A Design of a Ring Bandpass Filters with Wide Rejection Band Using DGS and Spur-line Coupling Structures

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***Abstract* — A novel inductive coupling (L-coupling) structure is presented to easily control the coupling value and to suppress the harmonics in ring bandpass filters using defected ground structure(DGS). DGSs are placed below the 50Ω microstrip feed lines at the input and output. This DGS is operated as inductor for L-coupling and stop resonator to suppress the harmonics. We also embedded spur line into the coupling section to suppress more harmonics at the input/output port. Therefore, coupling section consists of DGS and spur line. This coupling section inhibits signal propagation in the stopband frequency, allowing the desired passband. To demonstrate these novel techniques, we have designed and fabricated two ring bandpass filters with 150MHz bandwidth at center frequency, 2.3GHz. Experimental results show good harmonic suppression, up to the fourth harmonic with rejection levels near -23dB. Since this L-coupling does not need very narrow coupling gap, this approach can easily control the coupling level, be fabricated in the coupling section, and suppress the harmonics.**

***Index Terms* — Ring bandpass filters, DGS**

I. INTRODUCTION

Bandpass filters (BPF) are essential high frequency components of wireless communication systems and handsets to in order to achieve high performance, small size, and low cost and to comply with strictly required transmission specifications. There are many types of bandpass filter design techniques to meet the above requirements, such as the use of high-permittivity materials, variation of resonator structures, and use of multiple resonant modes. In the conventional microstrip and strip line BPFs having parallel coupled lines, the size is quite large because of use of λ/2 resonators, while the realization is simple. On the other hand, the BPFs having hairpin resonator structures, which is a modification of parallel coupled lines, have relatively smaller size than the BPF having parallel coupled lines. However, these filters are of limited utility due to their typically high insertion loss and the practical problem to achieve passbands of less than 5% bandwidth. To achieve narrow bandwidth a very narrow gap between coupled lines to get the required strong coupling to the first inverter is needed in the conventional BPF.

In the case of ring resonators, it is well known that two orthogonal resonant modes exist within a one wavelength ring resonator[1-2]. It has several advantages of compact size, narrow bandwidth, low radiation loss, and dual mode characteristic. Therefore, the ring resonators are widely used in the design of filters, oscillators, and antennas[3-4]. However, ring resonator also has the same problems as mentioned above. They exhibit a passband at every harmonic frequency and need a narrow gap for capacitive coupling (C-coupling).

In this paper, we introduce a new inductive coupling (L-coupling) structure and a technique to suppress higher harmonics. We used the defected ground structure (DGS) for L-coupling in ring bandpass filter instead of C-coupling using coupled lines with narrow gap. This DGS operates as inductor for L-coupling and also as a stop resonator to suppress harmonics, simultaneously. Use of DGS lets us easily control the coupling value. We also embedded spur line into the coupling section to suppress more harmonics at the input/output ports. By using spur lines the conventional structure is suppressed only the second harmonic. The presented structure with DGS and spur line can suppress up to the fourth harmonic. This filter also has two transmission zeros located on either side of the passband according to line length ratio between upper and lower lines. The new ring bandpass filter using DGS and spur line is presented and measured to prove the validity of this design method.

II. THE PROPOSED L-COUPLING STRUCTURE USING DGS

The transmission zeros of ring resonators of which resonator length is one λ can be adjusted according to the coupling angle and conditions [5]. However, the conventional ring bandpass filter has a practical problem in realization. The gap between coupled lines must be very small to get the required coupling. So, we present a new coupling structure to control and fabricate the coupling easily as shown in Fig. 1. Fig. 1 shows that the projected structure consisting of a microstrip ring resonator on the top plane and DGS etched in the bottom ground plane, respectively. We used DGS for coupling to the ring resonator instead of conventional coupling method with coupled lines.

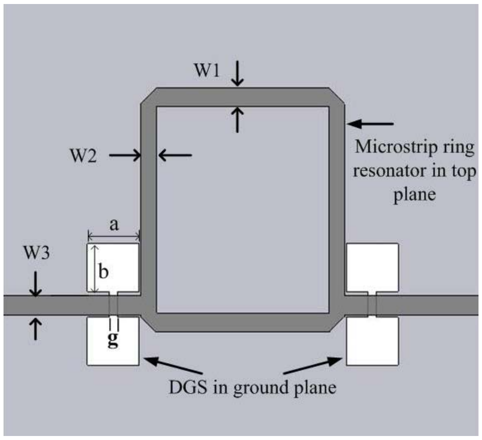


Fig. 1. Structure of the new ring bandpass filter

The feed line impedance at input/output port is 50Ω and the length of ring resonator is one λ at 3.1GHz. The lattice dimension '*a*' is 6mm and gap '*g*' is 1mm for the DGS etched defects in the backside metallic ground plane. The substrate with .787mm thick and dielectric constant of 2.5 was used for all cases.

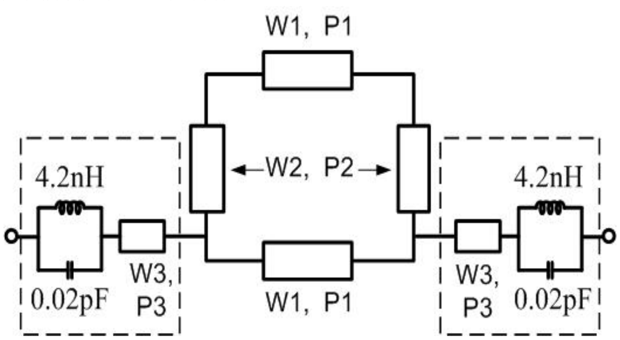


Fig. 2. Equivalent circuit of ring bandpass filter (W1=2.5mm, W2=1.9mm, W3=2.4mm, P1=20mm, P2=22mm, P3=5mm)

Fig. 2 shows the equivalent circuit of the proposed bandpass filter. The dashed boxes indicate the equivalent circuit of the DGS embedded within feed lines. This DGS provides the effective inductance along with the parallel capacitance in the transmission line. In order to extract the equivalent circuit parameters for the DGS section, *S*-parameters of the proposed DGS unit section were calculated by using Ansoft HFSS V9.0. The method for finding the equivalent circuit parameters is detailed in reference [6]. This DGS section acts as an inductor due to the defected area, even though the characteristic impedance of line is 50Ω. The ring BPF has a good attenuation slope by proper assignment of attenuation poles according to length ratio between two lines. This is because there exists two propagation paths between the input and output ports. This characteristic becomes highly effective for obtaining excellent attenuation slope near the passband of BPF structure by using ring resonator.

Fig. 3 illustrates the simulated performance of the equivalent circuit using Ansoft Serenade and the full-wave simulation results using HFSS, and measured results of the proposed BPF. The equivalent circuit shown in Fig. 2 is reliable in design and predicting performances of the proposed BPF. The measured result shows good performance with a sharp skirt characteristic due to two attenuation poles and -0.55dB of low insertion loss.

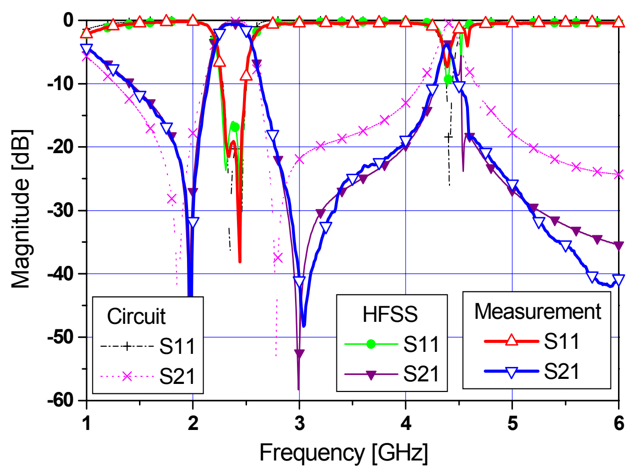
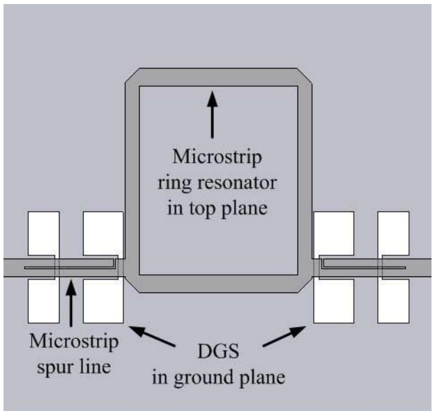


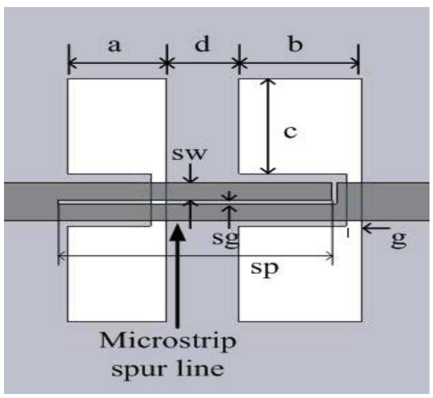
Fig. 3. Simulated characteristics of ring bandpass filter with DGS

III. The Ring Bandpass Filter with DGS and Spur Line

The above structure also has the second harmonic as other conventional structures such as edge coupled line, hairpin and ring type BPFs. In order to suppress more harmonics we adopted the spur line along with the DGS in the coupling section. Fig. 4 shows the structure of ring BPF with DGS and spur line. This spur line is already reported in reference [7] that it can suppress the second harmonic. But we implemented the new coupling section to suppress more harmonics which consists of two DGSs and spur line in input/output feed lines. The combination of one DGS and spur line suppresses the second harmonic reasonably well. However, to improve the BPF's performance, a second DGS was added for increased harmonic suppression characteristics.



(a)



(b)

Fig. 4. (a) The structure of ring BPF (b) coupling section with DGS and spur line
(a=4mm, b=5mm, c=5.5mm, d=3mm, sw=1mm, sg=0.2mm, sp=11.2mm)

Fig. 5 shows the simulated and measured result of the proposed ring bandpass filter with DGS and spur line shown in Fig. 4. The ring resonator has the same dimensions as shown in Fig. 1. The measured insertion loss and return loss are less than -0.67dB and -23dB at the passband of ring BPF with center frequency 2.3GHz, respectively. The stop band characteristics for fabricated ring BPF are better than -23dB up to 10GHz. It means that this coupling structure can suppress up to the fourth harmonics due to attenuation characteristic of DGS and spur line combinations, while harmonic responses of conventional microstrip ring BPF has every harmonic. Furthermore, the conventional ring BPF[7] which uses only the spur line, can suppress only the second harmonic. Furthermore, there are two attenuation poles near the passband to create the sharp skirt characteristics as the original feature of ring resonator. The experimental results show excellent agreement with simulated result. Fig. 6 shows the photographs for the two kinds of the proposed ring bandpass filters.

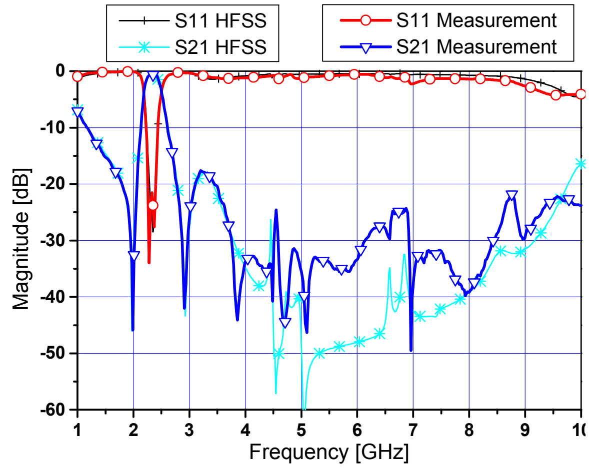
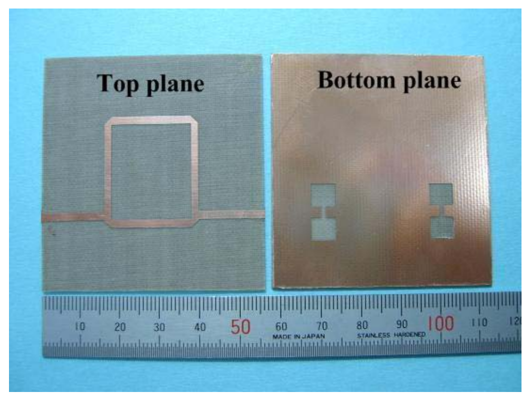
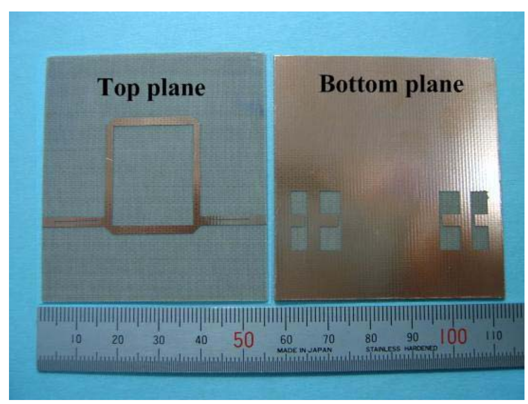


Fig. 5. Simulated and measured results of ring BPF with DGS and spur line.



(a)



(b)

Fig. 6 Photos of the ring BPFs with (a) DGS (b) DGS and spur line

IV. CONCLUSION

Novel coupling structures for ring bandpass filters has been demonstrated to suppress harmonics and to make implementation less challenging by using DGS. To demonstrate its potential, ring bandpass filters with suppressed spurious bands have been designed and fabricated. The measured insertion loss and return loss are less than -0.67dB and -22dB in the passband of 150MHz at center frequency 2.3GHz, respectively. This filter also has the steep attenuation slope as a result of the two attenuation poles at both sides of the passband. The stop band characteristics of ring BPF with DGS and spur line are less than -23dB up to 10GHz. Therefore, this coupling structure can suppress the harmonics up to the fourth harmonic due to attenuation characteristics of DGS and spur line embedded within the feed lines of the ring resonator without added area. It is expected that the proposed structure can be applied to improve the stopband performances of other microwave circuits as well as other types of filters.

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