Conductor disc used to suppress spurious mode and enhance electric coupling in a dielectric loaded combline resonator

T M Pholele¹ and J M Chuma²

¹ Department of Basic Sciences, Botswana College of Agriculture, Private Bag 0027, Gaborone, Botswana
² Department of Electrical, Electronic, Computer and Telecommunication Engineering, Botswana International University of Science and Technology, Private Bag 0016, Phalapye, Botswana
tpholele@bca.bw

Abstract. The effects of conductor disc in a dielectric loaded combline resonator on its spurious performance, unloaded quality factor \(Q_u\), and coupling coefficients are analysed using a commercial electromagnetic software package CST Microwave Studio (CST MWS). The disc improves the spurious free band but simultaneously deteriorates the \(Q_u\). The presence of the disc substantially improves the electric coupling by a factor of 1.891 for an aperture opening of 12 mm, while it has insignificant effect on the magnetic coupling.

1. Introduction

Today telecommunication systems operate under strict requirements of high selectivity, low loss, high rejection, wide spurious free stop-bands, small size, low cost and temperature stability [1]. Dielectric loaded combline filters have in the recent past received great attention due to the fact that they offer high \(Q_u\). Their drawback has however been their relatively poor spurious performance. The presence of the dielectric puck significantly reduces the size of the filter.

The spurious free performance of dielectric loaded filters have been improved by among other things, choosing the correct aspect ratio (ratio of diameter to the height of the dielectric) [2], using sandwiched conductor dielectric resonators [3], drilling a hole through the dielectric (ring resonators) [4], correctly positioning the dielectric in the cavity and using conductor loaded dielectric cavity resonators [5]. On the other hand spurious free performance of combline filters has been improved by using stepped impedance resonators [6]. There is a need to design dielectric loaded combline resonators with improved spurious free band.

Coupling is very important in building filters as it is through it that we control the filter bandwidth and selectivity. The selectivity of the filter mainly depends on the position of transmission zeros. These transmission zeros are brought about by cross couplings through apertures or coupling through non resonating modes [7]. Electric coupling (resonators interacting through electric fields) is generally weak compared to magnetic coupling hence there is a need to enhance it (electric coupling).

CST MWS was used to investigate the effect of loading a conductor disc on top of both the post and the dielectric in a dielectric loaded combline resonator on the spurious free performance, \(Q_u\) and both the electric and magnetic coupling. The spurious free band improves as the diameter and height of the conductor disc increases but simultaneously deteriorates the \(Q_u\). On the other hand, the presence of the conductor disc improves the electric coupling by 1.891 for an aperture opening of 12 mm, while it has insignificant effect on the magnetic coupling.

2. The effect of the diameter of the disc on the spurious performance and \(Q_u\)

Figure 1 shows a resonator which consists of a rectangular enclosure, a cylindrical ring made of high-\(Q\)
ceramic with dielectric constant $\varepsilon_0 = 37$, a centre post and a conductor disc. The dimensions of each resonator are $b = 20$ mm, $L = 23$ mm, $l = 20$ mm, $d = 12.70$ mm, $d_c = 18$ mm, aluminum disc thickness $t = 1.6$ mm. A dielectric loaded combline resonator filter was initially designed without a conductor disc on top of both the centre conductor post and the cylindrical ring puck. The dielectric loaded combline resonator was then simulated in CST MWS which has been proven to provide accurate results [8]. The resonant frequency and the first spurious mode were noted as 1.758 GHz and 3.698 GHz respectively.

A conductor disc of thickness $t$ was then introduced on top of both the centre conductor and the cylindrical dielectric ring puck (figure 1 right) and the simulations in CST MWS run. In this part of the investigation, the height of the disc was kept the same at 1.6 mm, while the diameter of the disc was varied. The height $L$, of the enclosure was increased and kept at 24.6 mm so that the effect of the space between the top of the disc and the top of the enclosure remained the same. In this process the resonant frequencies of the modes, the field configurations and the quality factors were observed. It was observed that as the diameter of the disc increases, the frequency of the first spurious mode is driven up in frequency and the resonant mode has its frequency pushed down. The presence of the disc results in reconfiguration of the modes as the electric field that was initially there may not deeply penetrate the conducting disc. This leads to the spurious free region of the resonator improving as the diameter of the disc is increased all the way up to the edge of the dielectric before briefly becoming constant, as indicated in figure 2.

The effect of the diameter of the conductor disc on the $Q_p$ of the resonator was simulated in the CST MWS and the $Q_p$ was found to consistently deteriorate as the diameter increased, as shown in figure 2. Increased surface area of the disc means more resistive losses due to conduction current. A change of the diameter of the disc form 14 mm to 18 mm leads to the spurious free band improving by 109 MHz, and the $Q_p$ deteriorating by 76.3. This therefore calls for a trade-off between obtaining better spurious free performance and reduced $Q_p$.

3. The effect of the height of the conducting disc on the spurious performance and $Q_p$.
The configuration in figure 1 was used in this part of the investigation, but the diameter of the conducting disc was kept constant at 15.75 mm (a diameter which is almost half way between 12.7 mm and 18 mm, the diameter of the dielectric). At this diameter of 15.75 mm we get a spurious free band of 2.045 GHz, an improvement by 132 MHz on the spurious free band of the dielectric loaded combline resonator filter without the conducting disc, and reduction of the $Q_u$ by 32.2 due to the introduction of the conducting disc. The height of the conducting disc was increased and the space between the disc and the top cavity wall was kept the same at 3 mm, that is, every time the height of the disc was increased, the height of the cavity was also increased so that the gap between the disc and the cavity top wall stayed the same.

The simulations in CST MWS revealed that the spurious free band improves as the height of the disc increases. As the height of the conducting disc increases, the frequency of the first spurious mode remains almost the same at around 3.755 GHz (height of 0.2 mm to 1.4 mm) and then drops slightly from 3.753 GHz for a disc height of 1.8 mm to 3.749 GHz for a height of 2.6 mm. On the other hand, the resonant frequency of the resonator gradually reduces from 1.745 GHz for a disc height of 0.2 mm to 1.676 GHz for a disc height of 2.6 mm. This leads to the spurious free band increasing as the height of the disc increases as shown in figure 3.

The $Q_u$ deteriorate as the height of the conducting disc is increased. This relationship is shown in figure 3. A change of the height of the disc from 0.2 mm to 2.6 mm improves the spurious free band by 64 MHz and reduces $Q_u$ by 27.5, which calls for a trade-off.

**Figure 3.** Q factor and spurious free band vary with height of the disc.

### 4. Effect of the disc on the coupling coefficients

A cylindrical conductor disc of diameter of 15.75 mm and height of 1.6 mm in figure 1 was used in the study. To get $f_e$ and $f_m$ (the resonant frequencies when the symmetry walls were assigned electric and magnetic respectively) two coupled identical combline resonators were built and the symmetry option in boundary conditions was used to assign the common wall as electric and then magnetic. Apertures were milled on the common wall and in each case $f_e$ and $f_m$ noted and coupling coefficient, $k$ computed. Coupling coefficient for identical resonators can be calculated using equation (1) [9]:

$$k = \frac{f_e^2 - f_m^2}{f_e^2 + f_m^2}$$

The disc has minimum effect on magnetic coupling since its presence mainly affects the electric field at the capacitive end of the structure. An aperture milled from the short circuit end of the resonator, for both cases when the disc is loaded and when it is not loaded, show similar results indicating that the disc has minimum effect on magnetic coupling, see figure 4. On the other hand, the electric coupling (aperture milled from the capacitive end of the common wall) of the resonator is significantly affected, particularly from aperture opening from 8 mm to 14 mm, as shown in figure 4. This capacitive aperture opening enhances electric coupling, particularly between aperture openings of 10 mm to 14 mm. A 10 mm aperture opening enhances coupling by a factor of 1.677, while 12 mm aperture opening results in electric coupling.
being improved by a factor of 1.891. The presence of the disc provides greater surface on which the electric field can begin and end.

![Figure 4. Magnitudes of electric and magnetic coupling coefficients against aperture opening.](image-url)

**Conclusion**

It has been shown that the spurious free band of the resonator improves as the height of the loaded disc increases. A change of the height of the disc from 0.2 mm to 2.6 mm improves the spurious free band by 64 MHz and reduces $Q_r$ by 27.5. Similarly, increasing the diameter of the disc also leads to the spurious free band increasing. A change of the diameter of the disc from 14 mm to 18 mm leads to the spurious free band improving by 109 MHz, and the $Q_r$ deteriorating by 76.3. Since increasing the both the height and the diameter of the disc increases the spurious free band and simultaneously deteriorates the $Q_r$, there is need for a trade-off among the three. The presence of the disc enhances electric coupling, while it has minimum effect on the magnetic coupling. A 10 mm aperture opening enhances electric coupling by a factor of 1.677, while 12 mm aperture opening results in electric coupling being improved by a factor of 1.891.

**References**

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