# DIELECTRIC COMBLINE RESONATORS AND FILTERS

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## ABSTRACT

By replacing the inner conductor of the conventional combline resonator with a high $\epsilon_r$ dielectric rod, higher unloaded $Q$ of the resonator can be expected. Resonant frequency, unloaded $Q$ and coupling coefficient of the resonator are obtained by rigorous mode matching method. An 8-pole elliptic function dielectric combline resonator filter is designed. Good frequency responses are obtained.

## I. INTRODUCTION

High performance microwave cavity filters are finding increasing applications in satellite and mobile communication systems. Coaxial combline resonator filters and dielectric loaded resonator filters are commonly used in the systems, because of small size and their unique characteristics. Coaxial resonators have low cost, wide tuning range and excellent spurious free performance[1][2][9]; while dielectric loaded resonator filters have very low loss and high temperature stability [3]-[8]. The draw back of the combline resonator filters is their relatively high loss, because of the low unloaded $Q$ of the resonator. The draw back of the dielectric loaded resonator is higher cost and poor spurious performance.

The lower unloaded $Q$ of the combline resonator compared with the dielectric loaded resonator is mostly due to the additional conductor loss from the inner conductor. The electromagnetic fields vary according to $1/r$ relation along the radial direction. As a result, large current is induced on the surface of the inner conductor, and limits the unloaded $Q$ of the coaxial resonator. The perfect conducting boundary condition (PEC) can be replaced by dielectric material with infinite dielectric constant ($\epsilon_r \rightarrow \infty$). Although infinite dielectric constant material can not be obtained, dielectrics with high relative dielectric constant can achieve similar condition. Since the magnetic field is continuous at the boundary of the dielectrics, no electric current is induced on the dielectric rod, thus higher unloaded $Q$ can be expected. Replacing the inner conductor of the re-entrant resonator by a high $\epsilon_r$ dielectric rod, a novel type of coaxial resonator, *i.e.* Dielectric Combline Resonator, with high unloaded $Q$ and the merits of the re-entrant cavity can be obtained.

In this paper, the dielectric combline resonator and filter, are introduced. By replacing the inner conductor of the conventional combline resonator by a high $\epsilon_r$ dielectric rod, higher unloaded $Q$ than the conventional combline resonator is obtained. The use of the dielectric combline resonator in the filters to replace the conventional combline resonators either fully or partially achieve the advantage of both combline resonator filters and the dielectric loaded resonator filters.

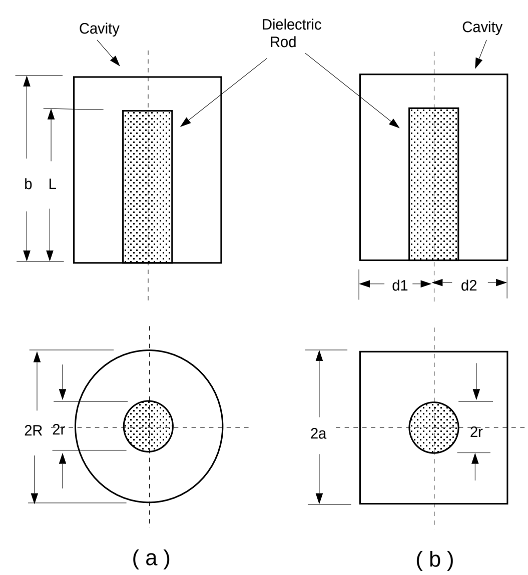


Fig. 1. Configurations of the dielectric combline resonators (a) cylindrical enclosure; (b) rectangular enclosure

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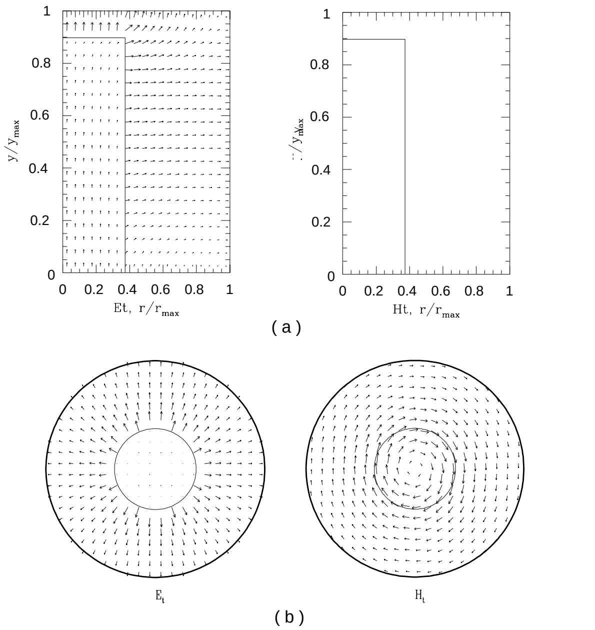


Fig. 2. Field distributions of a dielectric combline resonator (a) $r-y$ plane; (b) $r-\phi$ plane

## II. CONFIGURATION AND ANALYSIS

Typical configurations of the dielectric combline resonators are shown in Fig. 1. Dielectric rod with radius $r$, length $L$ is mounted in a cylindrical or rectangular enclosure of length $b$. The inner dielectric rod cross section can also be rectangular or other shape depending on the manufacturing process.

Rigorous mode matching method can be used for modeling of the dielectric combline resonators shown in Fig. 1 [6]-[9]. In this method, the resonator is divided into dielectric rod region, cylindrical air region and the rectangular air region ( Fig. 1(b) only ). The electromagnetic fields in each region are expressed as linear combinations of the eigen mode fields. The boundary conditions at the interface of the regions require that the tangential electric and magnetic fields be continuous. Taking the proper inner products on the continuity equations of the boundary condition, a characteristic equation for the resonant frequency of the resonator can be obtained. Searching for the zero determinant of the characteristic equation and solving the equation, resonant frequency and the field coefficients of the resonant mode can be obtained. The unloaded $Q$ of the resonator can be computed by calculating the stored energy and total conductor and dielectric losses of the resonator. Large aperture approximation method can be used to compute the coupling coefficient of the resonator with the cylindrical enclosure [10]. The coupling of the resonator with the rectangular enclosure is computed rigorously by cascading the generalized scattering matrices of all the discontinuities of the coupling structure [8][9].

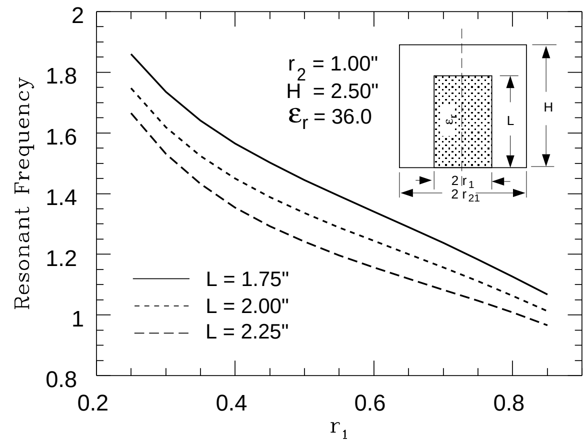


Fig. 3. Resonant frequency of a dielectric combline resonator versus the radius of the dielectric rod

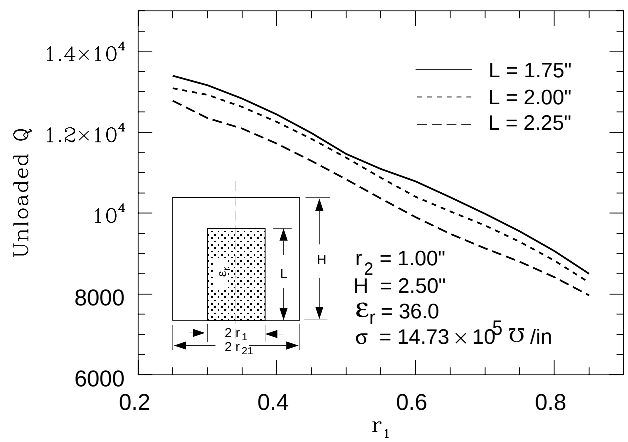


Fig. 4. Unloaded $Q$ of a dielectric combline resonator versus the radius of the dielectric rod

Table I shows the typical computed unloaded $Q$ of a conventional combline resonator and a dielectric combline resonator with the same enclosure dimensions and resonant frequency. It is seen that both inner and outer conductor of conventional combline resonator contribute approximately the same loss to the resonator, which results in relatively low unloaded $Q$ of the combline resonator. The loss due to the dielectric rod of the DR combline resonator is very small, thus the dielectric combline resonator has nearly twice the unloaded $Q$ as that of the conventional combline resonator.

Fig. 2 shows the typical field distributions of a dielectric combline resonator with cylindrical enclosure in the $r-y$ and the $r-\phi$ planes. It is seen that both

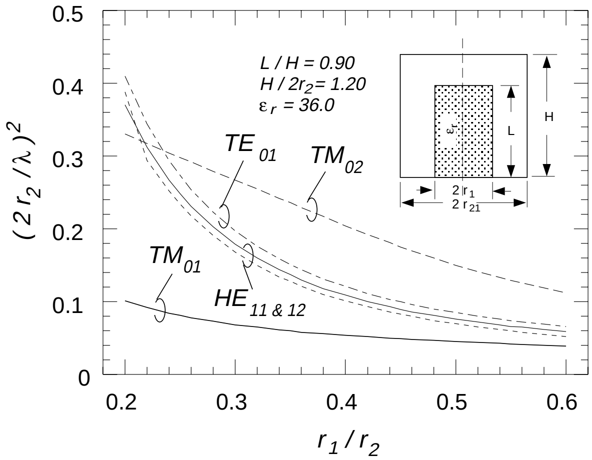


Fig. 5. Mode chart of a dielectric combline resonator with radius of the dielectric rod as variable

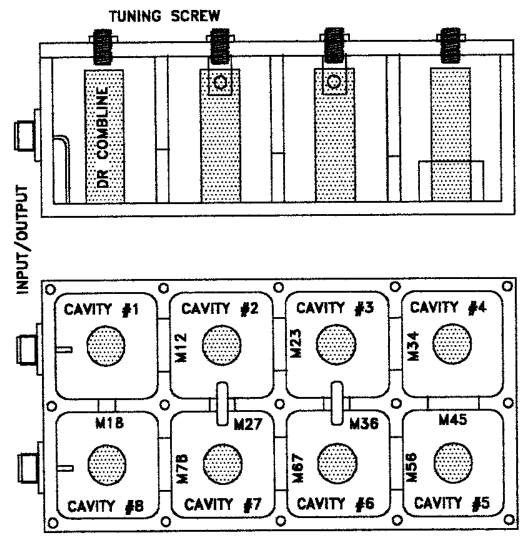


Fig. 6. Configuration of the 8-pole elliptic function dielectric combline resonator filter

electric and magnetic fields in the air filled region are quite similar to that of the re-entrant resonator as expected. Within the dielectric rod, electric field $E_y$ and magnetic field $H_\phi$ exist. The continuous magnetic field at the boundary eliminates the current on the dielectric rod.

TABLE I

Unloaded Q of a conventional combline ($r = 0.21$", $L = 1.12$") and a dielectric combline resonator ($r = 0.28$", $L = 1.20$"), due to the inner rod and enclosure

| Region | Combline | DR combline |
|---|---|---|
| Rod $Q$ | 9733.2 | 39064.6 |
| Enclosure $Q$ | 13146.0 | 13578.6 |
| Total $Q$ | 5592.5 | 10076.2 |

$f_o = 1.87$ GHz, $R = 0.75$", $b = 1.26$", $\sigma = 15.67 \times 10^5$ $mho/inch$ and $tan\delta = 4.0 \times 10^{-5}$

The computed resonant frequency and the unloaded $Q$ of a dielectric combline resonator versus the radius of the dielectric rod and with different length of the rod are presented in Fig. 3 and Fig. 4, respectively. Both resonant frequency and the unloaded $Q$ decrease as the radius and the length of the dielectric rod increases, which is very similar to the case of the conventional combline resonator. The DR combline resonators have much higher unloaded $Q$ than that of the combline resonators. Fig. 5 presents the mode chart of the dielectric combline resonator as a function of the radius of the dielectric rod. It is seen that all the resonant modes are sensitive to the rod diameter, and dielectric rod with smaller radius has better mode separation.

## III. FILTER REALIZATION AND RESULTS

As application of the dielectric combline resonator, the conventional combline resonators can be fully or partially replaced by the new type resonator. The similarity of both types of resonators in shape, size and the field distributions provide the principal advantages of the dielectric combline resonators. An 8-pole self equalized elliptic function filter with center frequency of 2.595 GHz, bandwidth of 29.0 MHz is designed. The normalized input/output resistance and the coupling matrix elements of the filter are: $R_{in} = R_{out} = 1.2224$, $M_{12} = M_{78} = 0.9234$, $M_{23} = M_{67} = 0.6193$, $M_{34} = M_{56} = 0.5442$, $M_{45} = 0.6957$, $M_{36} = -0.1207$, $M_{27} = -0.0518$, $M_{18} = 0.0292$.

The configuration of the filter is shown in Fig. 6. In the filter, the positive couplings are achieved by irises, and the negative couplings are obtained by probes. The dimensions of the resonators and irises are determined by computer program using the modeling method described above. Tuning screws are used for fine tuning the resonant frequencies of the resonators. Fig. 7 presents the measured frequency responses of the designed filter. It is seen that the filter achieves the desired center frequency, bandwidth and more than 20 dB return loss. However the insertion loss of the filter is larger than the expected value which is traced to be due to the poor mechanical contact between the housing and cover ( not enough screws being used ), and the loss from the lossy adhesive used for mounting the dielectric rods.

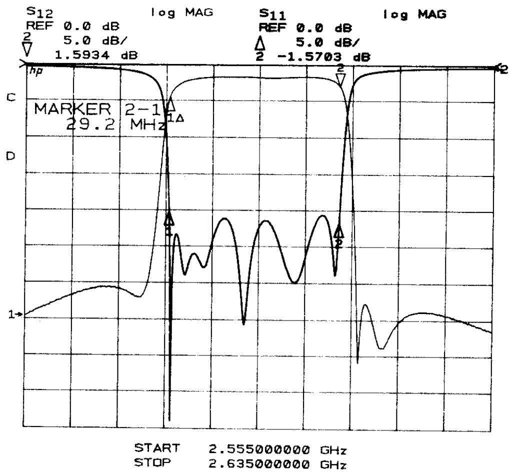


Fig. 7. Measured frequency responses of the 8-pole elliptic function dielectric combline resonator filter

## IV. CONCLUSIONS

A new type of dielectric resonator, *i.e.* dielectric combline resonator, is introduced by replacing the inner conductor rod of the conventional combline resonator by a high $\epsilon_r$ dielectric rod. Properties of the new type resonator is investigated. The resonant frequency, field distribution, unloaded $Q$ and the coupling coefficient of the resonator are obtained by rigorous mode matching method. An 8-pole self equalized elliptic function dielectric combline resonator filter is designed. Good frequency responses of the filter are obtained.

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