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Microstrip Filters: A Review of Different Filter Designs Used in Ultrawide Band Technology

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Abstract

In this study, optimization techniques applied in designing microstrip bandpass ultra-wideband (UWB) filters are presented. Optimization based on various defected ground structure techniques, resonator designs, and type of dielectric materials is discussed. Microstrip bandpass filters implemented at UWB frequency bands used in wireless communication systems have key features to control frequency response in passband and stopband. Optimization techniques are studied to attain optimum performance of bandpass microstrip filters to ensure minimum insertion loss, high selectivity, compactness, sharp transitions at cut-off frequencies, high return loss, and excellent linearity. Extensive study shows that proper selection of fabrication techniques and type of material optimizes the performance of microstrip filter design, thereby increasing its practicability for emerging wireless communication systems.

Abstrak

Filter Garis Mikro: Suatu Resensi tentang Rancangan Filter yang Berbeda yang Digunakan di dalam Teknologi Pita Ultra Lebar. Di dalam kajian ini, ditampilkan teknik-teknik optimasi yang diterapkan dalam merancang filter pita ultra lebar (UWB) lintas pita garis mikro. Di sini dibahas optimasi yang didasarkan pada berbagai teknik struktur dasar cacat, rancangan resonator, dan tipe bahan dielektrik. Filter-filter lintas pita garis mikro yang diimplementasikan pada pita-pita frekuensi UWB yang digunakan di dalam sistem komunikasi tanpa kabel memiliki fitur-fitur kunci untuk mengendalikan respons frekuensi di dalam pita lintasan dan pita penghentian. Teknik optimasi dikaji untuk mencapai kinerja yang optimum bagi filter garis mikro lintas pita untuk menjamin kerugian penyisipan minimum, selektivitas tinggi, kekompakkan, transisi yang tajam pada frekuensi penggalan, pengembalian modal tinggi (*high return loss*), dan linieritas yang sangat baik. Kajian yang panjang lebar menunjukkan bahwa pemilihan teknik pabrikasi yang benar dan tipe bahan mengoptimalkan kinerja rancangan filter garis mikro, sehingga meningkatkan kemampuan dipraktekkan untuk menampilkan sistem-sistem komunikasi tanpa kabel.

Keywords: bandpass filter, microstrip, optimization, resonator, ultra wideband

1. Introduction

Microstrip bandpass filters are prominent components in emerging wireless communication devices due to their light weight, cost effectiveness, and compact size. A generic tool that is compatible with transceiver systems at high frequency with transfer functions that are derived using generic Chebyshev/Butterworth prototypes is needed. In the design of these microstrip filters, key parameters such as fractional bandwidth, group delay, steep passband, sharp transition bands, flat passbands, and appropriately placed transmission zeros at the cut-off frequencies are also necessary.

In Alaydrus [1], a methodology is discussed to fabricate a bandpass filter (BPF) for Wi-MAX applications at a frequency of 3.2 GHz with parallel-coupled microstrips that developed a filter for wireless local area network (WLAN) at a frequency of 5.75 GHz. The BPF is incorporated with resonators and stepped-impedance resonators for a filter acknowledgment. In Abbosh *et al.* [2], an ultra-wideband microstrip BPF is proposed, with wide stopband characteristics and down-to-earth measurements. The filter is incorporated with a stepped-impedance resonator structure along with a parallel-coupled section divided into three subsections.

In Ala'a [3], a non-uniform bandpass filter with defected ground structure (DGS) is presented. The width of the presented filter was obtained using an improved operation with U shape and non-uniform form. Moreover, a DGS is employed to acquire multiple bands. The proposed design was implemented using high-frequency software such as HFSS and CST-Studio. Another methodology for designing harmonics was a suppressed microstrip ultra-wideband (UWB) BPF proposed in Bi [4]. The design was implemented using a T-shape resonator to attain a high degree of freedom, and a stub-loaded structure is incorporated to obtain additional zeros at cut-off frequencies.

In Chakravorty [5], a collaborative split-ring resonator technique is adopted to roughly anticipate the center frequency and design of microstrip bandpass filters that are generally below the class of heuristic structures. Bended transmission lines are often needed to minimize channel structures physically; however, in the hypothetical (planned) prediction of complete or focal frequencies for the bandpass channel plan, ebb-and-flow effects may cause errors. Previous suggestions on bend corrections were accurate, but continuing structure standards require an improvement in accuracy.

The objective of Hennings [6] is to build up a reasonably featured low-pass LTCC filter. Along these lines, unique plan potential outcomes of the proposed design are incorporated with tapped feed-line structures have been studied. Hsu [7] presents a bandpass filter designed using short-circuited stubs to resolve the issues in microstrip portable Wi-MAX today. The Wi-MAX "Worldwide Interoperability Microwave Access" bandpass frequency fabricated on the FR4 dielectric substrate has a thickness of 0.81 mm and an area of approximately 39.05 sq. mm.

Another lower ultra-wideband less than hybrid bandpass filter is proposed in Jeon [8] depending on the concept of right- and left-handed transmission line (CRLH-TL) metamaterial features. In Khan [9], another compact DGS incorporated end coupled line microstrip bandpass filter is presented. DGS technique was utilized to attain the compact size of the proposed filter and enhance the coupling characteristics of the resonator. The proposed compact filter incorporated with DGS has a center frequency of 2.4 GHz with recorded dimensions of 43.95 mm x 17.95 mm. The tunability of the filter obtained by varying the dimensions of the DGS cell (up to 0.65 GHz frequency tuning) approximately. The DGS has a peculiar feature of slow-wave characteristics, which in turn contributes to the rejection of a particular frequency. This impact can be attributed to the DGS equivalent and elements. DGS deployment in a microstrip filter enhances its electrical length compared with its physical length. The proposed manually molded DGS is centered at 2.4 GHz frequency with a compact size of 792 sq. mm.

In Kumar [10], an electromagnetic bandgap (EGB) incorporated with metamaterials was implemented to achieve the DGS effects. In relation to complicated EBGs/PBGs, which demonstrate DGS as an L-C, proportionate circuits are easy to implement. In this review, the microstrip channels using DGS enabled a point-by-point record. An advancement plan dependent on crossbreed genetic algorithm (GA) strategies is shown in Lai [11] to configure smaller dual-bandpass filters that incorporate microstrip lines. New schemes have been presented for communication based on a large number of data structures to a discretionary microstrip circuit. The proposed algorithm based on GA was implemented to enhance electrical parameters and circuit structures for optimum yield.

A novel bandpass channel based on a minimum ring resonator with second consonant dismissal ability was proposed in Mezaal [12]. A stepped-impedance open-stub ring resonator at bolstering lines was used for the suggested bandpass filter. Stepped-impedance open-circuited stubs in the second consonant frequency band have been implemented to achieve a superior rate of rejection. The range of the ring resonator is determined by examining and explaining the value of the ring resonator.

In Mezaal [13], a narrower double-mode microstrip bandpass channel that uses a geometric room is presented. The geometric opening relies on the first cycle of the fractal bend of Cantor square. Compared with microstrip filters incorporated with single- and dual-mode resonators, the filter designed with the proposed technique has a significant advantage of obtaining lower and stiffer spectral characteristics. Microwave Office EM is used to implement the filter. The substrate of 10.8 dielectric constant has a thickness of 1.6 mm at the center frequency of 2 GHz used for fabrication. The filter parameter revealed the insertion loss (> 0.165 dB) when return loss (> 21 dB) with data rate (> 10 Mbps) in the passband of the proposed filter.

Several cutting-edge EBGS plans are provided in Parvez [14] and explained with detailed parametric inquiries. Planar-EBG structures are respected in traditional standardized circular, square, and disc-shaped ring design. Comparative analysis reveals that the optimal filling factor was investigated by breaking down the usual frequency response of the bandpass filter from three fundamental perspectives, for instance, beginning the inquiry on the stopband, passing the band test, and convincing the inquiry of the stopband.

Miniaturized bandpass filter operates in ultra-wideband frequencies using triangular DGS with double-scored bands proposed in Song [15]. Enhancing the features of the bandpass filter needed two balanced free-weight-molded interdigital capacitors. Three sets of reduced abandoned floor structures are considered and adopted by distributing their transmission zeros to the rejected frequency band to stifle the ripples in passband frequencies. By consolidating the aforementioned two constructions, ultra compactness in the proposed filter can be achieved. It offers a unique ultra-wideband (UWB) bandpass filter with twin-touched bands across triangular DGS. To boost the efficiency of the bandpass filter, we employ symmetric pairs of interdigitated dumbbell-shaped condensers.

Microstrip bandpass filters are proposed in Wang [16]; these filters utilize a piece-type coupling framework on multi-target streamlining. This coupling structure allows for improved qualities in the plan of bandpass filters. Proposed filters have the advantage of obtaining wide upper stopband and smooth passband responses. As a result, the segment-type coupling structure plan is implemented with multi-target progress based on compact structure objectives representing bandpass filters.

Yun [17] recommends enhanced features of an ultra-wideband (UWB) filter consisting of a resonator with a single-cell consisting of a CRLH-TL and two spur lines. However, the proposed resonator is compact with broad passband characteristics. The combination of spur lines with single-cell topology eliminates unwanted frequency components outside the ultra-wideband range and distant neighborhood (WLAN) band (5.15–5.825 GHz).

The impact of DGS on reduced microstrip filter design execution is investigated. In the examination with periodic channels, the proposed design accomplishes an ultra-broad stopband with elevated constriction in a small surface area. The channel parameters are enhanced by using an in-house AGA code. The hybrid and conversion probabilities adaptively altered by the employee wellness are estimated in the suggested AGA algorithm. Zhang [18] introduces ASM and constructs a sixth application dual-layer microstrip interdigital channel with 20.4 GHz frequency and 1.6 GHz data transmission using ASM. After seven cycles, the channel reaches setting lists, thereby facilitating the filter design.

Concerning the proposed first Sierpinski structure, −15 dB reenacted fragmentary transfer speed is 5.5% at 1.505 GHz and with insertion loss of −0.16 dB. Transmission zeros are recorded at 2.25 GHz and 3.78 GHz. Furthermore, to include another transmission zero at 3.84 GHz, we added stepped-impedance open-circuited stubs to the ports of the resonator. The proposed structure at 2.9 GHz, the second harmonic band, achieves dismissal of −6.7 dB instead of −1.7 dB for the periodic band. The suggested partial transfer velocity −15 dB recreated structure is 3% at 1.42 GHz. Development is achieved by transmission zero incorporation, controlling zero dismissal esteems, fusing stubs, and symmetric nourishing lines in a comparable resonator area and sensitive ability of the suggested structure.

Although the reenacted outcomes were near the ideal detail, they are not coordinated with the ideal determination. One fundamental explanation behind this situation is the limitation of the product, such as the failure of the PC to deal with enormous memory reenactment records. Some product confinements were conducted to finish the reproduction within an attractive period with exact outcomes. Although the structured channel did not meet the particular objective perfectly in this manner, certain areas can be improved.

Once manufacturing is completed, moderation is conducted on the surface of the substrate to remove unwanted polymers deposited on it. An ultra-wideband filter can be designed by minimizing the narrow gaps between the neighboring resonators. The filters designed were mounted on two packages: one covered and the other uncovered. The uncovered filter design is centered at 63.9 GHz with a recorded return loss of more than 10 dB while insertion losses are lower than 4 dB. By contrast, the covered filter is centered at 59.95 GHz frequency with RL (> 13 dB) and IL (< 4 dB). The 3-dB bandwidth of the covered filter exceeds that of the uncovered one by 4% [19].

2. Microstrip Bandpass Filter Designs using Optimization Techniques

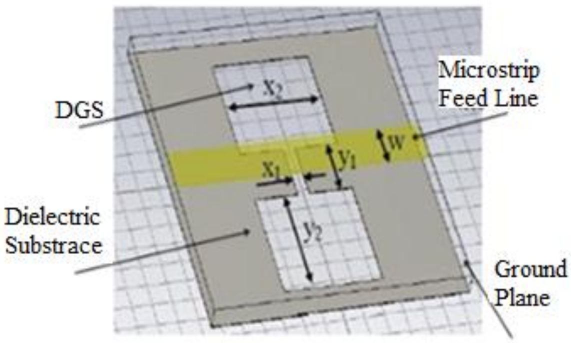
Various optimization techniques reported in this section for designing microstrip bandpass filter are as follows:

DGS-based optimization. An ultra-wideband microstrip bandpass filter assisted by a quadruple-mode ring resonator is proposed in Fan [20]. The proposed design incorporates stepped-impedance topology alongside a wavelength (λ) ring resonator.

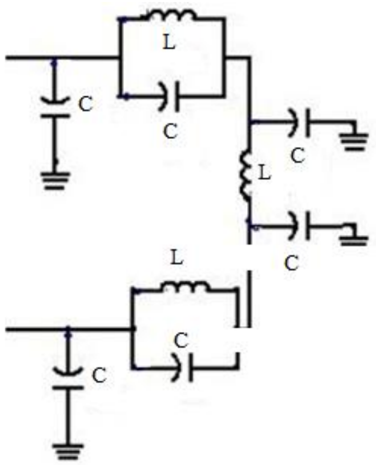
A stub-loaded resonator-based dual-band bandpass filter is presented in Hasan [21]. The planned filter is fabricated by the combination of two stubs, thereby giving the shape-ring form resonator. The dual-response is obtained by a stub-resonator combination, i.e., an open-ring resonator coupled with stubs.

Recent advancements in the development of ultra-wideband microstrip filters should meet certain features such as compactness, high data rate, reasonable insertion/return loss, affordability, and ease of production. The researchers have introduced photonic bandgap structures, which seem difficult to implement in enhancing the performance of these filters. To circumvent this issue, DGS is proposed, which introduces high effective inductive/capacitive impedances, thereby increasing slow-wave characteristics. The DGS layout and its equivalent circuit, as shown in Figure 1 and engraved in the ground plane of the substrate, not only reduces the size of the filters but also enables wide rejection of the stopband, thereby improving the frequency response of the filter. Different topologies of DGS, such as dumbbell-DGS, was ab initio accustomed notice a filter, and different shapes were rumored to appreciate completely different microwave circuits such as filters, amplifiers, routine couplers, railway line couplers, and Wilkinson power dividers. DGS is widely used today in active and passive devices. Owing to its unique features, the microstrip filters designed are ultra-compact with wide out-of-band rejection, which makes them fit for use in numerous modern wireless applications.

In Mezaal [22], a microstrip bandpass filter based on a square loop resonator is proposed. The proposed filter has a center frequency of 5.85 GHz and was fabricated on a Roger substrate with 10.8 dielectric constant value. The design of the proposed filter with its simulation results is conducted with a Sonnet machine and later fabricated based on measurement results compared with simulation results.



(a)



(b)

Figure 1. (a) Layout of Dumbbell-DGS Unit in Ground Plane of Substrate, and (b) Equivalent Model of Dumbbell-DGS Unit

DGS was usually employed in designing microstrip filters to achieve unique features such as high return loss, compactness, wide out-of-band rejection, minimum insertion loss, and removal of unwanted harmonics that can interrupt the passband signal and therefore disturb the operation of the filter. Numerous topologies, as shown in Figure 2, such as H-shaped, open I-shaped, interdigitated shaped, spiral-shaped, and triangular-shaped have been considered for designing low-pass, high-pass, bandpass, and band-reject filter. The type of structure employed is application-specific. Engraved DGS disturbs the magnetic field associated with the substrate and increases effective inductance, thereby increasing its electrical length and keeping the physical length constant. Thus, the filter size does not increase and the design is compact, which makes the filter suitable for numerous modern wireless communication systems.

Another ultra-compact microstrip bandpass filter that works in an ultra-wideband range is proposed in Sahu [23]; it is implemented by using a multimode resonator aside from DGS in the ground plane. The combined action of these two structures promotes the wide stopband, smooth passband, and reduced size. In Sahu [24], a microstrip bandpass filter operating in the ultra-wideband range is proposed. This filter is designed by a combination of L-shaped microstrip topology and T-shaped resonator structure. The filter is implemented with tunable notched bands through various dimensions of microstrip structure and resonator.

Zhao [25] presents another microstrip bandpass filter operating in ultra-wideband range with notch-band characteristics. The filter is implemented using a combination of DGS and E-shaped modified resonator. The combination of these two structures results in flat passband response, sharp selectivity, two sharp notch bands, a wide stopband, and linear group delay. Owing to these elegant characteristics, the filters are widely employed in microwave communication systems.

At the outset, the characteristics and advantages of incorporating DGS in microstrip ultra-wideband filters are presented in Table 1.

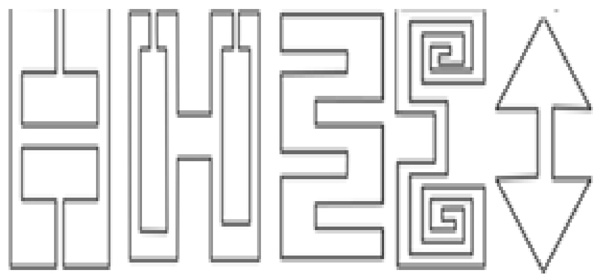


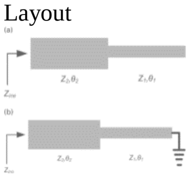
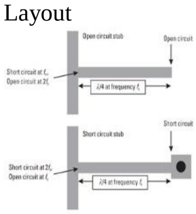
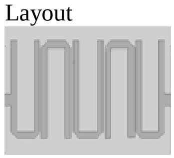
Figure 2. Various DGS Topologies

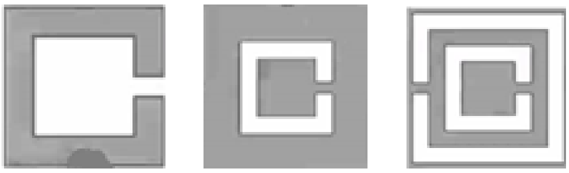
Resonator design-based optimization. MMR is used to design compact bandpass filters and also helps to optimize the insertion loss and return loss of a filter. Multiple mode resonators incorporate more transmission poles inside the passband and transmission zeros outside the passband, thereby enhancing the performance of a filter. Transmission zeros decide the selectivity, and transmission poles decide the order of the designed filter. A large number of resonator designs are available in the literature. Figures 3 and 4 exhibit some of the basic designs of resonators used in microstrip ultra-wideband filter design.

Table 1. DGS Characteristics and Advantages

S. No.	DGS Characteristics	DGS Advantages
1	DGS has two main characteristics: slow-wave effect and bandstop properties.	It rejects higher harmonics from the stopband in microwave circuits.
2	The slow-wave effect arises due to the defect in the ground plane of the microstrip line. The equivalent LC components cause it. This slow-wave effect assists in size reduction of components.	It reduces the size of filters.
3	An increased slow-wave factor means a longer electrical length for the same physical length.	It improves the passband response of microstrip filters.
4	DGS exhibits sharp-selectivity at cut-off frequency and spurious-free wide stopband. The stopband is useful to suppress unwanted surface waves, spurious …, and leakage transmission.	It achieves broader stopband responses.
5	DGS adds an extra degree of freedom in microwave circuit design and opens the door to a wide range of applications.	It provides sharp cut-off slopes at transitions from passbands to stop bands; usually at upper stopband (improves selectivity of filter).

Table 2. Characteristics of Resonators

	Stepped-Impedance Resonator	Stub-Loaded Resonator	Hairpin Resonator
	Layout  (a) Open SIR, (b) Shorted SIR	Layout  Open-circuit stub and short circuit stub-resonator	Layout  Conventional hairpin resonator
		Characteristics	
1	Shifts or suppresses higher-order frequencies, i.e., $2f_0$ and $3f_0$.	It improves upper stopband characteristics.	Compact design.
2	Good passband performance.	It achieves sharp out-of-band rejection and achieves low insertion loss and high return loss.	It enhances energy coupling for better band rejection of bandstop filter.
3	Easy to design and implement in BPF.	It achieves high selectivity.	Attractive narrow bandwidth characteristics.



(a) (b) (c)

Figure 3. (a) Square Split-ring Resonator, (b) Square Complementary Split-ring Resonator, and (c) Double

(a) (b) (c)

Figure 4. (a) Circular Split-ring Resonator, (b) Circular Complementary Split-ring Resonator, and (c) Double Circular Split-ring Resonator

Considering their characteristics, we can select different MMRs to optimize various parameters in filter design. Moreover, the optimum response of the designed microstrip filter can be attained by further modifying the structure of resonators in a more compact form. Some topologies of MMR, such as step impedance resonator, stub-loaded resonator, and hairpin resonator, along with their characteristics, are presented in Table 2.

Boutejdar [26] presents a plan of dual-band bandpass filter that utilizes a novel ring resonator and H-deserted ground. The bandpass filter is enhanced by using blended-coupled microstrip twofold ring resonators and two electrically coupled H-cell DGS resonators, which are scratched in the foundation of the structure. Utilizing this new ring structure prompts the production of a specific bandpass filter with two confined passbands. The estimation results demonstrate that the enhanced channel has two passbands: the principal band from 1.6 GHz to 2 GHz and the other from 3.6 GHz to 5.5 GHz.

A methodology created for structuring a novel microstrip ultra-wideband BPF has a fractional bandwidth of over 105%. A combination of low-pass filter (LPF) and high-pass filter (HPF) is used to design the proposed filter. Optimization is conducted in high-frequency software to enhance the performance of the designed filter. Tuning is conducted to achieve smooth passband characteristics. The stepped-impedance LPF is employed to control and reject unwanted stopband frequencies while λ/4 shorted stubs are used to evaluate the lower cut-off frequencies.

Singh [27] presents four unique plan models on low-pass and bandpass filters using DGS and avoiding DGS. Plan strategy, improvement subtleties, creation subtleties, and tentatively gotten information are introduced for all of the structures. The models are validated using a vector network analyzer.

Dielectric material type optimization. For ultra-wideband applications, an optimization-based matching-layer layout method is applied. The substrate is manufactured as a serial connection of the transmission line and the optimum signal power through a feed line to air conducted by extensively reducing the reflections at the dielectric-air interface. Various dielectric materials are available to attain desired relative permittivity needed in various microstrip designs. Notably, the microstrip line (ML) planned via the proposed approach can also be useful for ultra-wideband applications. The radiation traits of the dielectric focal point reception apparatus, e.g., front-to-back ratio, directive gain, and SLL are stepped forward with the streamlined MLs in each restricted and large recurrence group.

3. Performance analysis

Table 3 provides a comparative summary based on the preceding discussion.

Table 3. Performance Analysis

Ref. No	Methodology	Features	Drawback	Applications
1	Parallel-coupled techniques employed for the design of BPF.	Applicable for Wi-MAX at a wide range of the spectrum.	Losses are frequent.	Used in the design of a variety of BPFs at different center frequencies.
2	Parallel-Coupled Microstrip Lines	Wide stop band (up to 30 GHz) and insertion loss (< 1 dB).	The tight coupling may not exist sideways of a filter.	Applicable in the design of various UWB filters.
3	DGS techniques used	Enhances performance by alleviating non-uniformity in filter design	Research is ongoing.	Used to design multiband filters at various frequency bands
5	Microstrip BPF based on corrected curvature shape and implemented using a split-path method	Good approximation is attained in width of curvature and mean radius of resonator ring shape.	Detailed analysis is lacking.	Various BPF topologies can be developed.
6	Resonator-based designed with high dielectric substrate material.	Sharp transitions at cut-off frequency with properly positioned transmission zeros.	Impedance matching optimization cannot be adequately analyzed.	To develop any LTCC filter, the methodology has to be updated.
7	Stubs with a shorted configuration bandpass filter.	They are easily designed with low-pass prototype parameters.	LPF and BPF need to be designed side by side to conserve circuit space.	Wi-MAX and mobile

Table 3. Performance Analysis (*Continue*)

Ref. No	Methodology	Features	Drawback	Applications
8	BPF employs interdigitated lines using stubs.	Reasonable values of parameters such as IL less than 1 dB while RL is more than 14.45 dB.	Inaccuracy observed in computation of zeroth-order resonance.	These microstrip BPFs are used in modern wireless communication systems.
11	Hybrid-coded GA algorithms employed for optimization purposes.	Designed filters are compact with elegant frequency-response characteristics.	Calculations are cumbersome and time consuming.	They are widely employed in artificial intelligence-related systems such as filters.
16	Fragmented coupling topology microstrip BPF in conjunction with multi-objective optimization algorithms.	It attains a high degree of freedom and diversified structure.	Attenuation is high and had to be fixed.	They are used to design various microstrips BPF in the communication transceiver system.
17	An improved particle swarm optimization process to design a high-performance compact ultra-wideband (UWB) filter.	They can suppress unwanted harmonics and interfering components from passbands and stopbands.	The system undergoes performance degradation due to unwanted ripples noticed in the passband of the filter.	It can design the filter and RF components with complex structures automatically and accurately.
28	Microstrip bandpass filter operating in ultrawide range engraved with DGS topology.	Excellent parameter values with very low IL and high RL, ultra compactness, wider out-of- rejection band, and passband range varies from 4.4 GHz to 9.28 GHz.	Simulated and measurement results are slightly compromised.	It can be employed to design a hybrid filter with slight improvement in the design method.
29	Harmonics suppressed microstrip wideband BPF	Removal of undesired harmonics and increases its sensitivity up to a greater extent.	The proposed filter is dominant.	It is employed in modern wireless communication systems.
30	Microstrip BPF using DGS techniques with back to back E-shaped also with two-side loading scheme for compact dual-band substrate integrated waveguide (SIW).	It exhibits high selectivity, sharp skirts, smooth passband, and quick transitions at the cut-off frequency with low deceptive reaction and compact size. It also supports evanescent-mode wave.	The fractional bandwidth is low.	It can be used to design various compact multiband BPF.
31	Microstrip filter incorporated with dual layers of ML and interdigitated topology.	A higher degree of freedom and optimum values of various filter parameters obtained.	Filter parameter such as transmission coefficient magnitude S12 is high, thereby exhibiting poor transmission passband characteristics.	Most are widely used in modern wireless transceiver systems.

4. Conclusion

This study presented reviews on different optimization techniques applied in the design of microstrip filters used in ultra-wideband technology. These filters have good features, such as accommodating steep passband inclines. Furthermore, transmission zeros occur at limited bandwidth. The location of transmission zeros is challenging to predict because they exhibit near λ/4 resonant frequencies. The study showed that semi-TEM estimation and TLT are suitable for displaying microstrip channels/filters. However, the non-continuous structure of MLs ought to be addressed deliberately. A bandpass frequency is a significant issue that should be solved using a mix of step impedance LPF and the ideal circulated HPF. Concerning the stringent requirements of modern microwave communication systems, the idea of DGS evolved. This technology has emerged from electromagnetic bandgap and photonic bandgap structures. Implementation of DGS techniques and metamaterials for designing inductive–capacitive resonant circuits is much more straightforward than that of complex EBGs/PBGs. Traditional microstrip systems, such as filters and antennas, suffered from large size, single band operation, low fractional bandwidth, high insertion loss, low return loss, low gain, and improper polarization. Different techniques are available in the literature to alleviate these issues, such as photo bandgap, frequency selective surfaces, stacking, various feeding schemes, metamaterials, electromagnetic bandgap, DGS, and defected microstrip structures. Among all these techniques, DGS is most preferred because of its peculiar features such as compactness, ease of fabrication, low cost, optimum performance, and simple design. Furthermore, the frequency response of the proposed filter can be varied simply by modifying the topology and dimensions of the DGS unit cell. The study also revealed that the multiband filter operation could be attained at a higher pace by incorporating various typical DGS designs in the ground plane of a substrate. In addition, DGS exhibits excellent slow-wave characteristics that not only promote compactness in filter size but also help achieve elegant out-of-band rejection characteristics and suppression of harmonics in higher modes. At present, DGS is becoming an integral part of most ultra-wideband microstrip filters, which are used in various microwave communication applications.

References

[1] M. Alaydrus, Int. J. Elect. Eng. Inform. 2/2 (2010) 71.
[2] A.M. Abbosh, IEEE Trans. Microw. Theor. Tech. 60/1 (2011) 31.
[3] I.H. Ala'a, M.H. Bataineh, I. Ahmad, A.S. Al-Zoubi, F. Elmegri, Internet Technologies and Applications (ITA), 2017, p. 290.
[4] X.K. Bi, T. Cheng, P. Cheong, S.K. Ho, K.W. Tam, (2018). IEEE Trans. Circuits Syst. II-Express Briefs. 66/3 (2018) 317.
[5] P. Chakravorty, D. Mandal, Int. J. Numer. Model.-Electron. Netw. Devices Fields. 29/3 (2016) 520.
[6] A. Hennings, E. Semouchkina, A. Baker, G. Semouchkin, IEEE Trans. Microw. Theor. Tech. 54/3 (2006) 1253.
[7] C.L. Hsu, F.C. Hsu, J.K. Kuo, IEEE MTT-S International Microwave Symposium Digest, 2005, p. 4.
[8] J. Jeon, S. Kahng, H. Kim, J. Electromagn. Eng. Sci. 15/1 (2015) 31.
[9] M.T. Khan, M.A. Zakariya, M.N.M. Saad, Z. Baharudin, M.U. Rehman, 5th International Conference on Intelligent and Advanced Systems (ICIAS), 2014, p. 1.
[10] A. Kumar, K.V. Machavaram, Int. J. Microw. Wirel. Technol. 5/5 (2013) 589.
[11] M.I. Lai, S.K. Jeng, IEEE Trans. Microw. Theor. Tech. 54/1 (2006) 160.
[12] Y.S. Mezaal, H.T. Eyyuboğlu, J.K. Ali, IETE J. Res. 60/3 (2014) 257.
[13] Y.S. Mezaal, H.T. Eyyuboglu, PloS One 11/4 (2016) e0152615.
[14] S. Parvez, N. Sakib, M.N. Mollah, International Conference on Electrical Engineering and Information Communication Technology (ICEEICT), 2015, p. 1.
[15] Y. Song, G.M. Yang, W. Geyi, IEEE Microw. Wirel. Compon. Lett. 24/4 (2014) 230.
[16] L. Wang, G. Wang, Y. He, R. Zhang, IEEE MTT-S International Microwave Symposium (IMS), 2017, p. 1620.
[17] Y.C. Yun, S.H. Oh, J.H. Lee, K. Choi, T.K. Chung, H.S. Kim, IEEE Trans. Magn. 52/3 (2015) 1.
[18] X. Zhang, Q. Zhai, Z. Li, W. Ou, Y. Ou, J. Electromagn. Waves Appl. 32/17 (2018) 2281.
[19] D.D. Zhang, L. Zhou, L.S. Wu, L.F. Qiu, W.Y. Yin, J.F. Mao, IEEE Trans. Microw. Theor. Tech. 62/5 (2014) 1173.
[20] J. Fan, D. Zhan, C. Jin, J. Luo, IEEE Microw. Wirel. Compon. Lett. 22/7 (2012) 348.
[21] M.F. Hasan, A.S.A. Jalal, E.S. Ahmed, Progress in Electromagnetics Research Symposium-Spring (PIERS), 2017, p. 1810.
[22] Y.S. Mezaal, A.S. Al-Zayed, Int. J. Electron. 106/3 (2019) 477.
[23] B. Sahu, S. Singh, M.K. Meshram, S.P. Singh, Int. J. RF Microw. Comput.-Aided Eng. 28/4 (2018) e21209.
[24] B. Sahu, S. Singh, M.K. Meshram, S.P. Singh, J. Electromagn. Waves Appl. 32(5) (2018) 635.
[25] J. Zhao, J. Wang, G. Zhang, J.L. Li, IEEE Microw. Wirel. Compon. Lett. 23/12 (2013) 638.
[26] A. Boutejdar, N.M. Eltabit, A.A. Ibrahim, E.P. Burte, M.A. Abdalla, Appl. Comput. Electromagn. Soc. J. 31/2 (2016) 132.
[27] P. Singh, R. Tomar, Procedia Technol. 17 (2014) 58.
[28] J.K. Lee, Y.S. Kim, IEEE Microw. Wirel. Compon. Lett. 20/6 (2010) 316.
[29] J. Lu, H. Gu, W. Wu, IEEE International Conference on Microwave and Millimeter Wave Technology (ICMMT), 2016, p. 401.
[30] S. Xu, K. Ma, F. Meng, K.S. Yeo, IEEE Microw. Wirel. Compon. Lett. 25/4 (2015) 217.
[31] A. Zhan, Y. Hu, M. Yu, J. Coast. Res. 83/sp1 (2018) 585.