Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 09, September-2023

Design, Modeling, and Fabrication of Defected Microstrip Coupled Resonator Filter for S-Band Applications

Reza Hosseini, Gholamreza Moradi, Reza Sarraf shirazi

***Abstract* - In this paper, a defected microstrip structure (DMS) based coupled resonator is incorporated to realize a bandpass filter. The filter operates at the center frequency of 2.71GHz with the bandwidth of 330MHz. The frequency response of the proposed filter is studied using full wave simulations and compared with a circuit modeling approach and later verified by experimental results.**

***Index Terms* - Defected Microstrip structure (DMS), wide band filters, coupled resonators**

I. INTRODUCTION

As one of the most important passive circuit blocks, novel filters has become subject of numerous recent studies. Novel metamaterial resonators similar to the structures introduced in [1,2] have shown promising capability to operate in high frequencies where conventional lumped circuit elements fail to operate due to high parasitic values. Besides the conventional filters, new structures have been presented for different applications such as bandwidth increase, size reduction, and dual-band features. Defected ground structures (DGS), defected microstrip structures (DMS), ring resonators, coupled resonators, diplexers [3-12] are some of the new approaches to design and implement microwave filters to be employed and integrated in high frequency circuits where waveguide structures limit the use of lumped components.

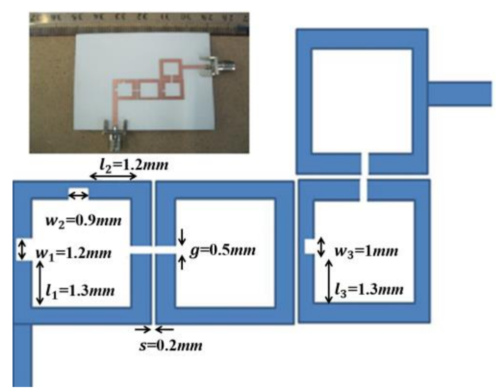
DMS is a slit or defect on the microstrip that has found various applications in microwave engineering namely ultra-wideband (UWB) filter applications [13,14]. These defects manipulate RF waves by changing the current distribution on the ground layer or the strip line leading to a significant impact on the insertion loss, return loss and phase linearity of filters. Therefore, using an optimization algorithm, one can design an improved filter structure. Convenient design algorithms can change the design procedures from blind trial-and-error to efficient planned and well-thought-out processes [15]. This method can be applied to different types of filters, i.e. LPFs, BPF, and HPFs. Here the focus is on BPFs.

Combination of defected microstrip structure (DMS) and the coupled resonators results in a novel method in designing bandpass filters. This type of filter is proposed here as a base for other similar circuits. The design, fabrication, and measurement results of this filter are presented in this manuscript and a good agreement is reported between the simulation and measurement results.

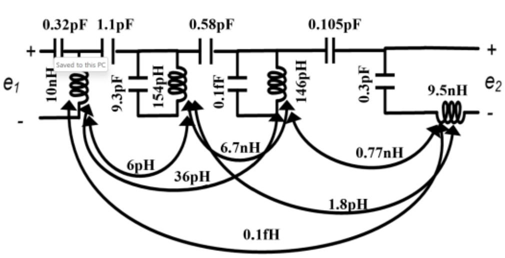
The paper is organized in four sections described as follows: In section 2, the proposed DMS structure is introduced. The circuit model of the filter is studied in section 3. In section 4, the simulation and measured results are presented and discussed, and the paper ends with a conclusion.

II. DEFECTED MICROSTRIP STRUCTURE

As the initial structure, the coupled resonator filter is composed of four square-shaped resonator structures. Due to the small gap between each square, field and therefore the energy



(a)



(b)

Fig. 1. DMS coupled resonators bandpass filter, a) microstrip structure b) its equivalent circuit model.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 09, September-2023

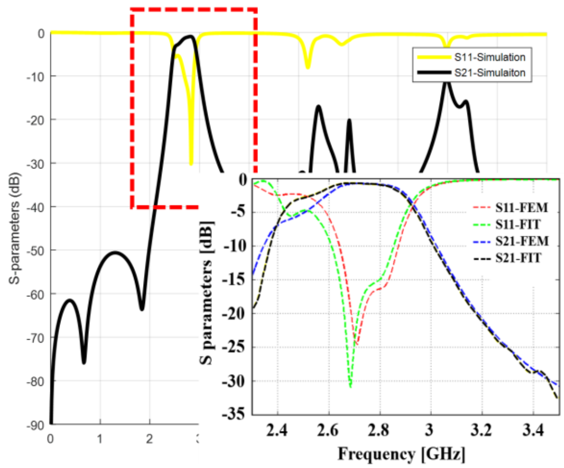


Fig. 2. DMS coupled resonator S parameters.

coupling between squres plays a major role in studying the electromagnetic response of the structure. However as shown in Fig. 1(a), introducing defects on the microstrip is pursued to optimize the characteristics of the initial structure. These defects disturb/change the surface current distribution causing different possible resonances. In other words, some extra resonant frequencies are added to the standard transmission line's models in order to predict the new structure's behavior. It is known that these resonance frequencies could generally result in band-stop frequency response. However, the DMS position and frequency spectrum could be engineered to achieve an optimized coupled resonator filter. Following a full wave optimization algorithm, the final design as schematically illustrated in Fig. 1, has been obtained. The structure dimensions including the gaps and slit's sizes are presented in Fig.1(a).

The DMS resonances are engineered in frequency spectrum so that a bandpass pattern in the filter insertion loss could be achieved. Following such strategy, full-wave EM simulations depict a bandpass filter. The numerical studies are conducted using two different approaches: the Finite Integration Method (FIT) and Finite Element Method (FEM) techniques. The proposed filter shows a 3dB bandwidth of about 330 MHz spanning from 2.57GHz to 2.9GHz centered at 2.71GHz, so a relative bandwidth of twelve percent is obtained. The full wave simulation results are shown in Fig .2.

III. CIRCUIT MODELING

To gain a circuit insight of the proposed microstrip filter, a circuit modeling has been used and the integrity of the structure is verified. Furthermore, the circuit model is important for optimizing the filter's structure.

As in [16], a *LC* circuit model is commonly used to represent each resonator in the proposed structure. Since the squared-shape resonators lie in the proximity of each other, the strong field coupling between them is expected. Therefore, in the proposed circuit model, some capacitances and mutual inductances are included to address the electric and the magnetic couplings, respectively. The proposed circuit model is shown in Fig. 1(b).

The analysis of the proposed circuit is done using the circuit theory [17] and the scattering parameters are extracted from Y-parameters using the two-port network approach.

The circuit elements must be selected so that the circuit

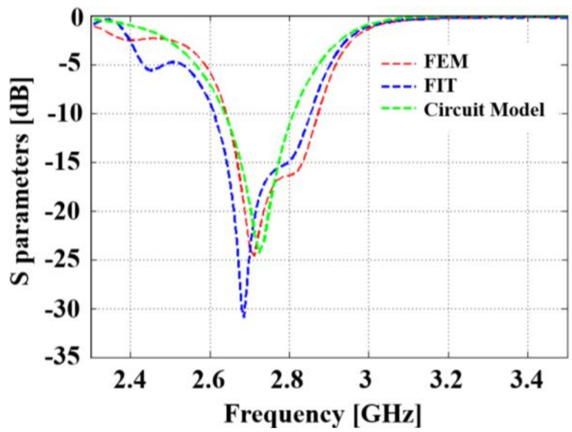


Fig. 3. S11 comparison between coupled resonators and its circuit model.

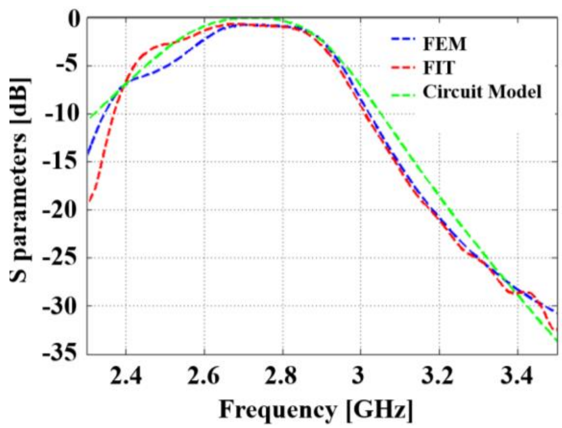


Fig. 4. S21 comparison between coupled resonators and its circuit model.

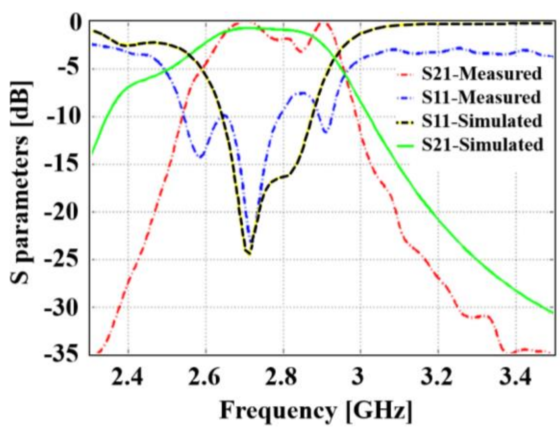


Fig. 5. S-parameters comparison between measurement and simulation.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 09, September-2023

model's result could follow the full-wave simulations in the desired frequency range. Therefore, a commercial EDA tool is employed to find and optimize the circuit values. The final circuit elements are presented Fig. 1(b). The mutual inductances between two adjacent couplers have a higher role comparing to other elements located away from each other. Although in a complete circuit model, the mutual capacitances should have also been considered, it can be intuitively understood that these capacitances do not have huge impacts on the model behavior, as their values are negligible due to their corresponding resonators' relative distances. Therefore, these capacitors have not been included in the model, making the circuit simpler.

It should also be noted that there are no resistors considered in the circuit modeling to address the possible dissipation, which may occur in the component. Since a relatively low loss dielectric is employed, it is expected that neglecting resisances will not effect the circuit result accuracies dramatically.

Figs. 3, 4 show good agreement between the circuit model and the full-wave results. Negligible differences between the two results can be related to the loss tangent of the desired substrate, which, unlike circuit modeling, has been considered in full-wave simulations.

IV. FABRICATION AND EXPERIMENTAL RESULTS

The filter is fabricated using the 31mil thick RO4003C substrate with a relative permittivity of 3.55 and loss tangent of 0.0027. In order to have a 50Ω line, the width of the microstrip line is calculated to be 1.9mm.

The filter is characterized in terms of return loss and insertion loss by a Rhode & Schwarz Vector Network Analyzer (VNA). The results are compared to the simulation results and shown in Fig. 5. It should also be mentioned that the effects of SMA connectors have not been covered in the simulation results. Thus, a minor discrepancy between measurement and simulation results can be expected.

V. CONCLUSION

It was numerically and experimentally shown that the DMS coupled resonators could be used for designing and implementing bandpass filters. A circuit modeling approach was pursued to represent an alternative and fast way of systematic study for the coupled resonator-based filters. The circuit model elements were extracted using the optimization process and a good agreement was demonstrated between full-wave simulation, the model results, and the fabricated protoype. The experimental results confirm the scattering parameters' outcomes predicted by all numerical simulations.

REFERENCES

[1] S. Pahlavan and V. Ahmadi, "A Systematic Approach to Photonic Crystal Based Metamaterial Design," *International Journal of Optics and Photonics*, vol. 10, no. 1 (2016), pp. 55-64.

[2] S. Pahlavan and V. Ahmadi, "Novel Optical Demultiplexer Design Using Oblique Boundary in Hetero Photonic Crystals," *IEEE Photonic Technology Letters*, vol. 29, no. 6 (2017), pp. 511-514.

[3] Xue, Quan, and Jun Ye Jin., "Bandpass filters designed by transmission zero resonator pairs with proximity coupling," *IEEE Transactions on Microwave Theory and Techniques*, vol. 65, no. 11 (2017), pp. 4103-4110.

[4] Xu, Shanshan, Kaixue Ma, Fanyi Meng, and Kiat Seng Yeo., "Novel defected ground structure and two-side loading scheme for miniaturized dual-band SIW bandpass filter designs," *IEEE microwave and wireless components letters*, vol. 25, no. 4 (2015), pp. 217-219.

[5] Ma, Zhewang, Chun-Ping Chen, and Tetsuo Anada., "Microwave and millimeter-wave UWB banpass filters using microstrip ring resonators," *2010 International Symposium on Signals, Systems and Electronics*. vol. 2. IEEE, 2010.

[6] P. Pahlavan, SI. Choi, A. Wilcher, HI. Kim, H. Jang and Yk. Yoon, "Metamaterial Based Compact Patch Antenna Array for Antenna-in-Package Solutions in Frequency Handover Applications," *2023 IEEE 73rd Electronic Components and Technology Conference*.

[7] Chao-Hsiung Tseng, and Hsin-Yung Shao, "A New Dual-Band Microstrip Bandpass Filter Using Net-Type Resonators," *IEEE Microwave and Wireless Components letters*, vol 20, No 4, pp.196-198, 2010.

[8] Ieu, Wangshuxing, Dewei Zhang, Dalong Lv, and Ying Wu., "Dual-band microstrip bandpass filter with independently-tunable passbands using patch resonator," *Electronics Letters*, vol. 54, no. 10 (2018), pp. 665-667.

[9] H. Jang, P. Pahlavan, and Y.K. Yoon, "Highly Compact and High Gain 2 x 2 Patch Array Antenna with Slotted Meanderline Loading, " *2023 IEEE 73rd Electronic Components and Technology Conference*.

[10] Hong, Jia-Shen G., and Michael J. Lancaster, "Microstrip filters for RF/microwave applications," John Wiley & Sons, 2004.

[11] Q. Zhong et al., "CMOS terahertz receivers," *2018 IEEE Custom Integrated Circuits Conference (CICC)*, 2018, pp. 1-8, doi: 10.1109/CICC.2018.8357054.

[12] Abbaszadeh, S., Pahlavan, P., & Jalali, M. A new wiggly technique for ultra-wideband two-line directional couplers. *Microwave and Optical Technology Letters*.

[13] Hosseini, S. R., R. Sarraf Shirazi, and Gh. Moradi, "A novel Defected Microstrip Structure (DMS) for microstrip gaps," *PIERS Proceedings*, Kuala Lumpur, Malaysia (2012).

[14] Fallahzadeh and M. Tayarani, "A new microstrip UWB bandpass filter using defected microstrip structures," *Journal of Electromagnetic Waves and Applications*, vol. 24, no. 7, pp. 893–902, 2010.

[15] S. Pahlavan, "Super-Dispersive Demultiplexer Design Using Positive-Negative Refraction Boundary and Hetero-Photonic Crystals," *The European Physical Journal D*, vol. 77, no. 6 (2023), pp. 102-109.

[16] Boutejdar, A., "A new approach to design compact tunable BPF starting from simple LPF topology using a single T-DGS-resonator and ceramic capacitors," *Microwave and Optical Technology Letters*, vol. 58, no. 5, pp. 1142-1148, 2016.

[17] Pahlavan, P., Aslam, S. Z., & Ebrahimi, N. (2022, June). A Novel Dual-band and Bidirectional Nonlinear RFID Transponder Circuitry. In *2022 IEEE/MTT-S International Microwave Symposium-IMS 2022* (pp. 44-47). IEEE.

[18] Meng, Wei, Hong-Ming Lee, Kawthar A. Zaki, and Ali E. Atia, "Synthesis of multi-coupled resonator filters with frequency-dependent couplings," *In Microwave Symposium Digest (MTT), 2010 IEEE MTT-S International*, pp. 1716-1719. IEEE, 2010.