International Journal of Engineering & Technology, 7 (3.4) (2018) 96-99

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

New Microstrip Diplexer for Recent Wireless Applications

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Abstract

In this study, dual-channel diplexer using microstrip open loop coupled resonators has been designed and simulated; each channel has two operating band frequencies. This microstrip diplexer is designed for (1.424/1.732GHz) for first channel and (2.014/2.318GHz) for second channel. The simulated results for this device have insertion loss (1.8 and 1 dB) at load 1, and (1.5 and 3 dB) at load 2. Additionally, it has reasonable return loss magnitudes better than 10 dB and effective isolation between channels of35 dB. The proposed design has shown an uncomplicated topology, an effectual design method, small circuit size and narrowband frequency responses that are fitting for multi service wireless schemes.

Keywords:*Dual Band Bandpass Filter; Diplexer; Dual-Channel; Narrowband Frequency Responses; Compactness*

1. Introduction

Newly, in microwave circuits, microstrip diplexers and filters have been developed due to low cost,easy fabrication, low dispersion and radiation losses [1-6]. In view of that, much attention has been devoted for compact diplexers with reasonable frequency responses, since miniaturization is one of the imperative demands. Multiplexers are the strategic constituents in communication systems involving cellular network, radio transmission, broadband wireless communications and satellite-communication systems. They can be employed for separating or combining signals with various frequencies in multi-port networks.

A diplexer is a variety of a multiplexer. It multiplexes two signal ports into one port. On the other hand, triplexer multiplexes three-port for one-port. Microstrip diplexers create a center of attention because of their benefits of economical, uncomplicated circuit outline, and they are straightforwardly set up on the dielectric substrate. Diplexers allocate dual transmitters (on dissimilar frequencies) to employ a universal antenna at the same time. In addition, they can be used in different topologies, which allow receiver and transmitter in service with diverse frequencies to allocate single joint antenna with a lower interface among the received and transmitted signals. As a result of single antenna use, it is possible to reduce the mass and volume of overall system [6], [7].

This work is a continuance of previously wide-ranging investigations carried out by others to come to the finest solutions for realizing practicable, sustainable, and cost-effective diplexers apposite for present day and future necessities and applications.A survey of such determinations is considered essential to by-pass the complications and drawbacks of such speedy emergent work. The survey afterward overviews the published literature chronologically to cover the development phases of such activities. Yang et al. 2010 [8], presented a miniaturized microstrip diplexer with high isolation by using compact hybrid resonators. The diplexer has operating frequencies at 1.8 and 2.45 GHz, and the output isolation is better than 55 dB. Deng and Jheng 2011 [9] presented an autonomously switched and reconfigurable dual-band filter of high isolation between two bands. Two mid-band frequencies $f_A$and f_B are at 1.5 GHz and 2 GHz and the isolation result is better than 37 dB.Deng, and Tung 2011 [10], proposed an innovative dualband filter using branch-line resonators with adjacent output and input ports. The coupling coefficients can be obtained separately because every passband response of the suggested filter configuration can be exclusively constructed.Zeng et al. 2011 [11], presented a microstrip quadruplexer with high isolation using distributed coupling feeding line, uniform resonator pairs and output feeding lines. The proposed design has flexible passband frequencies because each pair of resonators controls a particular channel frequency autonomously with very small loading effect among channels. Deng and Tsai 2013 [12] presented a lowpass-bandpass diplexer with a straightforward matching design.For lowpass channel, the simulated cutoff frequency is at 1.5 GHz.In bandpass channel, the simulated mid-band frequency is at 2.4 GHz. The isolation between bands is 35 dB.Wu et al. 2013 [13], presented a quad channel diplexer with compact design operating at (1.5/ 2 GHz, 2.4/ 3.5 GHz) for each channel by means of coupled pair of stepped impedance resonators (SIRs). The quad channel diplexer had shown an undemanding design and miniature dimensions. Sun et al. 2013 [14], proposed a short-ended stepped impedance dual resonator. The 1stdesign is a bandpass filter with the 1stspurious response appearing at 4.2 GHz. The 2nddesign is dual/tri-band bandpass filters. Three filters with one, two, and three passbands are manufactured and measured. Zhang et al. 2014 [15], presented a six band triplexer using short-and open-ended stub-loaded stepped impedance resonators. It is formed by using three dual-band channels joint with a universal T-shaped SIR feed line. Six bands has been realized at (1.9/2.4, 3.5/4.2 and 5.2/5.8 GHz) with compact circuit size, high isolation and low insertion loss. Lin et al.2015 [16], presented miniature quad-channel diplexer utilizing quad-mode stub-loaded resonators (QMSLRs). This device has

two dualband BPFsusing QMSLRs and source-load coupling lines. The quad-channel diplexer has been designed for 0.9/1.2GHz at Load 1 and 1.5/1.8GHz at Load 2 by means of quad-mode resonator.In [17], dual-mode square loop resonatorshas been used toconstructinnovative microstrip diplexer with switchable channels and tunable bandwidths. The proposed diplexer consists of dual coupled resonators applied for channel frequencies of 1.8 and 2.6 GHz for 4.5G relevance.
In this paper, miniature microstrip diplexer has been designed at(1.424/1.732GHz) for first channel and (2.014/2.318GHz) for second channelusing open loop coupled resonators. The suggested diplexer has extremely narrow bands with sensible S11 and S21 responses.

2. Simulation of Dual-Channel Diplexer

ADS electromagnetic simulator has been adopted in the diplexer design in this study. It determines the diplexer response by splitting the resonators in trivial mesh divisions in relation to the chosen accuracy, and thenceforth resolving a collection of linear equations resulting from integral equations. The modeled diplexer design was processed under explicit frequency range and desired frequency step. Seemly boundary settings were consigned and meshing was subsequently accomplished on the model to acquire ending refined mesh. In meshing, it is familiar that a better-quality mesh (additional number of divisions) will afford further accurate solution. Nevertheless, a better-quality mesh will also involve supplemental time for design processing. For that reason, it is needed to resolve the appropriate steadiness amid response processing time and satisfactory amount of accurateness. The electromagnetic solver involving parametric sweeps manages a linear solver procedure for solution resolve. The implementation was executed using Intel(R) Core(TM) i5-3770 @2.67 GHz CPU. The routine steps of ADS modelling for microstrip diplexer is explained by Fig.1.
The design of dual-channel diplexer is constructed by using the open loop coupled microstrip resonators. It has compacted and powerful design operability. It is designed on a substrate of Roger RT Duriod 5880 with thickness 0.787 mm. Fig.2 and Fig.3 show the simulated design of dual channel diplexer by using ADS simulator. Table 1 explains the dimensions for each microstrip coupled open loop resonator.

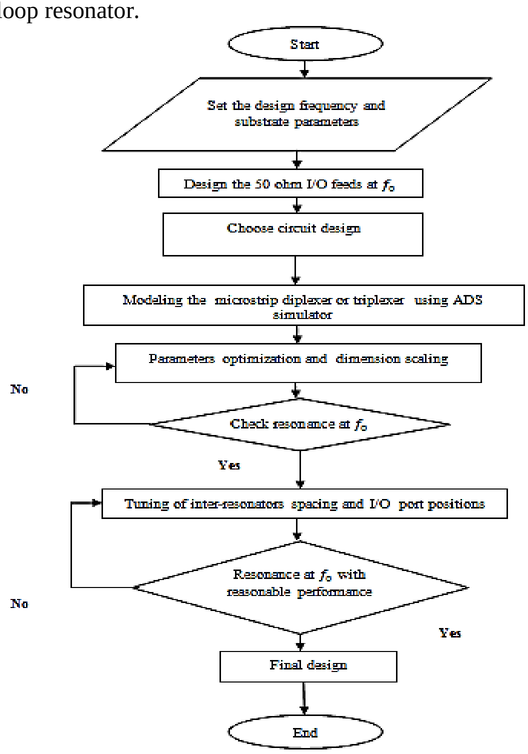


Fig. 1:ADS Simulation Flowchart for Microstrip Diplexer Design.

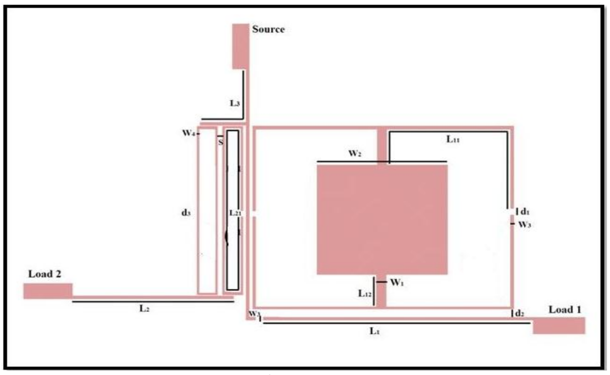


Fig. 2: Implementation of Planned Dual Channel Diplexer.

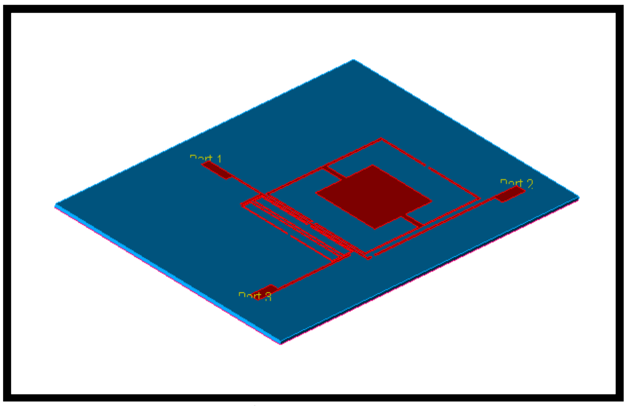


Fig. 3: Implementation of Actual Layout Dual Channel Diplexer.

Table 1: The Dimensions for Each Resonator

Dimension (mm)	Resonator (at Load 1)	Resonator(at Load 2)
Length	$L_1 = 37$ $L_{11} = 33,\ L_{12} = 5$	$L_2 = 23$ $L_3 = 14$ $L_{21} = 48,$
Width	$W_1 = 19$ $W_2 = 1.5$ $W_3 = 0.5$	$W_4 = 0.3$
Space	-----	$S = 0.6$
Distance	$d_1 = 1, d_2 = 2$	$d_3 = 0.8$

The guided wave length (λ_{go})can be evaluated by [18] :

$$\lambda_{go} = \frac{c}{f_0\sqrt{\varepsilon_{eff}}} \tag{1}$$

Where c stands for light speed, f_0 is mid-band frequency and $\varepsilon_{eff}$is effective dielectric coefficient that is computed by [18]:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \cdot \frac{1}{\sqrt{1 + \frac{12H}{W}}} \tag{2}$$

Wand H arethe conductor width andsubstrate thickness respectively, while ε_r stands for relative substrate constant. Eq. (1) is tooadvantageousto relate the size of microstrip diplexers in terms of λ_{go} with the intention of comparing evidently the smallness of miscellaneous structuresregardless of their operating frequency, sort of substrate and exterior dimensions.
The coupling coefficient can be determined by [18]:

$$K_{12} = \frac{2(f_2 - f_1)}{(f_2 + f_1)} \tag{3}$$

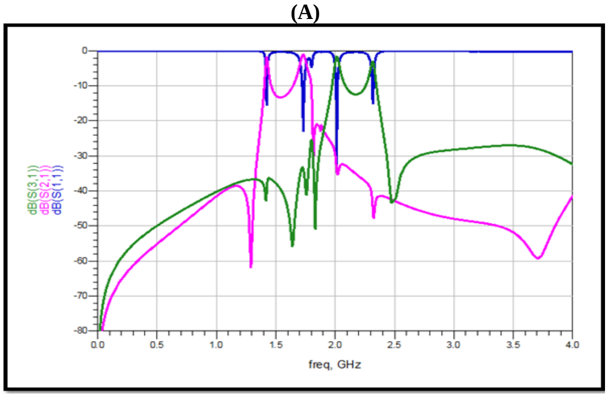
On the other hand, the external quality factor is feasibly extracted from 3dB bandwidth transmission peak by:

$$Q_{ext} = \frac{2f_0}{BW_{3dB}} \tag{4}$$

3. Results and Discussions

The dual-channel diplexer has been simulated with center frequencies at (1.424/1.732GHz) for load 1 and at (2.014/2.318GHz) for load 2. The simulated results have insertion loss (1.8 and 1 dB) at load 1, and (1.5 and 3 dB) at load 2. The isolation levels between channels are around 35 dB as it is clear from Fig.4.
The completely tuning of the source-load coupling lines and coupled microstrip resonatorsgenerate transmission zeroes nearby passband edges. This design helps to create multi-path signal diffusion by this adopted compact microstrip diplexer.Table 2 shows the electrical specifications of proposed diplexer for each channel. By this table, it is noticeable that each channel has dual verynarrow bands and interesting external quality factor magnitudes that make the proposed microstrip diplexer of high selectivity device for recent wireless applications.

(A)



(B)

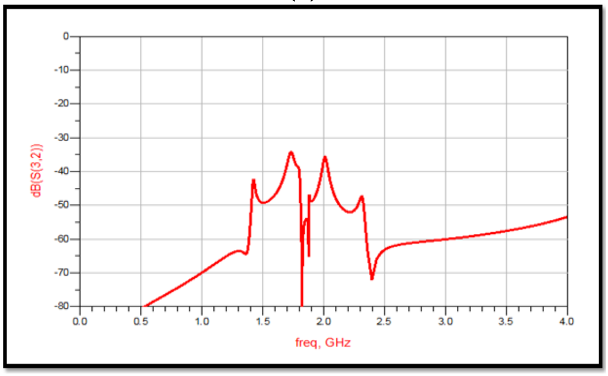


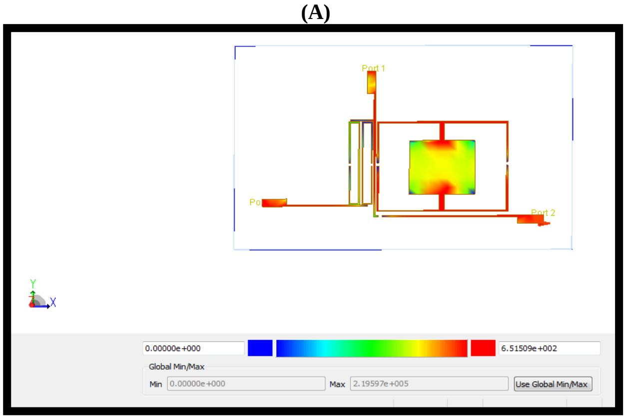
Fig. 4:S- Parameter of the Simulation Results: A) Insertion and Return Loss B) Isolation between Bands.

Table 2: Electrical Specifications of Projected Diplexer for Each Channel

	1st band/1st channel	2nd band/1st channel	1st band/2nd channel	2nd band/2nd channel
Resonant frequency (GHz)	1.424	1.732	2.014	2.318
bandwidth (MHz)	12	49	33	23
Coupling Factor	0.008	0.028	0.164	0.001
External Quality Factor	237.333	70.694	122.06	201.565

Fig.5 and Fig.6illustrate the current distribution of the dual-band diplexer at two channels at each band frequency. The highest and lowest couplings are signified by red and blue colors correspondingly. It is noticeable that the highest current distributions are patterned in the right loop resonator with central square patch at first channel frequencies. Vice versa, the utmost current distributionare patterned in the left loop resonators at second channel frequencies that represent an evidence that first and second channel frequencies are originated from right and left microstrip resonators.

(A)



(B)

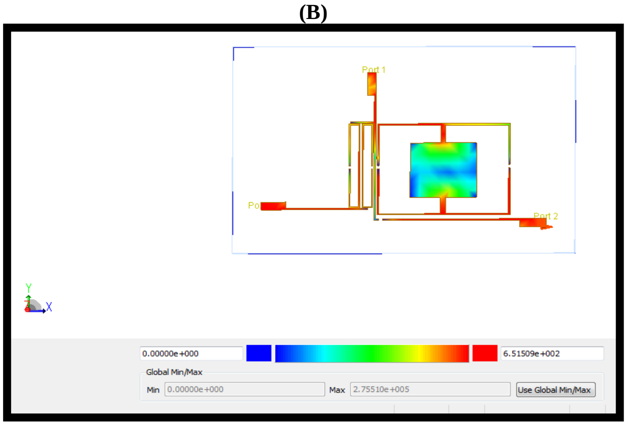
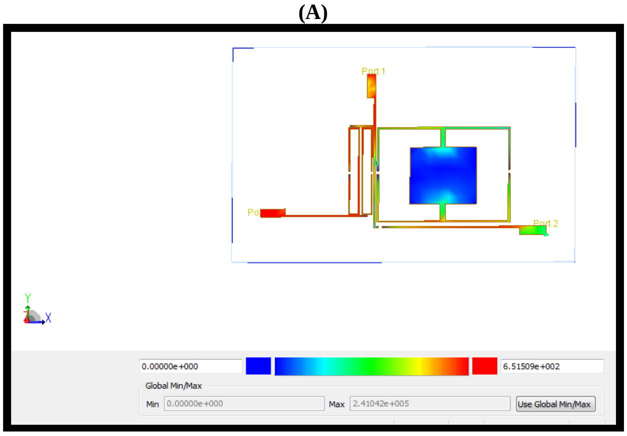


Fig. 5: Current Intensity Depiction of the Designed Diplexer at (1.424 /1.732 Ghz) of Channel 1 Frequencies.

(A)



(B)

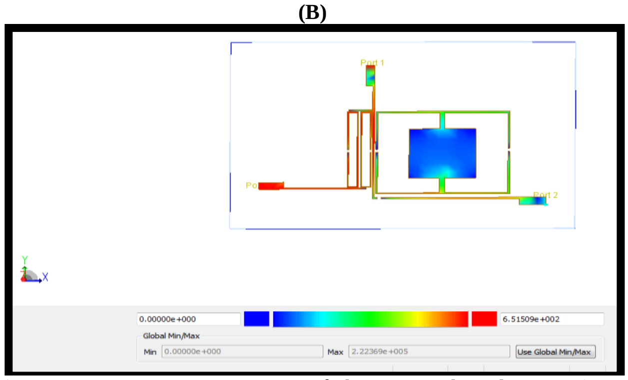


Fig. 6: Current Intensity Depiction of the Designed Diplexer at (2.014 /2.318 Ghz)of Channel 2 Frequencies.

The developed dual channel diplexer has been designed to achieve tolerable insertion loss, miniature circuit size, and good passband selectivity for all channels. Table 3 explains the comparison results among this design and other reported designs in the literature.In view of that, the modified dual channel diplexer in this study is mostly better than the reported designs in [11, 13, and 19] as shown in Table 3because of the high isolation between channels and compact size.

Table 3: Comparison between This Design and Other Reported Designs

Ref.	Passband(GHz)	Insertion losses (dB)	Isolation (dB)	Substrate Type (ε_r)	Substrate Thickness (mm)	Size
[11]	2.3 / 3.7 / 5/ 6.1	2.2/ 2.5/ 1.8/2.1	> 40	RT Duroid (ε_r=10.2)	0.635	$0.39\ \lambda_g \times 0.4\lambda_g$
[13]	1.5/ 2/ 2.4/ 3.5	0.8/ 1/ 0.7/ 1.5	> 30	Roger 5880 (ε_r=2.2)	0.787	$0.19\ \lambda_g \times 0.4\lambda_g$
[19]	1.75 / 2.35	1.34 / 1.44	> 25	Roger 5880 (ε_r=2.2)	0.508	$0.12\lambda_g \times 0.23\lambda_g$
This work	1.424/ 1.732/ 2.014/ 2.318	1.8/ 1 /1.5/3	35	Roger 5880 (ε_r= 2.2)	0.787	$0.194\ \lambda_g \times 0.316\ \lambda_g$

4. Conclusions

Compact dual-channel diplexer is proposed employing coupled open loop microstrip resonators and investigated through ADS simulator. By using microstrip open loop resonators and the source-load coupling lines, channels bands with very good isolation of 35 dB have been efficiently accomplished. Simulated results expose that proposed diplexer has sensible frequency responses and high-quality passband selectivity at each channel. The band isolation is mostly better than reported designs in [11, 13, and 19]. Also, it has more compact dimensions in terms of λ_g of about $0.194\ \lambda_g \times 0.316\ \lambda_g$ and extremely narrowband responses. As a result of above, the designed diplexer is appropriate for multi-band and multi-service wireless systems. This diplexer can be extended to microstrip triplexer as future work of scope by inserting additional open loop resonator and port to be in service for recent wireless applications.

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