

Chebyshev Quasilumped High-Pass Filter for Low-Power Microwave Applications at 1.5 GHz

Vijay Pal Singh¹, Ram Mehar Singh Dhariwal²

¹Department of Electrical & Electronics Engg, Guru Jambheshwar University of Sc. & Technology, Hisar

²Group Captain (Retd.), Indian Air Force

vijaypalece@rediffmail.com

Abstract: A compact high-pass filter operating at 1.5 GHz is developed in this work by employing quasilumped microstrip components whose physical lengths remain well below one-quarter of the guided wavelength. The circuit is a third-order Chebyshev structure that combines two series interdigital capacitors with a single shunt short-circuited stub. Fabrication is assumed on a low-cost commercial laminate characterized by $\epsilon_r = 4.7$ and a thickness of 1.6 mm. Classical prototype transformation together with standard microstrip synthesis equations are used to obtain the initial layout; subsequent refinement is performed through full-wave electromagnetic analysis in IE3D. Simulated scattering parameters confirm a well-defined transition at 1.5 GHz, a nearly flat transmission response that continues past 2 GHz, and stop-band rejection reaching approximately -85 dB.

Keywords: Quasilumped element, high-pass filter, interdigital capacitor, short-circuited stub, microstrip technology, 1.5 GHz, Chebyshev response.

1. Introduction

Frequency-selective circuits fabricated in microstrip technology remain indispensable in contemporary RF and microwave systems. Such filters isolate desired spectral regions while rejecting unwanted interference, and they appear routinely in communication front-ends, radar modules, electronic-warfare receivers, and space-borne sensing instruments [1], [2]. The planar geometry of microstrip offers low fabrication cost, modest mass, straightforward integration with active circuitry, and compatibility with standard photolithographic processes [3].

When the physical length of a transmission-line segment is kept much shorter than a quarter of the guided wavelength λ_g , the segment may be regarded as a quasilumped element. An open-circuited microstrip stub of this length approximates a shunt capacitor, whereas a short-circuited stub of comparable electrical length behaves as a shunt inductor [1], [4]. Cascading several such elements yields higher-order filter responses with improved selectivity [2], [5].

Relative to fully distributed topologies (for example, optimum multi-stub high-pass networks), a quasilumped realization occupies less board area because each reactive element is realized by a

structure whose length is only a fraction of $\lambda_g/4$ [3], [6]. Interdigital geometries are especially convenient for implementing the series capacitances of a high-pass prototype; they furnish a large capacitance per unit area and admit accurate characterization by full-wave simulation [7], [8].

The present work describes a third-order quasilumped high-pass filter centered at 1.5 GHz. Two identical interdigital capacitors furnish the series reactances, while a single short-circuited stub supplies the shunt inductance. Element values are obtained from a 0.1 dB-ripple Chebyshev prototype via the classical low-pass-to-high-pass transformation. Initial dimensions are calculated with conventional microstrip formulas and the PCAAD package [1]–[3], [9]; the complete layout is then refined and verified by means of the IE3D electromagnetic solver [10]. The resulting structure exhibits a sharp transition near 1.5 GHz, a flat pass-band extending beyond 2 GHz, and stop-band attenuation that exceeds that of comparable distributed designs.

2. Design Parameters and Analysis

The circuit topology appears in Fig. 1. Design begins with a normalized third-order Chebyshev

low-pass prototype that possesses 0.1 dB pass-band ripple. The corresponding g-values are $g_1 = g_3 = 1.0316$ and $g_2 = 1.1474$ [1], [2]. After frequency and impedance scaling to a cutoff of $f_c = 1.5$ GHz and a reference impedance of 50Ω , the required lumped elements become

$$C_1 = C_3 = 1 / (\omega_c Z_0 g_1) \approx 2.057 \text{ pF},$$

$$L_2 = Z_0 / (\omega_c g_2) \approx 4.624 \text{ nH}.$$

Series capacitances are realized by a pair of identical interdigital capacitors, while the shunt inductance is realized by a short-circuited microstrip stub [3], [6]. Substrate and circuit parameters employed in the design are listed below:

Cutoff frequency $f_c = 1.5$ GHz

Relative permittivity $\epsilon_r = 4.7$

Substrate height $h = 1.6$ mm

Laminate type: commercial (RT/D-5880 class)

System impedance $Z_0 = 50 \Omega$

$W_c = 2.91$

$Z_{oc} = 20 \Omega$

$Z_{OL} = 90 \Omega$

$g_1 = g_3 = 1.0316$

$g_2 = 1.1474$

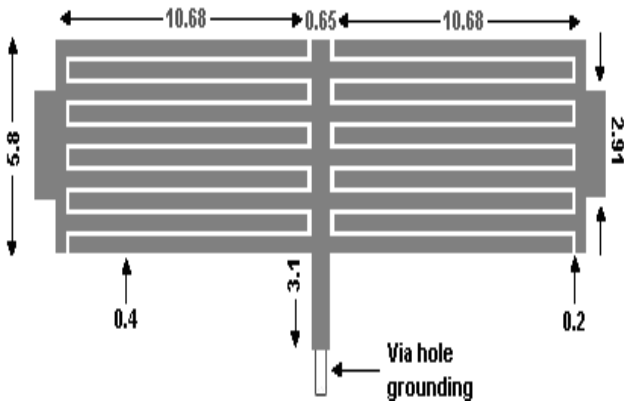


Fig. 1. Quasilumped Microstrip Highpass Filter

Finger length, width and spacing of each interdigital capacitor are chosen so that the extracted series capacitance equals the prototype value at f_c . Two-port Y-parameters obtained from full-wave simulation are used to refine the geometry [7], [8]. Final interdigital dimensions appear in Table 1. The short-circuited stub that realizes L_2 obeys the classical input-impedance relation

$$Z_{in} = j Z_c \tan(\beta l) \approx j \omega L_2 \quad (\text{electrically short approximation}).$$

Once approximate dimensions are known, the entire filter—including open-end effects, T-junction discontinuities and via parasitics—is

optimized by electromagnetic simulation. The resulting physical parameters are collected in Table 2.

Table 1: Interdigital capacitor geometry

Number of fingers	$n = 10$
Finger length	$l = 10.68$ mm
Finger width	$W = 0.4$ mm
Gap between fingers	0.2 mm

Table 2: Final microstrip dimensions

Quantity	Capacitive	Inductive
Line width (mm)	$WOC = 10.684$	$WOL = 0.654$
Guided wavelength (mm)	$\lambda_{gc} = 4.021$	$\lambda_{gL} = 3.217$
Physical length (mm)	$l_C = 5.87$	$l_L = 8.77$

3. Results and Discussion

Full-wave analysis of the completed layout was carried out in IE3D [10]. The resulting S-parameters are plotted in Fig. 2. A clear cutoff is observed at approximately 1.5 GHz, in agreement with the design target. Above this frequency the insertion loss remains low and the transmission response stays essentially flat through at least 2.0 GHz, furnishing more than 500 MHz of usable high-pass bandwidth. Within the stop-band the attenuation reaches values near -85 dB—noticeably deeper than the rejection customarily obtained from optimum distributed high-pass filters of the same order [3], [6].

The strong stop-band performance is ascribed to the accurate realization of the series capacitances by the interdigital structures and to the careful absorption of parasitic reactances associated with the discontinuities. Because every quasilumped element remains electrically short, higher-order distributed effects appear only at appreciably higher frequencies, preserving a clean high-pass characteristic over a useful operating range. These attributes render the filter attractive for systems that must process weak microwave signals while providing substantial isolation from out-of-band interference, for example satellite remote-sensing receivers and electronic-warfare equipment [5], [11].

4. Conclusion

A third-order quasilumped microstrip high-pass filter with a 1.5 GHz cutoff has been synthesized and verified by full-wave simulation. Series interdigital capacitors and a single short-circuited stub realize the required Chebyshev element values on a substrate of permittivity 4.7 and thickness 1.6 mm. Electromagnetic results obtained with IE3D demonstrate a sharp transition, a flat pass-band extending beyond 2 GHz, and stop-band attenuation approaching -85 dB. The compact footprint and superior rejection relative to purely distributed alternatives make the design well suited to low-power microwave applications such as satellite remote sensing and electronic-warfare systems.

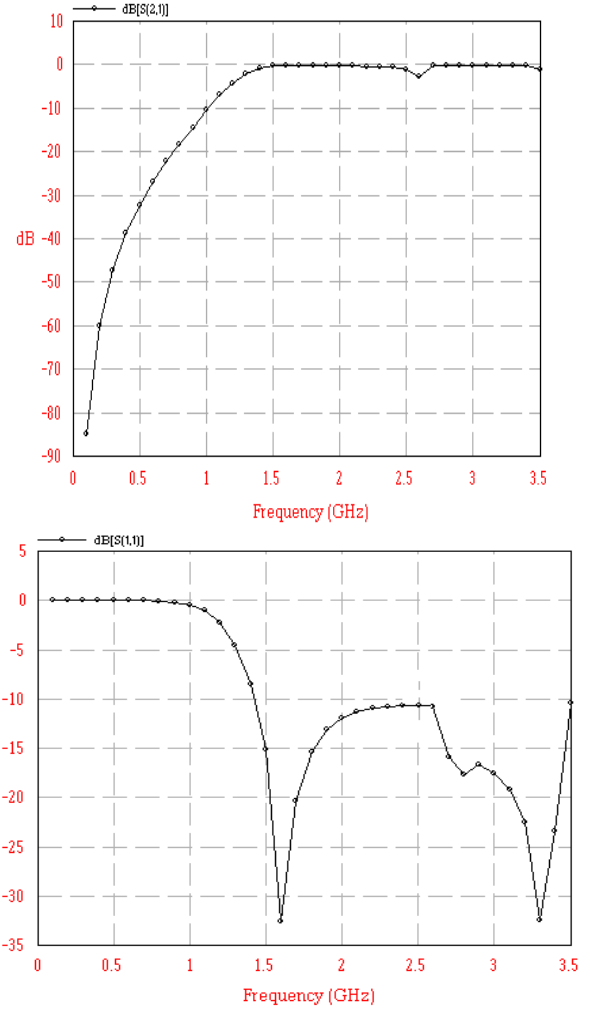
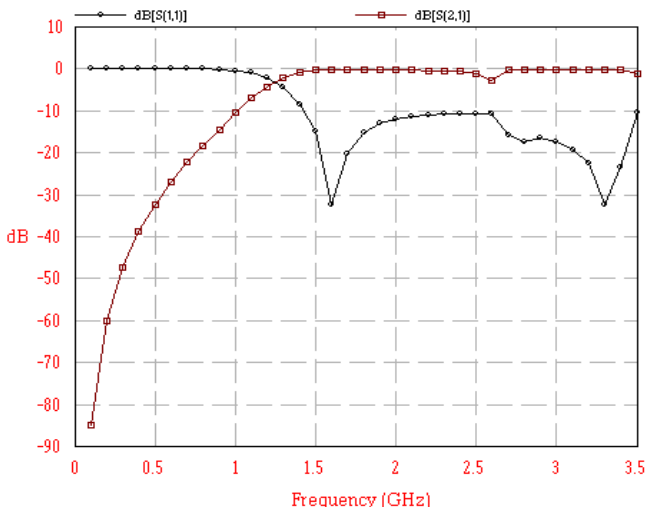


Fig. 2. Simulated S-parameters of Designed Quasilumped High Pass Filter

References

- [1] D. M. Pozar, *Microwave Engineering*, 2nd ed., John Wiley & Sons, New York, 2000.
- [2] G. L. Matthaei, L. Young and E. M. T. Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures*, Artech House, Dedham, MA, 1980.
- [3] J.-S. Hong and M. J. Lancaster, *Microstrip Filters for RF/Microwave Applications*, John Wiley & Sons, New York, 2001.
- [4] R. E. Collin, *Foundations for Microwave Engineering*, 2nd ed., McGraw-Hill, New York, 1992.
- [5] I. Bahl, *Lumped Elements for RF and Microwave Circuits*, Artech House, Norwood, MA, 2003.
- [6] K. C. Gupta, R. Garg, I. Bahl and P. Bhartia, *Microstrip Lines and Slotlines*, 2nd ed., Artech House, Norwood, MA, 1996.
- [7] G. D. Alley, "Interdigital capacitors and their application to lumped-element microwave integrated circuits," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-18, no. 12, pp. 1028–1033, Dec. 1970.
- [8] J. L. Hobdell, "Optimization of interdigital capacitors," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-27, no. 9, pp. 788–791, Sept. 1979.
- [9] PCAAD – Personal Computer Aided Antenna Design, software package, Antenna Design Associates.
- [10] IE3D Software, Release 8, Zeland Software Inc., Fremont, CA.
- [11] R. Ludwig and P. Bretchko, *RF Circuit Design: Theory and Applications*, Prentice Hall, Upper Saddle River, NJ, 2000.
- [12] D. M. Pozar, *Microwave Engineering*, 4th ed., John Wiley & Sons, Hoboken, NJ, 2012.