Indian J.Sci.Res. 17(2): 5-7, 2018 ISSN: 0976-2876 (Print)
ISSN: 2250-0138(Online)

NOTCHED IMPLEMENTATION IN NOVEL WIDE BAND PASS FILTER TOPOLOGIES

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Abstract- In this article compact microstrip wideband topologies at C-band are presented and concept of implementation of desired notch is presented. Concept of periodic impedance steps in conjunction with interdigitated comb fingers are incorporated to achieve FBW of >100%. Multiple attenuation poles and placement of transmission zeros are achieved utilizing shunt stubs consisting of open ended radial stub and interdigitated combs to achieve wider response. Further due to implementation of interdigital comb resonators better selectivity is achieved. Proposed filters cover 2-10 GHz band and stub length tuning is implemented for achieving sharp rejection notch at 4GHz. Two microstrip topologies having simpler implementations are demonstrated and compared. Measured results of the topologies show close analogy with the proposed concept.

Keywords - Band pass filter, Interdigital sections, Notch band, Microstrip, Wide-band

I. Introduction

Band pass filters are the key component in various microwave application such as radar and satellite systems, radio transreceivers, measurement instruments and wireless applications. Development of the high-speed wireless systems for short range data communication put increasing demand on integrated low-cost devices with multi-GHz operations. This prompt to develop wide band filters so as to enable high data rate transfer and having greater immunity to multipath components. Various topologies are developed to have tighter coupling to meet the desired performances. Reported topologies such as parallel coupled lines with multi mode resonator [1], photonic band gap topologies, split ring resonators, loop resonators, multi-layered structures [2], composite structures [3], Inter-digital topologies [4] are employed to achieve the wider band structures. Reported structures poses various limitations in terms of fabrication for realization of impractical gaps, compatibility due to incorporation of defective ground structures, selectivity due to wider topology, circuit size, imperfect group delay, incorporation of multiple vias and other similar techniques resulting in performance compromise to achieve the desired characteristics. Further all these topologies need extensive optimization techniques to achieve the desired performances.

Main aim of this work is to demonstrate highly selective wide band filter with notch characteristics to reject the undesired frequency for ground based applications in satellite operations. This is achieved by implementation of impedance steps to achieved tight external coupling. Internal coupling is achieved by utilizing inter-digital comb resonator terminated with the open-ended stub. As the requirement of notch characteristics in band pass filters is desired so as to avoid interference of certain channel, which is achieved in the present topology by simple stub length tuning to have notch at 4 GHz for mitigating transmitter frequency effect in satellite communication. The reported structure by Wei et al [5] to achieve the notch by employing defective ground structure but having performance degradation in the desired frequency range and also incompatible for integration. The present configuration is compact and simpler with better performances compared to reported structures.

II. Design and Analysis

A. Interdigital structure

Proposed structures consist of a interdigital resonator loaded with the open circuited stubs. Compared to standard filter topologies of parallel coupled, the inter-digitated topology offers the advantage of reducing the circuit size by two-thirds. A single cell of interdigital resonator can be construed as periodic structure loaded with open ended stubs as depicted in Fig 1. The periodic structure loaded with reactive element is standard filter topology and can be solved mathematically with the assumption of capacitive loaded line. These stubs can be treated as indentation which at the desired frequencies acts as capacitive element as per transmission line theory. These stubs are equally placed and have the same width and spacing. This periodic structure is a well-known slow–wave structure which can be useful to compensate the difference in even-odd phase velocities[6].

Total numbers of sections are optimized to have the desired performance and for the present design four sections are employed. Due to the above topology consisting of equal width and spacing, which results in tighter coupling , thus enhancing the band width in contrast to the application of Dishal's method in which varied spacing is employed to achieve varied couplings.

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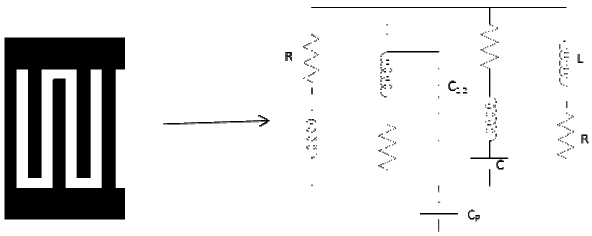

Fig 1.Interdigital section and equivalence periodic structure

Further, the indentation length of the fingers in the proposed topology is ~ λ/16 than conventional length of quarter wave-length; thus making it a compact structure.

In the above topology, centre frequency of the designed filter can be altered by optimizing number of interdigital fingers (N) and spacing between them as associated interdigital capacitances affects the centre frequency of the designed filter.

B. Open Circuited Stepped Impedance Resonator [OCSIR]

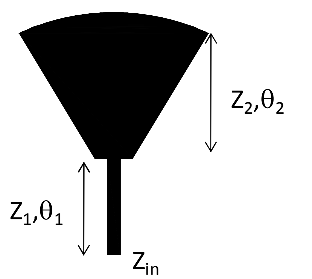

Fig 2. Open –circuited step –impedance resonator

The input impedance can be written as

Meeting the above criteria will have resonance condition (n=1) and for achieving multiple zeros the odd integer value can be taken. The value of T for the above is taken as T<1 as Z1>>Z2 results in comparatively wider band width. The value of Z1 and Z2 is chosen such that the spread between them is larger so that λ becomes shorter. In the present topologies, λ is optimized in such a way that transmission zeros are placed at higher frequency band so as to achieve wider response. Moreover, the concept of interdigital resonator with tapped input and output [6] is implemented for FBW of ~4%, but present approach in which structural modifications are carried out is based on the coupling between cascaded interdigital resonators with inline excitation. Mentioned approach results in the strong coupling without constraining finger spacing to achieve wider bandwidth

III. Description

Two topologies are demonstrated in the article to achieve wider band. Dielectric substrate chosen is RT Duroid 6010 with εr=10.8, tan δ=0.001 and thickness of 0.635 mm. The interdigital comb resonator section is modelled as shown in Fig 1. The model takes into consideration of the mutual coupling along with effect of fringing and other parasitic associated with the resonator section. Internal coupling coefficient is based on the strip width and spacing between the sections (0.1 mm). Compared to traditional interdigital topology having quarter wavelength coupled sections[8], the main advantage of this topology is the small coupled sections to achieve multiple TZs. Also, the symmetrical sections by employing multiple resonators results in the phase delay.

The section connecting open ended radial stub to inter-digital section consist of Stepped impedance resonators of quarter wavelength resulting in two extra transmission zeros. Concept of wider band width is achieved with the inter-digital section resulting in quasi-elliptic response, but to achieve better selectivity at lower and higher end of the frequency band, SIR concept is implemented for the open stub. The resulting structure provides the FBW of >110% having flat response and steep skirt.

$$Zin = jZ_1\left(\frac{Z_1\tan\theta_1 - Z_2\cot\theta_2}{Z_1 + Z_2\tan\theta_1\cot\theta_2}\right) \text{------------} (5)$$

$$\Rightarrow Zin = 0; Z_1\tan\theta_1 = Z_2\cot\theta_2$$

$$As\,T = \frac{Z_2}{Z_1}; so\,T = \frac{Z_2}{Z_1} = \tan\theta_1\tan\theta_2 \text{------------} (6)$$

$$so\,for \Rightarrow \theta = \theta_1 + \theta_2 = n\frac{\pi}{2} \text{---------------} (7)$$

To realize a notch as per applications, the shunt length with 50 ohms is optimized which results in creating attenuation poles due to creation of double tuned structures. The section connecting open ended radial stub to inter-digital section consist of Stepped impedance resonators of quarter wavelength resulting in two extra transmission zeros. Concept of wider band width is achieved with the inter-digital section resulting in quasi-elliptic response, but to achieve better selectivity at lower and higher end of the frequency band, SIR concept is implemented for the open stub. The resulting structure provides the FBW of >110% having flat response and steep skirt. To realize a notch as per applications, the shunt length with 50 ohms is optimized which results in creating attenuation poles due to creation of double tuned structures.

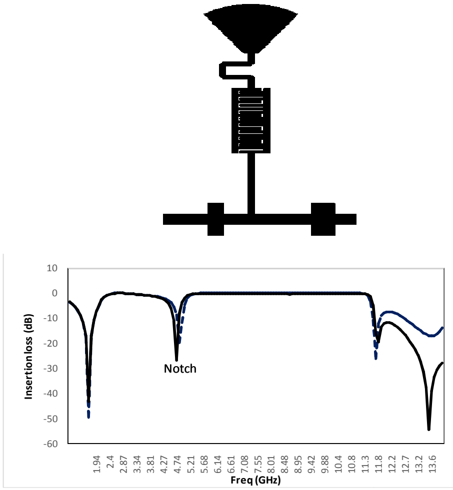

Fig. 3 : Part of the layout of the proposed 1st topology and performance comparison

Another topology is the extension of the above consisting of the single section of interdigital comb resonator part which is symmetrical placed between the impedance steps. The introduction of closed loop resonators is introduced to increase the internal coupling which in turns affects the circuit Q. The control of TZs can be carried out by the varying the spacing of the coupled and closed loop resonators.

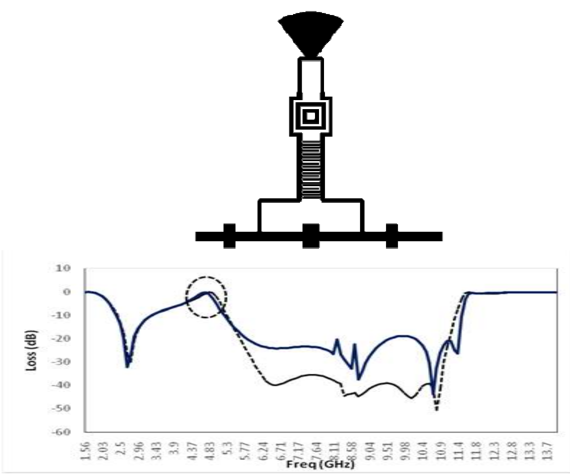

Fig 4:Part of the layout of the proposed 2nd topology

The effect of varying the spacing is also studied and described in the article. The size of the structures is 10mm × 26 mm with minimum line width of 0.1 mm. Position of transmission zeros can be controlled by changing the impedance ratio. The insertion loss in both the topologies are better than 0.8 dB with return loss of min 20 dB in the pass band. The suppression after the higher band is superior in the 2nd topology due to incorporation of extra transmission zeros with the introduction of resonators.

This article will discuss close analogy between the measured and simulated results. Both the circuit and MOM based simulations are carried out which are further verified with FEM based simulation[9]. Further, these simpler topologies can be implemented for wider band applications without or with notch as per the applications. This topology is inherently broad band and notch frequency can be tweaked with least optimization. Extremely steep cut-off skirts are achieved in the proposed microstrip topologies which are compatible with the MIC structures.

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