that of $TE_{01\delta}$ mode.

For the applications at higher frequencies, as the reduced volume V of the dielectric resonator creates coupling problems, a figure of merit f_0Q_0V can be defined. Referring to the table above, for example, in the case of resonator 5 and 6, the improvement in f_0Q_0V is 2.3 by using the $HE_{11\delta+1}$ mode instead of $TE_{01\delta}$ mode.

Acknowledgements

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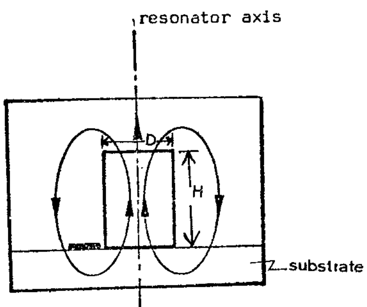

Fig.2a-$TE_{01\delta}$ mode excitation - resonator axis perpendicular to substrate plane.

TABLE 1

N°	D. Resonat. Dimensions ($\varepsilon_r = 37$) Diam.D mms	Height H mms	D/H	Volume mm3	$TE_{01\delta}$ f_0 MHz	Q_0	$HE_{11\delta+1}$ f_0 MHz	Q_0
1	4	4	1	50	11 529	3 043	11 535	3062
2	6	4	1.5	113	8 563	3 592	9 305	4 896
3	8	5	1.6	257	6 743	4 000	7 401	5 340
4	5.5	3	1.83	71	9 577	3 870	11 034	4 597
5	7	3.6	1.94	138	7 865	3 745	9 168	4 990
6	6	3	2	84	9 179	3 530	10 827	3 866
7	4.6	2.16	2.12	36	11 912	3 219	14 288	3 663
8	8.5	3.7	2.29	209	6 894	4 055	8 270	5 069
9	6	2.4	2.5	67	9 980	2 625	12 480	2 773
10	10	2.7	3.7	212	6 950	3 120	11 144	3 520

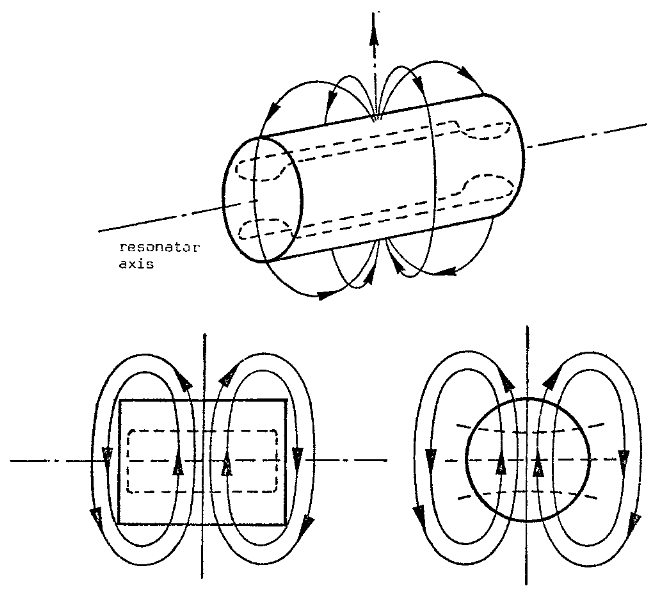

Fig.1: $HE_{11\delta+1}$ transversal magnetic dipolar mode field configuration.

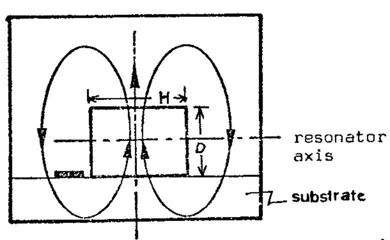

Fig.2b-$HE_{11\delta+1}$ transversal magnetic dipolar mode excitation-resonator axis perpendicular to microstrip line.

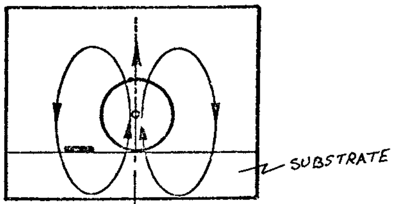

Fig.2c-$HE_{11\delta+1}$ tranversal magnetic dipolar mode excitation-resonator axis parallel to microstrip line.

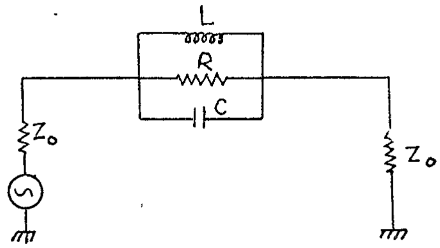

Fig.3 : Equivalent Circuit of a D.R. $HE_{11\delta+1}$ mode coupled to a microstrip line.

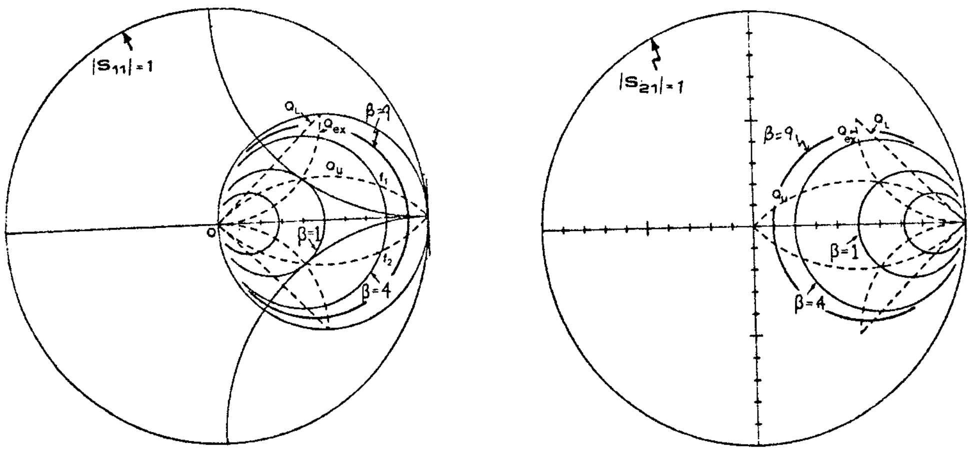

Fig.4 : Reflection and transmission coefficient of a dielectric resonator $HE_{11\delta+1}$ mode coupled to a shielded microstrip line.

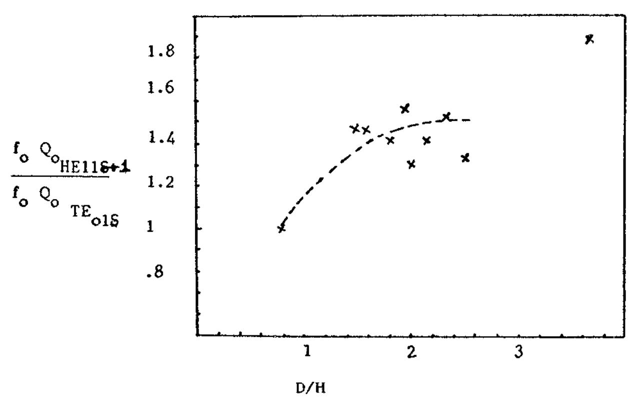

Fig.5 Comparison of $f_o\ Q_o$ product of $TE_{o1\delta}$ and $HE_{11\delta+1}$ mode coupled to a microstrip line