Spurline structures and its application on microwave coupled line filter

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We propose and demonstrate experimentally that spurline structures enhance the rejection bandwidth of microwave bandstop coupled line filters. We have investigated the influence of spurlines structures on the rejection bandwidth of a typical microwave coupled line filters (with a notch frequency at 3.0 GHz). Momentum simulations and experimental results show that using spurline structures (designed to present a notch frequency at 2.4 GHz and 3.2 GHz) enhance in high percentage the performance of microwave coupled line filters (CLF).

Keywords: Filters; microwave circuits.

En este trabajo se propone y demuestra experimentalmente que las estructuras "spurlines" son capaces de mejorar el ancho de banda de los filtros de microondas de líneas acopladas. Se ha investigado la influencia de las estructuras "spurlines" sobre la banda de rechazo de un filtro de microondas de líneas acopladas típico (con una frecuencia de supresión de 3.0 GHz). Simulaciones con el método de Momentos y resultados experimentales muestran que utilizando las estructuras "spurlines" (diseñadas para rechazar frecuencias de 2.4 y 3.2 GHz) mejoran en un alto porcentaje el ancho de banda del filtros de microondas de líneas acopladas (FLA).

Descriptores: Filtros; circuitos de microonda.

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1. Introduction

Since several decades ago, both active and passive filters are widely used to suppress unwanted signals. At microwave frequencies, passive components like transmission lines have been used for designing passive filters oriented to wireless communications applications [1], where open, short stubs, and coupled lined are some common proposals. In particular, bandstop and bandpass filters can be designed by using coupled line structures as shown in Fig. 1a-b, respectively. However, these filters are narrowband designs. In recent years, the so-called metamaterials have been developed for the fabrication of special substrates to design microwave filters [2,3]. Some of those designs include periodic band gap filters like defected ground structure (DGS), that is actually a transmission line along with a well-defined etching in the backside ground plane (see Fig. 1c) [4]. In the practice, the advantage of DGS filters lies in the sharp cut-off frequency response, presenting a low pass behavior. An alternative periodic band gap filter is based on spurline structure [5]. The frequency response of a spurline filter is a notch type, with narrow rejection bandwidth. How to enhance the rejection bandwidth in spurline filters is an open research field, from which Liu *et al* have proposed the design of a bandstop filter (from 2.3 to 5.6 GHz) based on a meander spurline [6]. In that proposal, the simulation-based in optimization process implies optimize five design parameters, representing a difficult work because the time interval between calculated points is long, *i.e.* one need to run the simulation for a long time in order to get optimized values.

In this paper, we propose to use spurline structures to enhance the rejection bandwidth of a microwave coupled line filter. The proposed design, fabricated on Rogers substrate RT/D 5880, was theoretically verified using EM simulations, based on the method of momentum from ADS.

2. Experiment

Figure 2a shows the basic structure of a spurline, which works as a narrow bandstop filter, where the frequency response is determined by optimizing three parameters: length (a), height (b), and gap (s) [7]. The length a and height b dictate the frequency of the notch characteristic. However, it is more properly, in a non-reflective transmission line (Z_0=50 Ω), tune the notch frequency by modifying the length a instead of the height b. Moreover, Fig. 2b shows simulations results of the frequency response for the spurline structure as a function of the internal gap, s. It is evident that the bandwidth of the rejection band is directly related with this parameter. Another characteristic of the filter, not shown in the figure, is that the frequency response at which the notch occurs increases when the length a decreases. According to that, the main idea to design a CLF with an enhanced rejection bandwidth is to get a total frequency response based on

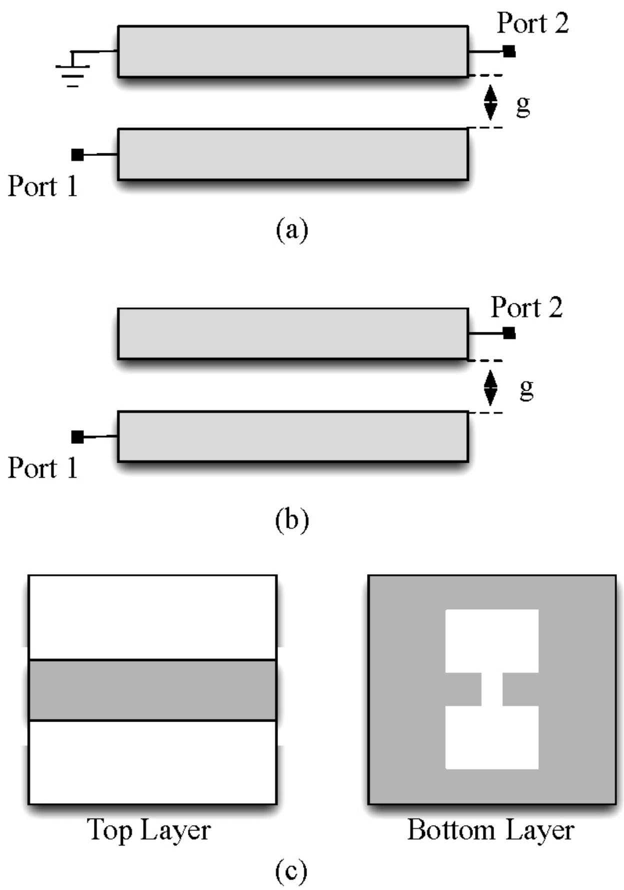

FIGURE 1. Microwave couple line filters. Bandstop (a); bandpass (b); Defected Ground Structure (c).

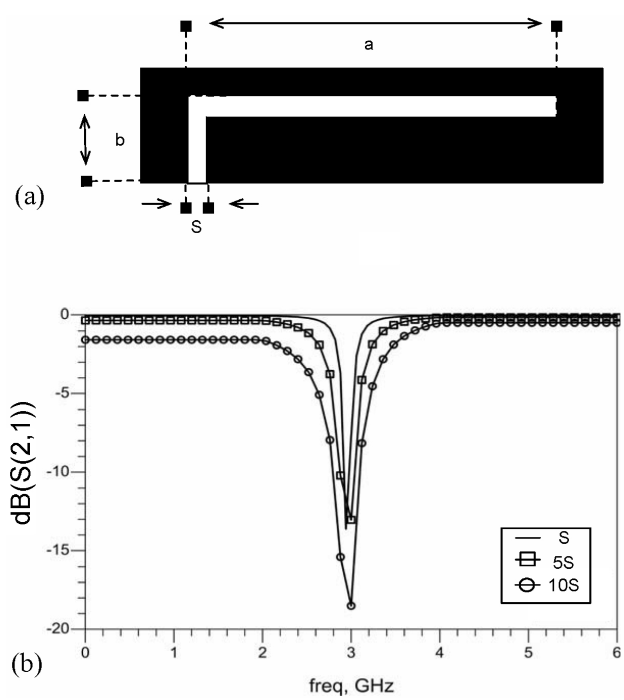

FIGURE 2. Spurline structure. Transmission line with an etching process describing an L shape (a); frequency response at different internal gap, s=0.2 mm (b).

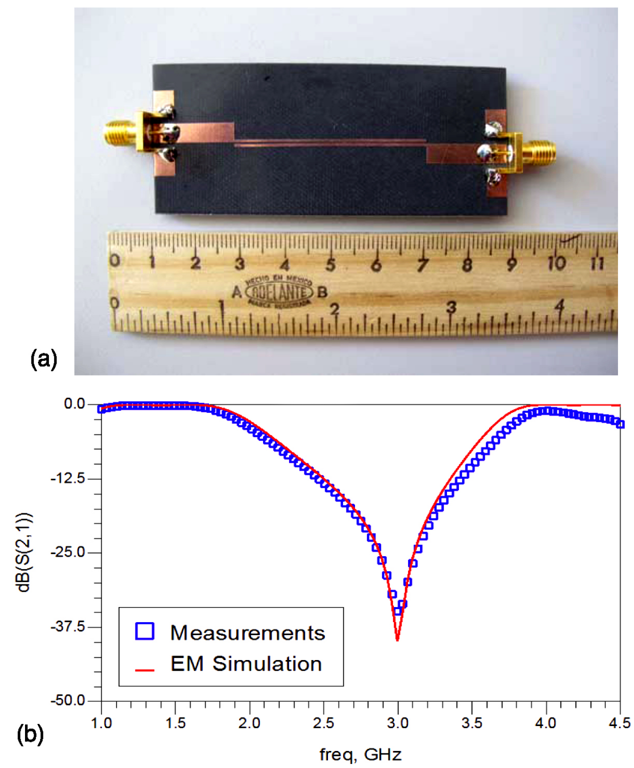

FIGURE 3. Bandstop filter. Coupled line filter on RT/D 5880 substrate at 3 GHz (a); S_{21} frequency response (b).

the response of three narrow bandstop filters (a CLF embedded into spurlines structures), where each notch frequency will represent the lowest (f_L), central (f_0) and highest (f_H) frequency of the rejection bandwidth. To validate our hypothesis the proposed filter will be compared with the response of a typical 3 GHz coupled transmission line filter (see Fig. 3a), which correspond to an electrical length of 210° with a characteristic impedance $Z_0 > 100\ \Omega$.

Figure 3b compares the S_{21} between Momentum results and experimental data of the bandstop coupled line filter; EM simulation was performed without SMA connectors, and the experimental data were collected using a VNA (Anritsu, 37347D) that was calibrated according to the SOLT technique. Note that this design is composed by three sections, one of them is the gap g between transmission lines; the electrical characteristics of the microstrips used in each section are depicted in Table I. Moreover, Fig. 3b shows that experimental data have a good agreement with simulation. The error between both results, around 3.5 GHz, is attributed to a poor coplanar to microstrip transition. Defining 10 dB of insertion loss, the resulting rejection bandwidth of the bandpass is of the order of 1.042 GHz.

2.1. Proposed filter

Figure 4a shows the proposed bandstop filter, where the coupled lines section was also designed according to the physical dimension reported in the Table I. As we can see in Fig. 4b

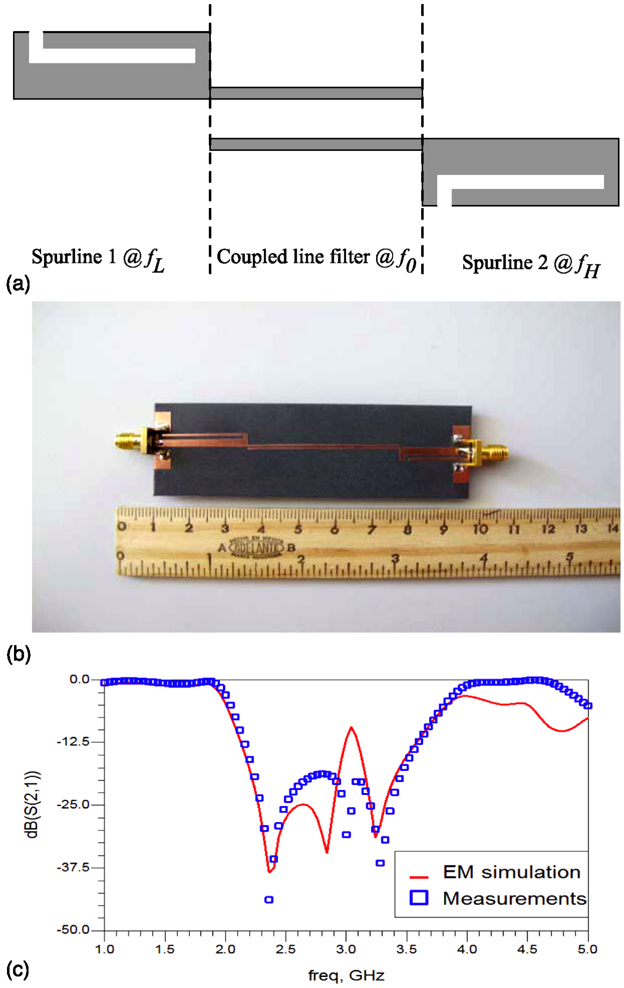

FIGURE 4. Layout of the proposed filter (a); coupled line filter with spurline structure (b); S_{21} frequency response (c).

the length "a" of the spurline 1 is slightly larger than the length "a" of the spurline 2, because the first one has to present the notch at the lowest frequency (2.4 GHz); the spurline 2 was designed at a notch frequency of 3.2 GHz. Table II reports the physical dimensions of the spurline structures. Figure 4c shows, a comparison between EM simulation results and experimental data. The experimental response of each section, not shown in the figure, presents approximately a value S_{21}=-40 dB at the notch frequency.

This characteristic is well reproduced also by measuring the response of the proposed filter, as shown in Fig. 4c. However, from experimental point-of-view, even when are presented the expected notch frequencies, one of them is approximately at 2.7 GHz. This value can be explained by calculating the central frequency of the bandwidth given by

$$f_0 = \sqrt{f_L f_H} \approx 2.7713 \text{ GHz} \qquad (1)$$

TABLE I. Characteristics of the transmission line of the bandstop coupled line filter.

Section 1	Section 2	Section 3
Z_0 = 50 Ω	Z_0= 128.8 Ω	Z_0 = 50 Ω
L = 90.0°	L = 192.0°	L = 90.0°
	g = 0.3 mm	

TABLE II. Spurlines structure characteristics.

	Spurline 1	Spurline 2
a	23.6 mm	17.3 mm
b	2.0 mm	2.0 mm
s	1.0 mm	1.0 mm

where f_L= 2.4 GHz and f_H= 3.2 GHz. This result, by one hand, affects the symmetry of the bandwidth. Such a frequency shift, respect to the notch frequency of the gap between coupled lines, also affects the value of S_{21}(≈-7 dB) around 3.0 GHz. On the other hand, the rejection bandwidth in general is increased in a 50% compared with the response of bandpass coupled line filter.

3. Conclusions

We have used a technique based on spurline structure to enhance the rejection bandwidth of coupled line filters for microwave applications. This technique was used to also demonstrate that the notch frequency of an individual spurline structure could be tuned by optimizing just three basic parameters: length (a), height (b), and internal gap (s). Hence, the proposed filter is to superimpose the frequency response of three narrow bandstop filters. Simulated results, using Momentum, have a high correlation with experimental data. The rejection bandwidth of the filter (up to this work not investigated) increased in a 50% respect to the response of typical bandpass coupled line filters. Finally, we present the origin of the central frequency (2.7 GHz) as a function of the notch frequency of both spurline structures.

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