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Advanced Tunable Compact Planar Bandpass Filters Utilizing SMV2019 Schottky Diodes

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Abstract. This paper presents a new compact and reconfigurable bandpass filter developed to operate within the [6–9] GHz frequency range. The substrate used is Rogers 4003C, with a thickness of 0.76 mm, known for its low dielectric losses, characterized by a loss tangent (tan δ) of 0.0022. Schottky diodes were selected due to their ability to vary their capacitance according to the bias voltage, thus offering a wide tuning range that enables a bandwidth extension of over 2 GHz. Co-simulation results show that insertion losses vary from 2 dB at 5.9 GHz to 0.25 dB at 8.5 GHz. Furthermore, the return loss ranges between 15 dB and 24.6 dB across the entire studied band.

1 INTRODUCTION

The ability to dynamically reconfigure wireless communication systems to operate on specific frequencies or bands has become one of the major areas of research worldwide. The problem under consideration relates to the need for efficient utilization of the electromagnetic spectrum a highly valuable resource in many critical areas [1].

Therefore, reconfigurability is applied in a variety of important fields. In the space industry, it is utilized in satellite systems as a means of flexible coverage [2]. In the military sphere, reconfigurability is applied in radar systems to improve their detection and stealth performance [3]. In the healthcare sector, it is utilized as a tool in designing advanced detection devices, such as those for the early diagnosis of breast cancer [4]. Furthermore, the spread of IoT puts pressure on spectral flexibility needed for interconnecting numerous types of devices via optimized wireless communication networks [5,6].

The possibility to reconfigure the mentioned systems is ensured by the use of active elements allowing modification of the electrical characteristics of the devices in real time. Such elements include Schottky diodes, PIN diodes, bipolar junction transistors and FETs [7-10].

Bandpass filters are some of the most important and delicate parts of such flexible systems. The role of the bandpass filters is vital because their task is to filter the relevant signals in the

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specified frequency range and block the unwanted signals that are picked up by the antennas. Selective filtering is crucial for protecting such sensitive parts as LNAs, PAs, mixers, and oscillators.

The design of reconfigurable filters is generally aimed at achieving the following three main goals: separation into sub-bands; flexible widening of the bandwidth in response to system demands; and changing the frequency range of operation.

Runqi Zhang proposes a new generation of multifunctional and reconfigurable BPFs capable of tuning their operational frequencies and adding or subtracting notched bands. This approach employs a combination of the progressive filtering approach using resonators (or stubs), as well as the design approach using frequency mapping functions. The two experimental designs are shown to illustrate the approach, which offers more flexibility and clarity compared to previous methods [11].

Moustapha El bakkali presents an innovative structure of a multifunctional filter mounted on a 0.8 mm thick Rogers 4003C substrate. The filter allows for flexible adjustment of its bandwidth, ranging from narrow to wide, and vice versa. Through the optimal arrangement of SMV1405 diodes, it transitions from a single-band configuration to a dual-band configuration while maintaining a narrow band [12]. In another work, the author presents a new miniaturized and reconfigurable filter structure for C-band applications. The filter allows for a bandwidth variation of 1 GHz while maintaining a fractional bandwidth (FBW) of 13.33%. The design uses four SMV2019 varactor diodes and a 0.8 mm thick Rogers 4003C substrate [13].

In this context, the objective of the present work is to design and analyze a new reconfigurable bandpass filter structure. The configuration uses four SMV2019 Schottky diodes that are designed in such a way that it becomes possible to move the chosen frequency band from 5.9 GHz to 8.5 GHz. The major challenge is that it should be possible to maintain a high degree of selectivity together with low insertion losses and high flexibility.

2 Design Methodology

Designing a high performance reconfigurable filter requires taking into account a number of critical issues from the early stages, including the choice of substrate, active device, filter approximation technique, and the intended design topology.

2.1 Why Rogers 4003C Substrat ?

For planar technology-based active RF circuits, there are two types of substrate families which include the FR4 substrates and the Rogers substrate families, each having unique properties that affect their performance.

FR4 represents an ordinary and easily available material which provides cost efficiency. However, this material possesses certain disadvantages when it comes to high frequency applications. Namely, FR4 has quite significant dielectric loss ($\tan \delta = 0.02$ @1GHz). In addition, this loss increases rapidly with the growth of frequency and thus cannot be used in tunable filter design.

In contrast, the substrates based on Rogers are made specially for the radio frequency and microwave applications. Their choice is governed by many characteristics: the first one is the low dielectric losses that remain unchanged within a wide frequency range; another important one is the presence of many types of substrate, such as 4003C, 5880, 4350B, 4050 and other [14].

For the purposes of this research work, the Rogers 4003C substrate has been used due to its better electrical parameters and ability to withstand changes in temperatures. The Table 1 below represents the main electrical parameters of the Rogers 4003C substrate.

Table 1. Electrical and Physical Properties of Rogers 4003C.

h (mm)	$Z_{50\Omega}$ (mm)	tan δ	ε_r
0.76	1.76	0.0022	3.55

2.2 Diode Selection

This specific Schottky diode SMV2019-079LF was selected on purpose due to its good capacitance modulation properties. It shows great change in capacitance, starting with 2.22 pF at DC bias of 0 V up to 0.3 pF at DC bias of 22 V. Such a wide tunable range of capacitance helps achieve accurate control over filter's resonant frequency.

Moreover, the diode features a low series resistance of 4.5 Ω, which helps minimize insertion losses within the circuit. It also exhibits a very limited parasitic inductance, evaluated at 0.7 nH, which preserves the stability and overall performance of the filter across a wide frequency range. Additionally, this ensures that the intrinsic properties of the diode dominate over extrinsic effects, which is essential for guaranteeing predictable and reliable behavior during the filter's reconfiguration.

Additionally, the diode has a series resistance of 4.5 Ω, which helps reduce the losses that would be incurred due to the insertion of the device in the circuit. The diode also has an extremely low parasitic inductance value of 0.7 nH, hence keeping the stability of the filter intact within a wide frequency spectrum. This makes sure that the inherent characteristics of the diode overpower the external influences on its characteristics.

Figure 1 shows the schematic of this diode in nonlinear mode, accompanied by its SPICE model.

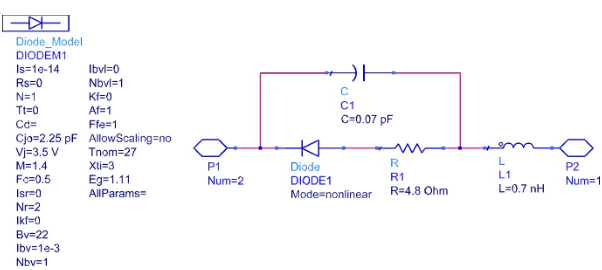

Fig. 1. Electrical model of the Schottky diode SMV2019_079LF.

2.3 Proposed Structure

The design of the structure presented in Figure 2 is based on the combination of two low-pass filters via the use of a gap produced by means of meandered lines. The structure demonstrates maximum performance when considering its filtering capabilities. Impedance-jump low-pass filters can be used successfully here since they provide an extremely clear distinction between passband and stopband frequencies. It is necessary for the effective blocking of unwanted frequencies and good impedance matching at the same time. In addition, it allows for faster and more precise blocking of unwanted frequencies.

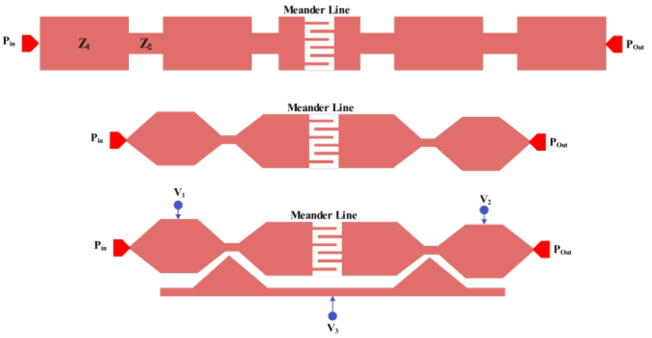

Fig. 2. Miniaturization process of the proposed topology.

The employment of a meandered line for creating the gap is essential for improving the performance of the filter significantly. Not only does it provide an optimized bandwidth but it also ensures that high rejection bands are created in order to ensure that unwanted harmonics are completely blocked out. The use of meandered structure in the transmission line ensures the creation of inductance and capacitance.

In this respect, there are several distinct benefits to using such a band-pass filter, including selective impedance matching for optimal signal transmission in the passband, harmonics cancellation, reduction of unwanted frequencies, and successful transmission of the desired signal.

In relation to the occupied area of the surface, the second and third structures are those that have been achieved using the process of optimizing to achieve a miniaturized structure compared to the first one, with the ability of high filtering capacity (refer Figure 2). It is noteworthy that biasing sources have been used on each side of the space made up of the meandered line, making it possible to achieve a very good control of the rejection band.

In addition to this, the use of V3 bias makes it possible to fine tune and sweep the bandwidth range. This makes it easier for the filter to become more adaptable depending on the needs of different applications. This kind of biasing increases the dynamic response of the filter.

Figure 3 illustrates the equivalent electrical schematic of the proposed filtering structure. The parallel LC resonator models the electrical behavior of the meandered line.

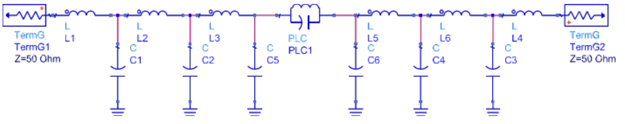

Fig. 3. Equivalent schematic of the first filtering structure.

For each section:

Equivalent Inductance (High Impedance) :

$$L = \frac{Z_2}{\omega_c} \qquad (1)$$

Equivalent Capacitance (Low Impedance) :

$$C = \frac{1}{Z_1 \omega_c} \qquad (2)$$

- ω_c : is the angular cutoff frequency,

- Z_1 and Z_2 are the characteristic impedances.

3 Results and discussion

The proposed tunable bandpass filter is carried out by using the Advanced Design System (ADS) simulation software. Figure 4 shows the layout of the optimized circuit, which has been designed to provide good performance along with small area of 22 × 14.7 mm².

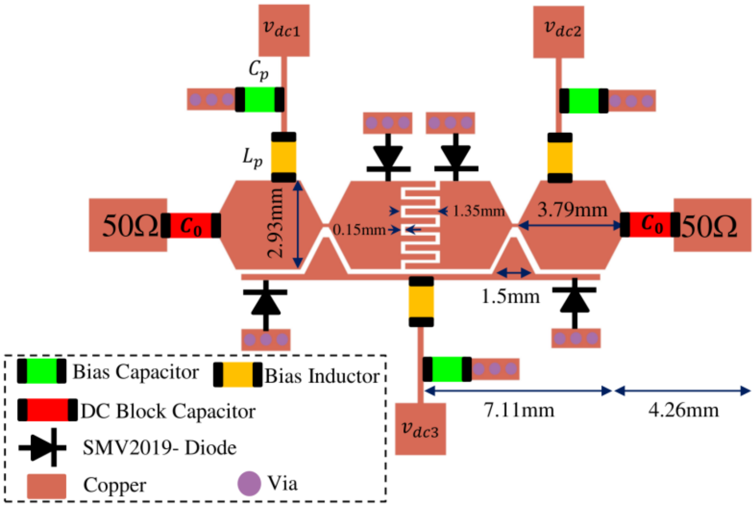

Fig. 4. Layout of the Proposed Tunable Compact Planar Bandpass Filters (22 x 14.7 mm²).

The lumped elements in this design are combined by incorporating the actual operation of the lumped elements in order to take into consideration any package parasitics. These components are of SMD 0805 type (Size : 2.1 mm x 1.3 mm).

To ensure DC signal stability, a biasing circuit, which consisted of a capacitor C_p = 8.2 pF and inductor L_p = 50 nH, was added. In addition, two blocking capacitors, known as C_o, are inserted to prevent the flow of DC current to the input and output of the filter.

The structure also integrates four control diodes. Two of them are individually controlled by DC voltages V_{dc1} and V_{dc2}, which allow the independent adjustment of the lower and upper passbands, respectively. The other two diodes are jointly controlled by a single DC voltage source V_{dc3}. Thanks to this control system, the filter's bandwidth can be dynamically adjusted over a wide frequency range from 5.9 GHz to 8.5 GHz, thus offering great flexibility to meet the specific needs of the intended application.

Results of diffraction parameter Sij for different biasing states, which were obtained by means of co-simulation, are shown in Figure 5. Every curve represents one of the biasing schemes; that allows performing comparison of device performance under various polarization states.

Fractional Bandwidth (FBW), which is related to the biasing conditions listed in Table 2, stays nearly consistent at around 3.33%. This stability indicates that the developed filter exhibits high selectivity. Moreover, the measured return losses range from 16 dB to 27 dB, demonstrating good impedance matching and low signal reflection.

The graph for insertion loss is shown in Figure 5-b, which vary between 0.25 dB and 2 dB depending on the frequency. thus confirming the low losses introduced by the filter. In addition to this, the attenuation levels in the transmission zeros, located in the lower and upper band regions, are greater than 20 dB. This strong out-of-band attenuation highlights the high performance of the designed filter, particularly in terms of selectivity and suppression of unwanted signals.

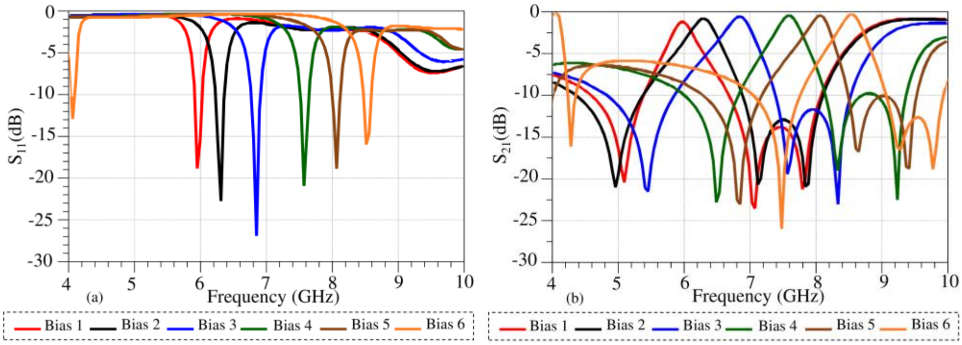

Fig. 5. Co-simulation results of the tunable filter for six different biasing states.

Table 2. Different polarization states of the proposed filter structure.

Volt	Bias 1	Bias 2	Bias 3	Bias 4	Bias 5	Bias 6
V_1	5.6	5	6.3	9.8	10.6	20
V_2	12.6	12.5	14	17.8	18.5	13.4
V_3	0	2.2	5.8	11.2	15.2	20

Table 3 presents a comparison of the performance between the designed tunable filter and other recently published works.

TABLE 3. Comparison of performance improvements compared to recently published works.

Paper	**This work**	[13]	[15]
Years	This year	2025	2021
Substrate	Roger 4003c	Roger 4003c	Roger 4003c
Diode type	SMV2019	SMV2019	BAR9002ELS
Number of diode	4	4	12
FBW (%)	3.63	13.33	36.36
Tunable of BW (GHz)	5.9 - 8.5	3.8 - 4.8	2.25 - 3.25
Return loss (dB)	17 - 27	25	>8
Insertion loss (dB)	0.25 - 2	0.85 - 2	2.25
Size (mm^2)	22 x 14.7	18.27 x 18.48	20 x 20

The 4003C substrate is particularly well-suited for active circuits due to its high thermal resistance when using bias voltages and diodes, as well as its low loss. The proposed structure uses a reduced number of diodes, which helps lower power consumption. The developed filter exhibits a fractional bandwidth of 3.63%, indicating higher sensitivity compared to works [13] and [15]. Moreover, it is capable of tuning over a bandwidth of 2.6 GHz, ranging from 5.9 GHz to 8.5 GHz, with a return loss greater than 17 dB and an insertion loss below 2 dB, demonstrating the filter's superior performance and quality compared to the reference works.

4 Conclusion

As part of this work, we have designed a miniaturized and tunable bandpass filter intended for advanced wireless communication applications. This filter was specifically developed to allow the reconfiguration of the center frequency over a wide range from 5.9 GHz to 8.5 GHz, thus meeting the growing need for spectral flexibility.

The simulation results confirm the effectiveness of the design structure proposed. The filter has impressive characteristics, which include an insertion loss of less than 2 dB throughout the tuning range, hence making sure that the transmission of the useful signal is efficient. Additionally, it has a return loss greater than 15 dB, which means that it is well-matched to the impedance and does not reflect much of the input signal.

References

1. F. Rahmani, A. Belbachir Kchairi, M. El Bakkali, N. Taher, N. Amar Touhami, et T.-E. Elhamadi, Sub-6 GHz Reconfigurable Beam-Switched Circular Antenna for Wireless Networks, Arab J Sci Eng, vol. 50, no 8, p. 5589 5602, avr. (2025), doi: 10.1007/s13369-024-09445-0.
2. A. D. George et C. M. Wilson, Onboard processing with hybrid and reconfigurable computing on small satellites, Proceedings of the IEEE, vol. 106, no 3, p. 458 470, (2018).
3. S. Dubal et A. Chaudhari, Mechanisms of reconfigurable antenna: A review , in 2020 10th international conference on cloud computing, data science & engineering (confluence), IEEE, (2020), p. 576 580.
4. M. El Bakkali, F. Rahmani, O. Douass, D. El Khamlichi, S. El Khaldi, et N. A. Touhami, Improving Sensitivity And Selectivity of Breast Cancer Detection Systems Through the Development of a High-Performance LNA, in 2024 6th International Symposium on Advanced Electrical and Communication Technologies (ISAECT), IEEE, (2024), p. 1 6: https://ieeexplore.ieee.org/abstract/document/10799521/
5. M. D. V. Pena, J. J. Rodriguez-Andina, et M. Manic, The internet of things: The role of reconfigurable platforms, IEEE Industrial Electronics Magazine, vol. 11, no 3, p. 6 19, (2017).
6. R. F. Molanes, K. Amarasinghe, J. Rodriguez-Andina, et M. Manic, Deep learning and reconfigurable platforms in the internet of things: Challenges and opportunities in algorithms and hardware, IEEE industrial electronics magazine, vol. 12, no 2, p. 36 49, (2018).
7. D. F. Mamedes, A. Gomes Neto, J. Costa E Silva, et J. Bornemann, Design of reconfigurable frequency-selective surfaces including the PIN diode threshold region , IET Microwaves Antenna & Prop, vol. 12, no 9, p. 1483 1486, juill. (2018), doi: 10.1049/iet-map.2017.0761.
8. X. Jin, S. Liu, Y. Yang, et Y. Zhou, A frequency-reconfigurable planar slot antenna using S-PIN diode, IEEE Antennas and Wireless Propagation Letters, vol. 21, no 5, p. 1007 1011, 2022.
9. W.-J. Liao, Y.-F. Chen, C.-L. Liao, et Y.-C. Hou, Reconfigurable frequency selective surfaces with complementary reflection and transmission responses using duality theorem-based elements, IEEE Transactions on Antennas and Propagation, vol. 70, no 10, p. 9406 9414, (2022).

10. S.-Y. Peng et al., A power-efficient reconfigurable OTA-C filter for low-frequency biomedical applications, IEEE transactions on circuits and systems I: regular papers, vol. 65, no 2, p. 543 555, (2017).
11. R. Zhang, R. Gómez-García, et D. Peroulis, Multifunctional bandpass filters with reconfigurable and switchable band control, IEEE Transactions on Microwave Theory and Techniques, vol. 67, no 6, p. 2355 2369, (2019).
12. [12] M. El Bakkali, S. Achraou, O. Douass, N. A. Touhami, A. Mimouni, et A. Zakriti, Contribution to the Development of a Multifunctional Planar Filter Based on SMV-1405 Diodes for 5G Mobile Applications , in 2024 6th International Symposium on Advanced Electrical and Communication Technologies (ISAECT), IEEE, (2024), p. 1 4. https://ieeexplore.ieee.org/abstract/document/10799699/
13. M. El Bakkali et al., Miniaturized Planar Reconfigurable Frequency Band Filter for C-Band Applications , in The 18th International Conference Interdisciplinarity in Engineering, vol. 1249, L. Moldovan et A. Gligor, Éd., in Lecture Notes in Networks and Systems, vol. 1249. , Cham: Springer Nature Switzerland, (2025), p. 373 381. doi: 10.1007/978-3-031-81685-7_29.
14. M. El Bakkali, Analysis of current challenges in the design of low-noise broadband planar amplifiers: Review, e-Prime - Advances in Electrical Engineering, Electronics and Energy, vol. 12, p. 100986, juin (2025), doi: 10.1016/j.prime.2025.100986.
15. H. Yue, Tunable S-band Elliptic Bandpass Filter With Constant Absolute Bandwidth, in 2021 IEEE 21st Annual Wireless and Microwave Technology Conference (WAMICON), avr. (2021), p. 1 4. doi: 10.1109/WAMICON47156.2021.9443597.