NOVEL QUASI-ELLIPTIC MICROSTRIP FILTER CONFIGURATION USING HEXAGONAL OPEN-LOOP RESONATORS

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ABSTRACT

In this paper, a novel filter configuration in enhancing the selectivity of the quasi-elliptic microstrip bandpass filters is presented. The filter topology is based on hexagonal open-loop resonators and this offers additional electric coupling. This extra electric coupling together with the cross coupling between several pairs of adjacent hexagonal open-loop resonators relocate the attenuation poles of the quasi-elliptic filter so as to provide higher selectivity. Compared to a traditional six-pole square open-loop resonator microstrip filter with a fractional bandwidth of 7.8% and center frequency of 1GHz, this new filter configuration offers additional 13dB rejection improvement at the attenuation pole in the lower rejection band whilst the fractional bandwidth reduces about 5% of that traditional filter and the filter dimension diminishes by 27%.

1. INTRODUCTION

Modern mobile communication systems require high performance narrow-band RF/Microwave bandpass filters having high selectivity and low insertion loss. It is also important to reduce filter's size and weight in order to integrate with other components as a single chip system. Latest development of the high performance filter is either by active MMIC filter or passive planar filter [1-5]. Amongst these passive filters, Quasi-elliptic cross-coupled filter based on the open loop resonators recently becomes a successful candidate for developing high performance RF/Microwave bandpass filter because of its high attenuation poles at finite frequencies [6 – 8]. This filter's physical mechanism is that the coupling effects including electric, magnetic and mixed couplings can improve the filter performance as those of waveguide cavity cross-coupled filters [4],[5]. However, this cross-coupled planar structure requires large microstrip area due to its resonators configuration. It is thus the objective of this work to present a new cross-coupled planar filter configuration offering less microstrip area and retaining high selectivity.

Besides this introductory section, Section 2 presents the novel microstrip filter configuration using hexagonal open-loop resonator. Section 3, on the other hand, demonstrates the EM simulation results to illustrate the novel filter configuration usefulness. Finally, conclusion is then drawn in Section 4.

2. NOVEL FILTER CONFIGURATION

Figure 1 depicts a conventional six-pole square open-loop resonator quasi-elliptic microstrip filter configuration [6-9]. It consists of 6 square open-loop resonators with perimeter of half-wavelength. The adjacent pair of square open-loop resonators is realized with different kinds of coupling. The single pair of attenuation poles is contributed by an electric coupling of center square open-loop resonator pair 2 & 5 and a magnetic coupling of square open-loop resonator pair 3 & 4, whilst these two coupling types are indeed out of phase.

Whilst the other 4 resonators pairs: 1 & 2, 2 & 3, 5 & 4 and 5 & 6 offer the mixed couplings, these 4 mixed couplings indeed couple the single electric

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coupling pair 2 & 5 respectively and they contribute to the transmission zeros.

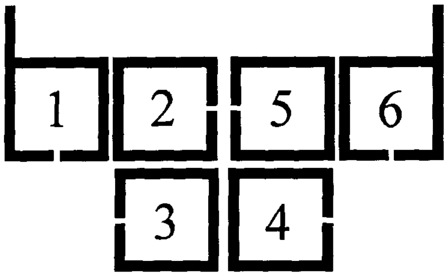

Figure. 1 Conventional square open-loop resonator microstrip quasi-elliptic filter configuration.

Instead of using square open-loop resonators, the novel filter configuration is implemented by hexagonal open-loop resonators as depicted in Figure 2. It is obvious that there are totally 2 electric coupling k_E, 1 magnetic coupling k_M and 4 mixed couplings k_B as follows [6]:

$$k_E = \frac{C_m}{C} \quad (1)$$

$$k_M = \frac{L_m}{L} \quad (2)$$

$$k_B \approx \frac{L'_m}{L} + \frac{C'_m}{C} \quad (3)$$

where L and C are self-inductance and self-capacitance of the resonator

L_m and C_m represent mutual inductance and mutual capacitance of the resonator pair

This configuration indeed offers an extra electric coupling in the resonator pairs of 3 & 4 and 4 & 5 when compared with the conventional structure as shown in Figure 1. This additional degree of freedom of number of electric coupling pair may contribute to the filter response in terms of attenuation pole improvement. In fact, these two electric couplings 3 & 4 and 4 & 5 together with the magnetic coupling pair 1 & 2 interact with all 4 mixed couplings 1 & 3, 1 & 4, 2 & 4 and 2 & 5. As such, the resonant frequency shifting may be significantly affected as follows [6]:

$$f_e = \frac{1}{2\pi\sqrt{(L - L'_m)(C - C'_m)}} \quad (4)$$

$$f_m = \frac{1}{2\pi\sqrt{(L + L'_m)(C + C'_m)}} \quad (5)$$

where f_e, f_m are two natural resonant frequencies.

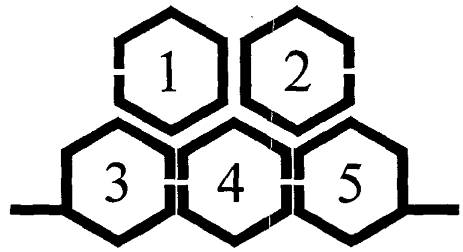

Figure 2 Novel microstrip quasi-elliptic filter configuration using hexagonal open-loop resonators.

To maintain the symmetry of the filter topology, the novel filter configuration is implemented with only odd number of hexagonal open-loop resonators [9],[10]. Although the size of one hexagonal open-loop resonator is larger than that of one square-loop resonator with equal resonant frequency, the hexagonal open-loop resonators can be compacted tightly so as the overall filter dimension can be diminished.

3. SIMULATION RESULTS

In order to demonstrate the proposed hexagonal open-loop resonator filter topology usefulness, the above two microstrip filter configurations are simulated using an IE3D electromagnetic simulator based on MoM (Method of Moments) numerical method subject to the same optimization goal [11]. Furthermore, in the simulation, all filters are assumed to be fabricated using a copper microstrip on an RT/Duroid substrate with a relative dielectric constant of 10.8 and a thickness of 1.27mm. For the microstrip filter with six square open-loop resonators (Figure 1), its size is about $0.55\lambda_{g0}$ by $0.32\lambda_{g0}$, where λ_{g0} is the guided wavelength of 50-Ω line on the substrate at the midband frequency. But, the size of the microstrip filter with five hexagonal open-loop resonators (Figure 2) is only about $0.39\lambda_{g0}$ by $0.33\lambda_{g0}$. There is 27% reduction in filter dimension compared with that of the conventional ones.

Figure 3 shows the electromagnetic simulation result of these two filters' responses whilst Table 1 summarizes comparison results of these two different filter topologies based on the dimension, the attenuation poles location, insertion loss and fractional bandwidth (FBW).

Filter Configuration	Square Open-Loop Resonator (Figure 1)	Hexagonal Open-Loop Resonator (Figure 2)
Dimension	$0.55\lambda_{g0} \times 0.32\lambda_{g0}$	$0.39\lambda_{g0} \times 0.33\lambda_{g0}$
Attenuation Poles Location	950MHz, 1.07GHz	964MHz, 1.06GHz
Maximum Insertion Loss (dB)	1.715@1GHz	2.378@1.02GHz
FBW	7.8%	3.2%

Table 1 Comparison of two microstrip filters

Note: λg_0 is the guided wavelength of 50-Ω line on the substrate at the midband frequency.

When observed the simulation results in Figure 3, the attenuation pole pair developed by the hexagonal open-loop resonator microstrip filter as shown in Figure 2 locates inside the passband of the square open-loop resonator filter as depicted in Figure 1. The attenuation pole in the lower rejection band of the hexagonal open-loop resonator microstrip filter acquires additional 13dB attenuation and is 14MHz closer to the center frequency. Another attenuation pole in the upper rejection band also resides 10MHz closer to the center frequency. The direct consequence of the closer attenuation pole pair reflects on the dramatic reduction in the fractional bandwidth (FBW). There is approximately 5% reduction in FBW, which greatly improves the selectivity. Accomplished with the selectivity improvement, the insertion loss (s_{21}) degrades less than 0.7dB. On the other hand, both filters report overall good matching of ~25dB.

4. CONCLUSION

In this paper, a novel filter configuration using hexagonal open-loop resonators for microstrip quasi-elliptic filter is proposed. The additional electric coupling together with the cross coupling between several pairs of adjacent hexagonal open-loop resonators cause the attenuation poles moving closer to the passband in order to increase the selectivity. The new filter configuration also diminishes the filter dimension. When compared with the conventional ones, simulation results show that there is 27% filter's size diminution, additional 13dB attenuation at the attenuation pole in the lower rejection band and approximately 5% reduction of FBW with less than 0.7dB additional insertion loss variation.

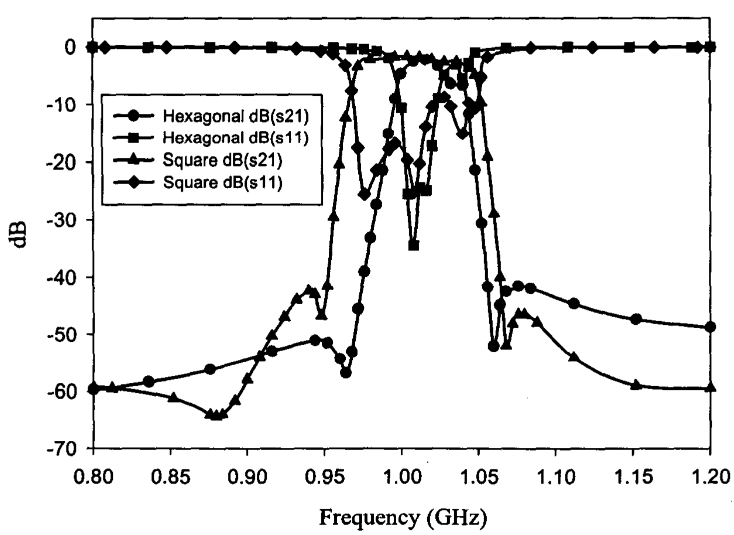

Figure 3 Performance comparison of two microstrip filters

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