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Design of microstrip Hairpin-Resonator filter for C-Band Application

Toulali Islam, Lahsaini Mohammed, Zenkouar Lahbib

Abstract— This paper proposes new development and design of microwave bandpass filter structure based on microstrip hairpin resonators. This filter has an operating frequency about 3.7 GHz. The design and implementation is based on micro-strip line technology, using epoxy material for high stability and low cost in the desired band. Good agreement of simulations has been obtained with low passband insertion loss and high return loss at the center frequency. Therefore the filter may be suitable for WiMAX and other wireless communication systems.

Index Terms— Bandpass, C-band, Filter, Hairpin-Resonator, Microstrip technology.

1 Introduction

THE development of wireless communication system and RF front ends has been made possible by advances in electronic. Different architectures of RF transceivers have been proposed by several authors [1],[2].

These radio frequency circuits are constituted by different blocks, mainly by an amplification structure and a RF filtering module. Our work focuses on the filtering function that is one of the performance criteria of the RF tranceiver. Indeed, filters are the most important passive components in RF and microwave subsystems and instruments to obtain a precise frequency response [3]. Thus, the miniaturization and the integration of the microwave filter should be carried out correctly in order to offer good frequency selectivity.

Microstrip hairpin resonators represent a new class of coupled microstrip bandpass filters. They can improve both frequency selectivity and bandpass loss. The main advantage is that the size that covers the parallel-coupled microstrip filter is reduced effectively in the Hairpin filter [4]. Based on this crucial criteria of wireless communication devices, a new concept of microwave band pass filter that can realizes a more compact structure and improves the performance of the whole RF circuit is presented in this article. The proposed design procedure will be discussed in Section II. Section III will display and analyze the simulated results of the filter. Section IV concludes the paper.

- ***Islam Toulali** is preparing her PhD in Mohammadia School of Engineers, Mohammed V University, Agdal, Rabat, Morocco. Her research interests include Microwave Circuits and Systems. E-mail: islamtoulali@gmail.com*
- ***Mohammed Lahsaini** has received the Doctoral degree and he is currently a professor at the Faculty of Science, Moulay Ismail University, Meknes, Morocco. His research interests include Microwave Circuits and Transmission and Reception Systems. E-mail: mohammed.lahsaini@gmail.com*
- ***Lahbib Zenkouar** Professor at Electrical Engineering Department, Mohammadia School of Engineers, Mohammed V University, Agdal, Rabat, Morocco. His research interests focuses on the design of Microwave Circuits and Systems and Information Technology*

2 System Overview

2.1 RF filter theory

The basic function of RF filter is to pass required band of frequencies with minimum loss and to attenuate unwanted frequency components to the desired levels. As the frequency increases, the design of RF filters becomes complex and many technologies are available to design the filters for varied application needs. Frequency, performance, size, and cost decide the appropriate technology for designing RF filters [5]. The most conventional description of a filter is by its frequency characteristic such as lowpass, bandpass, bandstop, or highpass [6].

Filters can be constituted by lumped or distributed elements or a combination of both. At microwave frequencies the discrete components are replaced by transmission lines. In this paper, microstrip line technology is employed to configure bandpass filter. The hairpin-line filter can be considered basically to be a folded version of a half-wave parallel coupled-line filter. It is much more compact, though, and gives approximately the same performance. [6]

A general topology of band pass hairpin line filter is displayed in Fig.1.

Fig. 1. Coupled line input Hairpin Filter

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2.2 Structure of bandpass filter

The design of band pass filter involves different steps:

- The first one is to precise the specifications of the filter, which are the center frequency of 3.7 GHz and the passband bandwidth of 110 MHz or the fractional bandwidth FBW = 0.11%. The filter is fabricated on FR4 substrate with the following characteristics: Relative dielectric constant of 4.32, a tangent loss of 0.0025 and a dielectric height of 1.5 mm.

- The next main step is to select an appropriate low pass prototype with equivalent element values obtained from [7]. In this design, a third pole chebyshev prototype filter with a passband ripple of 0.1 dB was used. The coefficients of Chebyshev polynomial corresponding to the required specifications are: $g_0 = g_4 = 1, g_1 = g_3 = 1.0315, g_2 = 1.1474$.

- The design equations for this bandpass filter are given by [matheai], the following equations are used for designing the parallel coupled filter:

$$J_{0,1} = \frac{1}{Z_0}\sqrt{\frac{\pi FBW}{2g_0 g_1}} \quad (1)$$

$$J_{i,i+1} = \frac{1}{Z_0}\frac{\pi FBW}{\sqrt{g_i g_{i+1}}} \quad (i = 1 \quad to \quad n-1) \quad (2)$$

$$J_{n,n+1} = \frac{1}{Z_0}\sqrt{\frac{\pi FBW}{2g_n g_{n+1}}} \quad (3)$$

Where g_0, g_1... g_n are the element of the lowpass prototype with a normalized cutoff $\Omega_0 = 1$, $J_{i,i+1}$ are the characteristic admittances of J inverters and Z_0 is the characteristic admittance of the terminating lines.

- The even-mode and odd-mode characteristic impedances of the coupled transmission lines are expressed as follows:

$$Z_{0e}\big|_{i,i+1} = Z_0\left[1 + Z_0 J_{i,i+1} + \left(J_{i,i+1}\right)^2\right] \quad (4)$$

$$Z_{0o}\big|_{i,i+1} = Z_0\left[1 - Z_0 J_{i,i+1} + \left(J_{i,i+1}\right)^2\right] \quad (5)$$

- The structural parameters of hairpin filter are as follows, these empirical equations are used to calculate the external quality factors of input and output, Qe1 and Qen, as well as the mutual coupling coefficients Mij, between the resonators i and i + 1:

$$Q_{e1} = \frac{g_0 g_1}{FBW} \quad (6)$$

$$Q_{en} = \frac{g_n g_{n+1}}{FBW} \quad (7)$$

$$M_{i,i+1} = \frac{FBW}{\sqrt{g_i g_{i+1}}} \quad for \quad i = 1 \quad to \quad n-1 \quad (8)$$

- To approximate the tapping length of the resonator, the formula given below was used by the designers:

$$t = \frac{2L}{\pi}\sin^{-1}\left(\sqrt{\frac{\pi}{2}\frac{Z_0/Z_r}{Q_e}}\right) \quad (9)$$

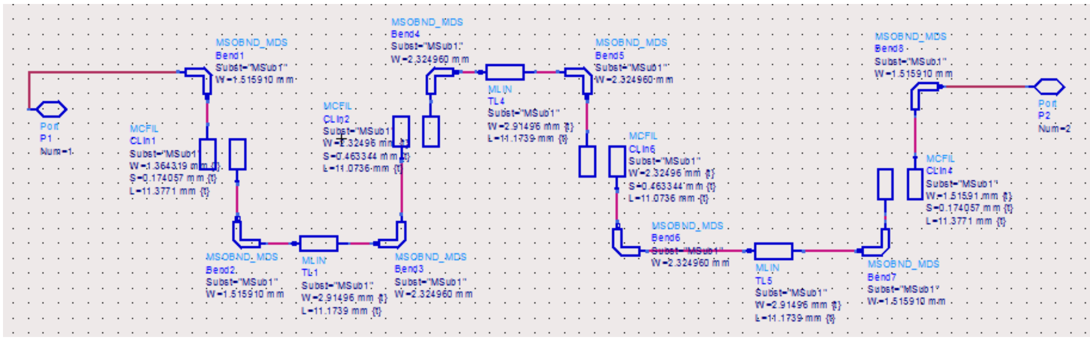
2.3 Circuit description

The values of the even and odd mode impedances were computed using equations (1) to (5). The obtained values are shown in Table 1:

TABLE 1
ODD AND EVEN IMPEDACES VALUES

(ZOE)0,1	(ZOE)1,2	(ZOE)2,3	(ZOE)3,4
94.26192	69.756335	94.26192	69.756335
(ZOO)0,1	(ZOO)1,2	(ZOO)2,3	(ZOO)3,4
37,71435	39.43655	37,71435	39.43655

Using tools of Advanced Design System software, we have calculated the spacing, width and length between resonators. The circuit schematic of hairpin filter with all the determined dimensions is illustrated in Fig.2.



3 F

After
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using
micr

of proposed hairpin bandpass filter

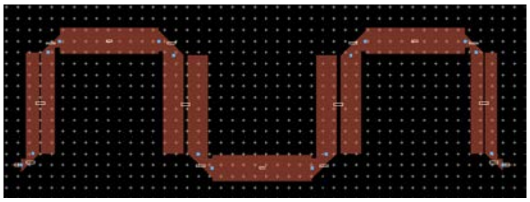

Fig. 3. Microstrip layout of the bandpass hairpin filter

The simulation results of the filter reach the design goals. The response of the proposed filter is shown in fig.4. Hence the hairpin bandpass filter is capable of passing the frequencies between range 3.910 GHz and 4.436 GHz and rejects all other frequencies. Table 2 gives a comparison between different research works.

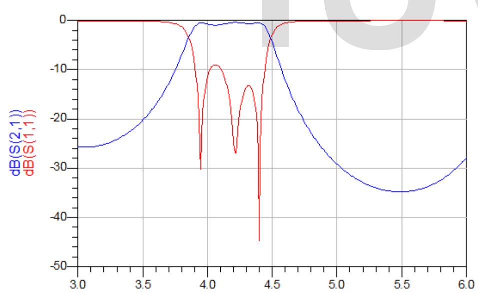

Fig. 4. Result for circuit diagram BPF

TABLE 2
PERFORMANCES COMPARISON WITH OTHER RESEARCH WORKS

	Band (GHz)	*S(1, 1) (dB)*	*S(2, 1) (dB)*
This work	[3–6]	<−10	0
[8]	[0–3]	–	−2
[9]	[1–4.5]	<−5	−3

4 CONCLUSION

In this paper, a four section hairpin bandpass filter for C-band applications has been designed and analyzed. The layout of the filter with all specified dimensions was illustrated. The use of microstrip line technology provides a small size circuit with low cost.

Response characteristics of the filter show that the capability of implementing transmission zeros, the compactness in the size, and the simplicity in the design make the microstrip hairpin-resonator filter useful for receiver front end circuit. The development of this filter for further use in specific applications can be studied later.

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