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A Novel Design of Microstrip Diplexer Using Meander-Line Resonators

Abdessamed Chinig*

Microwave Group, Faculty of Sciences and Techniques, Hassan 1st University, Settat, Morocco

Abstract

In this paper, a compact microstrip diplexer is proposed for Wimax and DCS applications at 2.5 GHz and 1710-1880 MHz respectively. The microstrip diplexer consists of two band-pass filters operating at different frequency bands and a coupled-junction. Each filter is formed by a meander-line resonator and two Input/Output feed lines. The frequency response of each filter can be easily controlled by modifying the dimensions of the meander-line resonators. ADS and CST-MWS solvers have been used to characterize the response of the diplexer. Good electrical performances are obtained after an optimization of the proposed circuit. The microstrip diplexer presents an insertion loss of 2.3 dB a return loss of 30 dB and an isolation between the two filters better than 22 dB for an overall size of 25×32 mm^2.

Keywords

Band-Pass Filter, Diplexer, Meander-Line Resonators, Microstrip, Isolation

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1. Introduction

Band-pass filters and Diplexer are key components in many modern wireless communication systems. These kinds of circuits are widely used in radio transmission, radar systems, satellite-communication systems, and broadband wireless communications. In the last decades, several attempts have been made in order to achieve RF filters and diplexers with compact size and good electrical performances in terms of insertion loss, selectivity, stopband, and isolation.

Today, the planar technology represents a good alternative to design band-pass filters and diplexers. In fact, this technology was widely studied and exploited. Many design methods, techniques and topologies have been proposed in literature to design filters and diplexers by using the planar technology such as: stepped impedance, parallel coupled, hairpin-line, interdigital, and combline filters. It should be noticed that even this technology suffers from many drawbacks like low quality factor and high loss, microstrip filters are very used to filter the unwanted signals.

It's known that the Wimax band at 2.5 GHz and the digital communication system (DCS) band at 1710-1880 MHz are extremely used in variety of wireless communication systems. For that, filters and diplexers operating at these frequency bands are much desired. This paper presents a novel design of band-pass filter and diplexer by using meander-line resonators. The main objective of this work is to introduce a new design method able to facilitate the control of the frequency and the electrical performances of the microstrip band-pass filters. Changing the dimensions of the meander-line resonator offers the possibility not only to ease the design process but also to reduce the circuit size. Two band-pass filters operating at different frequency bands were connected with a coupled-junction in order to achieve a microstrip diplexer. The proposed circuit shows an excellent frequency response and a compact size.

* Corresponding author
E-mail address: abdo.chinig@gmail.com

2. The Meander Line Resonators

Meander-line resonators are planar structures that can be easily manufactured. In fact, these resonators are very known for their remarkable performances and compact size thus they are widely used as delay lines and deflection systems [1, 3]. For that, they were very used in the design of antennas [4, 5], filters [6, 7], couplers [8], and phase shifters [9, 10].

The meander-line resonator presented in the figure 1.a can be modeled by a series L-C circuit as shown in the figure 1.b [11].

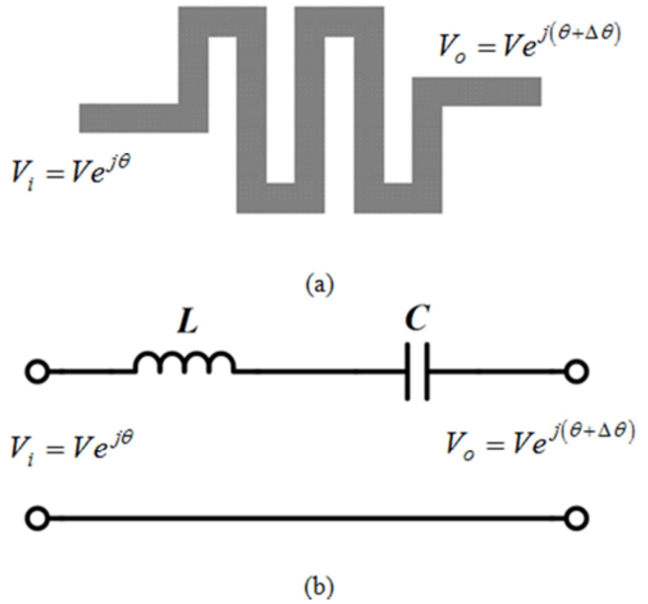

Figure 1. (a) The conventional structure of a meander line resonator (b) The equivalent circuit of the meander line resonator.

From the figure 1.b, the impedance of the series L-C can be expressed as follow: j(ωL-1/ωC). If we consider that, the load at the extremity of the meander-line resonator is a resistance of RLΩ, the phase delay in the output voltage is:

$$\Delta\theta = \tan^{-1}\frac{\omega L - \frac{1}{\omega C}}{R_L} \quad (1)$$

We know that the phase constant of the meander line resonator is:

$$\beta = \frac{2\pi}{\lambda_l} \quad (2)$$

Where λ_l is the wavelength of the resonator. From the previous equations, the synthetizing equation can be given by:

$$\Delta\theta = \beta l \quad (3)$$

Or

$$l = \frac{\Delta\theta}{\beta} = \frac{\lambda_l}{2\pi}\tan^{-1}\frac{\omega L - \frac{1}{\omega C}}{R_L} \quad (4)$$

So this resonator can be designed using the equation (3). It's know that the band pass filter may be a series connection of a capacitor C and an inductor L, as depicted in the figure 1.b. Therefore, the microstrip band-pass filter can be synthetized based on the equation (3).

3. Microstrip Band-Pass Filter Design

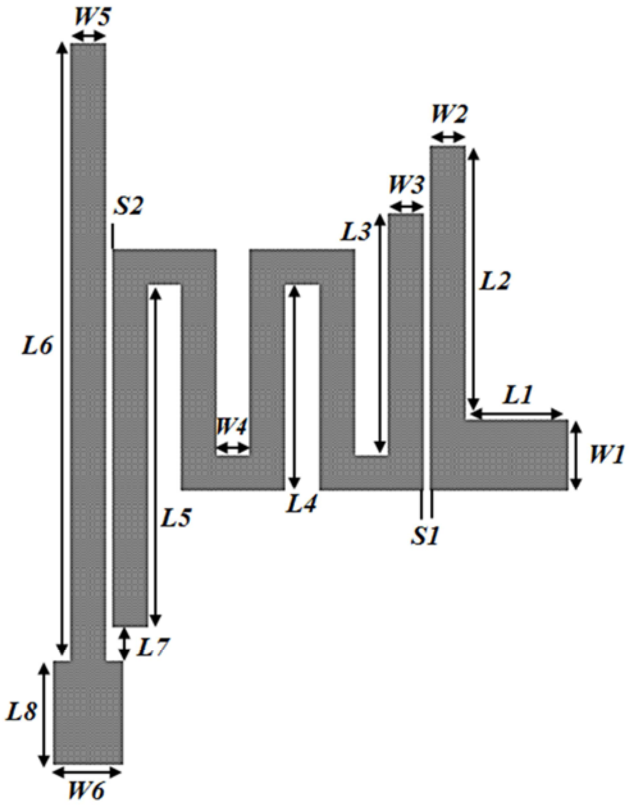

Figure 2. The layout of the proposed microstrip band-pass filter.

The structure of the proposed band-pass filter is shown in the figure 2. As can be seen the circuit consists of a meander-line resonator and two microstrip feed lines. Conceptually, this resonator can be obtained by folding a straight-line resonators into a meander-line resonator as can be seen from the figure 3. Each resonator is formed by a succession of N turns. Therefore, the resonant frequency of the band-pass filter is controlled by modifying the number of turns or the length of each turn.

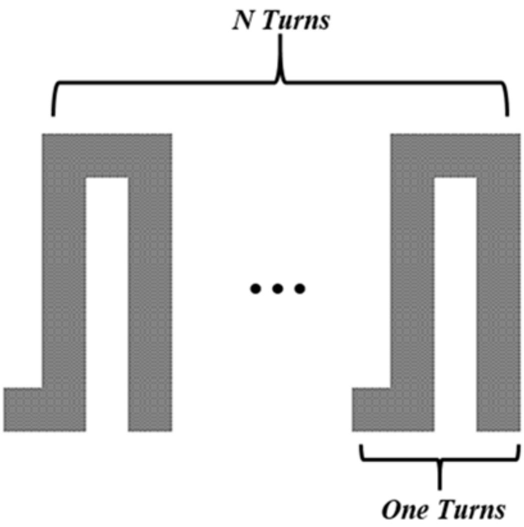

Figure 3. The layout of the meander-line sections.

With a good arrangement of the feed lines and the meander-line resonator, this resonator can provide a better miniaturization of the circuit and good electrical performances. This reduction size can be explained by the slow wave effect of the proposed filter. The figure 2 presents the structure of the designed band-pass filter.

The ADS solver was used to design and to simulate the proposed circuit. The microstrip diplexer was implemented on a FR4 substrate. This substrate has a relative dielectric constant ε_r of 4.4, a thickness of 1.6 mm, a loss tangent of 0.025, and a conductor thickness of 35 um.

The simulation results of the proposed band-pass filter are presented in figure 4. The proposed circuit presents good electrical performances with an insertion loss of 2.8 dB and a return loss of 19 dB for a center frequency of 2.5 GHz. Furthermore, this filter presents a transmission zero located at 4.9 GHz characterized by an attenuation of 34 dB. In fact, the presence of the transmission zeros beside the pass band enhance the selectivity of the filter which explains the attenuation of the first spurious frequency located at 4.7 GHz.

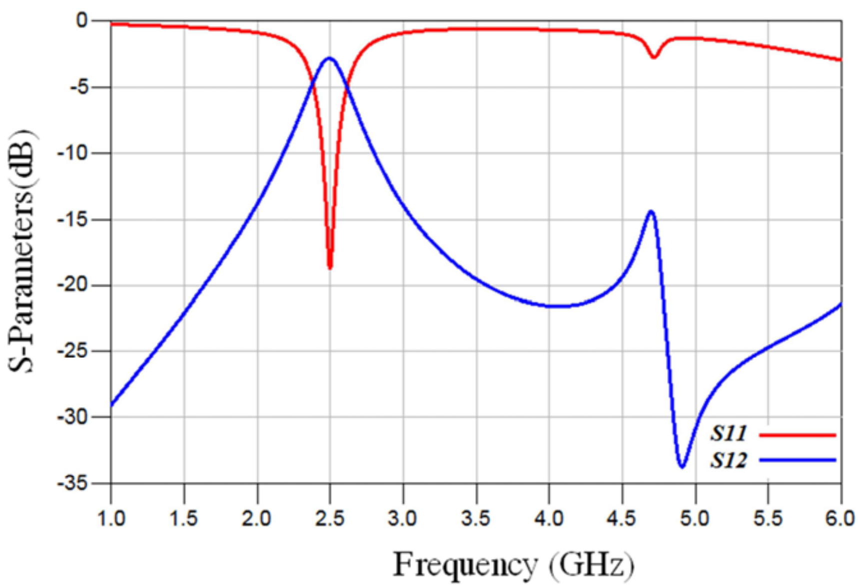

Figure 4. The simulation results of the proposed band-pass filter.

4. Microstrip Diplexer Design

This section will discuss the design approach used to design the proposed microstrip diplexer. It’s know that, the classical design approach needs the design of two band-pass filters operating at different frequency bands. For that, a second band-pass filter operating at GHz was achieved. It should be noticed that the modification of the center frequency and the bandwidth of the each filter can be obtained by changing the length of the proposed meander-line resonator.

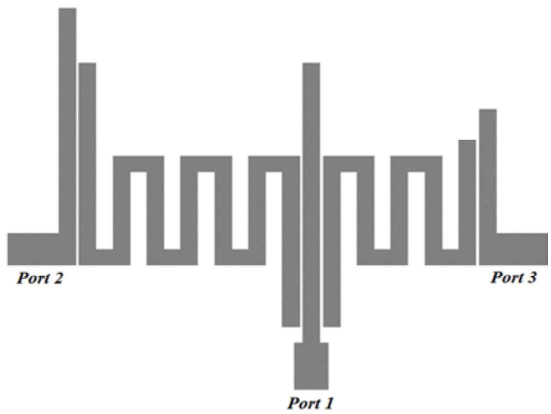

Figure 5. The structure of the microstrip diplexer using meander-line resonators.

In order to connect the two filters, the coupled-junction was used in this work. In fact, this type of junctions us very simple and guarantee a reduction size and good electrical performances. Generally, combining two band-pass filters generates a deterioration of the desired frequency response. Thereby, a careful optimization of each part of the circuit is needed. From the first section, we know that the length and the number of turns control the center frequency of the filter. Besides, the distance and the periphery between the meander-line resonators and the feed lines can also modify the simulation results.

ADS solver was used to design, to optimize and to simulate the proposed microstrip diplexer. The figure 5 presents the structure of the designed circuit. As can be seen, this structure is very simple and very compact with an overall size of 25×32 mm^2 and having the following dimensions:

For the Rx filter:

W_1=2, W_2=1, W_3=1, W_4=1, W_5=1, W_6=2, L_1=3, L_2=8, L_3=7, L_4=6, L_5=10, L_6=18, L_7=1, L_8=3, S_1=0.2, S_2=0.2, all in (mm).

For the Tx filter:

W_1=2, W_2=1, W_3=1, W_4=1, W_5=1, W_6=2, L_1=3, L_2=14.5, L_3=12, L_4=6, L_5=10, L_6=18, L_7=1, L_8=3, S_1=0.2, S_2=0.2, all in (mm).

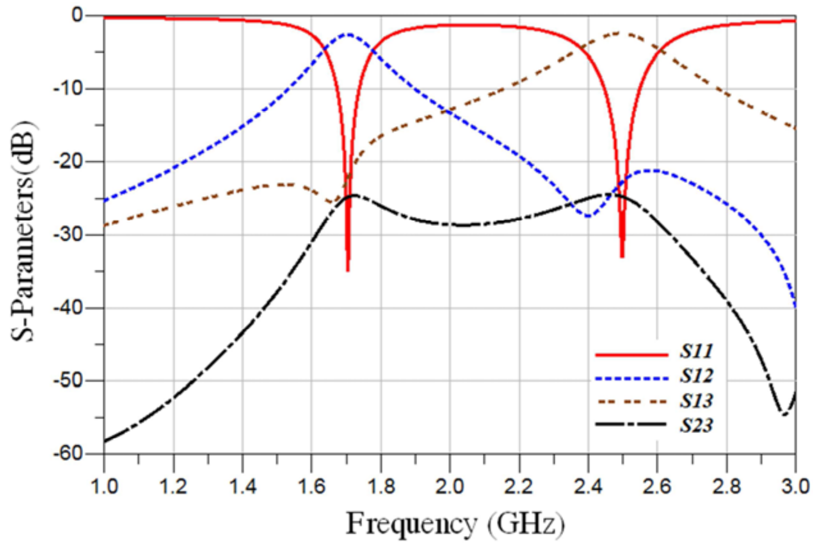

Figure 6. The simulation results of the proposed diplexer with ADS solver.

The figure 6 presents the simulation results obtained with ADS solver. We can clearly observe that this circuit presents remarkable frequency response. The insertion loss is about 2.6 dB and the return loss is better than 35 dB at the center frequency of 1.7 GHz. For the Rx filter, the insertion loss is around 2.4 dB and the return loss is better than 33 dB. Besides, the simulated isolation between the two channels keeps better than 24.4 dB.

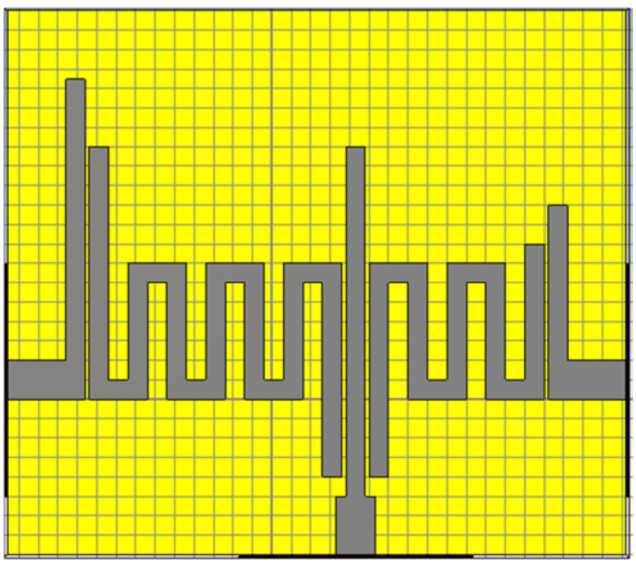

Figure 7. The proposed circuit designed with CST-MWS solver.

This circuit was designed and simulated by using a 3D solver. This process is achieved in order to verify the validity of the proposed design approach and to check the simulation results obtained with ADS solver. Thereby, we can avoid any surprise during the fabrication process which generally save time and resources. The figure 7 presents the microstrip diplexer under CST-MWS.

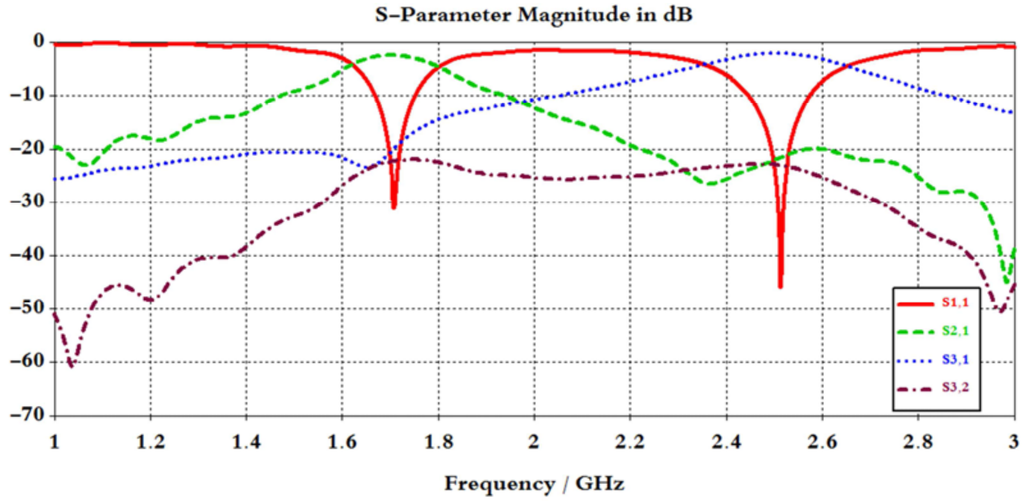

Figure 8. The frequency response of the proposed diplexer with CST-MWS.

The figure 8 depicts the simulation results of the proposed circuit. The simulated insertion loss at 1.7 GHz is approximately 2.35 dB while the return loss is around 31 dB. The simulated insertion loss and the return loss are about 1.96dB and 45.8 dB respectively at the center frequency of 2.5 GHz. The isolation between the two filters is better than 21.97 dB. As can be seen, an excellent agreement between the two simulation results is obtained. This agreement can prove the reliability of the proposed design approach introduced in this article.

The Table 1 gives a comparison between the simulation results obtained with ADS and CST-MWS solvers.

Table 1. A comparison between the simulation results of the micrsotrip diplexer under ADS and CST-MWS solvers.

Parameter	Simulation results (ADS)		Simulation results (CST)	
	TX	RX	TX	RX
Frequency GHz	1.7 GHz	2.49 GHz	1.7 GHz	2.5 GHz
Bandwidth	54 MHz	106 MHz	104 MHz	186 MHz
Insertion loss [dB]	2.6	2.4	2.35	1.96
Return loss [dB]	35	33	31	45.8
Isolation [dB]	24.4		21.97	

It should be noticed that the coupling effects of the filter can alter the frequency response of the diplexer and especially the isolation. In fact, reducing the distance between the feed lines and the resonators can enhance the insertion loss and the return loss however; the isolation between the two channels will be deteriorated. In opposite, decreasing the distance between the feed lines and the resonators will reduce the pass band, increase the insertion loss, and enhance the isolation. Therefore, it is necessary to make a compromise between the isolation, the insertion loss, and the pass band in order to obtain a good electrical performances. Thus, we can deduce that the distance between the feed lines and the resonators is a critical parameters that can control the electrical performances of the circuit.

4. Conclusion

In this paper, a novel compact microstrip diplexer using a meander-line resonators has been proposed. The microstrip circuit consists of two band-pass filters operating at 1.7 GHz and 2.5 GHz. The design approach proposed in this work offers the possibility to not only to design a compact microstrip diplexer, but also to control the frequency response. The desired electrical performances can be obtained by modifying the length and the number of turns in the meander-line resonator. Besides, the distance and the periphery between the resonators and the feed lines can also control the frequency response of the diplexer. The prototype diplexer was simulated under ADS and CST-MWS in order to verify the validity of the proposed design approach. This circuit presents good electrical performances with an insertion loss of 2.3 dB, a return loss better than 30 dB, and an isolation better than 22 dB.

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