Design and Optimization of Butterworth and Elliptic Band Pass Filters in 5G Application

Dina Riydh Ibrahim
dina.ibrahim@uoninevah.edu.iq

Communication Engineering Department, Electronic Engineering, Ninevah University, Mosul, Iraq

ABSTRACT

Filters are two-port networks that may pass or attenuate frequencies within defined ranges and can alter the frequency response of any system. In the present research study, the goals and optimization controller embedded with (ADS2019) are used to design Butterworth and Elliptic bandpass filters with frequency ranges of (18GHz – 38GHz), a bandwidth of (7GHz), stopband attenuation of (S21=-60dB), and passband attenuation of (S21=-1dB). Three types of each filter (Hp-Lp 6th order – 3rd order – 6th order) are simulated and optimized to choose the best (C, L) values. The selected filters are redesigned using the Design Filter Guide, and the simulation during this phase yields different values for (C, L). The designed circuit is then transformed into a microstrip model using transmission lines for open and short circuits. The study investigates the differences between each filter in BW-f center- attenuation at the stopband. In the last phase of the study, the circuit of each filter is transformed using a microstrip transmission line to obtain the (W, L) for each component of each filter. Finally, the study compares past studies and research projects in this field.

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1. INTRODUCTION

Filters are selective networks that separate the required signals from a mixture of signals [1]. They are electric circuits designed to process (attenuate, amplify, or reshape) signals. In any communication system, filters are used for noise extinction to isolate communication signal bands from many [2]. In communication/radar systems, filters have essential roles in rejecting unwanted frequency ranges and canceling noise and interference [3].

2. PREVIOUS WORK

In [2006], a 2.4GHz bandpass filter was designed, fabricated, and tested using microstrip technology. The parallel coupling lines filter topology simulated, analyzed, and verified the obtained results. A comparative analysis was later used to optimize the acquired experimental and analytical data. Other software tools such as MatLab, CorelDraw 12, and Microwave Office were later used to enhance those results[4].

In [2010], the C++ program was used to design a Butterworth passive low-pass filter with n^{th} order using modulating techniques. A passive synthesis network was implemented to develop such a filter of any order [1].

In [2011], the T-shaped patches-based filter was proposed. The T-shaped patches and folded open stub. The designed filter has a cut off frequency at (2.37GHz) (-3dB) and a (2.44GHz) (-40dB) rejection. The return loss was more significant than (- 14.5 dB), and the insertion loss was less than (0.164dB) [5].

In [2012], the anti-aliasing filter was designed at (2GHz – 4GHz) S-Band with a center frequency of (2.491GHz). The lambed component could not be used to achieve the

minimum aliasing interface at the desired enter frequency due to its distributed effects at this band. Alternatively, the optimization process was used [6].

In [2012], the low-pass filter was designed, simulated, and manufactured using a microstrip line in different software with a cut-off frequency at (1.8GHz) and attenuation of (-26dB) at stopband (4.6GHz). The features of the S-parameter of the low-pass filter were also studied and compared [7]. In [2013], a bandpass filter of (4.6GHz - 4.8GHz) bandwidth was designed using the ADS software tool and cascading a low pass filter for (4.8GHz) and a high pass filter for (4.6GHz) [8]. In [2014], the structure and design of a microstrip lowpass filter were analyzed through circuit simulation and layout simulation using Richard's transformation and Kuroda rule description. The filter design and simulation were carried out based on the ADS 2011 software platform [9].

In [2014], a stepped impedance filter was designed and optimized at a center frequency of 5 GHz to operate between 4 GHz and 6 GHz frequencies. The designed microstrip low pass filter was used to attenuate microwave frequency signals beyond the cut-off frequency of 5GHz and stopband attenuation of (32dB) [10]. In [2014], a low pass filter was proposed using the maximally flat Butterworth Technique, and the filter's seventh order was realized on a microstrip transmission line using MatLab and (AWR) software [3]. In [2015], the microstrip transmission line topology was used to design and implement a J-band symmetric coupled line pass band Butterworth filter.

The structure of the designed filter was developed using the ADS. The physical features of the designed filter's resonators were optimized to have the desired response. The Network Analyzer was used to measure the insertion loss of the optimized filter [11].

In [2016], a Butterworth filter up to 8th and 9th order was designed using the combination of 2nd and 3rd order [12]. In [2017], a dual-band passband filter was designed for the GSM application. Two frequency bands were used to pass the GSM1800 and GSM 900 signals. The first frequency band started from 1812.5 MHz to – 1887.5 MHz with a bandwidth of 75MHz and a center frequency of 1850 MHz. The second frequency band ranged from 962.5 MHz to 937.5 MHz with a 25MHz bandwidth and a center frequency of

950 MHz. The designed dual bandpass filter began with a center frequency of 950 MHz - 1850 MHz, respectively. The return loss of the combining filter was S11<-10dB), and the insertion loss was S21>-3dB [13].

In [2018], a complete procedure was adopted to develop, design, and simulate a microstrip bandpass filter at a center frequency of 5.25 GHz with lower and upper cut-off frequencies as 5 GHz and 5.5 GHz, respectively. In this work, the design of the low pass filter prototype was explained. The impedance and frequency scaling was then performed to achieve a bandpass filter. The bandpass filter was further designed using the lumped components (L & C), ideal microstrip lines, and practical microstrip lines. Finally, the microstrip layout version was also presented [14]. In [2019], a 5G band pass filter was designed and simulated to support a broadband application in telecommunications at a center frequency of 28GHz using ADS 2011. The designed filter was compared with an equivalent lumped circuit. The insertion loss was -0.12dB and the return loss was -10dB [15].

In [2019], the ADS software was used to design a microstrip low pass filter with a cut-off frequency of 2.4GHz and with more than 60dB attenuation at 4GHz. The band stop filter was designed with a reject characteristic at 2.4GHz using a step impedance resonator (SIR) and couple line structure techniques. At the notch, the attenuation of a 2.4GHz frequency was more than 117dB in (SIR). This filter was easy to implement and more compact compared with its coupled line structure equivalent. The designed filter can be used in wireless communication systems [16].

At [2019], a Butterworth 5th order bandpass filter was designed based on a quarter-wave resonator in ISM (2.4GHz -2.48GHz) band with a fractional bandwidth of 50% for a center 2.1GHz frequency. The insertion loss was 21dB at a cut-off frequency of 2.1GHz and a passband of 1.8GHz – 2.7GHz used for GSM and Wi-Fi applications [17].

3. THEORITICAL BASIS OF PROPOSED FILTERS

Filters, in general, can be classified into two categories; active and passive. This classification is based on the essential components used in the design [2]. Active filters are constructed from resistors, capacitors, and op-amps — no inductors are needed [18]. In contrast, passive filter circuits containing passive element capacitors, inductors,

and resistors are passive with high sensitivity when there are low losses. The response is highly resonant where the passband gain cannot supply greater than one and suffers from the loading effect [2]. The insertion loss (S_{21}) and return loss (S_{11}) are used to determine the characteristic of the filter [19].

3.1 Butterworth Filter

Butterworth filters are maximally flat in the passband, but their out-of-band attenuation slopes are unsuitable [13]. These filters are designed to process signals with flat frequency response in the passband (no ripple) and zero roll-off in the stopband [12]. A steep attenuation transmission from passband to stopband requires Butterworth filters to have more components and provide monotonic attenuation for the low pass filters, as shown in Fig 1. [18].
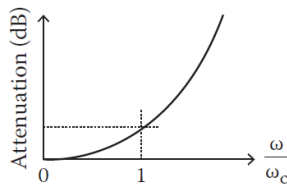
Fig1. Butterworth Filter Response

3.2 Elliptic Filter

Elliptic filters are particular types of analog and digital filters characterized by passband ripples of equal amplitude. Their passband is associated with a maximal nonlinearity regarding their phase response. Elliptic filters give the smallest filter order compared to the other filter types for the same values of the filter design parameters [20]. Elliptic filters have the sharpest out-of-band attenuation, but they have undesired ripples in and out of the passband [3]. Elliptic filters have a steeper transition from passband to stopband as shown in Fig 2. [18].
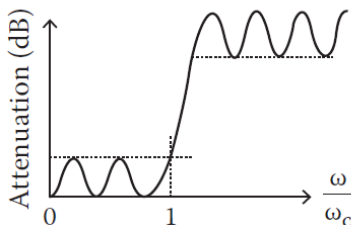

Fig 2. Elliptic Filter Response

4.   OPTIMIZATION PROCESS

The proposed Butterworth bandpass filter comprises 3rd order high pass and 3rd order low pass filter, which introduces the bandpass filter of 6th order as shown in Fig 3. This filter is designed using ADS simulation; hence the specified GOALs are evaluated on the cockpit OPTIM controller[6]. The filter offers the desired performance with frequency ranges illustrated in Table (1)

Table (1) Specifications of the designed filters

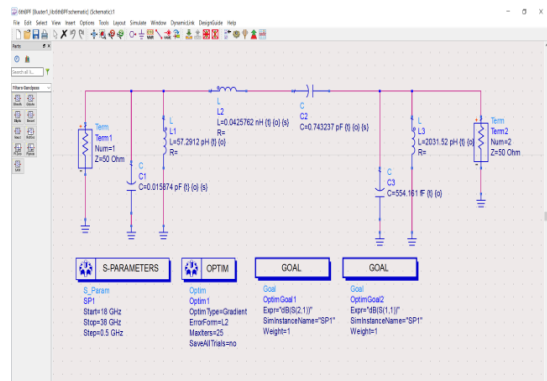| Parameter	Value
F stop 1	18GHz
F pass 1	25GHz
F pass 2	32GHz
F stop 2	32 GHz
Stop Band Attenuation	-60dB
Pass Band Attenuation	-1dB

Fig 3. Circuit Diagram of Butterworth BPF (HPLP) 6th order

The simulation of this circuit with optimum filter component values (L, C) necessitates selecting the circuit components as simulation variables and the optimization option, as shown in Fig 4.
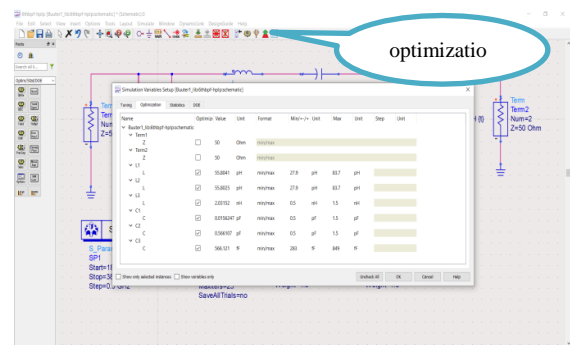

Fig 4. Select (L,C) Component and Optimization Option

Fig 5. shows the optimization window with the optimization algorithm (Gradient) and maximum iteration (25). After the optimization process is finished, the (L, C) component of the filter updates with new values, and the frequency

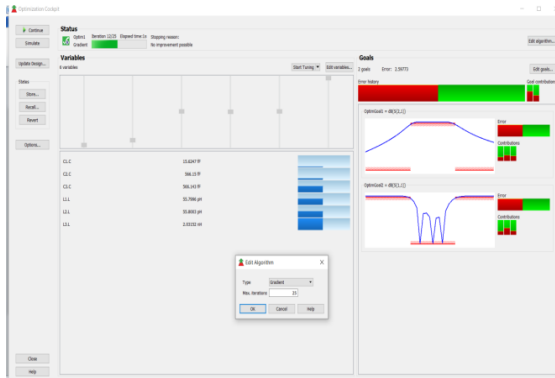response of insertion loss (S$_{21}$) and return loss (S$_{11}$) result, as shown in Fig 6.
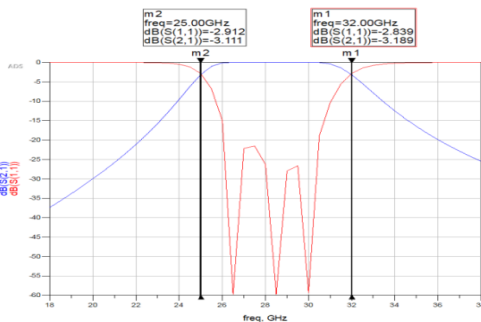

Fig 5. Optimization Window

Fig 5. Frequency Response (S$_{11}$) (S$_{21}$) Butterworth BPF (HPLP) 6th order

The same steps follow to get the (L, C) component, optimization error, and frequency response of Butterworth BPF 3rd as illustrated in Fig 7. and Fig 8. showing the circuit diagram and the frequency response of insertion loss (S$_{21}$) and return loss (S$_{11}$) of order respectively.
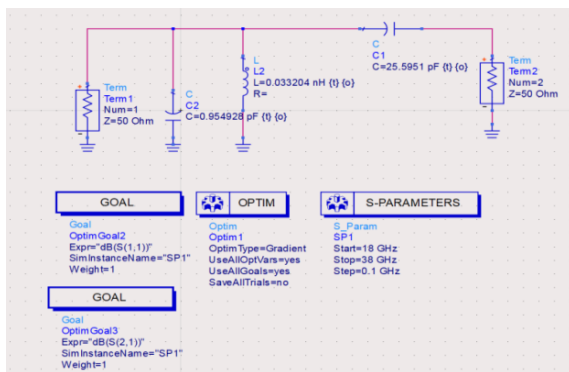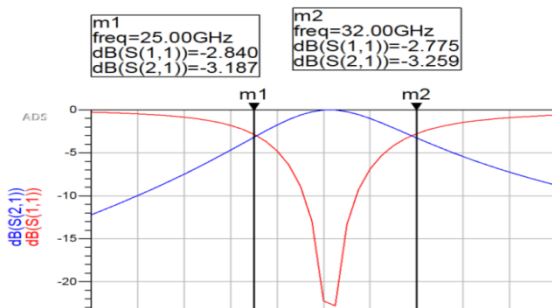

Fig 7. Circuit Diagram of Butterworth BPF 3rd Order

Fig 8. Frequency Response (S$_{11}$) (S$_{21}$) Butterworth BPF 3rd Order

Fig 9. and Fig 10. show the circuit diagram and frequency response of insertion loss (S$_{21}$) and return loss (S$_{11}$) of Butterworth BPF 6th order.
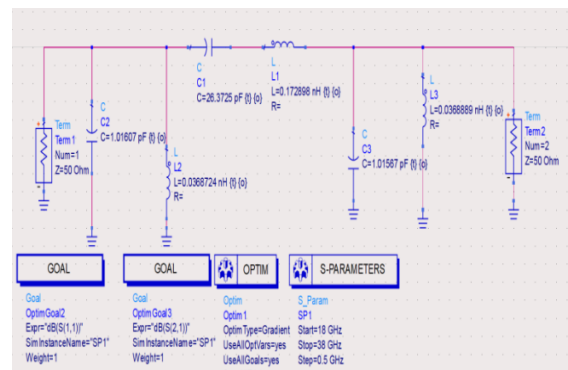

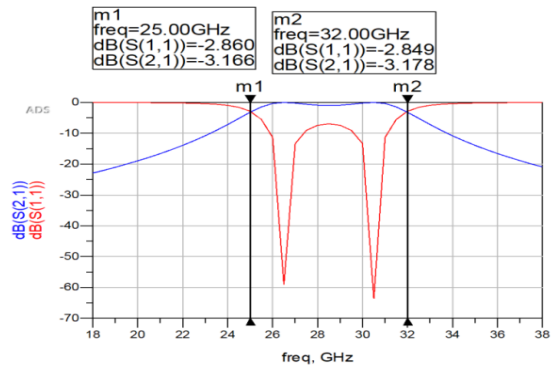Fig 9. Circuit Diagram of Butterworth BPF 6th Order

Fig 10. Frequency Response (S$_{11}$) (S$_{21}$) Butterworth BPF 6th Order

The result can be rearranged from the frequency response of all filters, as shown in Table (2). The optimization error, ripple, and transition region are the best for the bandpass filter (HPLP) 6th order. The Butterworth bandpass 6th order characteristic is the second, and bandpass 3rd order with constant bandwidth (7GHz) comes last.

Table 2. Butterworth Filter Result

Butterworth Band pass	(HP-LP) 6th	3rd Order	6th order
Optimization error	2.5	4.32867	3.05249
Bandwidth	7GHz	7GHz	7GHz
Ripple	Flat	No flat	Ripple

Fig 11. shows the Elliptic filter design with the same frequency ranges and goals of the Butterworth filter with a variance in circuit diagrams. Fig 12. Explain frequency response of insertion loss (S_{21}) and return loss (S_{11}) of Elliptic filter of 6th order consisting of 3rd order high pass and 3rd order low pass filter.
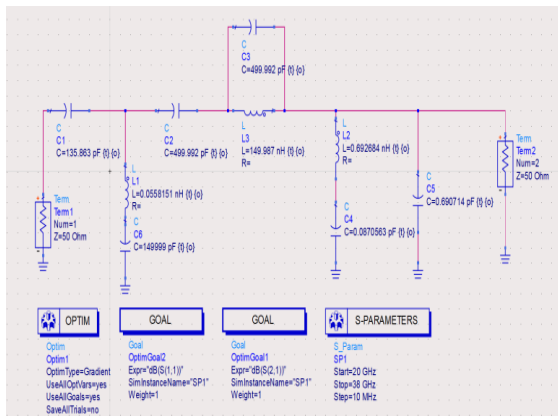

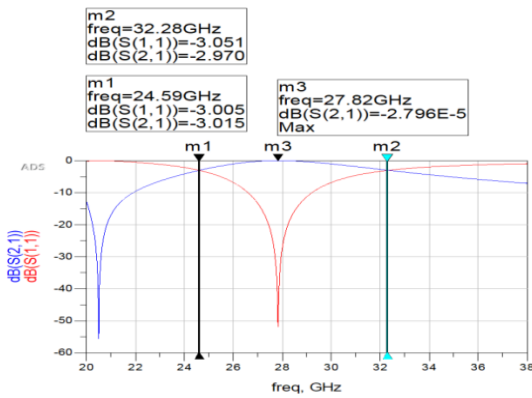Fig 11. Circuit Diagram of Elliptic BPF (HPLP)
6th order

Fig 12. Frequency Response (S_{11}) (S_{21}) Elliptic
BPF (HPLP) 6th order

Fig 13 and Fig 14 describe the circuit diagram and frequency response of insertion loss (S_{21}) and return loss (S_{11}) Elliptic bandpass filter of   3rd order.
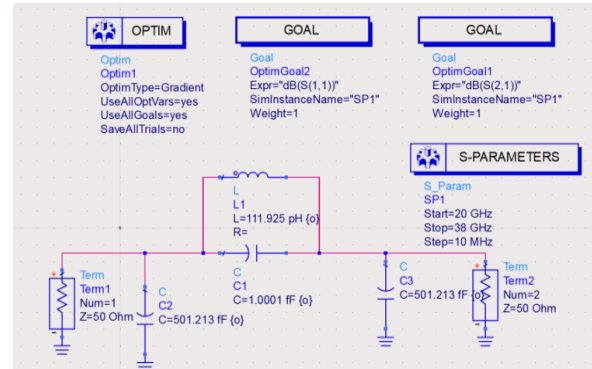

Fig 13. Circuit Diagram of Elliptic BPF 3rd
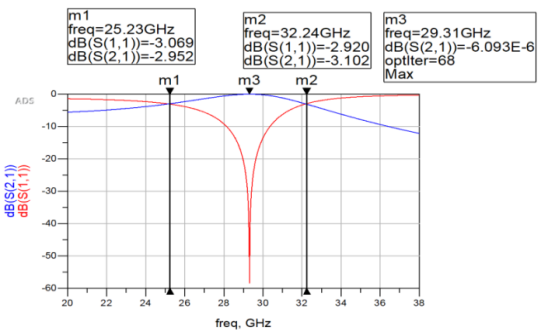Order

Fig 14. Frequency Response (S_{11}) (S_{21}) of Elliptic
BPF 3rd Order

Lastly, Fig 15 and Fig 16 show the circuit diagram and frequency response of insertion loss (S_{21}) and return loss (S_{11})   Elliptic bandpass filter of 6th order.
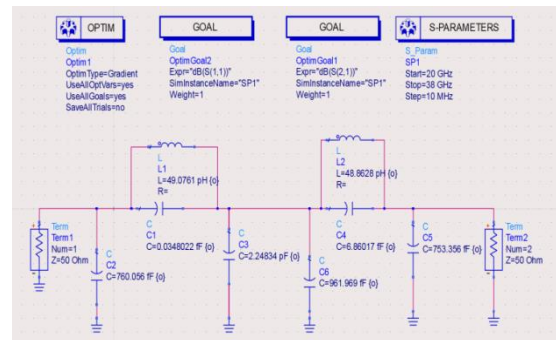

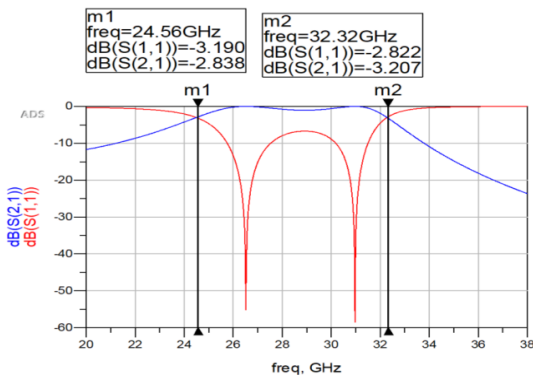Fig 15. Circuit Diagram of Elliptic BPF 6th
Order

Fig 16 Frequency Response (S_{11}) (S_{21}) of Elliptic BPF 6th Order

Table (3) shows the results of the designed Elliptic filter and indicates that the optimization error of the Elliptic bandpass 6th order filter is the best with a greater bandwidth (7.76 GHz). There is a ripple in the passband region. The second filter in terms of quality characteristics is the Elliptic bandpass filter (HPLP) 6th order. The Elliptic bandpass 3rd order comes last in this category.

Table (3) Elliptic Filter RESULT

Elliptic Bandpass	(HP-LP) 6th	3rd Order	6th order
Optimization error	2.677	3.39375	1.88557
Bandwidth	7.69	7.01	7.76
Ripple	Not flat	No flat	Ripple

5. MICROSTRIP TRANSMISSION LINE

Based on the simulation results and for the Butterworth bandpass filter in Table (2), the optimization error was 2.5 minimum for the HP-LP 6th order with a flat passband region and minimum value of insertion loss (S_{21}) in the low pass and high pass transition region. Thus, to obtain practical HP-LP 6th order filters, the lumped component filters must be converted into distribution element realizations using ADS simulation software tool [10] and a microstrip transmission line according to the following steps:

Step 1: Open a new Schismatic and add filter parameters (S-parameters – optimization – Goal1 for S21 – Goal 2 for S11) as shown in Fig 17.
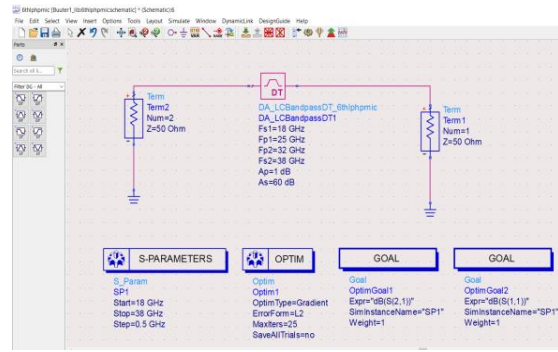

Fig 17. Microstrip Transmission Line Desing Step1

Step 2: Add filter (LC- Band Pass) block and enter the suggested specification (fs1 – fp1 – fp2 – fs2 – Ap – As), as shown in Fig 18.
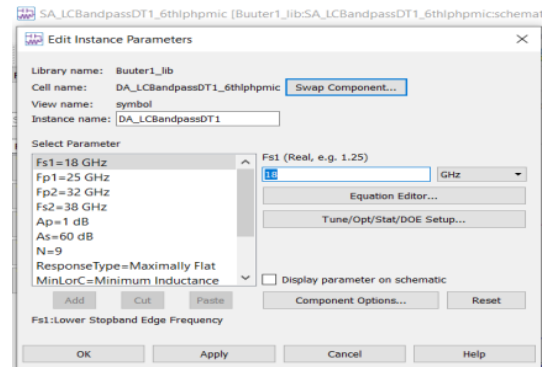

Fig 18. Microstrip Transmission Line Desing Step2

Step 3: Select the Design Guide from the menu bar - filter – filter control window, as shown in Fig 19.
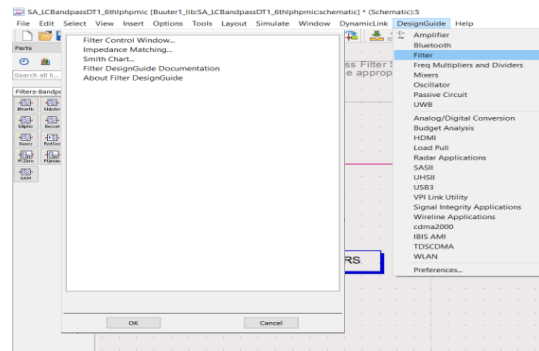

Fig 19. Microstrip Transmission Line Desing Step3

Step 4: Select filter assistant design from the filter control window, as shown in Fig 20.
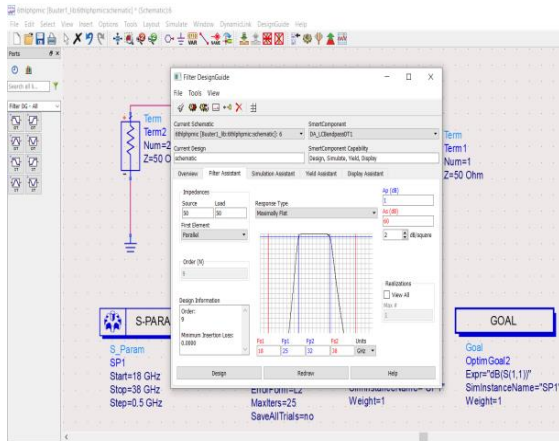
Fig 20. Microstrip Transmission Line Desing Step4

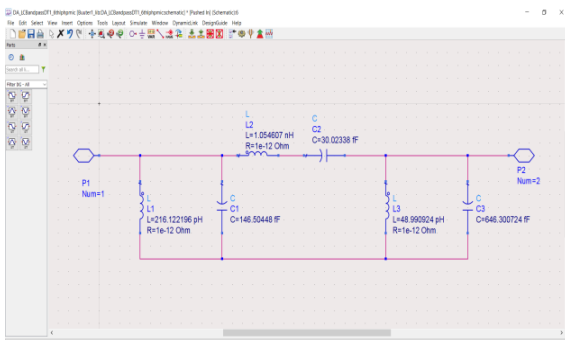The filter is redesigned in this step, as sown in Fig 21.

Fig 21. Butterworth BPF (HPLP) 6th Order Circuit Design Using Design Guide

Step 5: Select the simulation assistant and enter the simulation frequencies (f start – f stop – steps) from the filter control window and then select the transformation assistant, as shown in Fig 22. This step specifies whether the circuit is open or short.
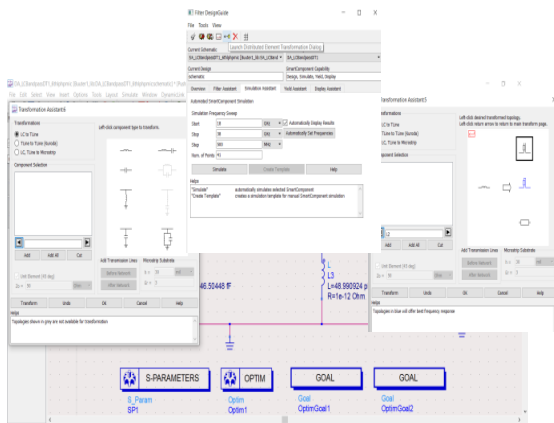
Fig 22. Microstrip Transmission Line Desing

Step 6: Select the parameter and type of transformation (open circuit – short circuit). Then, select add and transform. The open-circuit is firstly designed, as shown in Fig 23.

Fig 23. Microstrip Transmission Line with Open Circuit of Butterworth BPF (HPLP) 6th order Step6

The frequency response of the open circuit microstrip transmission line is shown in Fig 24.

Fig 24. Frequency Response Microstrip Transmission Line With Open Circuit of Butterworth BPF (HPLP) 6th order

$$f_{c1} = 24.77 \ GHz$$

$$f_{c2} = 32 \ GHz$$

$$BW = 7.23 \ GHz$$

Secondly, the (HP-LP 6th order) is designed using a short circuit microstrip transmission line, as shown in Fig 25.

Fig 25. Microstrip Transmission Line with Short Circuit of Butterworth BPF (HPLP) 6th order

The frequency response of the short circuit microstrip transmission line is shown in Fig 26.

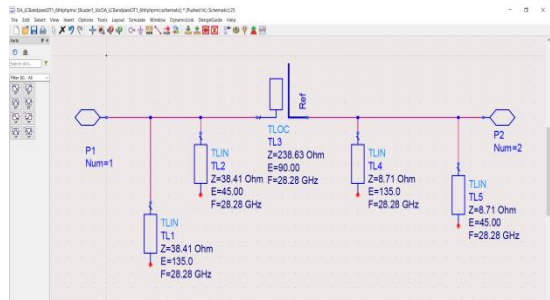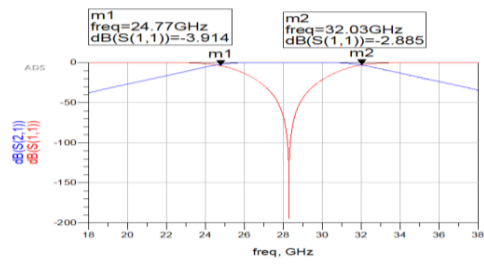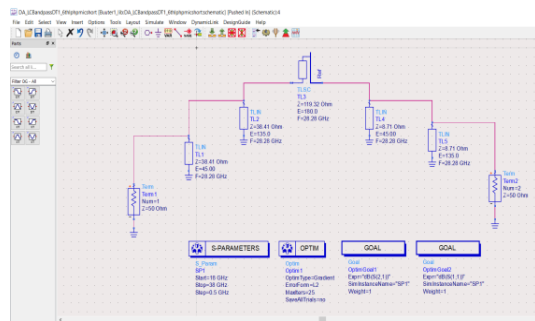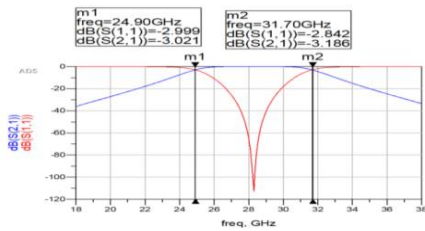Fig 26. Frequency Response Microstrip Transmission Line with Short Circuit of Butterworth BPF (HPLP) 6th order

From the frequency response of the short circuit microstrip transmission line of the Butterworth BPF (HPLP), 6th order, the following frequencies and bandwidth can be recorded:

$$f_{c1} = 24.9\ GHz$$

$$f_{c2} = 31.7\ GHz$$

$$BW = 5.8\ GHz$$

Table (3) shows the simulation result of the Elliptic filter. It can be noted that this filter has a tiny ripple for all types of the proposed filters. For this reason, the bandwidth is investigated, and it is pointed out that the 3rd order has less bandwidth than the others. Fig. 27 shows the circuit of the schematic form used to design the filter Guide.
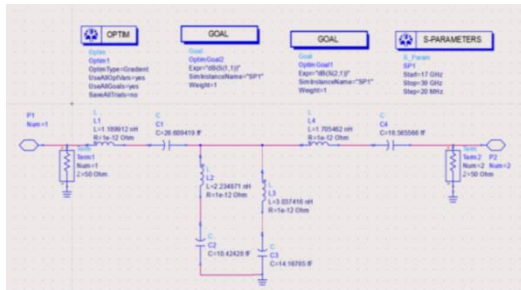
Fig 27. circuit diagram of Elliptic BPF 3rd order

This filter is designed using open circuit microstrip transmission, as shown in Fig. 28.
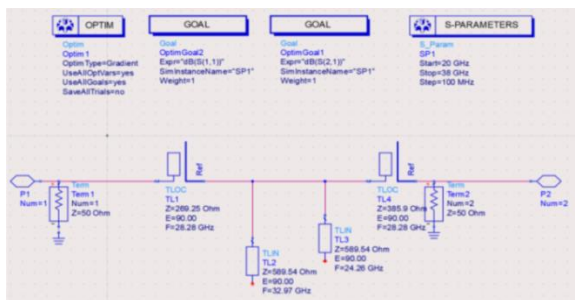
Fig 28. Microstrip Transmission Line with Open Circuit of Elliptic BPF 3rd Order

The frequency response of insertion loss (S_{21}) and return loss (S_{11}) of Open Circuit Elliptic BPF 3rd order is shown in figure (29).
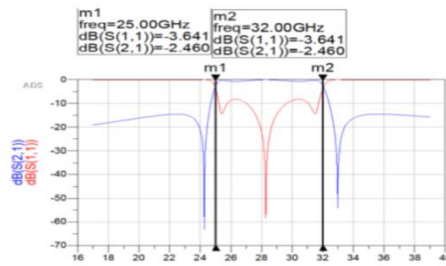
Fig 29. Frequency Response of Insertion Loss (S_{21}) and Return Loss (S_{11}) of Open Circuit Elliptic BPF 3rd order

The short circuit microstrip transmission line schismatic diagram is shown in Fig. 30.
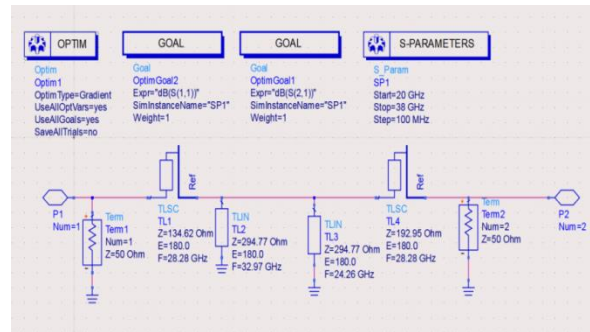
Fig 30. Microstrip Transmission Line with Short Circuit of Elliptic BPF 3rd order

The frequency response of the short circuit microstrip transmission line is shown in Fig. 31.
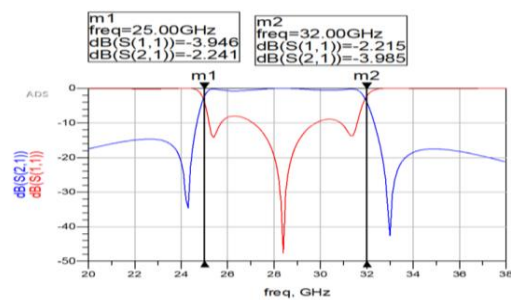
Fig 31. Frequency Response of Insertion Loss (S_{21}) and Return Loss (S_{11}) of Short Circuit Elliptic BPF 3rd Order

The frequency responses of the elliptic filters for open and short circuit design are shown in Fig. 29 and Fig. 31.

$$f_{c1} = 25\ GHz$$

$$f_{c2} = 32\ GHz$$

$$BW = 7\ GHz$$

6.   **RESULTS AND COMPARISION :**

After optimizing all the proposed filters and comparing them in terms of optimization error and bandwidth and based on tables (2) and (3), it can be noted that the Butterworth bandpass 6th order (HP-LP) has a good optimization error with constant bandwidth. However, the Elliptic bandpass 3rd order has less bandwidth. This filter is selected to be redesigned using a design filter guide then converted into a transmission line model to transform it into a microstrip using the Line Calc option. Table (4) shows the filter component values of Butterworth Bandpass 6th order (HP-LP) for the simulation and design filter guide.

Table (4) Butterworth 6th order (HP-LP) filter (L-C) component

Component	Simulation Value	Design Filter Guide Value
C_1	0.015874 pF	146.50448 fF
L_1	57.2912 pH	216.12296 pH
C_2	0.743227 pF	30.02338 fF
L_2	0.0425762 nH	1.054607 nH
C_3	544.161 f F	646.300724 fF
L_3	2031.52 pH	48.990924 pH

Table (5) shows the filter component values of the Elliptic bandpass 3rd order for the simulation and design filter guide.

Table (5) Elliptic 3rd order filter (L-C) component

| Component	Simulation Value	Design Filter Guide Value
C_1	1.0001 pF	26.609419 fF
L_1	111.925 pH	1.89912 nH
C_2	501.213 fF	10.42428 fF
L_2		2.234871 nH
C_3	501.1213 fF	14.16765 fF
L_3		3.037416 pH
C_4		18.565566 fF
L_4		1.705462 NH

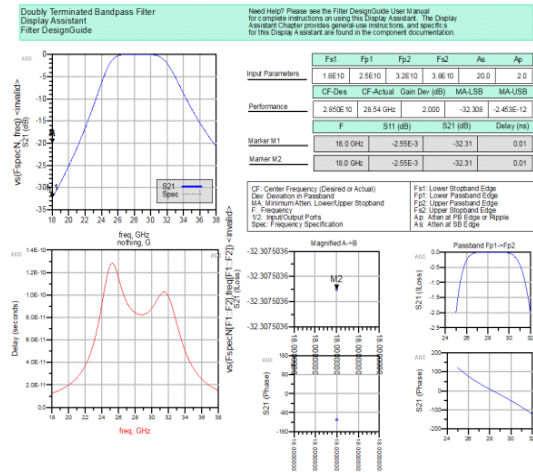Fig. 32 shows the filter design guide and its pertinent characteristics.

Fig 32. Filter Design Guide and Characteristic of Butterworth BPF (HPLP) 6th Order (Open Circuit)

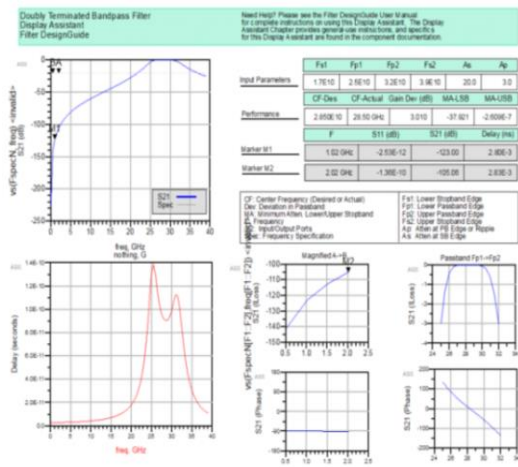Fig. 33 presents the filter design guide and its characteristics.

Fig (33) Filter Design Guide and Characteristic of Butterworth BPF (HPLP) 6th Order (Short Circuit)

Table (6) Filters Design Guide Characteristic Butterworth 6th Order(HP-LP)

		Open Circuit	Short Circuit
Input parameter	f_{s1} Lower Stop Band edge (LSB)	18 GHz	17 GHz
	f_{p1} lower Pass Band edge (LPB)	25 GHz	25 GHz
	f_{p2} Upper Pass Band edge (UPB)	32 GHz	32 GHz
	f_{s2} Upper Stop Band edge (USB)	38 GHz	39 GHz
	A_s attenuation at the stopband edge	20	60
	A_p attenuation at pass band edge (Ripple)	2	1
Performance	Desired f_{center}	28.5 GHz	28.5 GHz
	Actual f_{center}	28.54 GHz	28.54 GHz
	Maximum Attenuation lower stop band	-32.308 dB	-98.034 dB
	Maximum Attenuation Upper stopband	$-2453 * 10^{-12}$	$-1.124 * 10^{-11}$
	BW	7.23GHz	5.8GHz

Fig.34 shows the filter design guide and the Elliptic BPF 3rd Order (Open Circuit) characteristics.
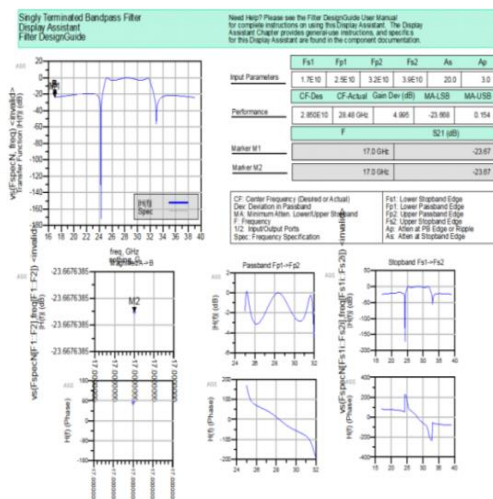
Fig 34. Filter Design Guide and Characteristic of Elliptic BPF 3rd Order (Open Circuit)

Fig 35 shows the filter design guide and the Elliptic BPF 3rd Order (Short Circuit) characteristics
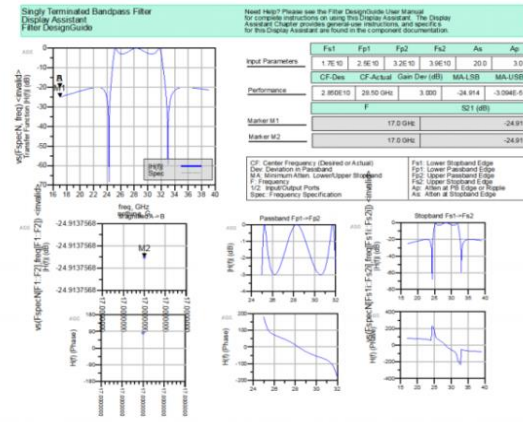
Fig35. Filter Design Guide and Characteristic of Elliptic BPF 3rd Order (Short Circuit)

Table (7) Filter Design Guide Characteristics Elliptic 3rd Order

		Open Circuit	Short Circuit
Input parameter	f_{s1} Lower Stop Band edge (LSB)	17 GHz	17 GHz
	f_{p1} lower Pass Band edge (LPB)	25 GHz	25 GHz
	f_{p2} Upper Pass Band edge (UPB)	32 GHz	32 GHz
	f_{s2} Upper Stop Band edge (USB)	39 GHz	39 GHz
	A_s attenuation at the stopband edge	20	20
	A_p attenuation at pass band edge (Ripple)	3	3
Performance	Desired f_{center}	28.5 GHz	28.5 GHz
	Actual f_{center}	28.48 GHz	28.5 GHz
	Maximum Attenuation lower stop band	-32.668 dB	-24.914 dB
	Maximum Attenuation Upper stopband	0.154 dB	$-3.095 * 10^{-5}$
	BW	7GHz	7GHz

To match the MLIN (Microstrip Line) components with the 50-ohm circuit, they are added to both sides of the filter, whose characteristic impedance is 50 ohms. The length and width of the transmission line

sections can be found using the Line Calc tool [10]. Finally, the transmission line model is converted into a microstrip with each filters component (W, L). Fig. 36 shows how to start line calculation.

Fig 36.   Startline Calculation

Fig. 37 shows the microstrip transmission line calculation. This is done by entering the Z, E, and F of each transmission line and synthesizing it to calculate (W, L) of each one

Fig 37. line calculation window

Table (8) shows the microstrip (W, L) values results from the line calculation process with (F=28.28GHz) constant for all calculations for the Butterworth 6th Order(HP-LP) filter (Open Circuit).

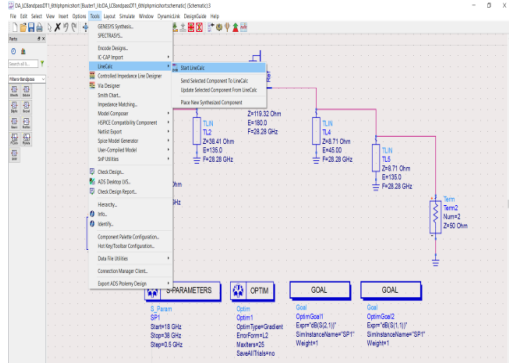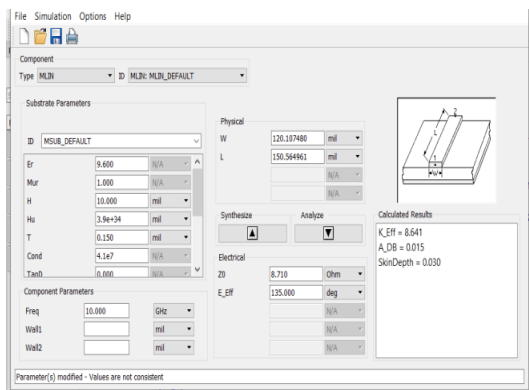Table (8) Microstrip (W, L) Values Butterworth 6th Order (HP-LP) Filter (Open Circuit)

Transmission Line	Microstrip
TL1 (C1) Z=38.41Ω E=45º	W=16.04476 mm L=56.491732mm
TL2 (L1) Z=38.41Ω E=135º	W=16.044764mm L=169.474803mm
TL3 (L2,C2) Z=119.32Ω E=180º	W=0.530118mm L=253.179921mm
TL4 (C3) Z=8.71Ω E=135º	W=120.107480mm L=150.564961mm
TL5 (L3) Z=8.71Ω E=45º	W=120.107480mm L=50.188189mm

Table (9) shows the microstrip (W, L) values result from the line calculation process with

(F=28.28GHz) constant for all the calculations of Butterworth 6th order (HP-LP) filter (Short Circuit).

Table (9) Microstrip (W, L) Values Butterworth 6th Order (HP-LP) Filter (Short Circuit)

Transmission Line	Microstrip
TL1 (C1) Z=38.41Ω E=45º	W=16.04476 mm L=56.491732mm
TL2 (L1) Z=38.41Ω E=135º	W=16.044764mm L=169.474803mm
TL3 (L2,C2) Z=238.63Ω E=90º	W=0.000575mm L=133.087402mm
TL4 (C3) Z=8.71Ω E=135º	W=120.107480mm L=150.564961mm
TL5 (L3) Z=8.71Ω E=45º	W=120.107480mm L=50.188189mm

Table (10) shows the microstrip (W, L) values results from the line calculation process for the Elliptic BPF 3rd order (short circuit).

Table (10) Microstrip (W, L) Values Elliptic BPF 3rd order (short circuit)

Transmission Line	Microstrip
TL1 (L1,C1) F=28.28GHz Z=134.62Ω E=180º	W=0.248898mm L=257.463780mm
TL2 (L2,C2) F=32.97GHz Z=294.77Ω E=180º	W=0.037414mm L=1265.426772mm
TL3 (L3,C3) F=24.26GHz Z=294.77Ω E=180º	W=0.037414mm L=1265.426772mm
TL4 (L4,C4) F=28.28GHz Z=385.9Ω E=180º	W=0.019182mm L=266.792126mm

Table (11) shows the microstrip (W, L) values result from line calculations for Elliptic BPF 3rd Order (Open Circuit)

Table (11) microstrip (W, L) values Elliptic BPF 3rd Order (Open Circuit)

Transmission Line	Microstrip
TL1 (L1,C1) F=28.28GHz Z=269.25Ω E=90º	W=0.001846mm L=130.767717mm
TL2 (L2,C2) F=32.97GHz Z=589.54Ω E=90º	W=0.001732mm L=130.755118mm
TL3 (L3,C3) F=24.26GHz Z=589.54Ω E=90º	W=0.001732mm L=130.755118mm
TL4 (L4,C4) F=28.28GHz Z=385.9Ω E=90º	W=0.001718mm L=130.754724mm

Table (12) compares the present results with those of the previous works regarding the type, cut-off frequencies, attenuation in the stopband, and bandwidth BW with the suggested filters.

Table (12) Comparison with Previous Works

ref	type	f_{p1}	f_{p2}	Stopband Atten. (S_{21})	BW
[3]	LPF	2.4 GHz		32.26 dB	
[4]	BPF	2.16 GHz	2.64 GHz	21.9 dB	240 MHz
[5]	LPF	2.37 GHz		13.2 dB	
[6]	Anti-alising	2.491 GHz		66 dB	
[7]	LPF	1.8 GHz		26 dB	
[8]	BPF	4.6 GHz	4.8 GHz	60 dB	200 MHz
[9]	LPF	4 GHz		26.034 dB	
[10]	LPF	5 GHz		32 dB	
[11]	BPF	14.4 GHz	18.4 GHz	18.75 dB	2 GHz
[12]	BPF	2.008K Hz	22.88 95KHz	43 dB	20.88 7 KHz
[13]	BPF	937.5M Hz	962.5 MHz	-34.9399 dB	25 KHz
		1812.5 MHz	1887. 5MHz		75 MHz
[14]	BPF	5 GHz	5.5 GHz	60dB-80dB	500 MHz
[15]	BPF	24.5 GHz	31.5 GHz	40 dB	7 GHz
Butter -open		24.77 GHz	32.03 GHz	32.308 dB	7.23 GHz
Butter - short		24.9 GHz	31.7 GHz	98.034 dB	5.8 GHz
Elliptic-open		25 GHz	32 GHz	32.668 dB	7 GHz
Elliptic- short		25 GHz	32 GHz	24.914 dB	7 GHz

7. CONCLUSION

Based on the results of the designed filters using the Design Filter Guide, the bandwidth of the open circuit is 7.23 GHz and 5.8GHz for the short circuit of the Butterworth BPF (HPLP) 6th order with stopband attenuation of 32.308dB and 98.034dB.

The (W, L) results obtained from converting each filter to microstrip transmission line model show that W= 0.530118 mm , L=253.179921mm and W=0.000575 mm and L=133.087402mm for the TL3 of the open and short circuit forms of the Butterworth BPF (HPLP) 6th with the other components being fixed.

This comparison gives a positive point for the Butterworth BPF (HPLP) 6th order short circuit. In the Elliptic BPF 3rd order, the bandwidth is constant (7 GHz) for the open and short circuit form, and the values of (W, L) in the open circuit

are less than the short circuit. Each proposed filter specification has its application in the (5G) communication system.

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تصميم والاختيار الامثل لمرشحات Butterworth و Elliptic ذات حزمة امرار وسطية في تطبيقات G5

دينا رياض ابراهيم
dina.ibrahim@uoninevah.edu.iq

قسم هندسة الاتصالات ـ كلية هندسة الالكترونيات ـ جامعة نينوى ـالموصل ـ العراق

الملخص

المرشحات عبارة عن شبكات ثنائية المنافذ. وللمرشحات القدرة على تمرير أو تخفيف الترددات ضمن نطاقات محددة وتغيير استجابة التردد لأي نظام. تم في الدراسة البحثية الحالية استخدام الأهداف ووحدة التحكم في التحسين المضمنة مع (ADS2019) لتصميم مرشحات تمرير النطاق الترددي Butterworth و Elliptic بنطاقات تردد (18 جيجا هرتز - 38 جيجا هرتز) ، وعرض نطاق (7 جيجا هرتز) واضعاف نطاق التوقف لـ (60dB- = S21) وكذلك اضعاف نطاق المرور لـ (1dB- = S21). جرى في هذه الدراسة محاكاة ثلاثة أنواع من كل مرشح) الترتيب السادس من فئة - Hp-Lp الترتيب الثالث ـ الترتيب السادس (واختيار أفضل القيم. كما تم إعادة تصميم المرشحات المحددة باستخدام ديزاين فلتر كايد (Design Filter Guide) والمحاكاة أثناء هذه المرحلة تنتج قيمًا مختلفة لـ C) ، (L.ليتم بعد ذلك تحويل الدائرة الناتجة باستخدام خطوط نقل لفتح دوائر قصيرة وقصيرة. تتناول هذه الدراسة الاختلافات بين كل مرشح في الاضعاف المركزي BW-f عند نطاق التوقف ليتم في المرحلة الأخيرة تحويل دائرة كل مرشح باستخدام خط نقل مايكروستيب (microstrip) للحصول على (WL) لكل مكون من كل مرشح. وتقارن الدراسة في النهاية النتائج التي توصلت لها هذه الدراسة مع نتائج الدراسات السابقة والمشاريع البحثية في هذا المجال.

الكلمات الداله :

مرشح سلبي ، خطأ في التحسين ، تموج ، خسارة الإدراج ، خسارة العودة