Waveguide Low-Pass Filter Design Using Anten'it Bricks

Abstract

This paper presents the design and implementation of a waveguide low-pass filter using Anten'it bricks. The filter is based on a 5th-order Chebyshev prototype with a 0.5 dB ripple. The design methodology includes impedance transformations, dimension calculations using Octave, and simulation verification using CST Microwave Studio. The fabricated filter's measured results are compared with simulations, demonstrating satisfactory performance in terms of insertion loss, return loss, and stopband attenuation.

1. Introduction

Waveguide filters are widely used in RF and microwave applications due to their low loss and high power-handling capabilities. A low-pass filter (LPF) allows frequencies below a certain cut-off while attenuating higher frequencies. The need for high-performance filters in communication and radar applications motivates this study, which focuses on designing and implementing a waveguide LPF using modular Anten'it bricks.

2. Design Methodology

2.1 Filter Specification

The design of this filter is realized by successively adding low and high impedance values with certain coefficients. These coefficients should be selected according to the desired filter characteristics. In this filter, Chebyshev equal ripple coefficients are used to determine the length of the high and low impedances of the filter.

The filter is designed with the following specifications:
- Waveguide dimensions: a = 48 mm, b = 20 mm
- Cutoff frequency: 3.7 GHz
- Low impedance: 30 Ω
- High impedance: 130 Ω
- Filter Order: 5th

2.2 Chebyshev Filter Design

For the 0.5 dB ripple filter prototype, it is understood that we need a 5th order filter for minimum 15dB attenuation at 4.5 GHz from the normalized frequency versus attenuation curves in Figure 1.

Normalized frequency calculation = $\left|\frac{\omega}{\omega_c} - 1\right| = \left|\frac{4.5}{3.7} - 1\right| = 0.21$

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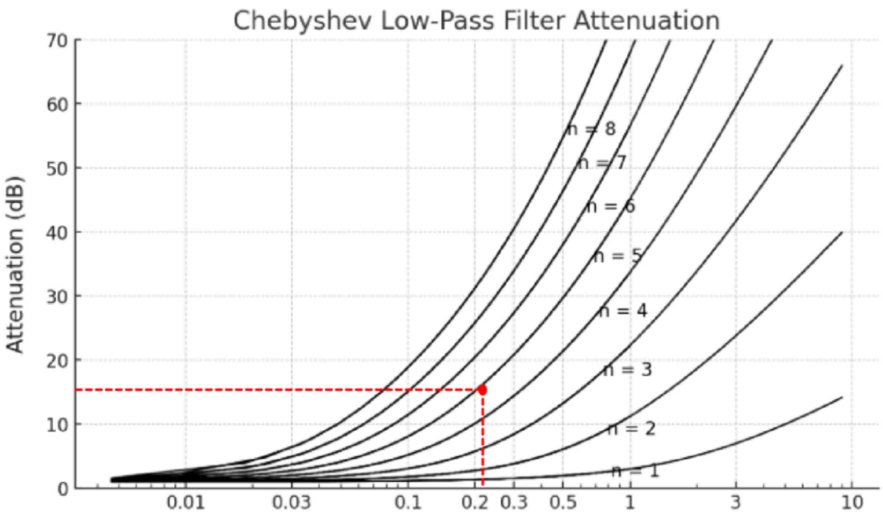

Figure 1: Attenuation versus normalized frequency 0.5 dB ripple Chebyshev filters (g_0=1, N=1 to 10)

A 5th-order Chebyshev filter with 0.5 dB ripple was selected to achieve the desired frequency response. The filter coefficients were used to determine the impedance steps and corresponding physical dimensions.

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	0.6986	1.0000									
2	1.4029	0.7071	1.9841								
3	1.5963	1.0967	1.5963	1.0000							
4	1.6703	1.1926	2.3661	0.8419	1.9841						
5	1.7058	1.2296	2.5408	1.2296	1.7058	1.0000					
6	1.7254	1.2479	2.6064	1.3137	2.4758	0.8696	1.9841				
7	1.7372	1.2583	2.6381	1.3444	2.6381	1.2583	1.7372	1.0000			
8	1.7451	1.2647	2.6564	1.3590	2.6964	1.3389	2.5093	0.8796	1.9841		
9	1.7504	1.2690	2.6678	1.3673	2.7239	1.3673	2.6678	1.2690	1.7504	1.0000	
10	1.7543	1.2721	2.6754	1.3725	2.7392	1.3806	2.7231	1.3485	2.5239	0.8842	1.9841

Figure 2: Element Values for 0.5 dB Ripple Chebyshev Filter (g_0=1, w_c=1, N=1 to 10)

3. Simulation and Implementation

3.1 Computational Analysis

The waveguide filter's dimensions were calculated using a Waveguide Low Pass Filter (LPF) Calculator by Anten'it Library Software, which incorporated the Chebychev coefficients and transformed impedance values into corresponding physical lengths.

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Anten’it Waveguide LPF toolbox screen is shown in Figure 3.

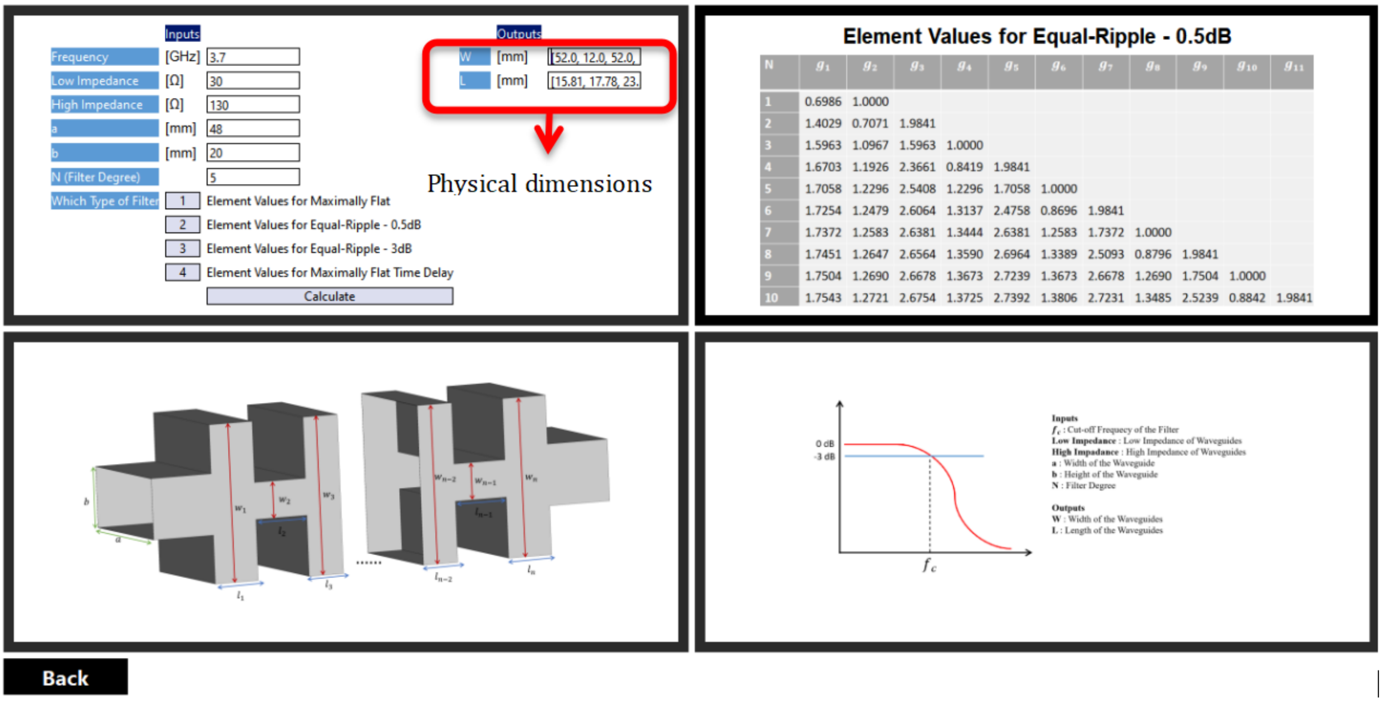

Figure 3: Anten’it Library Software Waveguide LPF design toolbox screen

According to the filter specifications, the physical dimensions output from the Anten'it Library Software Waveguide LPF design toolbox are given below.

Calculated Widths of the Filter [mm]	**Calculated Lengths of the Filter [mm]**
$w=20$	$L=39$
$w_1=52$	$L_1=15,81$
$w_2=12$	$L_2=17,78$
$w_3=52$	$L_3=23,55$
$w_4=12$	$L_4=17,78$
$w_5=52$	$L_5=15,81$
$w=20$	$L=39$

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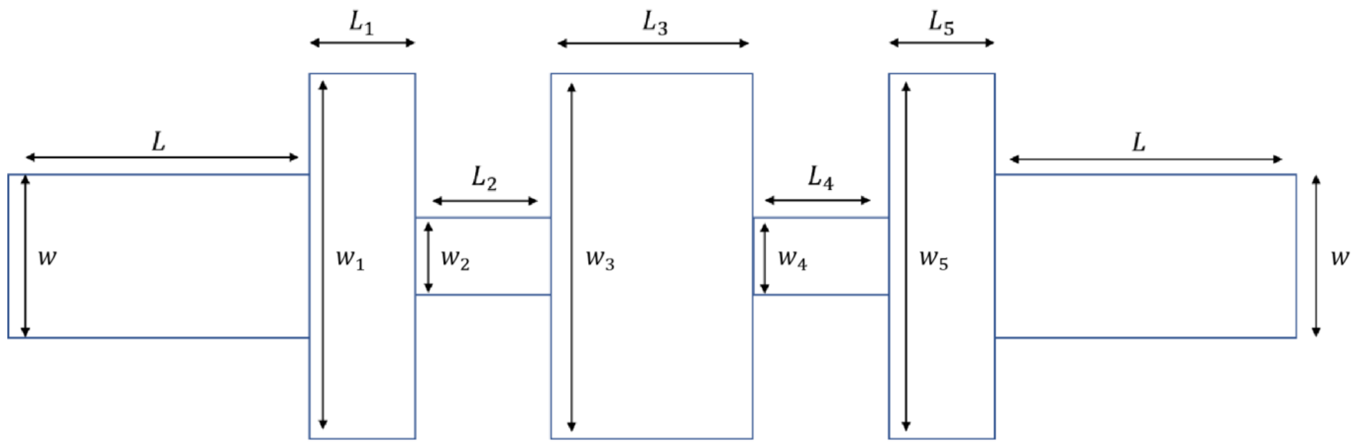

Figure 4: Dimensions of Waveguide Low Pass Filter

3.2 CST Studio Simulation

The designed filter was modeled and simulated in CST Studio to evaluate its performance before fabrication. The simulated S-parameters were analyzed to ensure the proper filter operation.

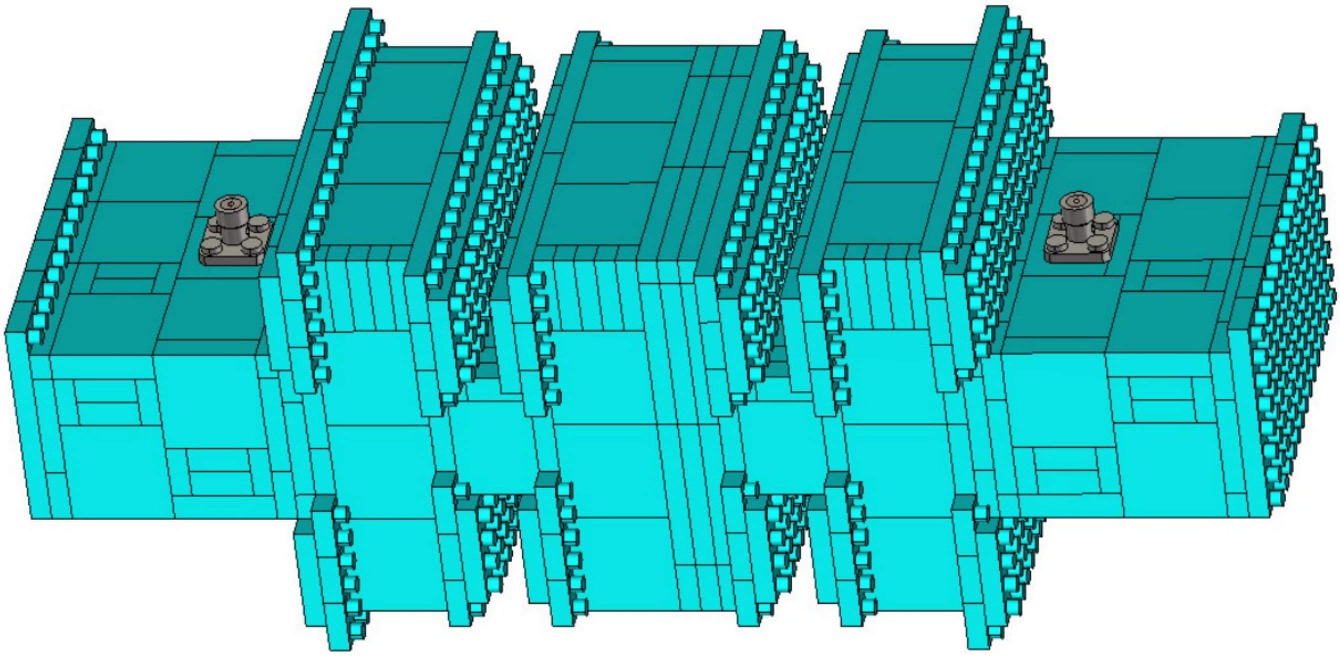

Figure 5: Waveguide Low Pass Filter designed in CST Studio

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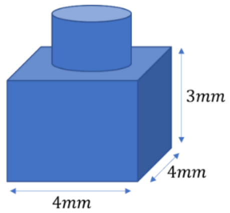
3.3 Fabrication and Testing

Waveguide impedance values were calculated to determine the appropriate step dimensions. The design was implemented using modular Anten'it bricks, which offer a convenient prototyping solution with:

◊ 3 mm resolution along the waveguide length

◊ 4 mm resolution in the width and height directions.



Calculated Lengths of the Filter [mm]	Anten'it Applicable Lengths of the Filter [mm]
L=39	L=39
L_1=15,81	L_1=15
L_2=17,78	L_2=18
L_3=23,55	L_3=24
L_4=17,78	L_4=18
L_5=15,81	L_5=15
L=39	L=39

The low pass filter is built by mounting the bricks. The connector inner conductor heights are iterated by changing the tuning ring over them. The optimum performance is achieved.

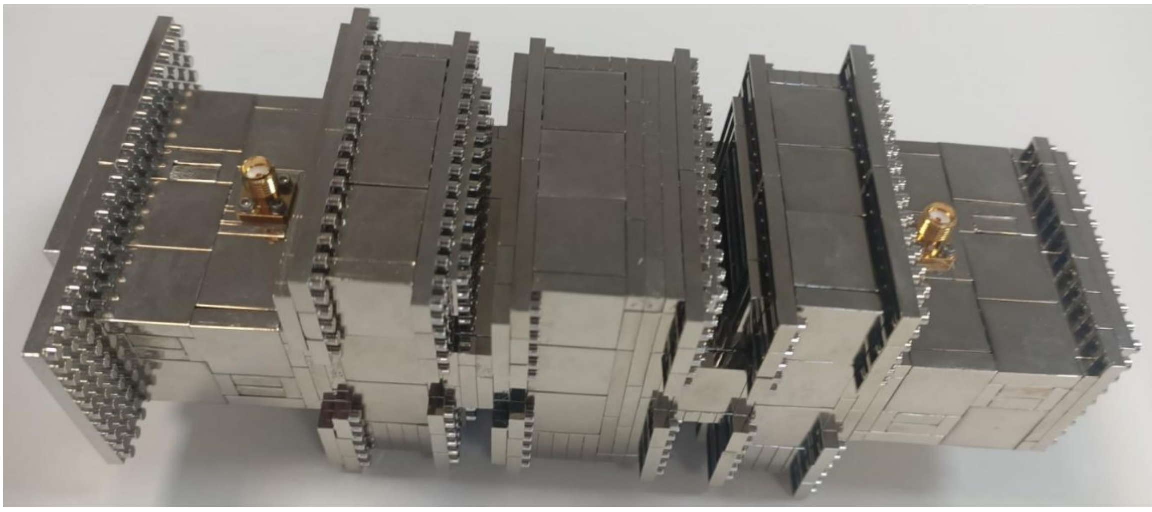


Figure 6: Waveguide Low Pass Filter with Anten'it Bricks

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4. Results and Discussion

4.1 Simulation Results

The CST simulations provided the following key parameters:

- Passband insertion loss: 1 dB (3160-3440 MHz)
- Cut-off frequency: 3 dB (3500 MHz)
- Return loss: 12 dB
- Stopband attenuation: ≥20 dB beyond 3750 MHz

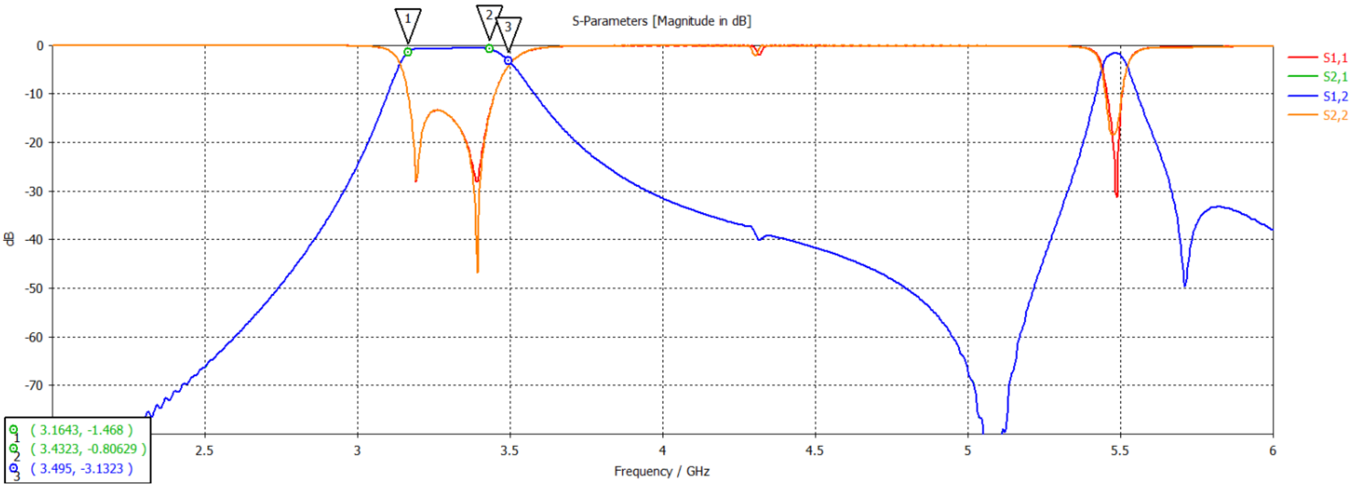

Figure 7: S-Parameters of Waveguide LPF in CST Studio

4.2 Measurement Results

The measured results obtained from the realized filter showed a strong correlation with the simulations:

- Passband insertion loss: 1.5 dB (3130-3410 MHz)
- Cut-off frequency: 3 dB (3480 MHz)
- Return loss: 12 dB
- Stopband attenuation: ≥20 dB beyond 3600 MHz

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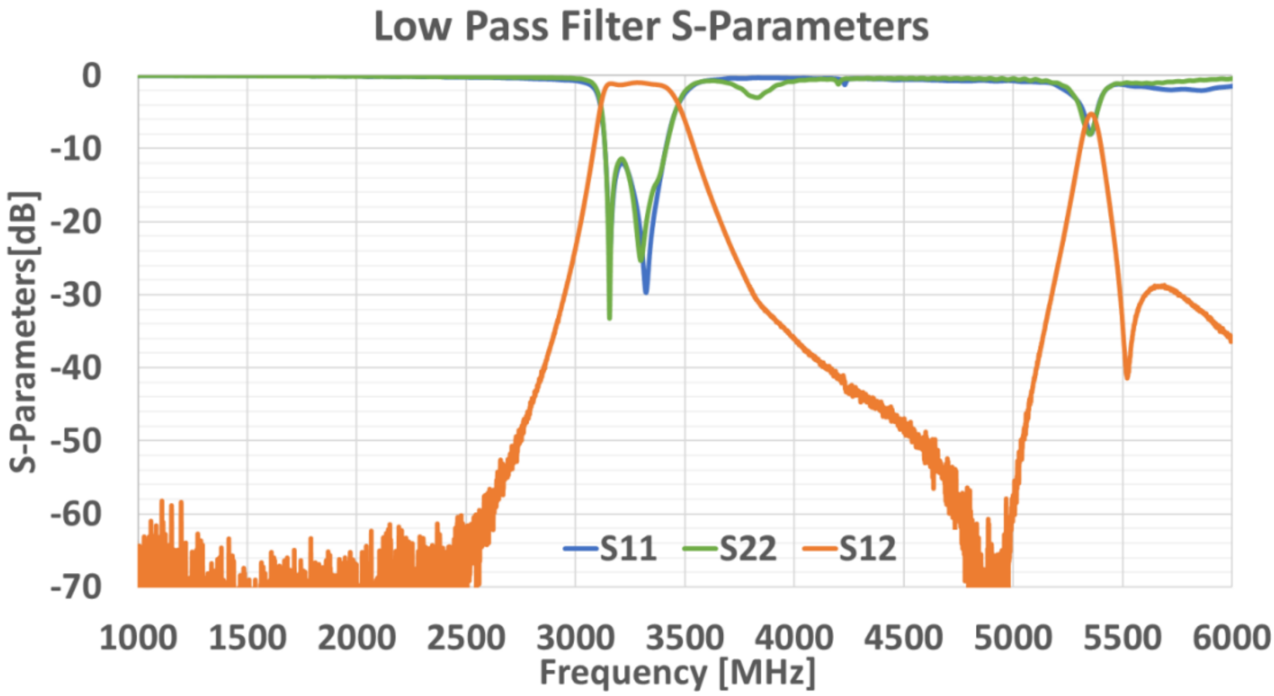

Figure 8: S-Parameters Measurements of Waveguide LPF

4.3 Comparison and Analysis

The minor discrepancies between the simulated and measured results were attributed to manufacturing tolerances and slight variations in Anten'it brick alignment. Overall, the designed filter achieved the intended performance.

5. Conclusion

A waveguide low-pass filter was successfully designed and implemented using Anten'it bricks. The combination of Anten'it Library Software calculations, CST Studio simulations, and practical testing verified the filter's functionality. This modular approach offers a flexible and cost-effective solution for prototyping microwave components. In waveguide filters, manufacturing tolerances can introduce small variations in dimensions, leading to mismatches and performance deviations. To compensate for these inaccuracies, tuning screws are strategically placed within the waveguide structure. By adjusting their depth and position, these screws modify the local electromagnetic field distribution, fine-tuning the filter's frequency response. This ensures optimal impedance matching, minimizing insertion loss and maximizing performance. Future work may involve optimizing the design for better precision and exploring the use of tuning screws for fine adjustments.