Design of a planar Transversal Signal Interference-Based Bandstop Filters for Millimeter-Wave Applications

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***Abstract*— This study presents the implementation of a millimeter-wave compact bandstop filter (BSF) using Microstrip technologies. The configuration relies on the principle of transversal signal interference, achieved by connecting two transmission lines in parallel with specific characteristic impedances and electrical lengths. This design allows for sharp rejection of unwanted signals without the need for additional resonators. The designed filter utilizes a ROGERS RT/Duroid 6002 substrate with specific properties, including a thickness of 0.252 mm, a dielectric permittivity constant of 2.94, and a loss tangent of 0.0012. To ensure its effectiveness, the filter undergoes optimization and validation using two electromagnetic solvers: ADS, and CST-MWS.**

Keywords*— Bandstop filter, microstrip, transversal signal interference

I. Introduction

In recent years, the demand for high-speed and high-capacity wireless communication systems has witnessed a significant surge. With the utilization of millimeter-wave frequencies, these systems hold the potential to revolutionize wireless communications by enabling multi-gigabit data rates and supporting emerging applications such as 5G, Internet of Things (IoT), and autonomous vehicles. However, one of the critical challenges in millimeter-wave communication is the effective management of interference and unwanted signals that can degrade the performance of these systems.

Research and development in this area have led to the creation of various types of bandstop filters, such as those based on inverted microstrip gap waveguide (IMGW) technology [1], reconfigurable bandstop to all pass filters using Defected Ground Structure (DGS) in K-Band [2], and millimeter-wave reconfigurable bandpass filters capable of operating between 60 GHz and the E-band [3]. These filters are designed to provide good channel isolation and are essential for the successful deployment of millimeter-wave communication systems.

To mitigate these challenges, bandstop filters play a crucial role in suppressing unwanted frequencies and ensuring reliable and efficient communication. Bandstop filters, also known as notch filters, are designed to attenuate specific frequency bands while allowing the transmission of other desired frequencies. These filters serve as essential components in millimeter-wave communication systems, enabling the coexistence of multiple frequency bands and mitigating interference issues.

In this paper, we present a comprehensive study on the design and analysis of bandstop filters operating at 28 GHz, utilizing the innovative transversal signal interference technique. The proposed filters are specifically tailored to attenuate unwanted frequencies while allowing the transmission of desired signals within the millimeter-wave spectrum. By leveraging the principles of transversal signal interference, we can achieve sharp rejection characteristics without the need for additional resonators.

II. Analysis Of The Transversal Filtering Section

The figure presented in Fig. 1 illustrates the transversal filtering section, which is based on the parallel connection of two transmission lines. This configuration involves specific characteristic impedances , Z_1 and Z_2 and electrical lengths , θ_1 and θ_2 for each line. The proposed topology operates by utilizing a feedforward combination of the two signal components from the input signal. These signals propagate through the various line segments within the transversal section, leading to the desired filtering action.

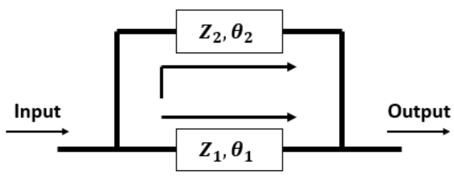

Fig. 1. BSF using transversal resonator signal-interference transmission line configuration.

The proper design of the line segments within the transversal section is crucial to achieve the desired amplitude and phase relationships between the signal components that need to be combined. A primary requirement is the generation of perfect constructive signal interference at the desired center frequency. The expressions for the power transmission and reflection coefficients of the transversal filtering section, referenced to a specific impedance, Z_0, can be easily derived from the admittance parameters of the line segments within the section [4].

To meet the design objectives, certain conditions need to be imposed on the transversal section parameters. The first condition is to enforce maximum power transmission at the center frequency, denoted as f_0. Additionally, spectral-symmetry requirements should be satisfied to achieve an overall frequency-symmetrical bandpass filtering profile with respect to f_0. These conditions and relationships guide the design process of the transversal section, enabling the achievement of the desired filtering characteristics. The derived relationships outline the design parameters that need to be satisfied for the transversal section [5].

$$Z_1 > Z_0 \qquad Z_2 = \frac{Z_1 Z_0}{Z_1 - Z_0} \tag{1}$$

$$\boldsymbol{\theta_1}(f_0) = \frac{m\,\pi}{2} \;\;,\;\; \boldsymbol{\theta_2}(f_0) = (2n + \frac{m}{2})\pi \tag{2}$$

where $\theta_2 > \theta_1$ is assumed without a loss of generality.

III. Design And Simulation Results

In this paper, a bandstop filter having a center frequency 28 GHz has been validated, the configuration of the proposed filter is shown in the Fg.2. The proposed BSF shows a stopband from 22 GHz to 30 GHz. To verify the accuracy of our calculations, we conducted simulations of the proposed filter using ADS. The filters were fabricated on a ROGERS RT/Duroid 6002 substrate with specific characteristics, including a dielectric constant ε_r = 2.94, a thickness h=0.252 mm, a loss tangent tan (δ) = 0.0012 and a metal thickness of t=0.035 mm.

Following the above procedures, the impedance values of Filter A are chosen as Z_1 = 100 Ω, Z_2 = 100 Ω and corresponding electrical lengths are as θ_1 = 90° and θ_2 = 270°, respectively. The dimensions of the proposal filter are illustrated in TABLE.I.

Table 1. Parameters values of the proposed filter.

Parameters	Values (mm)
W_1	0.14
W_2	0.14
L_1	1.84
L_2	5.53

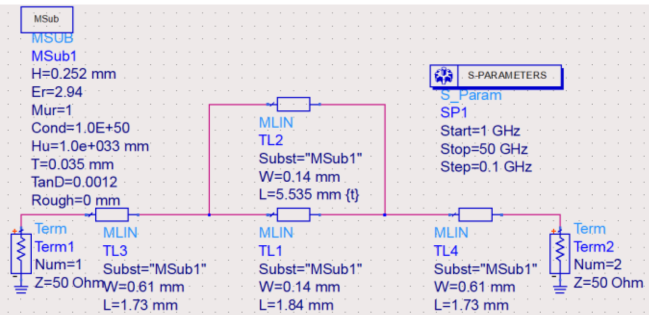

Fig. 2. Design of proposed filter simulated by ADS.

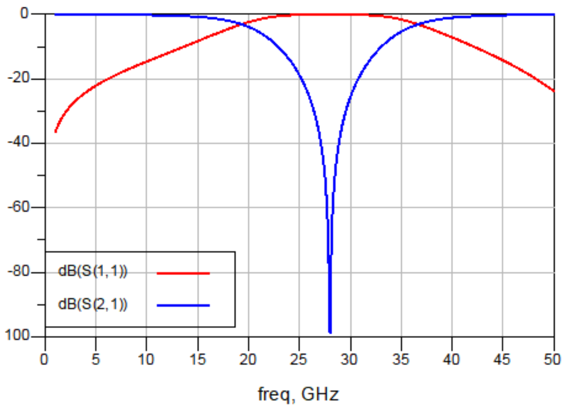

Fig. 3. S-parameters versus frequency of the proposed filter.

The experimental findings reveal the remarkable performance of our stopband filter design, showcasing a significantly wide rejection band. The transmission coefficient, a key indicator of signal attenuation, achieves an impressive level of up to -100 dB.

after validating the proposal filter, we will modify our structure as the width of the first line is too large compared to the second line. To address this, we will alter the shape by dividing the line into multiple lines, resulting in the following configuration. The dimensions of the lines are determined using the 'Tuning' option in ADS. The optimization process successfully determined the filter's dimensions depicted in Fig. 4 as follows: W = 0.14 mm, L1 = 2.04 mm, L2 = 1.38 mm, L3 = 0.78 mm, L4 = 0.84 mm, and L5 = 0.62 mm. These precise measurements are crucial for achieving the desired performance and efficiency of the filter, ensuring its effectiveness in the intended application.

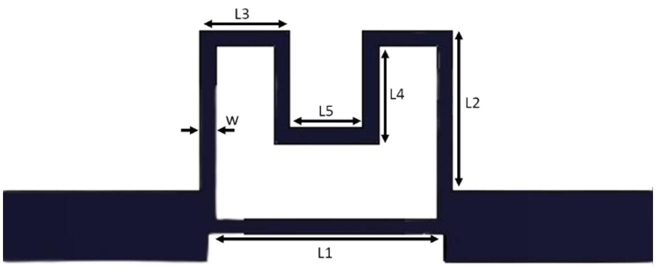

Fig. 4. Dimensions of the proposal filter.

Now, we will proceed to simulate our filter using ADS Momentum and analyze the obtained results.

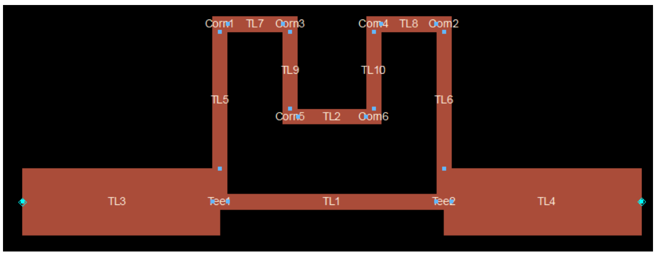

Fig. 5. Design of proposed filter simulated by ADS(Momentum).

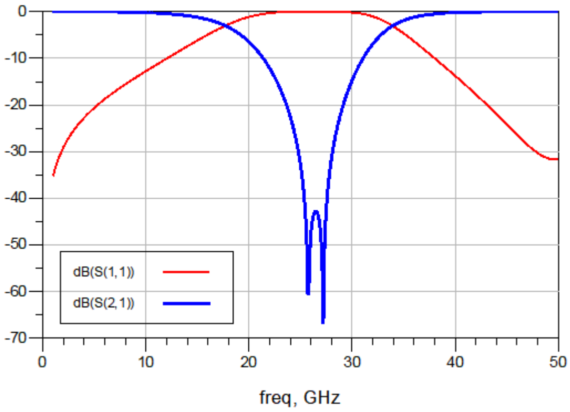

Fig. 6. S-parameters versus frequency of ADS(Momentum).

as we see there is no difference between our initial study and our new structure

To validate the simulation results obtained in ADS, we have replicated the study using an alternative electromagnetic solver, namely CST MW.

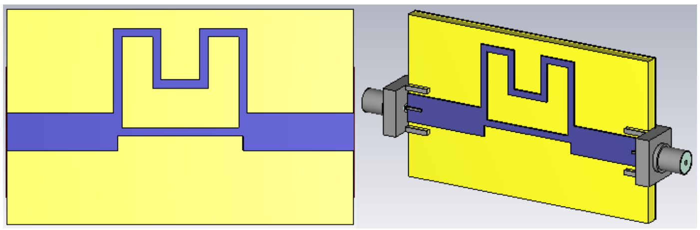

Fig. 7. Design of proposed filter simulated by CST MW.

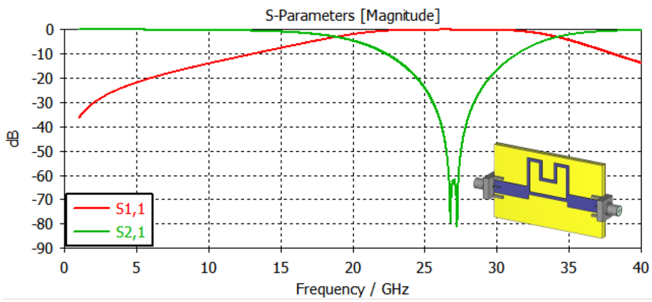

Fig. 8. S-parameters versus frequency of CST MW.

We can see that we have a BSF behavior with a slight difference which is due to the different numerical methods used in these electromagnetic solvers as shown in Fig.8.

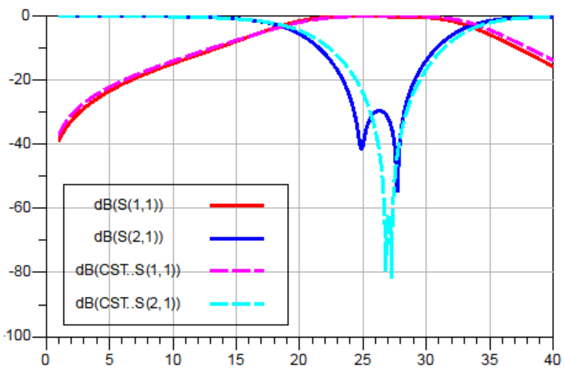

Fig. 9. A comparison between the simulation results of the proposed filter under ADS and CST MW solver.

Fg.9 describes the surface current results of the designed SBF at 22 GHz to 34 GHz. As we can see we have a rejection signal from port 1 to port 2 which validate the proposed BSF.

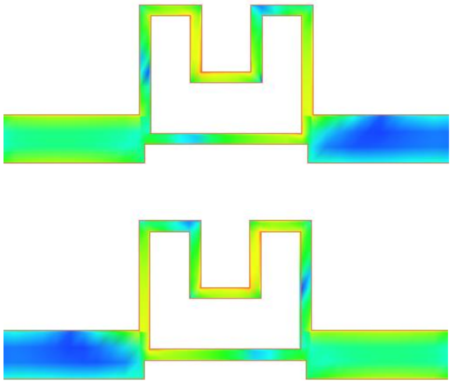

Fig. 10. Current distributions of the proposed filter at 28 GHz to 30 GHz.

In other side Fg.10 describes the surface current results of the bandwidth signal from port 1 to port 2.

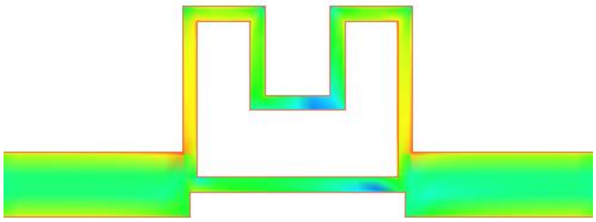

Fig. 11. Current distributions of the proposed filter under of 28 GHz and upper of 30 GHz.

The figure 11 shows the band variation when varying the line width. when the dimensions increase the band will be wide.

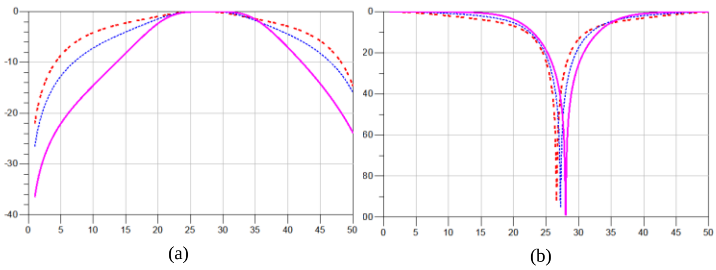

Fig. 11. S-parameters frequency variation. (a) – S21(dB), (b) – S11(dB)

A comparison is made between the performance of the current Bandstop Filter (BSF) and the previously published BSF, and the results are summarized in TABLE. II.

Table 2. Performance comparison with recently published

Ref.	***Center frequency (GHz)***	***Fractional Bandwidth (%)***	***Insertion loss (dB)***	***technology***	***Filter size (mm²)***
[6]	60	21%	-	0.18 µm CMOS	0.52×0.77
[7]	60	16.66%	18	0.18 µm CMOS	-
[3]	32	10%	-	GaAs	2.5 x 2

[4]	60 55	91.6% 90.9%	4 2.5	0.18 μm CMOS	0.78×0.77 1.51×0.32
This work	28	42.85%	5.52	MICROSTRIP	5.64 × 3.5

CONCLUSION

In this study, we have validated a planar bandstop filter using transversal signal interference filtering. This proposed circuit was designed and optimized by using two electromagnetic solvers ADS and CST Microwave studio. The proposed filter is mounted on a ROGERS RT/Duroid 6002 substrate. A compact geometry with meandered longer length line is chosen and the rectangular area of the overall filter is 5.64 ×3.5 mm².

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