OSRR-based BPF with Square Groundplane Window

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***Abstract*—In this paper, a bandpass filter (BPF) composed of open split-ring resonator (OSRR) structure with square groundplane windows underneath the structure is investigated numerically and experimentally. Square groundplane windows are proposed to enhance the property of OSRR-based BPF in overcoming the passband bandwidth response. The designed BPF is constructed of 3 cascaded OSRRs connected with microstrip lines. Some parametrical study to obtain the optimum bandwidth response is carried out by changing the dimension of square groundplane window in the design process. The filter is then deployed on a 0.8mm thick FR4 Epoxy dielectric substrate with the dimension of 60mm in length and 20mm in width. From the experimental characterization, the realized OSRR-based BPF with the dimension of each square groundplane window of 12mm × 12mm shows the bandwidth response of 0.81GHz ranges from 1.75GHz 2.56GHz which is comparable with the numerical one.**

Keywords*—Bandwidth response; bandpass filter; open splitring resonators; square groundplane windows

I. INTRODUCTION

In recent years, researches related with split-ring resonator (SRR) and its applications have been developed rapidly. The SRR which is known as a type of artificial materials or metamaterials is usually applied as an additional structure for planar technology implementation in compact microwave devices [1]– [3]. As is well-known, the structure of SRR which is basically made of nonmagnetic metal such as copper is composed of a pair of concentric enclosed-loops with splits at opposite ends. The shape of loop commonly used is circle or square loop. Due to the capability to produce large capacitance values, the SRR structures have been utilized to lower the resonant frequency for some applications [3]– [5].

Moreover, SRR is often used to improve performance of the communication and information technology devices, particularly filter and antenna, without changing the basic characteristics or increasing the size of device [6]– [7]. The effect which is produced depends on the type of SRR, structure pattern, structure composition, and distance of gap. Among the existing SRR types, the open split-ring resonator (OSRR) is a type of resonators which is frequently implemented for manufacturing a compact microstrip bandpass filter (BPF) dues to the strong coupling connection between the loops while working as lumped LC series [8]– [9]. In addition, the OSRR structure can provide smaller electrical size compared to the regular SRR or CSRR structures.

This work is partially supported by the Research Grant from ITB under the Program of Research and Innovation 2014.

In accordance to the advantages of OSRR structure, in this paper, a new method to enhance the property of BPF made of OSSR structure is proposed by introducing square groundplane window underneath the OSRR structure. The passband bandwidth response of OSRR-based BPF is investigated as the effect of the presence and dimension of square groundplane window. The proposed BPF which is constructed of 3 cascaded OSRRs connected with microstrip lines is designed on an FR4 Epoxy dielectric substrate with the thickness of 0.8mm. Some parametrical studies upon the square groundplane window are investigated to obtain the optimum bandwidth response. Hence, the filter parameters including return loss (S11), insertion loss (S12), and bandwidth response will be used as key indicators in evaluating the filter performance.

II. OSRR-BASED BPF DESIGN

Fig. 1 illustrates the geometry of each OSSR structure used for OSRR-based BPF design. The shape of loop is square loop in which the lengths of each side for outer and inner rings are 6.5mm and 4.1mm, respectively. The width of each ring and the separation between rings are set to be 0.8mm and 0.4mm, respectively. The thickness of loops made of metal copper is 0.035mm placed on a side of FR4 Epoxy dielectric substrate with the thickness of 0.8mm. Whilst the groundplane of BPF with the same thickness, i.e. 0.035mm, is placed on other side of the dielectric substrate.

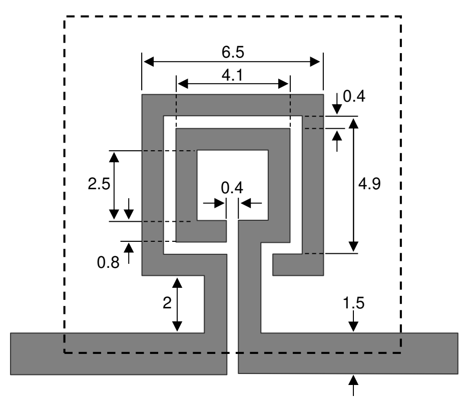
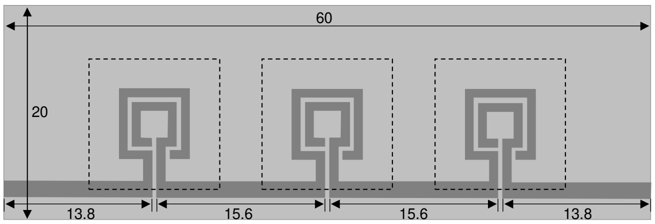
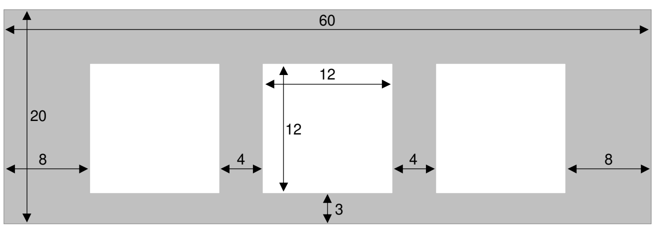


Fig. 1. Geometry of each OSRR structure used for design (unit in mm)

The overall designed OSRR-based BPF is constructed of 3 cascaded OSRRs as shown in Fig. 2(a). It shows that microstrip lines with the width of 1.5mm are used to connect the OSSR. Since the input and output signals for BPF are obtained from SMA connectors, therefore the width of microstrip line can be calculated theoretically to have the line impedance of 50Ω. The dimension of OSRR-based BPF is 60mm in length and 20mm in width. In case to investigate the passband bandwidth response of BPF, as shown in Fig. 2(b) a square groundplane windows is introduced for each OSRR structure which is located underneath the structure. The dimension of square groundplane window is varied in 3 different values, i.e. 10mm $\times$ 10with, 12mm $\times$ 12mm, and 14mm $\times$ 14mm, to analyze its effect to the property of BPF in obtaining the optimum bandwidth response.



(a) top view of OSRR-based BPF



(b) bottom view of OSRR-based BPF with square groundplane windows

Fig. 2. Overview of proposed OSRR-based bandpass filter (unit in mm)

The numerical characterization result of OSRR-based BPF as the effect of presence and dimension of square groundplane window is depicted in Fig. 3. It clearly shows that the presence of square groundplane window affects remarkably to the passband bandwidth response of OSRR-based BPF. From the result, it is seen that the BPF with square groundplane window has the value of return loss (S_{11}) much better than the BPF without square groundplane window. The value of S_{11} for BPF without square groundplane window is -1.64dB in which this will be suppressed up to -9dB when implementing square groundplane window. This can be figured out that the square groundplane window actuates the OSRR structure which actually has low resonant frequency due to the large capacitance values to work properly affecting to the lowering passband characteristic response.

By varying the dimension of square groundplane window, it shows that the OSSR-based BPF has the optimum bandwidth response when the dimension of square groundplane window is 12mm $\times$ 12mm. In this dimension, the filter produces the value of S_{11} up to -9.06dB at frequency of 2.24GHz. This can be understood that the larger dimension of square groundplane window increases the capacitance value of OSRR resulting the wider passband bandwidth response. In other side, however, the larger dimension increases the impedance mismatch of filter that causes the worse value of return loss.

Furthermore, the utilization of square groundplane window for proposed OSRR-based BPF is also useful to suppress insertion loss (S_{12}) without increasing the total dimension of filter.

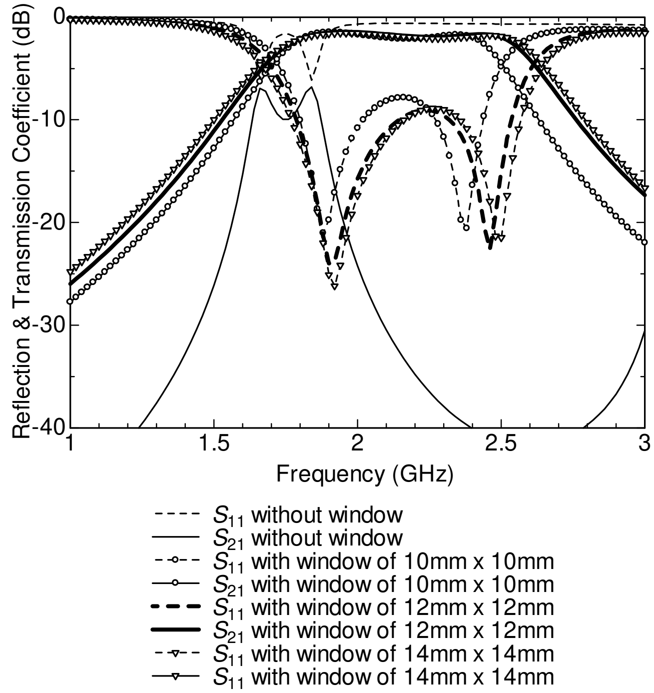


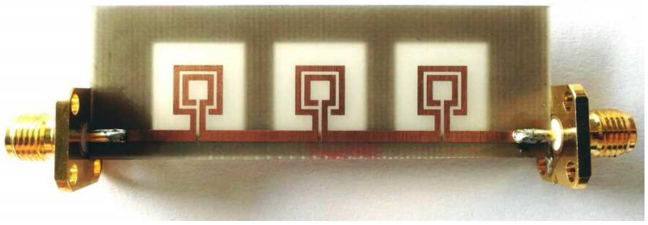
Fig. 3. Simulated frequency responses for several OSRR-based BPF with and without square groundplane window

Unfortunately, for 3 different values of square groundplane window, there is no significant distinction of S_{12} values which can be obtained. Although the values of S_{12} are almost similar each other, it seems that the OSRR-based BPF with 12mm x 12mm square groundplane window has the lowest value of S_{12} which indicates the largest amount of energy transmission. Therefore, this filter which has the bandwidth response of 0.82GHz ranges from 1.74GHz to 2.56GHz will be fabricated for experimental characterization.

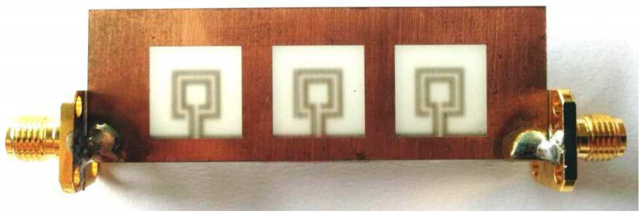
III. Fabrication, Characterization and Discussion

As the next step, a hardware realization of OSRR-based BPF is conducted to verify the numerical characterization result. The OSRR-based BPF with 12mm x 12mm square groundplane window is fabricated by deploying the designed filter on a 0.8mm thick FR4 Epoxy dielectric substrate through wet etching technique. Fig. 4 shows a picture of realized OSRR-based BPF with the total dimension of 60mm in length and 20mm in width. Two SMA connectors are connected at input and output ports of realized filter.

Fig. 5 depicts the measured results for experimental characterization of OSRR-based BPF in which the simulated results are plotted together for comparison. In general, it shows that the measured results are agreed very well with the simulated results, instead tend to be better at some frequency ranges compared to the numerical characterization. The discrepancy between measured results and simulated ones is probably evoked by the different value of tangent loss of FR4 Epoxy dielectric substrate for fabrication and simulation. From the results, it seems that the tangent loss of dielectric substrate for simulation is lower than for fabrication.



(a) top view of realized OSRR-based BPF



(b) bottom view of realized OSRR-based BPF

Fig. 4. Pictures of realized OSRR-based BPF with 12mm × 12mm square groundplane window

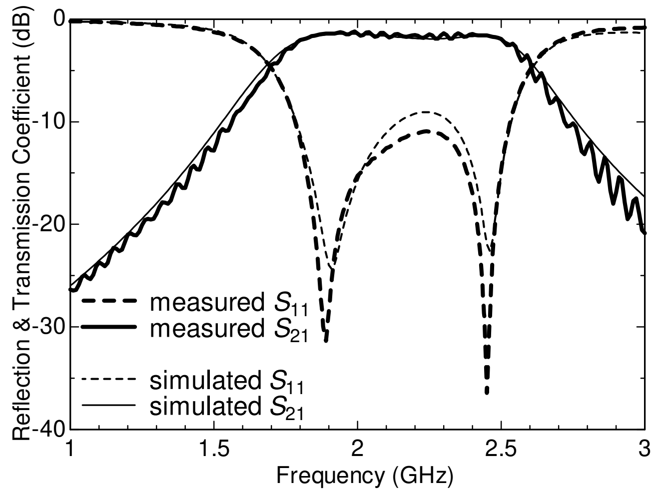


Fig. 5. Measured frequency responses of OSSR-based BPF with the simulated results as comparison

In addition, the value of return loss (S_{11}) from experimental characterization in the passband region is relatively better than the value of S_{11} from numerical characterization. As mentioned in the previous section, the value of S_{11} obtained from numerical characterization in the passband region is up to -9.06dB occurs at frequency of 2.24GHz, whilst from the experimental characterization the value of S_{11} is up to -10.97dB for the same frequency. Slightly different from the value of S_{11}, there is no significant result occurs in the passband region between the value of insertion loss (S_{12}) from experimental and numerical characterizations.

The discrepancies occur only at the stopband regions at lower and higher frequency ranges which are probably evoked by the relative permittivity of FR4 Epoxy dielectric substrate for fabrication lower than for simulation. This causes the bandwidth response of realized OSRR-based BPF is slightly narrower than of simulated one. It shows that the measured bandwidth response of OSRR-based BPF is 0.81GHz ranges from 1.75GHz to 2.56GHz in which this is narrower 10MHz than the simulated result of 0.82GHz ranges from 1.74GHz to 2.56GHz. Nevertheless, it is noticeable that the realized OSSR-based BPF has complied with the designed one where the realized filter can be used for various applications in the range of passband region such as GSM, 3G and WLAN communications.

IV. Conclusion

The design of OSSR-based BPF with square groundplane windows underneath the OSRR structure has been investigated numerically and experimentally. The presence and dimension of square groundplane window has also been demonstrated in connection to investigate the passband bandwidth response. The OSSR-based BPF with 12mm × 12mm square groundplane window has been fabricated on a 0.8mm thick FR4 Epoxy dielectric substrate with the total dimension of 60mm in length and 20mm in width. From numerical characterization, it has been shown that the square groundplane window affected to the lowering passband characteristic response of OSSR-based BPF. Hence, the dimension of square groundplane window has produced wider bandwidth response of filter. Whilst from the experimental characterization, it has been demonstrated that measured results have coincided with the simulated ones. Some discrepancies have occurred due to the possibility of different parameter values of dielectric substrate for simulation and fabrication. It has been shown that the realized OSRR-based BPF has the bandwidth response of 0.81GHz ranges from 1.75GHz to 2.56GHz which was comparable to the numerical characterization with the bandwidth response of 0.82GHz ranges from 1.74GHz to 2.56GHz. In addition, some improvement to enhance the bandwidth response of OSRR-based BPF is still in progress where the potential result will be reported later. In conclusion, the proposed OSRR-based BPF has shown acceptable performance which can be applied for various wireless communications.

Acknowledgment

The authors wish to thank to Dr. Mohammad Ridwan Effendi and Mr. Zenal Aripin, both from School of Electrical Engineering and Informatics, Institut Teknologi Bandung (ITB) for strong support and experimental characterization.

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