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# Miniaturized dual-band bandpass filter using E-shape microstrip structure

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ABSTRACT

This paper, for the first time, presents a design technique to realize a miniaturized dual-band bandpass filter based on E-shape microstrip structure for integrated wireless multi-band communication systems. The filter is patterned on a double layer substrate to achieve compact size. On the bottom layer, two E-shape microstrip structures are realized and coupled through a space gap $g_c$ to perform the specified dual passbands. The filtering response of the two passbands is improved using a top layer substrate employs two $\lambda/4$ short-circuited stubs coupled through one via hole. These two filter circuits are capacitively coupled using overlapping microstrip lines. To demonstrate the technique and design process, a multi-band bandpass filter is developed to serve a multi-communication system having center frequencies of 2.4/5.3 GHz. The filter is designed, simulated and measured. The results from the simulation and measurement show good agreement. The filter circuit size is very small about 4.24 mm × 6.76 mm × 0.63 mm excluding the feeding ports.



## 1. Introduction

Due to a high demand for wireless multi-band communication systems, a key passive component in these systems the front end dual-band bandpass filters required to meet some stringent specifications including compactness, low insertion loss, good isolation between bands, high selectivity, and wideband rejection. Considering some or all of these requirements, researchers have proposed and developed many dual-band bandpass filters using different methodologies and structures. However, miniaturizing dual-band bandpass filters with high performance has always been a challenging task.

The idea of dual band filter is initially introduced in [1] by directly cascading two individual filters with different passbands. However, it has double the size of a single band filter. Using a novel feed scheme, a planar of dual-band filter is developed in [2]. The resulted filter has four transmission zeros leading to a high skirt selectivity. In [3], a bandpass filter with a dual-passband response is designed using stepped-impedance resonators with different dimensions. This filter is developed with a good attenuation levels in the extended upper stopband by collocating the transmission zeros with the unwanted peaks. Using branch-line resonators near the input and output ports, [4] presented a dual-band filter in which each passband can be designed individually. Based on stub-loaded patch resonator, dual-band bandpass filter is reported in [5]. Moreover, [6] designed a dual-band filter with good isolation and upper stop-band performance using a single dual-mode resonator. Comparing with the so far presented filters, multilayer dual-mode ring resonator is used to develop a small dual-band bandpass filter [7]. For a miniaturized dual-band filter development, [8] and [9] adopted multilayer configuration in which the former used substrate integrated wave guide (SIW) with LTCC technology while the latter used stub-loaded stepped-impedance and uniform impedance resonators. Among the above mentioned techniques and structures, the reported one in [8] has the dominant in circuit size where the filter is developed with a circuit area about 170 $mm^2$.

In this work, a new technique is proposed to develop a miniaturized dual-band bandpass filters using E-shape microstrip structure. The new technique employs double layer substrate where on the bottom layer the desired passbands are developed using two coupled E-shape microstrip structures and on the top layer the circuit for filtering response enhancement is etched. The technique is demonstrated through the implementation of dual-band bandpass filter having center frequencies of 2.4/5.3 GHz. The response of the filter shows good performance with a very small circuit area less than 29 $mm^2$.

## 2. E-shape microstrip structure analysis

The schematic diagram of the conductor pattern of the planar E-shape microstrip structure is shown in Fig. 1(a). The structure

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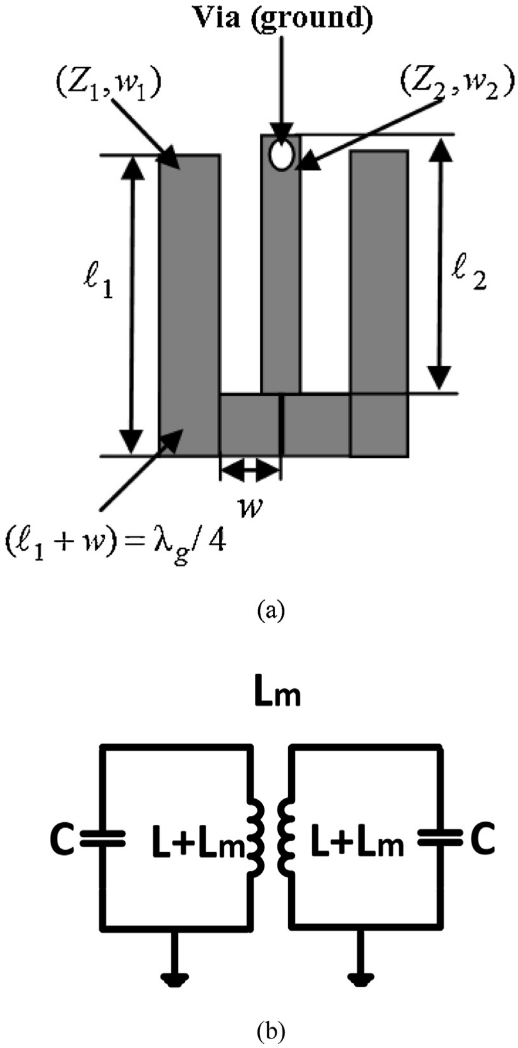


**Fig. 1.** (a) Conductor pattern on dielectric substrate and (b) equivalent circuit for the E-shape microstrip structure with grounded middle stub.

is patterned on a grounded dielectric substrate. The structure is composed of two quarter-wave open-circuited stubs at a hairpin resonant frequency loaded by a middle stub. The stub is short-circuited at its end to the ground through a via. In the layout, Fig. 1(a), the structure may be characterized by ($Z_1$, $w_1$, and $l_1+w=\lambda_g/4$) for the quarter-wave open-circuited stubs and ($Z_2$, $w_2$, and) for the middle stub. The theoretical analysis and equivalent circuit, Fig. 1(b), of the E-shape structure developed in [10] reveals that structure can be assumed as two coupled resonators. The middle stub adjusts the coupling between the two resonators.

As shown in [10], the values of elements and C in the equivalent circuit, Fig. 1(b), are given by the low frequency approximation (i.e. $l_2$ and $(l_1+w)<\lambda_g/8$ at sufficiently low frequencies). Hence,

$$L_m = \frac{Z_0 l}{V_p} \quad (1)$$

$$C = \frac{l}{Z_0 V_p} \quad (2)$$

where $V_p$, $Z_0$, and $l$ represents the wave velocity, characteristic impedance, and physical length of the transmission line involved in the structure of the element, respectively [11]. The value of $L$ in the equivalent circuit is obtained using the value of $C$ in Eq. (2) and the resonant frequency of the hairpin resonator set by length

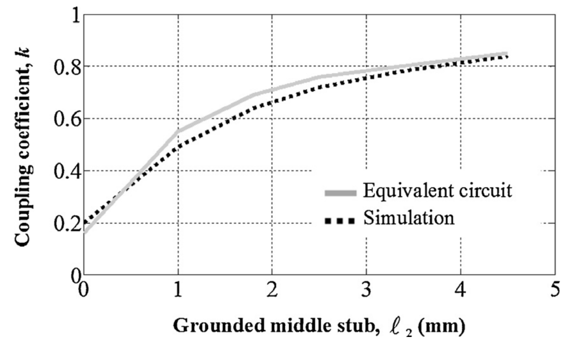


**Fig. 2.** The extracted coupling coefficient versus the grounded middle stub physical length where the hairpin resonance fixed at $2(l_1+w)=\lambda_g/2=6.74$ mm.

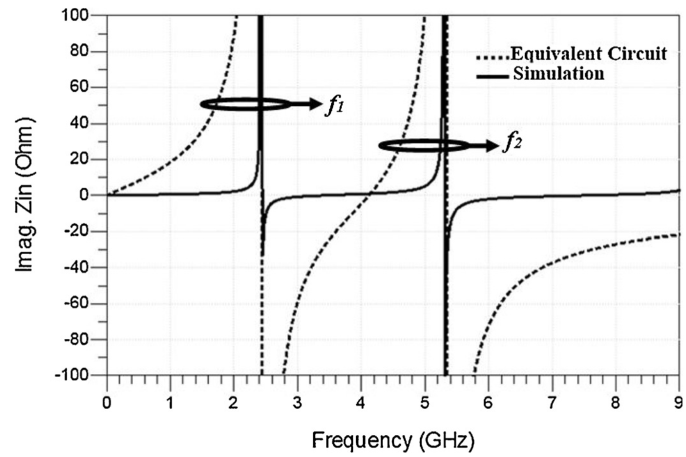


**Fig. 3.** Resonance characteristic of the E-shape microstrip structure and its equivalent circuit, Fig. 1,where $C=1.06$ pF, $L=0.85$ nH, $L_m=1.63$ nH.

$2(l_1+w)=\lambda_g/2$. This frequency is the chief resonant frequency of the E-shape microstrip structure.

Considering the equivalent circuit, Fig. 1(b), the resonant frequency of one of the resonators (in isolation) is

$$f_0 = \frac{1}{2\pi\sqrt{(L_m+L)C}} \quad (3)$$

and the coupling frequencies of the two coupled resonators are

$$f_1 = \frac{1}{2\pi\sqrt{(L_m+L+L_m)C}} = \frac{1}{2\pi\sqrt{(2L_m+L)C}} \quad (4)$$

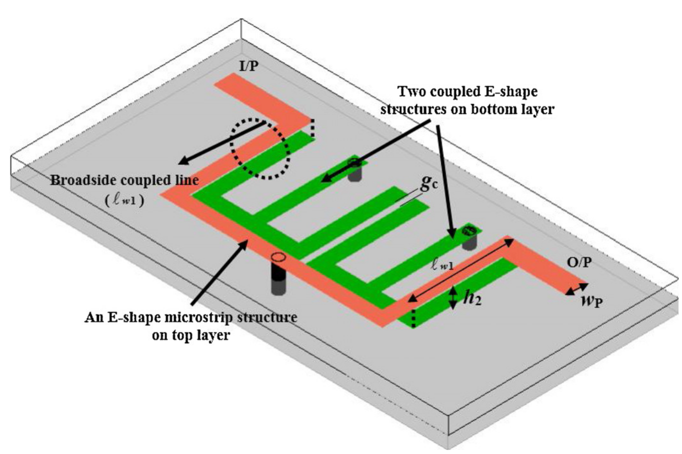


**Fig. 4.** Conductor patren of a specified dual-band bandpass filter having center frequencies of 2.4/5.3 GHz.