DESIGN AND ANALYSIS OF HAIRPIN RESONATOR

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Abstract— **The resonance characteristics of a hairpin resonator using parallel coupled line is presented. By designing a Hairpin resonator we model a single coil inductor and the properties of the system are studied using microstrip resonator with copper on FR-4 substrate which captures the desired frequencies. The effect of hairpin dimension on the filter characteristics is studied in detail. The optimum separation between the resonators for the parallel-stubs is provided and the effect of the side-coupling on the system is presented. The resonator offers a ~300MHz of pass band in desired frequency of operation. The equivalent circuit of the resonator is presented. The predicted values and the equivalent circuit values are found to be in good agreement.**

Index Terms— **Hairpin resonator, microstrip, Inter-digital capacitances, parallel-stubs.**

I. INTRODUCTION

Communication industries are facing increasing challenges in designing small, low cost, efficient and reliable inductor models. Effort in reducing the overall size for better solutions is increasing. The traditional high performance dielectric and waveguide resonator filters are usually too heavy and bulky for most of the applications. In case of satellite applications the elevated payload is not acceptable. L and S band is considered the range for message signals which can be modulated and reconstructed successfully.

Considering different filter technologies, microstrip possesses integration and compatibility with planar fabrication process. Compact, low cost device has been always the need of technology. Microstrip is cost and area efficient [4]. The disadvantage is low quality factor in high frequency or very narrow bandwidth. The square open loop microstrip resonator is the most commonly used structure in filter applications [1]. Lots of microstrip based resonator filters has been reported [3]. Open loop resonator is a good choice for this because planar cross section can easily be fabricated [8].

In this paper, an open loop resonator based resonator is presented. Interdigital capacitance in the folded arms square open loop resonator produce tunable filters. The dependence of open loop parameters on the pole location and bandwidth of the resonator filter is studied in detail.

The narrow bandpass filter designed can be explained with resonator structures. The resonator structure for analysis purpose can be chosen form maximum tunable, less complex, wide compatible and common structure. Hairpin structure is one such which is derived from planar spiral inductor. In the present study hairpin resonator is the fundamental resonance structure. For size reduction and tuning folded hairpin structure is obtained by folding an open microstrip resonator. Different coupling mechanisms are available in microstrip models [9]. In the present study parallel coupling is used to energize the resonator to reduce the dependence of impedance with respect to frequency [2].

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II. MICROSTRIP HAIRPIN FILTER

The proposed microstrip hairpin resonator filter is shown in Figure.1. Reported resonators have a physical dimension of the order of λ/8 [1]. The hairpin resonator under study is of the order of λ/16. This is achieved by loading of series lumped capacitor by folding the open ends of hairpin to obtain a stub. This has also resulted in a wider stop band.

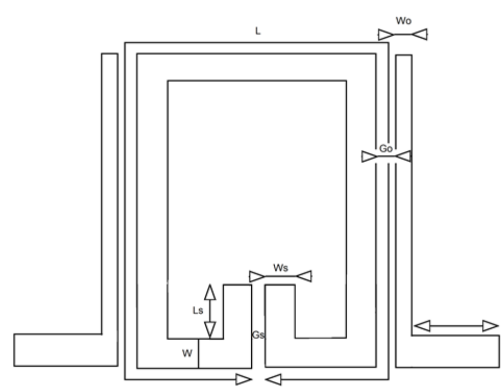

Fig. 1 Geometry of the Hairpin Resonator Filter

III. PARAMETRIC ANALYSIS OF THE RESONATOR

The hairpin resonator filter is fabricated on a substrate with permittivity ε_r = 4.4 and thickness 0.8 mm. The effect of the length (L) of the hairpin, width (W) of the hairpin are studied in detail and depicted in Figure.2 (a) and 2 (b) respectively. The FEM analysis shows that the length and width are in inverse proportion to frequency.

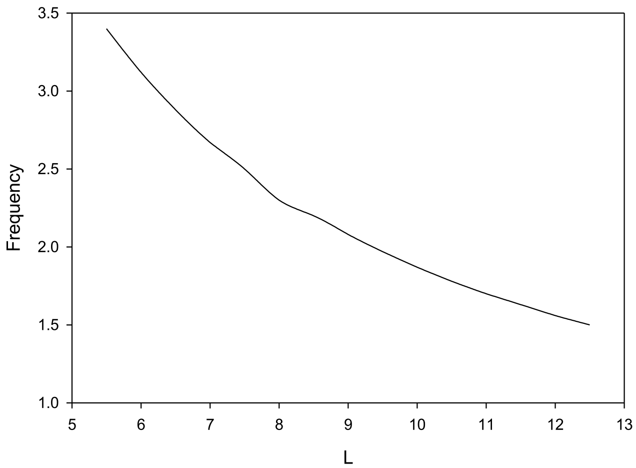

Fig. 3 (a) Variation of Frequency with Hairpin length

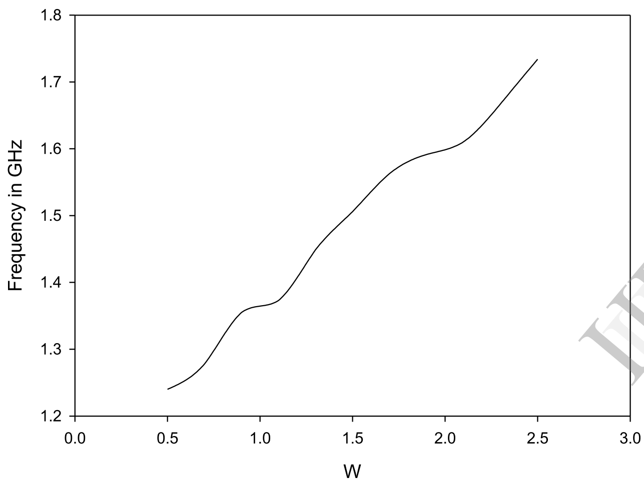

Fig. 3 (b) Variation of Frequency with Hairpin width

In the present analysis parallel coupling is used to energies the resonator. Since the parameters are varied with respect to design frequency, the output impedance matching should also be varied if coupled directly. The analysis of hairpin resonator with varying coupling gap is depicted in Figure.4.

The gap between stubs (gs) is a critical factor in tuning of hairpin around the design frequency. This factor has dependence on the magnetization of loop, exited with a small current. Studies say, it is difficult to incorporate such widely varying factors in modeling. The problem of series resistance of stub and its dependence on magnetization of loop makes it difficult to incorporate it in design frequency modelling. The effect of substrate parameters are also studied in detail. As permittivity varies the fringing capacitance will vary, this results in variation in design frequency. The analysis of hairpin resonator with dielectric constant is plotted in Figure.5.

The reflection and transmission characteristic of the parallel coupled hairpin resonator is plotted in Figure.6.

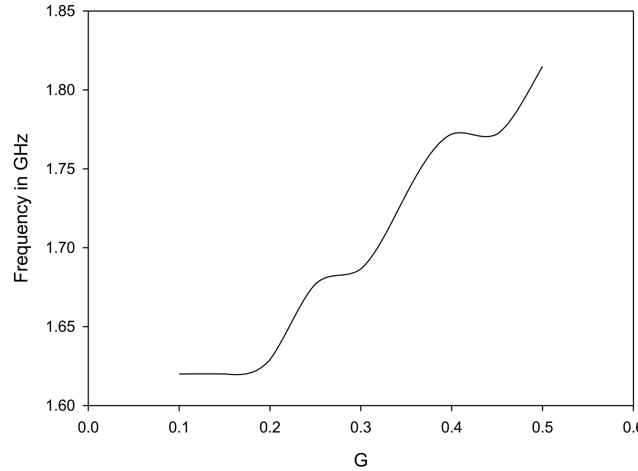

Fig.4 Variation of Frequency with Gap

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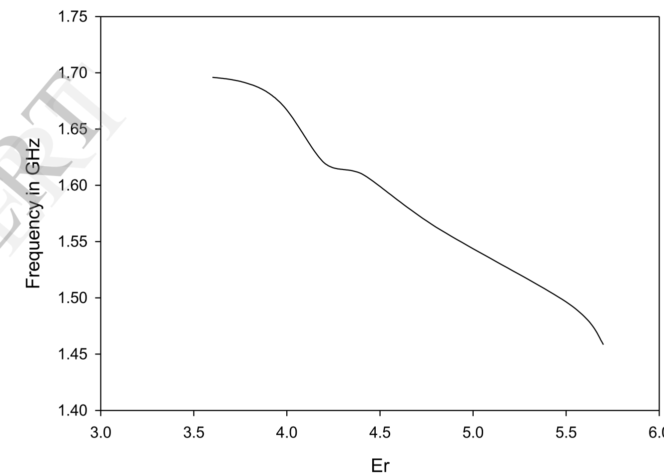

Fig. 5. Variation of Frequency with Permittivity

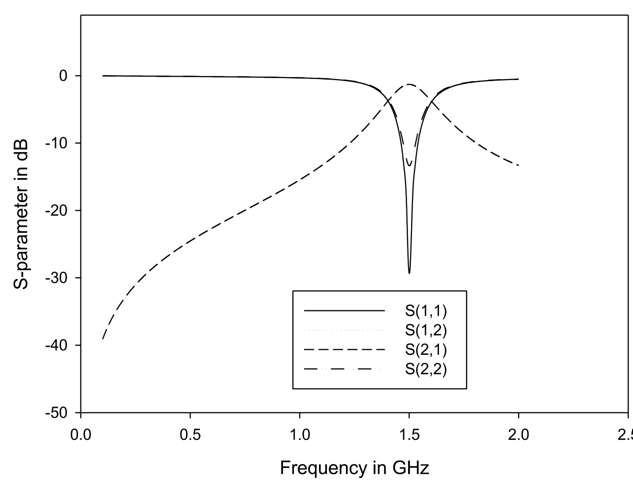

Fig. 6. Frequency Response of Parallel Coupled Resonator Filter

IV. Equivalent Circuit

The equivalent circuit of parallel coupled hairpin resonator is presented here. The additional stubs introduce a tuning capacitance between them. The modified circuit equivalent of the proposed hairpin resonator is shown in figure 6. The parameters C1, C2, L1 and coupling factor are analyzed.

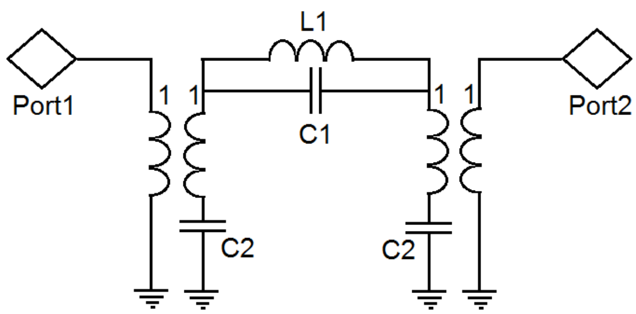

Fig. 6. Circuit Equivalent of Hairpin Resonator

The output ports are having fixed output impedance of 50Ω. This can be varied with respect to the coupling circuit to which this inductor is to be attached.

V. Conclusion

One of the most popular structures for microstrip implementations is the square open loop resonator due to its compact size and versatility. In this paper a compact open loop resonator with a capacitor stub is presented. A size reduction of ~ 50% is achieved with respect to a conventional square open loop resonator filter in the present approach. A pass band with 300MHz bandwidth and more than -15dB transmission is obtained. The stop band response is also appreciable for an RF filter.

The problem of estimating the effective series resistance of small capacitors at microwaves frequencies was also considered. It was proposed that the miniature square open loop resonator could be used to measure the ESR of the loading capacitor as long as an accurate model for the microstrip structure is obtained in advance.

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