Available online at www.dergipark.org.tr/en

INTERNATIONAL ADVANCED RESEARCHES
and
ENGINEERING JOURNAL

Journal homepage: www.dergipark.org.tr/en/pub/iarej

e-ISSN: 2618-575X

International Open Access

Volume 04
Issue 01

April, 2020

Research Article

Band-stop filter design based on split ring resonators loaded on the microstrip transmission line for GSM-900 and 2.4 GHz ISM band

Alparslan Cinar [a,*] **and *Sinan Bicer*** [a]

[a]*Akdeniz University, Elmali Vocational School, Antalya 0770, Turkey*

ARTICLE INFO

Article history:
Received 01 November 2020
Revised 18 February 2020
Accepted 22 February 2020

Keywords:
Band stop filter
Electromagnetic metamaterial
Microstrip transmission line
Split ring resonator
SRR

ABSTRACT

Split-ring resonator is a popular research topic in literature. As known, it may be used in the design of electromagnetic metamaterials. Additionally, these structures can be preferred in microwave filter devices. In this study, a band-stop filter was designed for GSM-900 and 2.4 GHz ISM band by using split-ring resonators. Two split-ring arrays (sizes of one of these arrays were larger than the other) were loaded on the transmission line and each array consisted of four identical rings. Thus, a dual-band pass filter was obtained and this filter covered the frequency of 0.91 (GSM) and 2.43 (ISM) GHz. Then, this proposed design was fabricated and measured. According to the measurement results, the fabricated structure operated at 0.93 GHz and 2.47. The experimental results were consistent with the simulation results. As a result, thanks to the proposed structure, two frequencies can be stopped at the same time. There is no need to design a different filter structure for each frequency.

1. Introduction

Metamaterials are artificial materials and in desired frequency, they may exhibit extraordinary electromagnetic properties (e.g., negative permeability, negative permittivity, reverse Doppler Effect and negative refractive) [1, 2]. Due to these features, it takes place in many applications such as filters [3-22], antenna [23, 24], absorbers [25, 26] and sensors [4, 5, 13, 14, 16, 18, 21, 22, 27, 28]. Split ring resonators (SRR) are one of the most preferred structures for electromagnetic metamaterials design [2-5, 8, 14, 18].

One of the applications in which metamaterials are widely used is filters [3-22]. In this study, it was aimed to design a band-stop filter for GSM-900 and 2.4 GHz ISM band. A lot of SRR-based dual/multi-band stop filter designs are available in the literature [4-10,14,17]. According to some of these studies, dual/multi-band filters can be obtained when two or more SRR structures with different resonance frequencies load the microstrip transmission line [4-6]. Also, resonance magnitude can be increased by increasing the number of rings having the same resonance frequency [6,12].

In this study, two resonator arrays were placed on the transmission line. Each array consisted of four identical rings and sizes of one of these arrays were smaller than the other. To enhance the transmission coefficients $|S_{21}|$ magnitude of the filter structure in operation frequency, the number of resonators was increased without changing their size. Thus, a dual band stop filter was achieved that operated at frequencies of 0.91/2.43 GHz and 0.93/2.47 GHz in simulation and measurement, respectively.

In the context of this study, a filter that stopped two different frequency bands was designed, fabricated and measured. Thus, thanks to this design, there is no need to design two-filter structures for two different frequencies. In addition, frequency tuning can also be made by changing the dimensions of the split ring resonators.

2. Simulation and Measurement

A 50 Ω microstrip transmission line was designed. Schematic view of the proposed transmission line with its design parameters is given in Figure 1. The structure consists of a line at the top, dielectric layer in the middle and ground plane at the bottom. FR4, which had thickness

* Corresponding author. Tel.: *+0-242-618-6334*.
E-mail addresses: alparslancinar@akdeniz.edu.tr *(A. Cinar)*, sinanbicer@akdeniz.edu.tr *(S. Bicer)*
ORCID: 0000-0002-9113-6549 *(A. Cinar)*, 0000-0001-7879-5462 *(S. Bicer)*
DOI: 10.35860/iarej.641459

of 1.6 mm, permittivity (ε_r) of 4.3, and loss tangent (tanδ) of 0.025, was used as the dielectric substrate layer. Line and ground plane were built using copper having a conductivity of 5.8 × 10^7 S/m and thickness of 0.035 mm. Design and analysis of the microstrip transmission line were performed using the CST microwave studio based on frequency domain solver. The proposed structure was excited by using a waveguide port. In addition, boundaries were selected as open for *x*, *y* and *z* axes. S-parameter results of the transmission line obtained from simulation were plotted in Figure 2.

Firstly, 1 SRR was loaded on the proposed transmission line in order for that the structure would behave like a band stop filter in 2.43 GHz. However, $|S_{21}|$ magnitude of the filter was not satisfactory in resonance frequency. Therefore, one more from the same SRR was placed again on this structure. Since it was observed that this was useful, the SRR placement process continued until the number of SRR was 4. The design parameters and schematic views of these structures (design 1 — design 4) are given in Figure 3. The transmission coefficients $|S_{21}|$ obtained from the simulation software are shown in Figure 4.

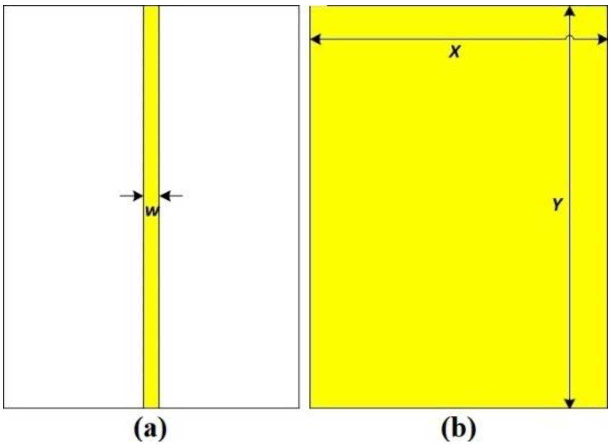

Figure 1. Schematic views of the transmission line a) front, b) back; w = 2.87, X = 80 and Y = 110 (all in mm)

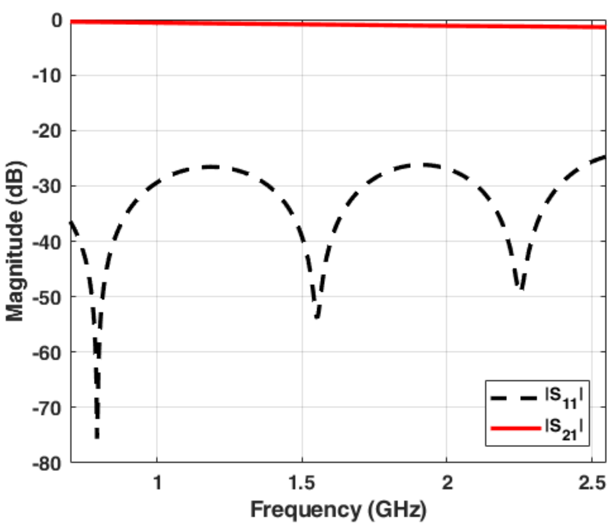

Figure 2. S-parameter simulation results of the transmission line

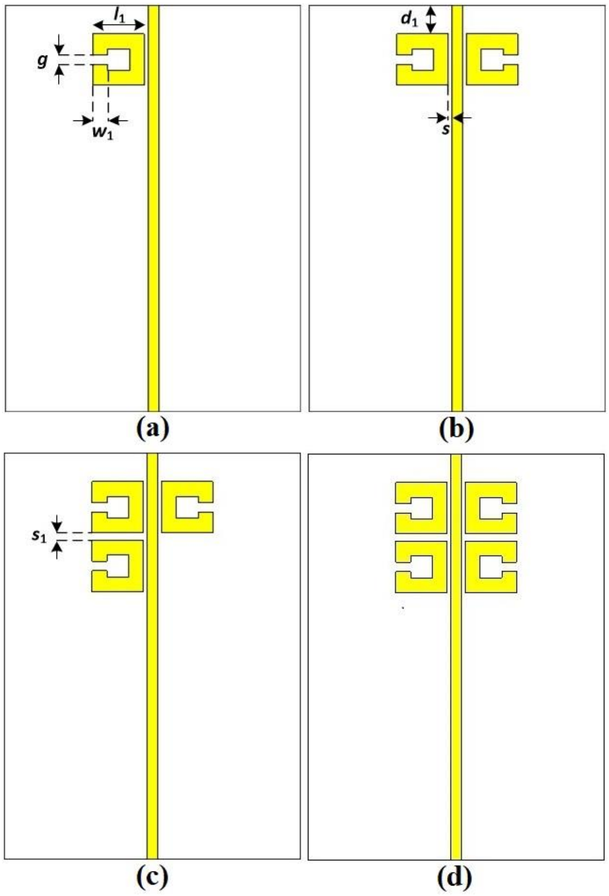

Figure 3. SRR loaded transmission line a) design 1, b) design 2, c) design 3, d) design 4; l_1 = 13.9, w_1 = 4, g = 2.5, d_1 = 7.7, s = 1 and s_1 = 2 (all in mm)

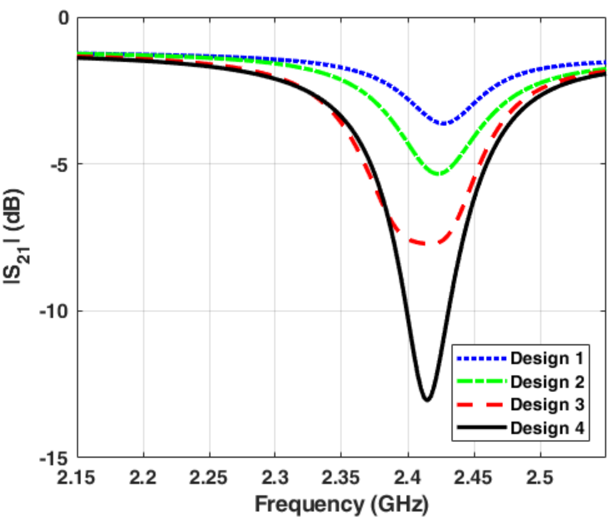

Figure 4. Simulation results of the transmission coefficients $|S_{21}|$ for design 1, design 2, design 3 and design 4

Secondly, 1 SRR was added again to the transmission line shown in Figure 1. However, size of this newly added ring was larger than the SRRs shown in Figure 3. The operation frequency decreases as the size of the resonator length increases. This structure behaves as a band stop filter and operates at 0.91 GHz. In order to enhance $|S_{21}|$ magnitude of the filter, SRR loading continued until the number of the SRR was 4. Schematic view of these structures are given in Figure 5. The transmission coefficients $|S_{21}|$ of the designed structures (design 5 — design 8) are shown in the figure 6.

Finally, design 4 and design 8 were combined; thus, two resonator arrays were loaded on the microstrip transmission line. Although each array consisted of 4 SRRs, the sizes of one of these arrays were larger than the other. In this way, a dual-band operation was achieved at 0.91 GHz and 2.43. Then, the proposed structure was fabricated and the ends of the transmission line were terminated with 50 Ω SMAs. Schematic and fabricated views of the proposed dual band stop filter are shown in Figure 7. The transmission coefficient $|S_{21}|$ of the fabricated filter was measured using the Anritsu MS4624B vector network analyzer operating in the frequency range of 10 MHz — 9 GHz. The fabricated structure operates at 0.93 GHz and 2.47. As seen in Figure 8, the experimental results are consistent with the simulation results.

Surface current distributions obtained from the simulation are demonstrated in Figure 9. As seen, the surface current behaviors are circular at resonance frequencies. In addition, it is seen that whereas the low frequency (0.91 GHz) is caused by large rings, the high frequency (2.43 GHz) is caused by small rings.

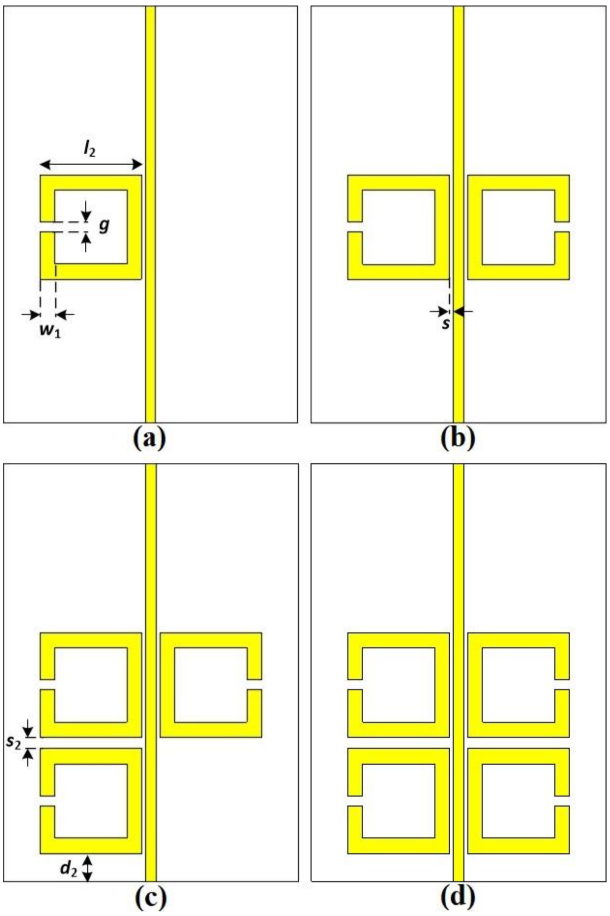

Figure 5. SRR loaded transmission line a) design 5, b) design 6, c) design 7, d) design 8; l_2 = 27.6, w_1 = 4, g = 2.5, d_2 = 7.7, s = 1 and s_2 = 3 (all in mm)

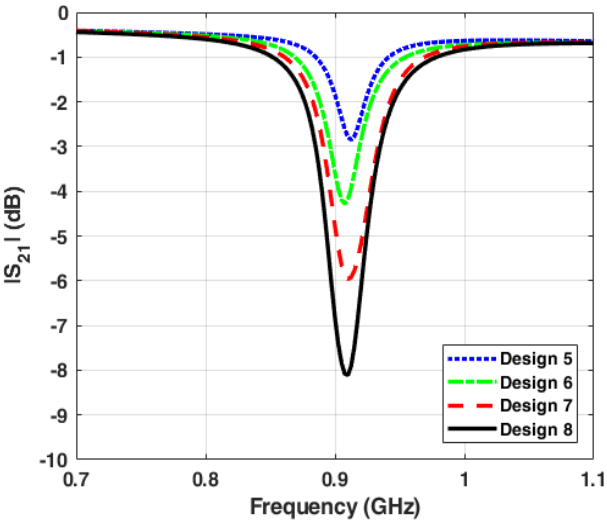

Figure 6. Simulation results of the transmission coefficients $|S_{21}|$ for design 5, design 6, design 7, and design 8

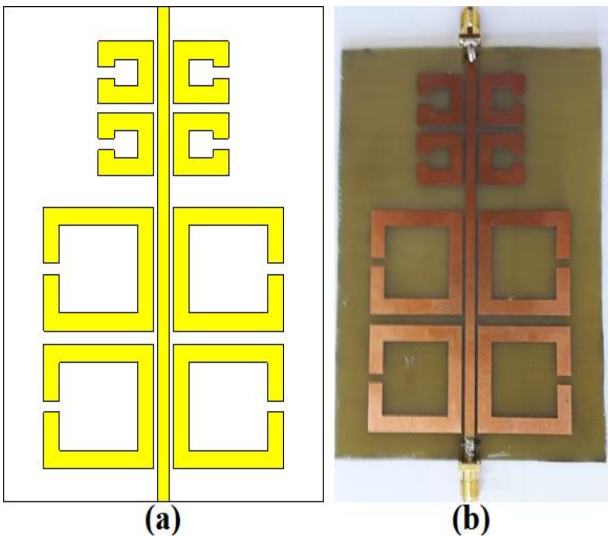

Figure 7. Views of the proposed dual band stop filter a) schematic, b) fabricated

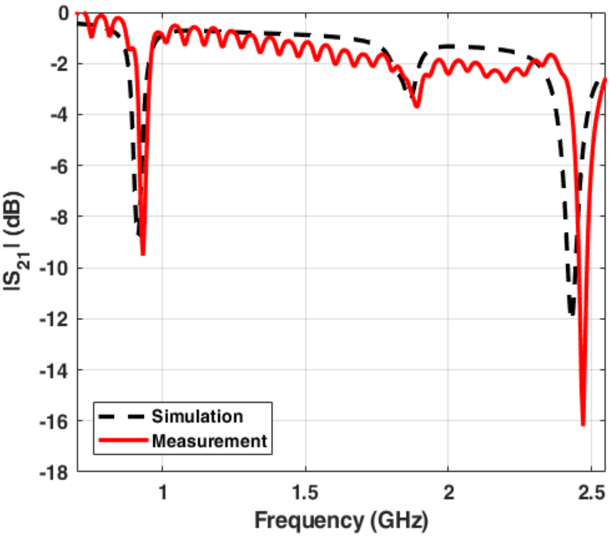

Figure 8. Simulation and measurement results of the transmission coefficients $|S_{21}|$ for the proposed dual band stop filter

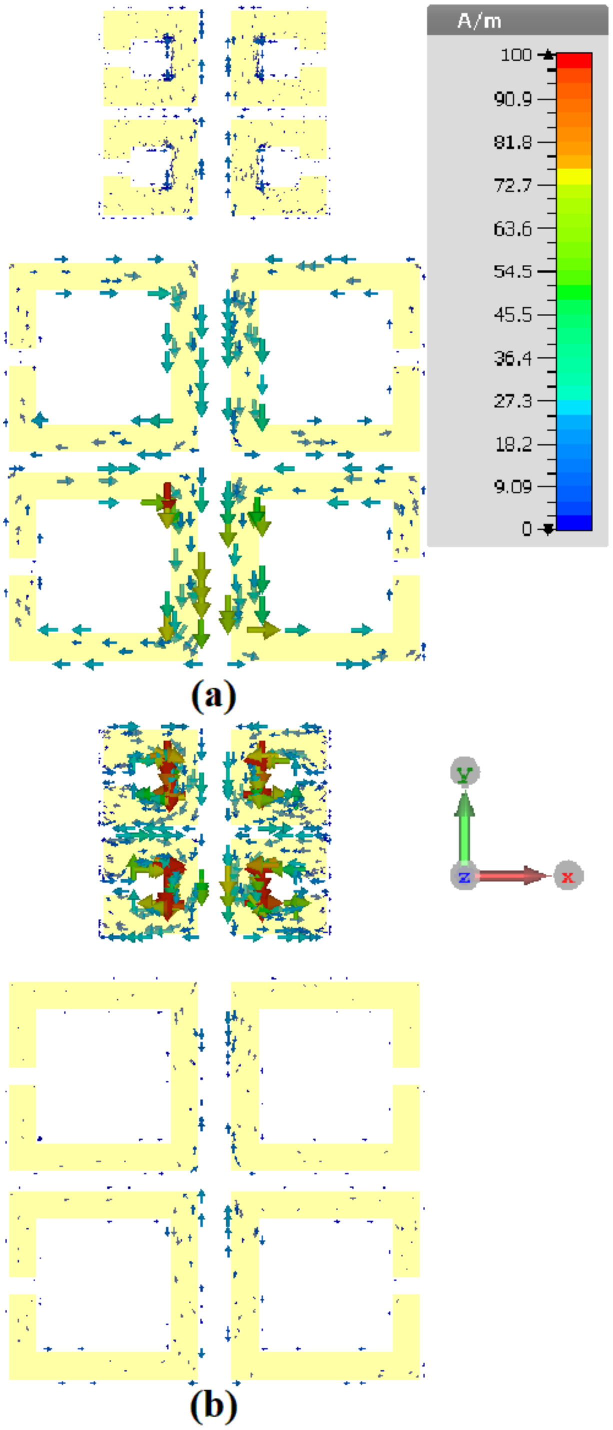

Figure 9. Surface current distributions obtained from the simulation at 0° phase angle a) 0.91 GHz, b) 2.43 GHz.

3. Conclusions

In this paper, a band-stop filter based on split ring resonators loaded on the microstrip transmission line for GSM-900 and 2.4 GHz ISM band was introduced. Two resonator arrays, which had different sizes, were placed on the transmission line. Sizes of one of these arrays were larger than the other and each array consisted of four identical rings. When the simulation and measurement results were examined, the dual-band operation was seen at 0.91/2.43 GHz and 0.93/2.47 GHz in simulation and measurement, respectively. The measured transmission coefficient $|S_{21}|$ of the fabricated filter proved good agreement with the simulated data obtained from simulation software. Finally, it can be said that the proposed structure can stop two frequencies at the same time and there is no need to design a different filter structure for each frequency.

Declaration

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The author(s) also declared that this article is original, was prepared in accordance with international publication and research ethics, and ethical committee permission or any special permission is not required.

References

1. Veselago, V.G., *The Electrodynamics of Substances With Simultaneously Negative Values of ε and μ*. Physics-Uspekhi, 1968. **10**(4): p. 509-514.
2. Caloz C. and T. Itoh, *Electromagnetic Metamaterials, Transmission Line Theory and Microwave Applications*. 2006, USA: John Wiley & Sons.
3. García-García, J., F. Martín, F. Falcone, J. Bonache, J.D. Baena, I. Gil, E. Amat, T. Lopetegi, M.A.G. Laso, J.A.M. Iturmendi, M. Sorolla and R. Marqués, *Microwave filters with improved stopband based on sub-wavelength resonators*. IEEE Transactions on Microwave theory and techniques, 2005. **53**(6): p. 1997-2006.
4. Puentes, M., M. Maasch, M. Schüßler and R. Jakoby, *Frequency multiplexed 2-dimensional sensor array based on split-ring resonators for organic tissue analysis*. IEEE Transactions on Microwave Theory and Techniques, 2012. **60**(6): p. 1720-1727.
5. Withayachumnankul, W., K. Jaruwongrungsee, C. Fumeaux and D. Abbott, *Metamaterial-inspired multichannel thin-film sensor*. IEEE Sensors Journal, 2012. **12**(5): p. 1455-1458.
6. Korucu H.D. and E. Ekmekçi, *Metamalzeme Tabanlı ve İki Bantlı Mikroşerit Bant Durduran Filtre Tasarımı Araştırmaları*, in İlk Bildiriler Konferansı 2013, Turkey. p. 64-67.
7. Hussain, S., J.M. Woo and J.H. Jang, *Dual-band terahertz metamaterials based on nested split ring resonators*. Applied Physics Letters, 2012. **101**(9): p. 091103.
8. Ali, W.A.E. and M.Z.M. Hamdalla, *Compact triple band-stop filter using novel epsilon-shaped metamaterial with lumped capacitor*. Journal of Instrumentation, 2018. **13**(04): p. P04007.
9. Kamma, A. and J. Mukherjee, *Multiple band notch and Dual-Band filter using concentric and contiguous split ring resonators (CCSRR)*. Journal of Electromagnetic Waves and Applications, 2017. **31**(1): p. 57-71.
10. Hu, X., Q. Zhang and S. He, *Dual-band-rejection filter based on split ring resonator (SRR) and complimentary SRR*. Microwave and Optical Technology Letters, 2009. **51**(10): p. 2519-2522.
11. Disken, G., F. Pala, E. Demir, H.D. Korucu and E. Ekmekci, *Electromagnetic Behavior of SRR Loaded Microstrip Transmission Lines: Investigation for Different SRR Types and Array Topologies*, in *PIERS Proceedings*

2013, Sweden. p. 1796-1799.

12. Çınar, A., U. Köse, Ö. Ertan, N. Karacan, C. Başer and E. Ekmekçi, *Ayrık Halkalı Rezonatör Tabanlı Bağlaşım Değeri Ayarlanabilir Mikroşerit Yönlü Bağlaç Tasarımı ve Benzetimleri*, in *8. URSI-Türkiye Bilimsel Kongresi 2016*, Turkey.
13. Çınar, A. and E. Ekmekçi, *Ayrık Halkalı Rezonatör Tabanlı Dönme Sensörü Tasarımı ve Nümerik Olarak İncelenmesi*, in *8. URSI-Türkiye Bilimsel Kongresi 2016*, Turkey.
14. Memon, M.U., H. Jeong and S. Lim, *Metamaterial-inspired radio frequency based touchpad sensor system*. IEEE Transactions on Instrumentation and Measurement, 2019.
15. Moradi, B., R. Fernández-García and I. Gil, *Effect of smart textile metamaterials on electromagnetic performance for wireless body area network systems*. Textile research journal, 2019. **89**(14): p. 2892-2899.
16. Liu, W., H. Sun and L. Xu, *A microwave method for dielectric characterization measurement of small liquids using a metamaterial-based sensor*. Sensors, 2018. **18**(5): p. 1438.
17. Asci, C., A. Sadeqi, W. Wang, H.R. Nejad and S. Sonkusale, *Design and implementation of magnetically–tunable quad–band filter utilizing split–ring resonators at microwave frequencies*. Scientific Reports, 2020. **10**(1): p. 1-8.
18. Tiwari, N.K., S.P. Singh and M.J. Akhtar, *Metamaterial inspired contactless angular displacement sensor with wide dynamic range and bandwidth*, in *2019 URSI Asia-Pacific Radio Science Conference (AP-RASC) IEEE,* India. p. 1-4.
19. Ahmed, B.A., H. Klaina, O. Aghzout, A.V. Alejos, A. Naghar and F. Falcone, *Miniaturization, Selectivity and Rejection Bandwidth Improvements of a Multi-Band Stopband Filter Based on Circular Split Ring Resonator*, in *2019 13th European Conference on Antennas and Propagation (EuCAP) IEEE*, Poland. p. 1-4.
20. Horestani, A.K., N. Varmazyar, F. Sadeghikia, M.T. Noghani, Z. Shaterian and F. Martín, *On the Applications of S-Shaped Split Ring Resonators (S-SRR) in Sensors, Filters, and Antennas*, in *2019 International Conference on Electromagnetics in Advanced Applications (ICEAA) IEEE*, Spain. p. 0485-0488.
21. Horestani, A.K., Z. Shaterian and F. Martín, *Detection Modalities of Displacement Sensors Based on Split Ring Resonators: Pros and Cons*, in *2019 International Conference on Electromagnetics in Advanced Applications (ICEAA) IEEE*, Spain. p. 0479-0484.
22. Albishi, A.M. and O.M. Ramahi, *Highly Sensitive Planar Microwaves Sensor*, in *2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting IEEE*, USA. p. 339-340.
23. Alici, K.B. and E. Ozbay, *Electrically small split ring resonator antennas*. Journal of applied physics, 2007. **101**(8): p. 083104.
24. Ekmekçi, E., A. Çınar, A. Ayan, H.D. Korucu and E. Demir, *Enine Kuplajlı ve AHR Tabanlı Anten Yapıları İçin Elektriksel Boyut ve Kazanç Analizi*, in *7. URSI-Türkiye Bilimsel Kongresi 2014*, Turkey. p. 379-381.
25. Landy, N.I., S. Sajuyigbe, J.J. Mock, D.R. Smith and W.J. Padilla, *Perfect metamaterial absorber*. Physical review letters, 2008. **100**(20): p. 207402.
26. Al-Badri, K.S., A. Cinar, U. Kose, O. Ertan and E. Ekmekci, *Monochromatic tuning of absorption strength based on angle-dependent closed-ring resonator-type metamaterial absorber*. IEEE Antennas and Wireless Propagation Letters, 2016. **16**: p. 1060-1063.
27. Ekmekci, E., U. Kose, A. Cinar, O. Ertan and Z. Ekmekci, *The use of metamaterial type double-sided resonator structures in humidity and concentration sensing applications*. Sensors and Actuators A: Physical, 2019. **297**: p. 111559.
28. Ertan, Ö., U. Köse, A. Çinar and E. Ekmekçi, *Sensitivity analysis of different resonator structure for sensor applications in microwave region*, in *2016 National Conference on Electrical, Electronics and Biomedical Engineering (ELECO) IEEE*, Turkey. p. 550-553.