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A Review of Microstrip Resonator for Bandpass Filter Design

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ABSTRACT

The increasing demand for good performance filters in the field of radio frequency and wireless communication leads to the advancement in the design and development of compact microstrip resonator. This paper presents the investigation and characterization microstrip resonator along with three common resonator filter design method. The first method uses cross-coupling resonators topology. The second method considers the distribution of the fundamental resonant frequencies of the resonator according to the Chebyshev's insertion loss function. The third approach is to design all fundamental resonant frequencies of the resonator to be located within the 3-dB frequencies.

Keywords— Microstrip filter, Bandpass filter, Multimode resonator

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I. INTRODUCTION

Recently, due to the rapid expansion of the various wireless communication service, multiband filters have attracted considerable attention as essential component for combination of GPS, WLAN, WIMAX and RFID applications. Compact microstrip resonators with superior performance are continuously developed to meet the demands. These microstrip resonators can be classified into single-mode and multimode resonators. The single mode resonator can be categorised into six sub classes. They are half wavelength resonator , quarter wavelength resonator, stepped impedance resonator, quarter wavelength stepped impedance resonator, patch resonator and ring resonator. These single mode resonator are the basic structure for the theory and design method of lowpass, highpass, bandpass, bandstop filter[1]. N number of single mode resonator is required for N-th order filter. One way of reducing the filter size is to use multimode resonators.

Multimode resonators can also be categorised according to the number of resonant modes. They include the dual-mode resonator, triple-mode resonator, quadruple-mode resonators, quintuple mode resonators and so on. The following section summarized the design and development of these multimode resonators, from dual mode (Section II) to quintuple-mode (Section V), with emphasis on centrally loaded open loop resonators in recent decade. (Section VI) summarises the different design approaches for these compact multimode resonators.

II.DUAL MODE REASONATORs

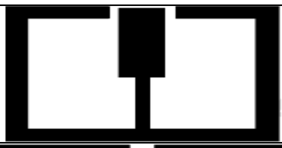
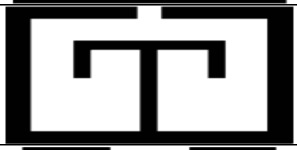
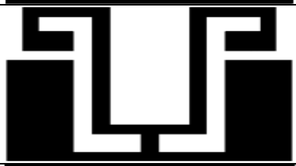
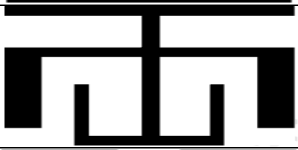
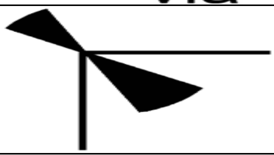
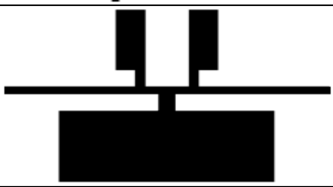
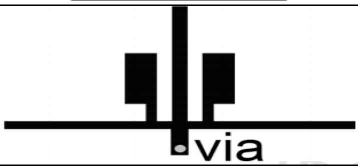
A conservative dual mode resonator have the following common design approaches[2] :

1. The resonator must be symmetric.
2. Two ports spatially separated at 90 degree in electrical length.
3. The resonator should have discontinuity to generate reflected wave against an incident wave in resonator.

The dual mode resonator can be classified into dual mode patch or ring resonator with perturbation and dual mode centrally loaded open loop resonator. Ring or patch resonators can be perturbed by adding stubs or cuts onto the symmetrical plane of the resonators. The most common design is to add open circuited stub(s) on ring resonators with the input and output ports are 90 degree in separation [3]. This will split the fundamental resonant frequency into two. The ring resonators can be meandered [4] to decrease the size of the filter. Dual-mode ring resonators are designed with defected grounding structure [5] and T-shaped coupling feed structure to improve the stopband response [6,7]. Dual-band filters can be designed by stacking two ring resonators on top of each other using multilayer of substrates [8].

The basic structure of the dual-mode centrally loaded open loop resonator is a half wavelength open loop resonator. The half wavelength open loop resonator is then centrally loaded with an open-circuited stub, a short-circuited stub or a grounded via .The centrally loaded element creates a grounding plane along the symmetrical plane of the resonator in odd mode condition,

hence splitting the resonant frequency into two. The open-circuited stub has various shapes. They include uniform impedance stubs [9], stepped impedance stubs [10],T-shaped stubs[11], Y-shaped stubs[12], and Q-shaped stubs [13].

Ref.	Resonator	Number of modes	Substrate/dielectric constant	fc	$IL(dB)$	RL(dB)
10		Dual	Duroid 6010.8/10.8	2.40	0.85	20
11		Dual(tunable)	Duroid 6010.8/10.8	0.83-0.93	3	10
12		Dual	Duroid 5880/2.2	1.53	1	23.4
16		Triple	Duroid 5880/2.2	2.35	3	11
17		Triple	Duroid 5880/2.2	13.9	2.5	9.6
18		Triple	Roger TMM /9.2	2	1.13	22
28		Quadruple	Duroid 5880/2.2	4.37	1	14.5
34		Quadruple	Duroid 5880/2.2	6.85	2	13

III.TRIPLE MODE RESONATOR

Triple-mode microstrip resonators are categorised into patch or ring resonators with perturbation(s) and centrally loaded open loop resonators. The patch or ring resonators designs follow the design guidelines as stated by Matsuo et al. [2], similar to the dual-mode resonators. Two concentric open-loop resonators [14] will produce three mode resonant frequencies. A straight line resonator can be centrally loaded with a patch to become a three-section stepped impedance triple-mode resonator as proposed by [15]. U-shaped three sections stepped impedance resonator can be centrally loaded with two open-circuited T-shaped stubs to form a triple mode resonator [16]. Three sections stepped impedance resonator can be bent into an open-loop resonator. It is then centrally loaded with an open-circuited T-shaped stub and a short circuited stub [17]. L-shaped resonator can be symmetrically loaded with two capacitive radial-line stubs to realise a triple-mode resonator [18].

A triple-mode resonator using a U-shaped uniform impedance resonator that is centrally loaded with an open circuited stub and a short-circuited stub is designed by [31]. The open circuited stub in the resonator [19] can be replaced with a radial-line stub to become the triple-mode resonator proposed by [20]. Deng et al. [21-23] researched a series of work on a triple-mode resonator designed using U-shaped resonator centrally loaded with open circuited T-shaped stub and two short-circuited stubs.

IV. QUADRUPLE MODE RESONATORS

Quadruple-mode resonators generally can be classified into four categories according to their structures.

1. Coupled-ring resonators [24,25].
2. Five-section stepped impedance resonators[26].
3. Tri-section stepped impedance resonator with embedded stubs[27].
4. Centrally loaded quadruple-mode resonators[28].

The authors in [24] have designed a concentric ring structure which has an inner ring with two open-circuited stubs. The two periodic stepped impedance concentric rings with two open loop resonators coupled to the outer ring are proposed by [25]. A straight line resonator is centrally loaded with an open circuited stepped impedance stub and two additional stepped impedance stubs at the symmetry plane of the resonator to form a quadruple-mode resonator proposed by [28]. These stepped impedance stubs can be replaced by uniform impedance open-circuited stub[29]. The straight line resonator can be bent into a U-shaped, and all the stubs must be located in the same direction .so, that the resonator can be made tuneable using varactors as described in [30]. The authors in [31] proposed the design of an open loop resonator also can be centrally loaded with Y-shaped open circuited stub and a grounding via to become a quadruple-mode resonator .

V.QUINTUPLE MODE RESONATORS

Quintuple-mode resonators are suitable for designing a wideband or ultra-wideband filter because they have sufficient amount of resonant frequencies to form the passband. The distribution of the resonant frequencies is also wide enough to cover a wider frequency range. Quintuple-mode resonators have five resonant modes. There are only a few quintuple-mode resonators reported. The quintuple mode resonators can be categorised into two groups. The first group is a square ring quintuple-mode resonator, first reported by [32]. This square ring resonator is located with two open-circuited stubs at its diagonal. The stubs are then further improved using T-shaped stubs. The second group consists of resonator with centrally loaded elements. The straight line resonator proposed by [33] is centrally loaded with an open-circuited stepped impedance stubs and another two open-circuited stubs are located at the symmetry plan of the resonator. The stepped impedance stub and the two open-circuited stubs of the resonator can then be replaced by an open-circuited stub and two stepped impedance stubs, respectively, and its centre is loaded with another short-circuited stub to form the resonator proposed by [34]. The straight line resonator proposed by [33] can be bent into a U-shaped.

VI.OVERVIEW OF DESIGN METHODOLOGIES USING MULTIMODE RESONATOR APPROACH

In general, three design methodologies are employed to design a bandpass filter using multimode resonator approach. First design method uses either coupling resonators topology [9] or the admittance inverter [38]. A dual-mode resonator filter [9,37] is normally designed using this method because the two resonant frequencies can be designed to match the separation of the resonant frequencies from two coupled single-mode resonators [37]. Each of the resonant frequencies on the dual-mode resonator can be taken as one resonant frequency from one single-mode resonator. Other parameters can be obtained from the design curve of the coupling coefficient values of the two adjacent resonators and the external quality factor values of the filter design.

Second design method deals with distributing the fundamental resonant frequencies of the resonator according to the insertion loss function of the Chebyshev pole in the passband [15]. The resonant frequencies of the resonator can be derived using odd and even mode analysis and can be adjusted to the desired frequencies. The desired pole frequencies, fn, are calculated [15] where

$$\mathrm{fn} = \mathrm{fc}(1 + \mathrm{xn}\frac{\mathrm{FBW}}{2}) \quad (1)$$

$$xn = cos(\frac{2k+1-2n}{2k}\pi) \quad , \quad n= 1 \text{ to } k \quad (2)$$

Here, fc is the centre frequency of the passband, FBW is the fractional bandwidth of the passband, k is the number of pole. Once the resonant frequencies are located at the pole frequencies, suitable feed structures can then be incorporated to form a good filter passband. The quintuple-mode resonator filters designed by [38] have the poles distribution which closely reassembles the Chebyshev pole frequency distribution.

Third design method, so-called 3 dB matching method, is more common for higher order resonator filter design, for examples, the quadruple-mode resonators [25,30] and quintuple-mode resonators [35,36] filter designs. The lowest and the highest resonant frequencies of the resonator are located close to or at the 3-dB pass band frequencies. The rest of the resonant frequencies are distributed in between these two 3-dB frequencies. By distributing the fundamental resonant frequencies within the 3-dB frequencies, the required passband response can be obtained using suitable feed structures.

VII. CONCLUSION

The development of the multimode resonators in the past 10 years is reviewed in this paper. These multimode resonators are used for designing filter with wider bandwidth since the resonators exhibit multiple fundamental resonant frequencies. The resonators with perturbation(s) and centrally loaded open-loop resonator is used because the resonator structure can be easily analysed using the odd- and even-mode analysis. The resonator filter can be designed using one of the three common filter design methods as discussed in this paper.

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