Compact dual-mode open loop microstrip resonators and filters.

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Compact Dual-Mode Open Loop Microstrip Resonators and Filters

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***Abstract*—A novel compact microstrip dual-mode resonator and filter are proposed. The characteristics of the dual mode resonator are investigated. It is found that the filter response exhibits a desirable stopband response where the first spurious passband naturally occurs at $3f_0$. Finally, methods of miniaturizing such resonators and filters are discussed. The proposed structure was able to achieve 60% size reduction.**

***Index Terms*—Compact resonators, dual-mode filters, dual-mode resonators, microstrip filters, microstrip resonators.**

I. Introduction

MICROSTRIP dual-mode bandpass filters (BPFs) and diplexers are generally preferred and are used extensively in low to medium power RF transceivers due to the relative size reductions that can be obtained.

This letter presents a novel microstrip dual-mode open loop resonator and filter. The proposed resonator may be designed as necessary to yield $\lambda_g/4$ to $\lambda_g/12$ type resonators, where λ_g is the guided wavelength. A filter example is provided for demonstration. This resonator/filter is more compact than the recent dual-mode open loop resonator [1] and [10], circular ring [2], square patch [3], square loop dual-mode resonators [4], [5] and [9] and stepped impedance type resonators such as in [6] and [8] and the filter proposed in [11].

The characteristics of the proposed resonator are presented in Section II. Section III demonstrates an application. Conclusions will be presented in Section IV.

II. Proposed Dual-Mode Resonator

The proposed dual mode resonator shown in Fig. 1 is excited via capacitive couplings by ports 1 and 2. The input feed lines are kept at 50 Ω. A single connection to ground is applied at the symmetry plane of the resonator as shown to achieve dual mode performance.

The line lengths L_1, L_2, L_3 and widths W_1, W_2 and W_3 determine the even and odd mode resonant frequencies. Modal decomposition provides a deeper insight to the operation of the resonator. Illustrated in Fig. 2 are the corresponding even and odd mode resonators assuming for now that $W_2 = 2W_1$.

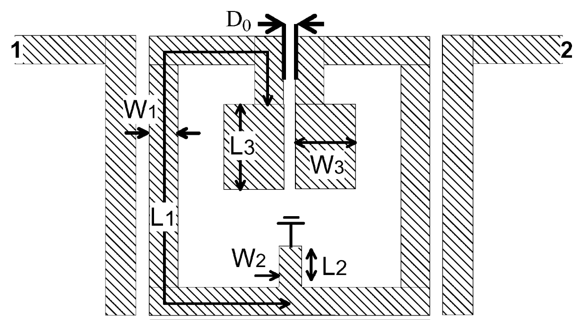

Fig. 1. Layout of proposed dual mode resonator.

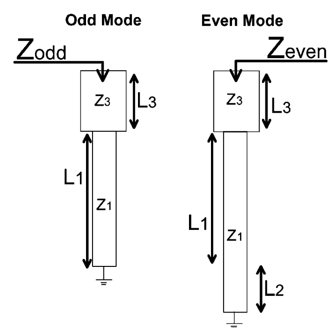

Fig. 2. Equivalent odd and even mode resonators.

The odd mode resonator is identical to that for the single mode open-loop resonator since a virtual ground exists in the symmetry plane. Therefore, the perturbation element has no effect on the odd mode. For the even mode resonance, the virtual ground is replaced by a virtual open circuit. The perturbation element is dissected and the width W_2 is split in half.

Both resonators here are of the type $\lambda_g/4$, where λ_g is the guided wavelength. Dual modes result from the difference in operating lengths of each resonator. The simplest case is when both the equivalent resonators are of the uniform impedance (UI) type where $W_2 = 2W_1$ and $W_1 = W_3$. In this case, when $L_2 = 0$, the unit behaves as the conventional single mode open loop resonator. However, when L_2 is non-zero, dual mode performance can be observed. In the UI case, the respective resonant frequencies can be calculated relatively simply with good accuracy.

For the purpose of analysis, such a resonator was simulated on a substrate of relative dielectric constant of 2.2 and thickness 0.51 mm. $W_1 = W_3 = 1$ mm and $W_2 = 2$ mm to maintain UIRs for both modes. Length of L_1 was 21 mm and the length

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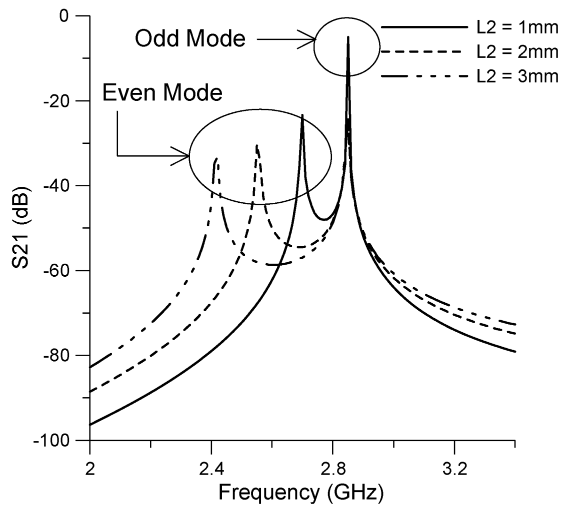


Fig. 3. Variation of modal resonant characteristics on L_2 while $L_1 = 21$ mm.

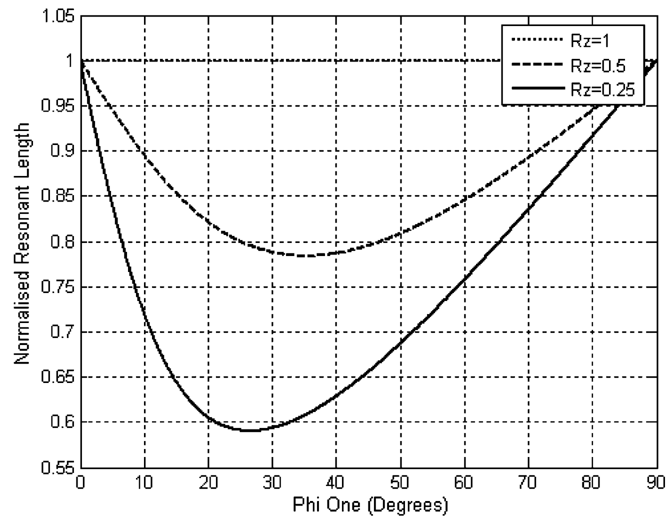


Fig. 4. Resonator length with φ_1 for various values of Rz.

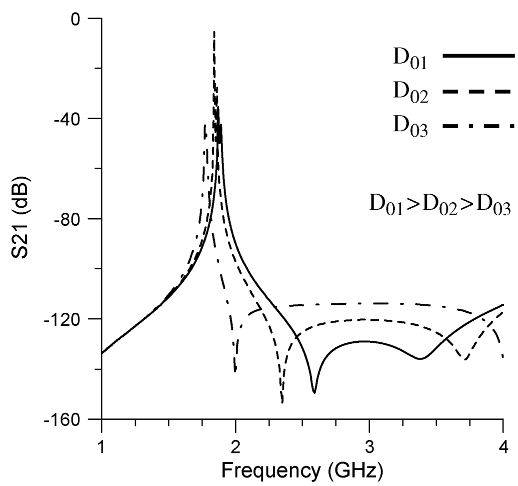


Fig. 5. Splitting of tx. zeros with inter-arm gap D_0.

of the perturbation element L_2 was varied to demonstrate the variation in even mode resonance. Fig. 3 illustrates the results.

The odd mode remains unaffected due to the virtual ground that forms in the symmetry plane while the even mode is directly dependant on L_2.

There are several methods that may be employed to miniaturise the proposed resonator such as elongating the length of L_1 and to use stepped impedance affects for miniaturisation.

Odd and even mode decomposition shows respective resonators to be of the form shown in Fig. 2 (assuming that the width $W_2 = 2W_1$). At their resonance, $\mathrm{Yodd} = 0$ and $\mathrm{Yeven} = 0$ give rise to these conditions for the odd mode resonator [7]:

$$\frac{Z_3}{Z_1} = \tan(\varphi_1) + \tan(\varphi_3) \tag{1}$$

and similarly for the even mode resonator

$$\frac{Z_3}{Z_1} = \tan(\varphi_1 + \varphi_2) + \tan(\varphi_3) \tag{2}$$

where φ_1, φ_2 and φ_3 refer to the electrical lengths of the sections of lengths L_1, L_2 and L_3 respectively. Z_1 and Z_3 are the characteristic impedances of the ordinary resonator section and the added stepped impedance respectively. The lengths of the odd and even mode resonators L_{odd} and L_{even} are found to be the following [7]:

$$Lodd = \varphi_1 + \arctan\left(\frac{Rz}{\tan(\varphi_1)}\right) \tag{3}$$

$$Leven = \varphi_1 + \arctan\left(\frac{Rz}{\tan(\varphi_1 + \varphi_2)}\right) \tag{4}$$

where Rz is the impedance ratio Z_3/Z_1. Both of the modes will be affected in an identical manner when the impedance ratio Rz is varied. Fig. 4 illustrates the variation of resonator length for various impedance ratios to illustrate size reduction.

The amount of size reduction that can be achieved is inversely proportional to the impedance ratio Rz and is a function of φ_1. Compact units may be obtained by having small impedance ratios and having an appropriate φ_1.

The resonator has two transmission zeros in the upper stopband which are illustrated in Fig. 5. The zeros are attributed to the folded arms of the resonator, which generate a virtual earth at the input/output coupling points. Tighter inter-arm coupling widens the split between the zeros as shown.

III. Dual Mode Compact Bandpass Filters

A 2nd order BPF at 1.35 GHz was designed and fabricated. Stepped impedance and folding had been employed to achieve compactness and the overall filter size amounted to 15.8 mm × 16.5 mm. This was equivalent to a $\lambda_g/10$ type resonator and achieves relative size reduction of 64% compared with an open loop filter. This filter is also 37% more compact compared to that proposed in [1] and [9] and 85% more compact than the filters in [11]. The filter was designed on a substrate with relative dielectric constant 2.2 and thickness 0.508 mm. The layout, response and photograph of the filter are depicted in Fig. 6 and Fig. 7. The FBW of this filter is approximately 5%. The wideband response of the fabricated filter is illustrated in Fig. 8. The first spurious response is at 4 GHz, which is at $3f_0$ as expected. Simulations and measurements are in good agreement. The higher insertion

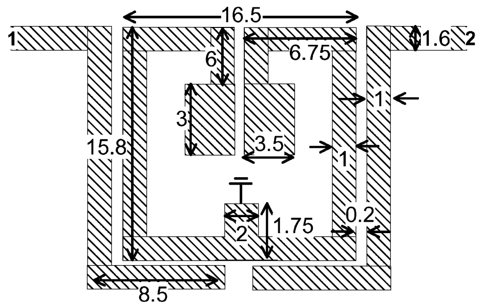
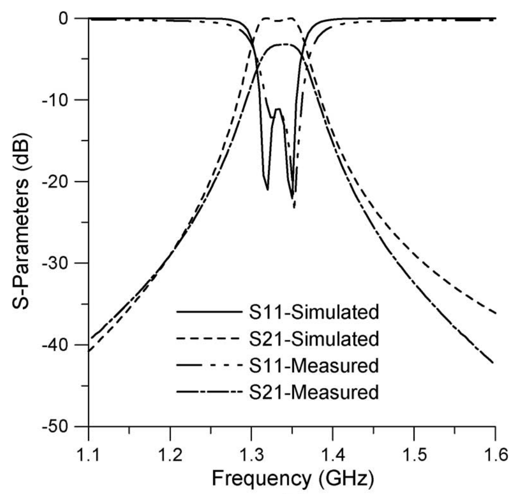
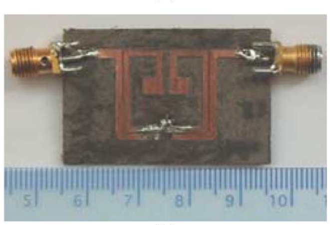


Fig. 6. Layout of Filter (all dimension in mm).



(a)



(b)

Fig. 7. (a) Measured and Simulated Response; (b) photograph of fabricated filter.

loss observed in the measurement is due to tolerances involved in the fabrication process which may be minimised with better fabrication tools or by meticulous use of available tools.

IV. Conclusion

A compact dual mode open-loop resonator has been proposed for filter applications. Operation of the dual mode resonator has been investigated with an analysis of the even and odd mode resonances. The resonator was shown to have two controllable transmission zeros on the upper stop-band. It was shown that the filters derived from the proposed resonator are capable of achieving significant size reduction.

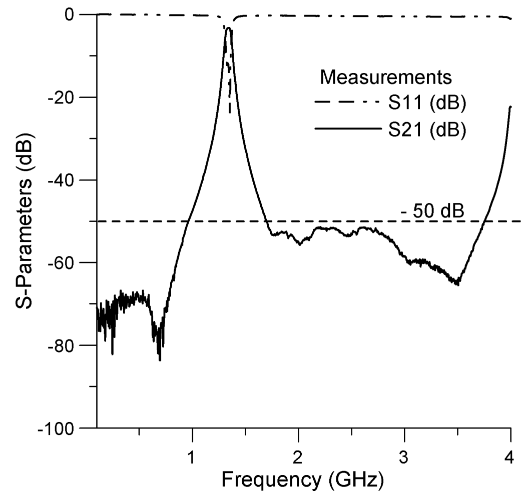


Fig. 8. Wideband response of filter.

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