Babylonian Journal of Networking
Vol.2023, **pp**. 30–40
DOI: https://doi.org/10.58496/BJN/2023/005; ISSN: 3006-5372
https://mesopotamian.press/journals/index.php/BJN

Research Article

A Survey on microstrip filters, diplexers, and triplexers state of art between 2018 and 2022

Juan H. Namdar[1,*], Mohammed Q. Mohammed [2], Waleed Y Hussein [3]

1 Al-Esraa University / Computer Technology Engineering Department, Baghdad, Iraq

2 Al-Esraa University / Department of Medical Device Technology Engineering, Iraq

3 University of Information Technology and Communications, Iraq

ARTICLE INFO

Article History

Received 25 Feb 2023
Accepted 29 Apr 2023
Published 17 May 2023

Keywords

Microstrip

Bandpass Filter

Diplexer

ABSTRACT

Communication plays an important role in life these days. Communications interfere in many applications, for example, military, medical and community systems. Communications have brought the world closer. This article shows a state of art of previous studies about many devices used in communication systems. These devices are categorized under the term microstrip devices. Filters, Diplexers, and Triplexers will be the scope of this article.

1. INTRODUCTION

The rapid advancement of information technology in the world today has led to the widespread adoption of microwave communications in both military and civilian contexts. Radio transmission, mobile phones, satellite communications, ultra-wideband wireless networks, fourth-generation networks, and fifth-generation networks (sometimes known as "5G") are all part of the current system. [1]. Due to the attractive properties of millimeter-wave frequency bands, millimeter-wave devices have been utilized in a range of applications, such as transceivers, automotive radars, and imaging systems. Channel security, lower spectral congestion, faster data rates, and better spatial resolution are all characteristics of these traits [2]. Receivers and transmitters often use multiplexers in their RF front ends. Planar microstrip multiplexers (microstrip diplexers, microstrip triplexers, and microstrip quadruplexes) are gaining popularity because of their small size, low cost of integration, and high practicality [5]. The filter, an integral part of the diplexer, can modify the incoming and outgoing signals, block unwanted ones, and dampen interference. Because of this, the diplexer's filter has a significant impact on the efficacy of the whole communication setup [1]. While numerous reports of multiband filters exist, the vast majority of these studies are devoted to the development of multiband bandpass filters. In fact, some applications, like mixers, also require multiband lowpass-bandpass filters to isolate DC, IF, and other relevant frequencies to reduce system complexity and enhance stability[2]. Furthermore, in communication systems using the diplexer which is a frequency-selective device that can be used either to combine or split signals with different fundamental frequencies. To be more specific, the diplexer performs filtering on the signal, isolates the two frequency bands' signals, and recombines them into a single channel with no crosstalk. The diplexer is made up of two separate channel filters and one shared input. A three-port circuit is formed by connecting the common input of the two-channel filters. A diplexer has three ports: one for the antenna, one for transmission, and one for reception. Transmission and reception are split between two filters in a diplexer. Diplexers are utilized to separate the signals coming from the transmitter and the receiver, as they operate on different frequency ranges [1]. The use of LTE, Bluetooth, Wi-Fi, WiMAX, and other similar wireless communication systems necessitates multiband or multimode transceivers. To construct multiband transceivers, multiplexers are crucial [2]. Mobile phone networks, radio transmissions, high-speed wireless Internet, and satellite-based technologies all fall under this category. Networks can separate or mix signals of different frequencies by using many ports on a single network. The microwave switch is an essential part of many communication

*Corresponding author. Email: XXXX@XXXX.com

systems, including those that use switched beam-forming arrays, multi-in, time-division multiplexing, multi-out, etc. [3]. Transmission lines are often cascaded with filtering structures to boost the electrical performance of a microwave system. This strategy is useful in rudimentary communication systems of the past. However, the complexity of the microwave front-end and the number of microwave components utilized have both grown as modern communication techniques have developed to accommodate the expanding spectrum environment and the growing variety of communication modalities. The drawbacks of traditional design methodologies, such as excessively large circuit size, high impedance matching loss, and high production costs, have become more apparent as time has progressed [3]. Many people are interested in developing multi-band wireless communication systems, which necessitate multiplexers with desirable characteristics including wide passbands, low insertion loss, good isolation, and small size. There is an increasing demand for more efficient multiplexers. To this end, numerous papers have been published to introduce multiplexer research and development. The multiplexer industry routinely employs the utilization of the stepped impedance resonator (SIR) [4]. Planar and nonplanar diplexers are commonly utilized at the front end of today's communication networks and test instruments to split a broadband common input signal into two separate sub bands before further signal processing. Another option is to deploy a diplexer to allow a single antenna to serve as both a transmitter and receiver. In addition, diplexers can cut down on the amount of radio frequency components required for subchannels when just one receiving mode is in use. Generally, diplexers are manufactured using a pair of lowpass and high pass filters or a mixture of band-pass filters. The most prevalent combining circuit for these filters utilizes E-plane and H-plane power dividers, circulators, Y-junctions, and T-junctions. Microstrip planar diplexers have been the topic of intensive research in recent years due to its many advantages, including tiny size, simple fabrication, and integration possibilities[4]. Several varieties of diplexers, based on their channel type, were introduced: Diplexers with six channels, four channels, two channels, and eight channels are available in many studies [5]. Multiplexers and diplexers, two types of multi-channel microstrip devices, are in high demand in today's cutting-edge multi-channel communication systems. They've been used to filter out unwanted transmissions from overused frequency ranges. Triplexers are a kind of multiplexer that can switch between three different signals. Microstrip triplexers, which are both small and efficient, have recently become a hot commodity on the market for multichannel wireless and mobile systems [6]. Microstrip triplexers have found widespread usage in contemporary communication systems for filtering out unwanted frequencies and isolating the signals of interest from overlapping ones. As such, a high-performance microstrip triplexer should be designed with minimal insertion losses and few physical dimensions[7]. Multiple resonators and a matching section at the input junction are the standard components of a triplexer. The matching network ensures good input matching and great port-to-port isolation when the resonators block out the unused channels[8]. Triplexers have established themselves as a reliable alternative for enhancing triband communication networks. Triplexers often combine bandpass filters and matching circuits into their design to provide band pass output at three distinct frequencies while keeping strong matching for in-band and isolating the output from any other bands of operation [9]..

2. LITERATURE REVIEW

The SD, IEEE, and Scopus databases were thoroughly searched for English-language publications published between 2018 and 2022.These indices were chosen because of their adequate coverage. Given that the trends of modern microwave technologies have been very active in telecommunication and radio frequency application services over the past six years, most of the studies were relevant to our research. This article performs a Boolean query search with several terms connected with widespread' contemporary microwave technologies' (e.g., ("Microwave" OR "Microwaves" OR "Wireless") AND ("Diplexers" OR "Diplexer") AND ("Triplexer" OR "Triplexers")) and a keyword that takes into account all these phrases generated under this approach. That is to say, this search term was used to further the exploration of a wide range of cutting-edge microwave technologies to resolve a wide range of communications and radio frequency challenges.

3. TAXONOMY RESULTS AND ANALYSIS

As a result, 42 papers were left considering the scope of the search. Figure 1 shows the taxonomy result implementing the types of microstrip devices and their articles.

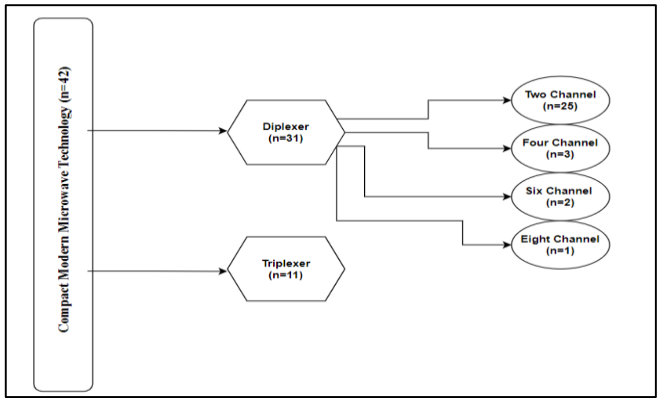

Fig.1. A classification scheme for academic literature.

4. TWO-CHANNEL DIPLEXER

The paper [10] proposed a diplexer has two channels, with a distinct bandpass filter for each channel (BPF). Using a novel suggested CMOS-based right-angled corner-modified split ring resonator (RAC-MSRR), the BPF of both channels is created on via-free CRLH TLs. The article [11] combines two coupled line bandpass filters to create a small, low-insertion-loss microstrip diplexer with high isolation (BPFs). There is a coupling capacitance that is tuned in the higher channel in order to produce an extra "zero" in the lower BPF transmission. Paper [1] employing a stub-loaded square ring resonator, a small wide-band diplexer was presented (SLSRR). Simply by altering the stub length, the SLSRR is able to realize a wide range of passband bandwidths and a tunable center frequency. For the first transmission path, using a 50% FBW with a passband that spans from 3.23-5.38 GHz. The channel's center frequency is 4.3 GHz.The second channel has an FBW of 51.4% and an average insertion loss of 2.3 dB. Article [12] suggests a new diplexer that can switch between 1.8 and 2.4 gigahertz of frequency. It has a low insertion loss, is small in size, and has a basic topology based on the linked microstrip line. Avoiding the need for channel-selecting filters and T-junctions is accomplished with the help of a set of coupled lines and a set of matching stubs. It has been accomplished the creation of a prototype circuit and its subsequent experimental evaluation. All of the measurements agree very well with the predicted results. The article [13] has developed a switchable filtering diplexer employing a repurposed resonator is proposed. The fabricated device achieves both a lower insertion loss and a smaller size in comparison to the reported state of the art.12 * 20 mmm is the size of the occupied area. The resonant frequency of the switchable resonator can be changed by manipulating the diode's bias state. Paper [14] has developed a diplexer that eliminates the need for an external matching circuit is proposed. Allocating TZs at the center frequency of the opposite channel and making use of the impedance transformations provided by the J-inverters allows for high isolation and good passband selectivity. Diplexers A and B have been tested and found to have isolation characteristics that are greater than 40 dB. Paper[15] has designed an alternative strategy for developing a compact, high-rejection diplexer that makes use of hybrid resonator (HR) bandpass filters has been proposed. Since the suggested HR only requires two lines, it takes up much less room in the RF module's shielding box. It is easy to combine with existing planar printed circuits and has excellent isolation, and strong selectivity.

The article [16] suggests approach based on configurable TZs that allows for both strong signal isolation and a wide stopband. A high selectivity microstrip diplexer with a stepped-impedance opened-end structure is used to reduce the size of a dual-mode resonator and its accompanying harmonics. Even-odd mode and transmission zero control are used to provide high signal isolation in the upper stopband (1.95GHz) and lower stopband region (2.14GHz). Researchers in the article [17] Innovative microstrip diplexer with electrically compact and excellent isolation was designed. The radio occultation method has found widespread use in analyzing a planet's atmosphere. Two intrinsic filters in a balanced architecture allow for multiple transmission zeroes, which results in a narrow stopband and high port isolation. At both frequencies, the separation is greater than 27 dB. In the paper [18] a lowpass/dual-band-bandpass filter architecture is proposed, which is both simple and compact, and which allows for tuning of the transmission zero, center frequency, and 3-dB bandwidth. Article [18] has suggestion about design a new compact metamaterial-based lowpass and dual-band bandpass filter using folded coupled line and an open-ended L-shaped stub. Only a small number of designs exist that can produce two distinct the response of filtering. Different bandpass response has been achieved by coupling two-unit cells with a strip. The location of TZs frequencies and 3-dB bandwidth characteristics may be independently manipulated by adjusting a physical component of the specified filter structure. Microstrip diplexer has two close channels, 1.67 GHz, and 1.88 GHz was proposed in [19]. The architecture of the proposed diplexer can be utilized by coupling two open loop meandrous resonators by spiral cells. The new resonator was conceptualized using an LC model. Despite the narrow bandwidth, there is only 0.43 dB and 0.35 dB of insertion loss in the first and second bands. It's used for FDD schemes and GSM applications because of its two close channels, 1.67 GHz, and 1.88 GHz. The study [20] has developed, manufactured, and characterized a compact low-pass (LP) and bandpass (BP) diplexer filter with the desired response characteristics. The LP filter has two parts: the main resonator and a suppressor resonator. The calculated BP filter performs brilliantly with a bandwidth of 0.2 GHz and a center frequency of 2.42 GHz, a lower stopband bandwidth of 4.68 GHz, and a larger bandwidth of 7.35 GHz. At long last, the suggested LP/BP filter has been built and tested, with good agreement between modeling and fabrication results. An LP/BP diplexer consisting of (LP) filter and (BP) filter with the requisite responses has been designed, manufactured, and evaluated in [21]. The measured bandwidths of the lower stopband (2 GHz) and upper bandwidth (4.68 GHz) confirm the calculated bandwidth of 0.2 GHz for the BP filter centered at 2.42 GHz. The suggested LP filter is developed using a single-resonator suppressor construction and a primary resonator. Transition band is 0.29 GHz; 3 dB cut-off frequency is 1.46 GHz. Rohde & Schwarz ZVL20 Network Analyzer microstrip diplexer that has minimal insertion loss, good selectivity, and excellent isolation has been proposed in [22]. With fractional bandwidths of 2.8% and 3.2%, the structure offers good insertion losses for the two channels of about 1.6 and 1.3 dB respectively. In the paper [23], the researchers have proposed a wide stopband with a high-isolation diplexer . The first step is the design of a composite resonator that achieves a 40dB isolation level. Second, a lowpass filter (LPF) can be constructed by including a broad passband in the device's common port. Finally, by adding PIN diodes to the circuit, a switchable response diplexer is constructed. Suppression is greater than 20 dB across the board. The article [24] has designed and constructed a microstrip diplexer with outstanding performance. It operates at 3.5 GHz for 5G communications below 6 GHz and 5 GHz for Wi-Fi communications. for both channels the insertion losses are less than (0.5) dB, which is significantly less than those of competitors. For fifth-generation applications and wireless communications, this structure is highly desirable. In this article [25], the researchers have proposed a straightforward method for designing a microstrip diplexer. microstrip diplexer is based on band-pass filters called Square Open Loop Resonators. The 2.45 GHz frequency used by these filters makes them ideal for Radio Frequency Identification systems. The results demonstrate that despite its small size, the diplexer offers excellent selectivity, the insertion loss is low, and low high isolation. In article [26], the researchers have a definition for diplexers, which are dual-filter circuits with three ports, that allow for the simultaneous use of an antenna by two separate frequency channels. However, this tech can be used with several transmitters operating at different frequencies as long as each band is used for sending and receiving signals. SIR combined with UIR provides all the benefits of fractal filters with much simpler modeling and manufacturing requirements. Kappa substrate, which has a very low loss tangent value, can be employed in diplexer, triplexer, and quadruplex components. The researchers in the study [27] have proposed a structure that is compact and has a negligible inserted loss at operating frequencies. All of the tests were run in the Ansoff HFSS, a specialized piece of software for simulating electrodynamic phenomena in three dimensions. There are two filters in the diplexer, and they both work at different frequencies. According to the results of the measurements, the first operational band has a value of 358 MHz, and the second is at 680 MHz A miniaturized microstrip diplexer for dual channels has been designed on paper [28]. It consists of two bandpass filters operating in different bands frequency that are joined by a single junction. Every BPF consists of an input/output feed line, a meandered line resonator, a step-impedance resonator, and a uniform impedance resonator. The filter has a meandered line resonator, SIR elements, UIR elements, and three feed lines. A high-performance microstrip diplexer utilizing connected triangular microstrip cells is presented here in [29]. Using frequencies of 1 GHz and 1.3 GHz, it is fully compatible with L-band networks. The insertion and return losses of the channels are improved to better than 0.21 dB and 25 dB, respectively. This gadget also features excellent channel isolation of 40 dB. The great isolation of 40 dB between its channels is another benefit of this diplexer. A dual-channel diplexer using linked open-loop microstrip resonators is proposed and investigated in the article [30] using an ADS simulator. Simulated results for this device indicate insertion loss values of (1.8 dB) and (1.0 dB) at loads first and second, respectively. With the use of microstrip open-loop resonators and source-load coupling lines, 35 dB-isolated channel bands have been efficiently created. Planar diplexer for use in cellular system frequencies between 900 and 1800 MHz was designed in [31] By adding external capacitors to hairpin resonators, the researchers were able to reduce their footprint by 40% compared to unloaded counterparts. With this setup, the researchers can save as much as 40 percent of their current space as a result of the resonators' smaller footprint. The configuration showed significant gains in isolation between ports, channel isolation, and stopband rejection compared to its predecessor design. A diplexer with multiple tunable (TZs) that share a common stub-loaded resonator SIR has been presented in [32]. Multiple TZs are created to increase selectiveness and isolation between the two channels. The design, build and evaluation of a device for use at 2.22 and 2.95 GHz are presented as examples. It has properties like low loss, high selectivity, and complete isolation. In the paper [33] diplexer has two meander transmission lines and two hook-shaped feeding lines, as well as two tri-band bandpass filters (BPFs). Stub-loaded stepped-impedance resonators form the basis of the BPFs' design (SLSIRs). Two meander networks operate at 1.46/1.74/2.96 GHz (for Load 1) and 0.89 / 2.40/3.15/4.40 GHz for Load 2. The proposed diplexer is supported by evidence from both simulation and experiment. The diplexer combines two distinct types of filters into a single device has been proposed in [34]. Microstrip line coupling techniques were used in the design of these filters. The 2.3 GHz band filter was designed using a coupled open loop ring resonator, while the 3.5 GHz band filter used a folded coupled line resonator. Figure 2 will show a two-channel diplexer sample.

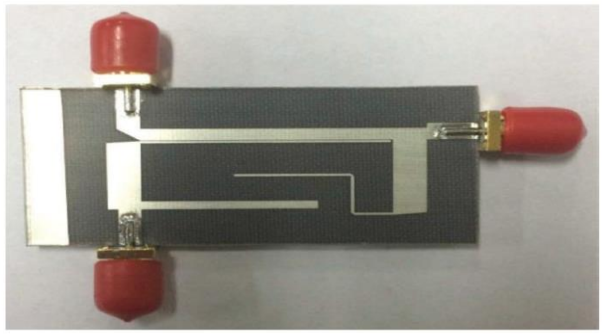

Fig.2. Two-Channel Diplexer Sample

5. Four-Channel Diplexer

In the study [35] the quad-channel diplexer is built out of two separate four-mode resonators and takes up very little space in the circuit. It has been proposed for use in the BPF and the dual-band bandpass filter (BPF). The advantages of the proposed circuits exhibit the benefits of both compact size and high performance. In Article [36] a quad-channel diplexer, made up of two separate dual-band bandpass filters, makes use of the proposed resonator. Using a combination of dual-mode and parallel quad-mode resonators, a triple-band BPF was developed. Three second-order resonators can be designed separately, tuned in a variety of ways, and use less space. The fundamental design of a triple-mode resonator is used for the multi-mode stub-loaded resonator. In the article [37], the researchers have designed to create a quad-channel diplexer, two QMSRRs are used. Quad-mode square ring resonators produce two TZs at frequencies between the four resonant frequencies. Isolation and passband selectivity in the resulting design is good. The vision will be clear when you see Figure 3 which represents a sample of four channel diplexer sample.

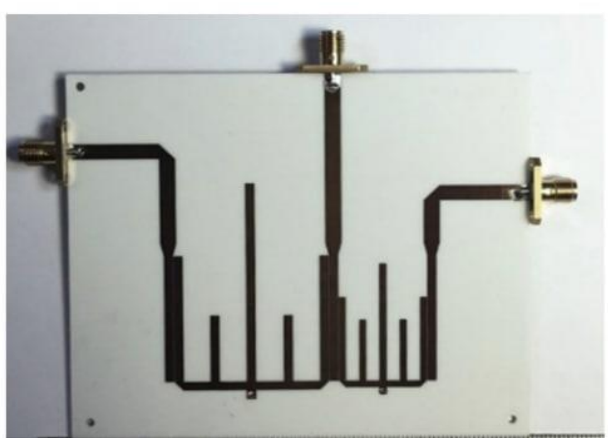

Fig.3. Four-Channel Diplexer Sample

6. SIX-CHANNEL DIPLEXER

In paper [5], The design and construction of a microstrip diplexer with six channels is described. The proposed structure has a compact size of 0.025 λg2 where λg is the guided wavelength calculated at 0.75 GHz taking the advantages of good

isolation of fewer than 22 decibels is obtained between the channels. In Article [38] There has been a proposal for a compact and highly isolating six-channel diplexer. To make it, using numerous coupling routes to connect two tri-band bandpass filters (BPFs) to a common feed. As an example, a 0.69 g and 0.21 g microstrip was fabricated using microstrip technology, with a third-order bandpass response. A sample of a six-channel diplexer will show in Figure 4.
Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

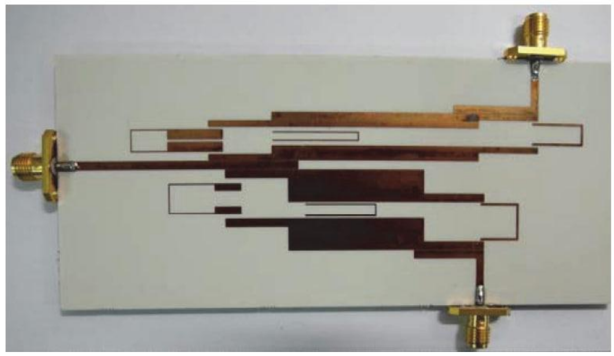

Fig.4. Six-Channel Diplexer Sample

7. EIGHT-CHANNEL DIPLEXER

In Article [39] an eight-channel diplexer comprised of four pairs of linked asymmetric stepped-impedance resonators (SIRs) is designed for use with GPS, GSM, WLAN, and 5G mid-band. SIRs provide four independent channels with great selectivity and low loss, and isolate signals from one another by more than 40dB. This means it can be used in cutting-edge wireless communication systems that employ several bands and services. So, the asymmetric SIR makes it simple to create a small multiplexer. Figure 5 will represent an eight-channel diplexer sample.

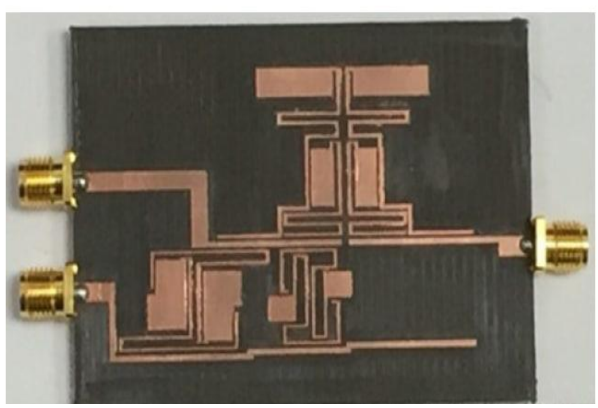

Fig.5. Eight-Channel Diplexer Sample

8. TRIPLEXER

The paper [6] shows the details of the planning and evaluation a novel planar four-port microstrip triplexer operating at 1.9GHz, 2.5GHz, and 3.35GHz. The proposed design features compact patch cells arranged in a spiral pattern. Simulated and measured insertion losses are less than 0.4dB and 0.7dB, respectively. In the article[40], Suspended line technology incorporated into the substrate is proposed for use in a revolutionary new triplexer design. The triplexer has low insertion losses of 1.4/1.3/0.8 dB for the 0.8, 2.5, and 5.8 GHz channels and good isolations across its three ports. As a result of the T-junction, the triplexer is able to produce isolation of greater than 35 dB between the two low-pass filters (LPFs) and the high-pass filter (HPF). Utilizing a suspended, patterned substrate for loss reduction significantly improves the proposed concept. Microstrip triplexer for wireless and WiMAX applications is proposed in [7]. The new 3.2–3.6 GHz resonator has a size of 0.35g0.26g, with g measured at 2.3 GHz. Aside from that, the measured insertion losses are 0.78 dB, 1.1 dB, and 0.62 dB. They employed a recently developed LC equivalent model of the resonator to fine-tune the resonance frequencies. The article [9] Describes how a small inline triplexer can be built for use in wireless transceivers that support several frequency bands. Three bandpass filters are interdigital and connected to a single feeding line. For maximum segregation, each band pass filter is built with at least one transmission zero in the other operational bands. A prototype triplexer working at 2.3GHz, 3.4GHz, and 5.6GHz has been created and evaluated. Full-wave EM modeling results are in good agreement with the measurements. The researchers in the article [41] a triplexer using E-stub-loaded composite right-/left-handed (ESL-CRLH) resonators with a quasi-lumped impedance matching network has been presented. The designed triplexer has excellent port-to-port isolation and low in-band insertion losses for its three filter channels at 1.86, 2.41, and 3.25 GHz. It is a suitable contender for modern multi-standard communication systems. The researchers in [3] have proposed a lowpass-bandpass triplexer integrated switch that has eight distinct states, with one LPC and two BPCs each having the ability to be turned ON or OFF. The LPC design utilizes an optimized set of parameters derived from the lowpass transformation approach and the traditional coupled-resonator filter design theory. Modern integrated circuit design can benefit from the proposed architectures' portability since they allow for smaller sizes and higher frequencies. The even- and odd-mode approach was used to establish the connection between the open stub DSLR's three resonant modes. For mobile communication applications, the DSLR resonator is linked with three sets of hairpin resonators to form the triplexer at 1.8, 2.1, and 2.6 GHz. The article [42] provides an analysis of a four-port triplexer by using a common resonator (DSLR). A six-pole high-tolerance switch (HTS) narrowband triplexer is developed, with switches implemented in each channel to enable one, two, or three channels in a total of eight distinct operational modes. Based on a three-mode common net-type resonator, the paper [43] presents the design of a small, switchable, narrow-band high-temperature superconducting triplexer. In the study [44], the researchers use the characteristics of steps , coupled lines, and spiral cells to design a new microstrip triplexer with adjustable resonance frequencies. Microstrip triplexer can support 4G LTE at 2.67 GHz and WiMAX at 3.1 GHz. Because of its close resonance frequencies, it can be used in frequency division duplex systems. The insertion loss of the suggested resonator is reduced by studying its LC equivalent circuit. In addition, the return losses are optimized by properly aligning the linked lines and step impedance structures. Problems with design include avoiding loading effects and integrating resonators for two or more bands into a single-band resonator's footprint. Stub-loaded resonators, which exhibit a wide variety of small-band loading effects, are used to get around these bottlenecks. On RO4003C substrates, the researchers in [45] have successfully fabricated all of the currently proposed circuits. Band matching conditions necessary to suppress loading effects are provided by the proposed SLR D and SLR T. integration of the matching circuit into the resonator, eliminating the need for a separate external matching circuit. Problems such as the input matching impedance section, the power combiner section, and the isolation section are all microstrip transmission line and resistor model components that make up a triplexer's overall architecture. The input impedance and the two losses (insertion, return) and isolation of triplexers #1, #2, and #3 at 0.915, 1.8, and 2.45 GHz have all been verified in [8]. To make the view clear, Figure 6 will show a sample of a triplexer.

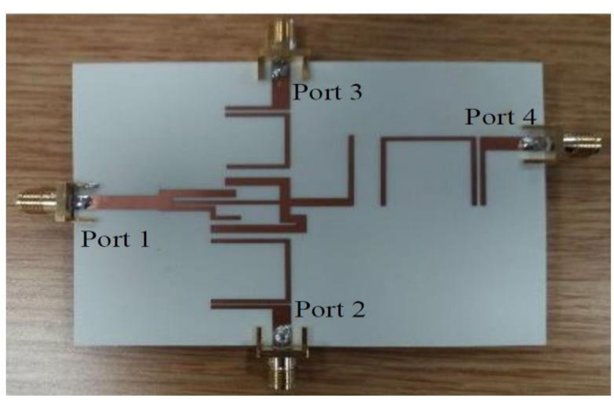

Fig.6. Triplexer Sample

9. CHALLENGES AND CRITICAL REVIEW

As the modern communication infrastructure evolves, reducing the size of microwave diplexers and improving their performance parameters has become an increasingly crucial and difficult problem[10]. Microstrip diplexers rely heavily on the branch length of the T or Y junction for impedance matching, as the frequency division diplexer is often made up of two passband filters. However, there is a possibility that this diplexer design will be too bulky to be practical. There are a variety of methods known to successfully reduce size [12]. The proposed microstrip diplexer construction must have a relatively compact size. However, significant insertion and return losses impact the design of diplexers[5]. So, getting the right coupling between two channels is sometimes a laborious process. The T-junction is the most prevalent in diplexer design, and the traditional method is frequently used. It is common practice to use a T-junction for connecting several BPFs that have been tuned to the same frequency so that they can continue to match and remain isolated from one another. T-junctions can be viewed as extra matching circuits in diplexers since they do not contribute to the resonant mode and the microstrip lines connected to T-junctions always occupy extra circuit area[14]. With the use of an I/O stub-loaded resonator. By altering the open circuit, the stub functions as a dual-mode filter with tunable cutoff selectivity. However, this microstrip filter is somewhat bulky to prevent higher sideband harmonics from diminishing the passband performance of filter and diplexer circuits, suppression of these frequencies is still challenging [16]. According to the literature review shown above, bandpass filters are commonly used in the implementation of multi-band filters and multiplexers. Moreover, designers still have a hard time making multi-band lowpass-bandpass filters, especially in the case of more than three-operation bands, as it is typically difficult to simultaneously satisfy all the design conditions required for all passbands due to the limited degrees of freedom in the design parameter. [2].Moreover, improving the insertion loss and isolation may be happening but the gap between channels of the microstrip diplexer will be large and that represents the main challenge to the designers[19]. Multiband and multiservice wireless communication systems can greatly benefit from a multichannel diplexer that features a small circuit size, low insertion loss, good isolation, and adjustable passband frequencies. But it's difficult to construct a multichannel diplexer with all those bells and whistles[39]. However, due to the common resonator's restriction on the mode, it is rarely promoted to multiplexers with numerous channels. To that end, it's important to think about the conditions under which the common port and each in-band port line up. For more leeway in the creative process[41].Since this is the case, designers of LP/BP diplexers need to be familiar with the principles of LP filter design as well as BP filter design[20]. Low insertion losses in the passbands, a high roll-off rate, a wide stopband, and strong isolation between the two output ports are some of the most pressing concerns in the design of LP/BP diplexers. When designing diplexers, it's important to keep in mind that the band passes of the filters shouldn't overlap[20]. Otherwise, the signal would be split, which will result in much higher insertion losses. The passband of the BP filter follows the passband of the LP filter in LP/BP diplexers. Second, the diplexer's two separate output ports are kept completely separate from one another. Diplexers, in contrast to Wilkinson power dividers, do not have an isolation resistor, hence signal transmission between the two output ports in the passbands must be very low (high isolation). In order to accommodate the requirements of the modern wireless communication system, known as the fifth generation (5G), a new diplexer integrated SPDT switch is required. Its usefulness is so restricted. Furthermore, designing an SPDT switch with an integrated diplexer is difficult [21]. However, delivering strong attenuation in one passband while giving excellent transmission in another is a difficult problem to build into a matching network. T-junction impedance matching networks have seen extensive use in diplexers as a three-port matching network. Though massive in scale, the T-dimension junctions must be chosen with care[22]. In cases where the number of multiplexer channels is greater than 2, however, the design of a matching circuit can be challenging[45]. Keeping very high impedance levels (preferably infinite) over a large bandwidth is difficult from a practical implementation standpoint, and this typically results in a decrease in the isolation level between channels[31]. From a power view, designing one is complex due to the difficulty of achieving perfect impedance matching across the whole frequency range of the rectifier. Rectifier impedances can be matched to antenna impedances at some frequencies while being significantly mismatched at others. Multiple stages in the wideband matching circuit might lead to a significant loss. Low incident power levels make high matching loss unfavorable for ambient energy gathering [46]. Finally, after all these challenges according to the literature it’s still lake to prove the design of diplexer and triplexer together using a similar shape of resonators.

10. CONCLUSION

According to the survey, many studies have designed two channel diplexers. However, little studies considered the other types of diplexers. The size of shape is still an issue considering the isolation and insertion loss. For future works many of these two-channel diplexer can be extending to (four, six, eight) channels. Furthermore, triplexer’s design can be extended from these diplexers taking into account the third filter that combined with the diplexers.

Conflicts Of Interest

The authors declare no conflict of interest.

Funding

None

Acknowledgment

I want to thank Dr. Waleed Y Hussein and Asst. Prof. Dr Mohammed Q. Mohammed. for their efforts and their notes to make this article complete.

References

[1] P. Zhang, M.-H. Weng, and R.-Y. Yang, "A compact wideband diplexer using stub-loaded square ring resonators," Electromagnetics, vol. 41, no. 3, pp. 167–184, 2021, doi: 10.1080/02726343.2021.1903204.

[2] C.-L. Wu and W.-H. Tu, "Design of microstrip quint-band lowpass–bandpass filters with flexible passband allocation," IET Microwaves, Antennas Propag., vol. 16, no. 6, pp. 378–390, 2022, doi: 10.1049/mia2.12253.

[3] J. Xu, Z.-Y. Chen, and H. Wan, "Lowpass-bandpass triplexer integrated switch design using common lumped-element triple-resonance resonator technique," IEEE Trans. Ind. Electron., vol. 67, no. 1, pp. 471–479, 2020, doi: 10.1109/TIE.2019.2898579.

[4] S.-M. Miri, K. Mohammadpour-Aghdam, and S.-O. Miri, "A wideband, sharp roll-off U-band diplexer in suspended stripline technology," Int. J. RF Microw. Comput. Eng., 2019, doi: 10.1002/mmce.21934.

[5] F. Fouladi and A. Rezaei, "A six-channel microstrip diplexer for multi-service wireless communication systems," Eng. Rev., vol. 41, no. 3, 2021, doi: 10.30765/ER.1556.

[6] A. Rezaei, S. I. Yahya, S. Moradi, and M. H. Jamaluddin, "A compact microstrip triplexer with a novel structure using patch and spiral cells for wireless communication applications," Prog. Electromagn. Res. Lett., vol. 86, pp. 73–81, 2019, doi: 10.2528/pierl19060104.

[7] A. Rezaei, S. I. Yahya, L. Noori, and M. H. Jamaluddin, "Design and fabrication of a compact microstrip triplexer for wimax and wireless applications," Eng. Rev., vol. 41, no. 1, 2020, doi: 10.30765/ER.1467.

[8] C. Sangdao, "Simulation of Triplexer Design for Improving Insertion Loss and Isolation," in 17th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, ECTI-CON 2020, 2020, pp. 603–606, doi: 10.1109/ECTI-CON49241.2020.9158285.

[9] D. Sen, E. Dillibabu, and M. Ramesh, "Design of compact inline triplexer for multi band receiver," 2018, doi: 10.1109/IMaRC.2018.8877199.

[10] A. Kumar and D. K. Upadhyay, "A compact planar diplexer based on via-free CRLH TL for WiMAX and WLAN applications," Int. J. Microw. Wirel. Technol., vol. 11, no. 2, pp. 130–138, 2019, doi: 10.1017/S1759078718001496.

[11] S. H. Esmaeli and S. H. Sedighy, "A compact size, high isolation and low insertion loss microstrip diplexer," J. Circuits, Syst. Comput., vol. 27, no. 13, 2018, doi: 10.1142/S0218126618502110.

[12] J. Zhou, J.-L. Li, C.-G. Sun, H. Li, and S.-S. Gao, "A novel microstrip diplexer based on coupled line," Electromagnetics, vol. 38, no. 2, pp. 87–95, 2018, doi: 10.1080/02726343.2018.1436668.

[13] X. Bi, Q. Ma, C. Ning, and Q. Xu, "A Compact Switchable Filtering Diplexer Based on Reused L-Shaped Resonator," IEEE Trans. Circuits Syst. II Express Briefs, vol. 65, no. 12, pp. 1934–1938, 2018, doi: 10.1109/TCSII.2018.2810066.

[14] X. Guan, W. Liu, B. Ren, H. Liu, and P. Wen, "A Novel Design Method for High Isolated Microstrip Diplexers without Extra Matching Circuit," IEEE Access, vol. 7, pp. 119681–119688, 2019, doi: 10.1109/ACCESS.2019.2936553.

[15] T.-H. Le, X.-W. Zhu, C. Ge, and T.-V. Duong, "A Novel Diplexer Integrated with a Shielding Case Using High Q -Factor Hybrid Resonator Bandpass Filters," IEEE Microw. Wirel. Components Lett., vol. 28, no. 3, pp. 215–217, 2018, doi: 10.1109/LMWC.2018.2804174.

[16] J. Konpang and N. Wattikornsirikul, "An analysis of high selectivity and harmonic suppression based on stepped-impedance resonator structure for dual-mode diplexer," Prog. Electromagn. Res. C, vol. 112, pp. 45–54, 2021, doi: 10.2528/PIERC21032102.

[17] T. Upadhyaya, J. Pabari, V. Sheel, A. Desai, R. Patel, and S. Jitarwal, "Compact and high isolation microstrip diplexer for future radio science planetary applications," AEU - Int. J. Electron. Commun., vol. 127, 2020, doi: 10.1016/j.aeue.2020.153497.

[18] D. K. Choudhary and R. K. Chaudhary, “Compact Lowpass and Dual-Band Bandpass Filter with Controllable Transmission Zero/Center Frequencies/Passband Bandwidth,” IEEE Trans. Circuits Syst. II Express Briefs, vol. 67, no. 6, pp. 1044–1048, 2020, doi: 10.1109/TCSII.2019.2931446.
[19] A. Rezaei, S. I. Yahya, L. Nouri, and M. H. Jamaluddin, “Design of a low-loss microstrip diplexer with a compact size based on coupled meandrous open-loop resonators,” Analog Integr. Circuits Signal Process., vol. 102, no. 3, pp. 579–584, 2020, doi: 10.1007/s10470-020-01625-w.
[20] M. Hayati, A.-R. Zarghami, S. Zarghami, and S. Alirezaee, “Designing a miniaturized microstrip lowpass-bandpass diplexer with wide stopband by examining the effects between filters,” AEU - Int. J. Electron. Commun., vol. 139, p. 153912, 2021, doi: https://doi.org/10.1016/j.aeue.2021.153912.
[21] J. Xu, F. Liu, Z.-Y. Feng, and Y.-F. Guo, “Diplexer-Integrated SPDT Switches with Multiple Operating Modes Using Common Fractal Stub-Loaded Resonator,” IEEE Trans. Microw. Theory Tech., vol. 69, no. 2, pp. 1464–1473, 2021, doi: 10.1109/TMTT.2020.3039603.
[22] A. E. Ammar, N. M. Mahmoud, M. A. Attia, and A. H. Hussein, “Efficient diplexer with high selectivity and low insertion loss based on SOLR and DGS for WIMAX,” Prog. Electromagn. Res. C, vol. 116, pp. 171–180, 2021, doi: 10.2528/PIERC21090104.
[23] X. Guan, M. Xu, B. Ren, W. Liu, X. Zhang, and B. Zhao, “High Isolated and Wide Stopband Switchable Diplexer with Inserted Lowpass Filter,” 2020, doi: 10.1109/CSRSWTC50769.2020.9372460.
[24] S. Ben Haddi, A. Zugari, and A. Zakriti, “Low Losses and Compact Size Microstrip Diplexer Based on Open-Loop Resonators with New Zigzag Junction for 5G Sub-6-GHz and Wi-Fi Communications,” Prog. Electromagn. Res. Lett., vol. 102, pp. 109–117, 2022, doi: 10.2528/PIERL21120305.
[25] H. Tizyi, F. Riouch, A. Tribak, A. Najid, and A. Mediavilla, “Microstrip diplexer design based on two square open loop bandpass filters for RFID applications,” Int. J. Microw. Wirel. Technol., vol. 10, no. 4, pp. 412–421, 2018, doi: 10.1017/S1759078718000314.
[26] K. Al-Majdi and Y. S. Mezaal, “Microstrip diplexer for recent wireless communities,” Period. Eng. Nat. Sci., vol. 10, no. 1, pp. 387–396, 2022, doi: 10.21533/pen.v10i1.2664.
[27] D. A. Letavin, “Microstrip diplexer implemented on high-pass and low-pass filters,” in International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices, EDM, 2018, vol. 2018-July, pp. 199–202, doi: 10.1109/EDM.2018.8435001.
[28] H. A. Hussein, Y. S. Mezaal, and B. M. Alameri, “Miniaturized microstrip diplexer based on fr4 substrate for wireless communications,” Elektron. ir Elektrotechnika, vol. 27, no. 5, pp. 34–40, 2021, doi: 10.5755/j02.eie.28942.
[29] A. Rezaei and L. Noori, “Miniaturized microstrip diplexer with high performance using a novel structure for wireless L-band applications,” Wirel. Networks, vol. 26, no. 3, pp. 1795–1802, 2020, doi: 10.1007/s11276-018-1870-5.
[30] Y. S. Mezaal, S. A. Hashim, A. H.Al-fatlawi, and H. A. Hussein, “New microstrip diplexer for recent wireless applications,” Int. J. Eng. Technol., vol. 7, no. 3.4 Special Issue 4, pp. 96–99, 2018, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85082370717&partnerID=40&md5=29671327ca11331ef98fa39d8d95a883.
[31] Y.-F. Tsao, T.-J. Huang, H.-T. Hsu, and C.-W. Wu, “Planar Diplexer Design Using Hairpin Resonators Loaded with External Capacitors for Improvement of Isolation and Stopband Rejection Levels,” in 2019 49th European Microwave Conference, EuMC 2019, 2019, pp. 368–371, doi: 10.23919/EuMC.2019.8910892.
[32] Y.-J. Zhang, J. Cai, and J.-X. Chen, “Separately-designable diplexer with multiple transmission zeroes using common stub-loaded SIR,” Int. J. Microw. Wirel. Technol., vol. 13, no. 1, pp. 39–45, 2021, doi: 10.1017/S1759078720000483.
[33] J. Liu, T. Su, H. Lv, L. Lin, and B. Wu, “Six-channel diplexer using stub-loaded stepped impedance resonators,” Appl. Comput. Electromagn. Soc. J., vol. 37, no. 10, pp. 1582–1587, 2019, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85074453270&partnerID=40&md5=1cfa615441d068f8c9ed93e35a37884d.
[34] M. A. Sazali, N. A. Shairi, and Z. Zakaria, “Hybrid microstrip diplexer design for multi-band WiMAX application in 2.3 and 3.5 GHz bands,” Int. J. Electr. Comput. Eng., vol. 8, no. 1, pp. 576–584, 2018, doi: 10.11591/ijece.v8i1.pp576-584.
[35] C.-F. Chen, G.-Y. Wang, and J.-J. Li, “Compact microstrip dual-band bandpass filter and quad-channel diplexer based on quintmode stub-loaded resonators,” IET Microwaves, Antennas Propag., vol. 12, no. 12, pp. 1913–1919, 2018, doi: 10.1049/iet-map.2018.0079.

[36] S. Tantiviwat, S. Z. Ibrahim, and M. S. Razalli, “Design of quad-channel diplexer and tri-band bandpass filter based on multiple-mode stub-loaded resonators,” Radioengineering, vol. 27, no. 1, pp. 129–135, 2019, doi: 10.13164/RE.2019.0129.

[37] J. Zhang, D. Pang, W. Wang, M. He, H. Chen, and L. Ji, “Microstrip quad-channel diplexer using quad-mode square ring resonators,” Microw. Opt. Technol. Lett., vol. 61, no. 8, pp. 2003–2007, 2019, doi: 10.1002/mop.31827.

[38] C.-F. Chen, B.-H. Tseng, B.-Y. Su, X.-L. Li, G.-Y. Wang, and J.-J. Li, “Compact and high isolation microstrip six-channel diplexer using multi-mode stepped-impedance resonators,” in Asia-Pacific Microwave Conference Proceedings, APMC, 2019, vol. 2018-Novem, pp. 16–18, doi: 10.23919/APMC.2018.8617131.

[39] Y.-W. Chen, H.-W. Wu, C.-T. Chiu, and Y.-K. Su, “Design of new eight-channel diplexer for multiband wireless communication system,” IEEE Access, vol. 6, pp. 49732–49739, 2018, doi: 10.1109/ACCESS.2018.2868991.

[40] Y. Chu, K. Ma, and Y. Wang, “A novel triplexer based on SISL platform,” IEEE Trans. Microw. Theory Tech., vol. 67, no. 3, pp. 997–1004, 2019, doi: 10.1109/TMTT.2019.2892732.

[41] K. D. Xu, M. Li, Y. Liu, Y. Yang, and Q. H. Liu, “Design of Triplexer Using E-Stub-Loaded Composite Right-/Left-Handed Resonators and Quasi-Lumped Impedance Matching Network,” IEEE Access, vol. 6, pp. 18814–18821, 2018, doi: 10.1109/ACCESS.2018.2819641.

[42] A. El-Tokhy, R. Wu, and Y. Wang, “Microstrip triplexer using a common triple-mode resonator,” Microw. Opt. Technol. Lett., vol. 60, no. 7, pp. 1815–1820, 2018, doi: 10.1002/mop.31244.

[43] J. Liu et al., “New design of a compact 6-pole reconfigurable narrowband triplexer based on common net-type resonator,” 2018, doi: 10.1109/ASEMD.2018.8558973.

[44] A. Rezaei and L. Noori, “Novel low-loss microstrip triplexer using coupled lines and step impedance cells for 4G and WiMAX applications,” Turkish J. Electr. Eng. Comput. Sci., vol. 26, no. 4, pp. 1871–1880, 2018, doi: 10.3906/elk-1708-48.

[45] P.-H. Deng, S.-W. Lei, W. Lo, and M.-W. Li, “Novel Diplexer and Triplexer Designs Avoiding Additional Matching Circuits Outside Filters,” IEEE Access, vol. 8, pp. 14714–14723, 2020, doi: 10.1109/ACCESS.2020.2966262.

[46] M. Q. Dinh and M. Thuy Le, “Triplexer-Based Multiband Rectenna for RF Energy Harvesting from 3G/4G and Wi-Fi,” IEEE Microw. Wirel. Components Lett., vol. 31, no. 9, pp. 1094–1097, 2021, doi: 10.1109/LMWC.2021.3095074.