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Dual-Band Filter Using Quarter-Wavelength Resonators with Hybrid Feeding Structure

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***Abstract*—This study proposes a concurrent dual-band filter that consists of two single-band filters using quarter-wavelength resonators. The two single-band filters, having different feeding structures, can be designed separately. The lower-band filter has tapped feeding structure and the higher-band filter has coupling feeding structure where the input/output line and the lower-band resonator constitute a feeding coupling line. Therefore, commonly used T-junction or other dual-band impedance transformer is avoided. The proposed filter is easy to design and has a compact size. A dual-band filter, operated in 0.9 GHz and 1.9 GHz, is designed to validate the proposed structure.**

***Index Terms*—Dual-band filter, quarter wavelength resonator, stepped impedance resonator, hybrid feeding structure.**

I. Introduction

Multi-band function has become a growing trend in modern wireless communication products. Therefore, a demand for multi-band filter, a critical device in the RF front-end, is increasing. Many researches concentrate on the dual-band filter design during the last decade. Dual-band filter can be realized using several approaches, such as cascaded connection of bandpass filters and bandstop filters [1]-[2], combination of two single-band filters [3]-[5], dual-frequency resonators [6]-[10], and resonators with multi-coupling paths [11]-[12]. A dual-band filter by combining two single-band filters is easy to design because the two single-band filters can be designed individually. This type of filters requires additional combining circuits and occupies a large PCB area. Two types of dual-frequency resonators, the stepped impedance resonator and the stub-loaded resonator, are widely used to construct a dual-band filter. Dual-band filter using dual-frequency resonators has a compact size because it use only one set of resonators. However, designing this type of filters is time consuming because the specifications of the two bands must be met simultaneously. Recently, modified dual-band filters based on the dual-frequency resonators are proposed to overcome the above drawbacks [13]-[16]. Some of this type still need additional dual-band impedance transformer. Some of them depend on the frequency selective current distribution, which limits the operating frequencies.

In this article, a dual-band coupled filter using quarter-wavelength resonators with hybrid feeding structure is proposed. The filter combines two individual single-band filters by using hybrid feeding structure, without any T-junction or other combining circuits. Therefore the filter is easily designing and compact size. The quarter-wavelength resonators reduce the filter size further and suppress the even-numbered harmonic responses, which improves the stopband response. A dual-band filter, operated at 0.9 GHz and 1.9 GHz concurrently, is demonstrated to validate the proposed structure.

II. Filter Structure

The proposed dual-band filter consists of two two-pole single-band filters. Figure 1 shows the coupling scheme of the dual-band filter with hybrid feeding structure. In Fig. 1, each solid node represents a resonator and line between two nodes represents coupling between two resonators. The corresponding layout is illustrated in Fig. 2. Quarter-wavelength resonators are used to reduce the circuit area and avoid even-numbered harmonic responses. In addition, the lower-band resonators, R_{1L} and R_{2L}, are stepped impedance resonators such that the first harmonic response is moved to a higher frequency [17].

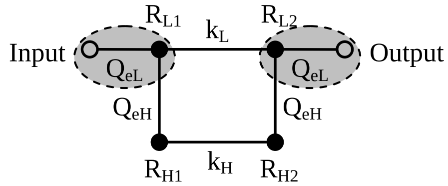

Fig. 1 Coupling scheme of the proposed dual-band filter.

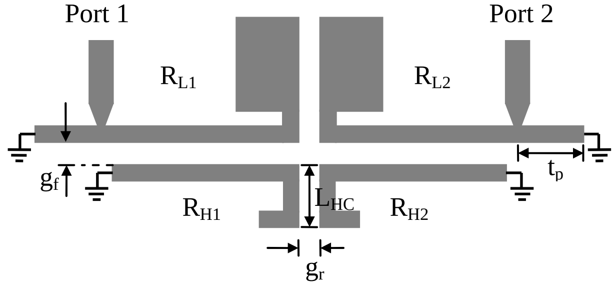

Fig. 2 Layout of the proposed dual-band filter using quarter-wavelength resonators..

The proposed dual-band filter uses different feeding structure for the two single-band filters. The lower-band filter uses tapped feeding and the external quality factor is

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controlled by the tapped position, t_p. Because the lower-band resonators and the higher-band resonators have different resonance frequencies, the higher-band resonators do not affect passband response of the lower-band filter. Therefore, the lower-band filter can be designed independently. On the other hand, the higher-band filter uses coupling feeding and the external quality factor is controlled by the gap, g_f, between the lower-band resonators. Precisely, the input/output line and the lower-band resonator constitute a coupled line, i.e. the grey region in Fig. 1, to feed the lower-band resonator.

Because the two single-band filters can be designed individually, the traditional single-band filter theory is applied [18]. The external quality factors and coupling coefficients are obtained by the EM simulated return loss of a singly loaded resonator and the EM simulation of synchronously tuned coupled resonator circuits, respectively. The detailed design procedure is described below. First, the resonators' dimensions are obtained by solving the resonance condition [17]. Second, the tapped position, t_p, is tuned to meet the required lower-band external quality factor. Third, the coupling gap, g_r, is calculated to meet the required lower-band coupling coefficient. Forth, once the lower-band filter is determined, the coupling length, L_{HC}, between two higher-band resonators, R_{1H} and R_{2H}, is tuned to meet the required higher-band coupling coefficient. In this study, the coupling gaps, g_p, between the two lower-band resonators is chosen the same as that in the higher-band filter. The last step is tuning the coupling gap, g_f, to meet the required higher-band external quality factor.

III. Design Example

A dual-band filter operated at 0.9 GHz and 1.9 GHz is designed and simulated to validate the proposed structure. Both single-band filters have Chebyshev responses with 0.5 dB passband ripple. The lower-band and higher-band fractional bandwidths are 5.6 % and 2.6 %, respectively. These specifications demand external quality factors of 25.3 and 53.3 for the two designated bands, respectively. The required coupling coefficients between two adjacent resonators are 0.0264 and 0.0558, respectively. The filter is designed on a 1.6 mm-thick FR4 substrate with a dielectric constant of 4.35 and a loss tangent of 0.016. Full wave simulation is conducted using EM software, Zeland IE3D 14.0.

The designed filter size is about $4.5 \times 1.8\, cm^2$, i.e. $0.25 \times 0.1\, \lambda_g^2$, where λ_g is the guided wavelength at 0.9 GHz. Figure 4 demonstrates the simulated results. The simulated central frequencies of the two bands are 0.915 GHz and 1.935 GHz, respectively. The bandwidths of the two bands are 55 MHz and 70 MHz which are corresponding to the fractional bandwidths of 6.1 % and 3.7 %, respectively. The passband insertion losses at the two bands are 1.7 dB and 2.8 dB, respectively. The passband return losses are lower than 15 dB and 12.5 dB, respectively.

Figure 4 illustrates the current distributions at both passbands. At 0.9 GHz, the current density is small on the higher-band resonators than that on the lower-band

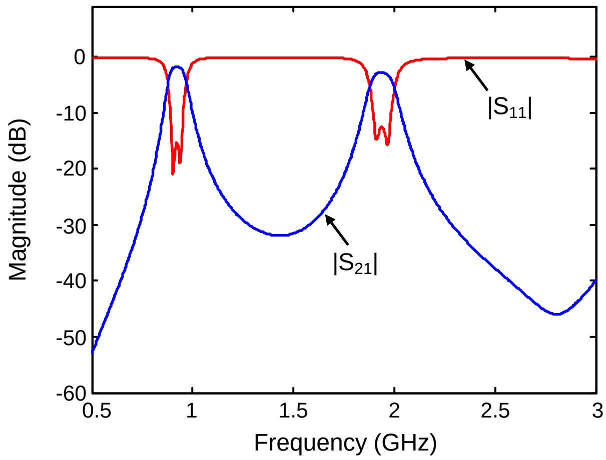
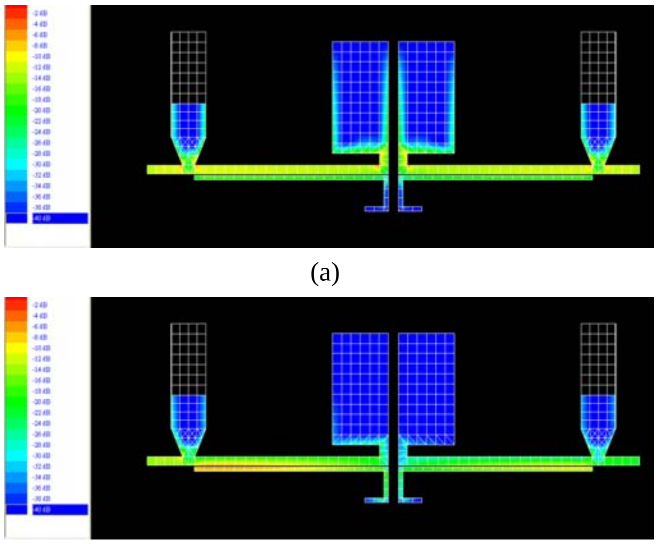


Fig. 3 Frequency response of the designed dual-band filter.



(a)

(b)

Fig. 4 Current distributions at (a) 0.9 GHz and (b) 1.9 GHz..

resonators. This current distribution explains the higher-band response is not affected by the lower-band resonators. At 1.9 GHz, the current concentrates on both sides of the coupled line formed by the lower-band resonator and the higher-band resonator. The current density on both sides of the coupled line formed by the two lower-band resonators at 1.9 GHz is small than that at 0.9 GHz. This current distribution explains the coupling between the two lower-band resonators is not affected by the higher-band resonators.

IV. Conclusion

A dual-band filter that consists of two single-band filters using quarter-wavelength resonators is demonstrated. The two single-band filters can be designed independently, such that the passband specifications can be met easily. The hybrid feeding structure makes the filter require no T-junction or other dual-band impedance matching circuit. The hybrid feeding structure and quarter-wavelength resonators make the proposed dual-band filter easily design and compact size. A dual-band filter, operated in 0.9 GHz and 1.9 GHz, is designed and simulated. The simulated results validate the proposed structure. Although only two-pole filters are demonstrated, the hybrid feeding structure can be applied to dual-band with higher order response.

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