Spurious-response suppression in microstrip Parallel-Coupled bandpass filters by using Defected Microstrip Structures

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Abstract: This paper presents a novel Parallel-Coupled Microstrip Line (PCML) bandpass filter by etching of some slot resonators on the strip for suppressing the first spurious response. These slots perform a serious LC resonance property in certain frequency and suppress the spurious signals. Slot on the strip that is called Defected Microstrip Structure (DMS). The DMS interconnection disturbs the current distribution only across the strip, thereby giving a modified microstrip line with certain stop band and slow-wave characteristics. The measured results show a satisfactory rejection level more than 30 dB at first spurious passband without affecting the passband response.

Keywords: Parallel Coupled-Line Filter (PCML), Defected Microstrip Structure (DMS), spurious response suppression

Classification: Microwave and millimeter wave devices, circuits, and systems

References


1 Introduction

High-Performance microwave filters are essential circuits in many microwave systems where they serve to pass the wanted signals and suppress unwanted ones in the frequency domain. Microstrip parallel coupled-line bandpass filters are widely used in microwave circuits due to their low sensitivity to fabrication tolerances, wide realizable bandwidth, and simple synthesis procedure. However, despite the aforementioned advantages, an undesirable disadvantage is the existence of the first spurious passband at twice the passband frequency. This spurious response degrades the rejection properties of the system. The undesired spurious passband is related to the inhomogeneous dielectric medium surrounding the conductors, which causes the odd-mode wave to propagate faster than the even mode wave in the coupled microstrip lines [1]. The even and odd mode phase velocities are different for coupled microstrip lines due to their different field configuration in the vicinity of the air–dielectric interface.

There are two basic methods to equalize the modal transmission phase: providing different lengths for the even and odd mode waves, or equalizing the modal phase velocities. In [2], an over-coupled resonator was constituted to extend the odd-mode phase length, thus compensating the phase velocity difference between two modes. The structure in [3] uses capacitors to extend the travelling route of the odd-mode. The strip-width modulation technique tries to modify or perturb the widths of the conventional lines in various forms, such as wiggly [4], grooved [5], or even fractal [6] shapes. The above periodic structures can be used to create Bragg reflections so that the first spurious passband is rejected, while the desired passband response is maintained almost unchanged. Split Ring Resonator (SSR) structure was proposed to achieve a large imaginary component in effective permeability due to its unique resonance nature [7]. In recent years, Complementary Split Ring Resonator (CSRR) is presented and investigated on the basis of De-
fected Ground Structure (DGS) [8]. It has been demonstrated that CSRRs etched in the ground plane or in the conductor strip of planar transmission media (microstrip or CPW) provide a negative effective permittivity to the structure, and signal propagation is precluded (stopband behaviour) in the vicinity of their resonant frequency [9].

The radiation from the defects of interconnection is a harmful phenomenon for measurements or integration of components. Compared to DGS, if DMS is used as a filter, the harmful radiation can be decreased with lower etched area of defect. Dissimilar DGS, the DMS has less radiated EMI ground noise. In addition, ground plane defect will significantly increase the crosstalk between parallel interconnections that cross over them [11].

In this paper, a new design of a parallel-coupled bandpass filter integrating Defected Microstrip Structure (DMS) technique by etching Split Square Ring Resonators on the coupled sections of the circuit is proposed. In DMS, there is no etching in ground plane. DMS is made by etching some uniform or non uniform slits or patterns over the signal strip. This defect causes band-stop frequency response. These resonators designed to resonate around $2f_0$ and will add a transmission zero at this frequency. Here, we merge DMS resonators in filter structure with no increase in used area while was excellent for the first harmonics suppression with rejection levels up to 30 dB. This structure can be integrated more easily with other microwave circuits. The full wave simulations are carried out using Ansoft HFSS v.12 (an electromagnetic simulator).

2 Filters Implementation

The DMS structure increases the electric length and the associated inductance of the microstrip. So, improvement in filter characteristics of the circuits can be achieved and size of the filter circuits can be reduced. DMS presents good cut off frequency characteristics due to the more effective inductance with respect to DGS.

Figure 1 illustrates the configuration of Complementary Split Square Ring-DMS (CSSR-DMS) in the center of the microstrip line and the full-wave simulated $S$-parameters depict more steep sharpness property. The resonant frequency of CSSR depends only on its total physical length for a constant value of space gap ($g$). The resonant frequency is independent of the physical width ($c$) of the CSSR. The physical width determines bandwidth of frequency response.

To demonstrate the suppression procedure of the first spurious passband, a conventional five order PCML bandpass filter is designed at center frequency of 4.7 GHz with bandwidth 600 MHz on Rogers RO4350 substrate which has a relative permittivity $\varepsilon_r = 3.66$ and thickness $h = 1.52$ mm. Figure 2 (a) displays the image of the fabricated proposed filter and the filter geometry integrated with the CSSR-DMS is shown in Figure 2 (b). $W_i$, $S_i$, and $L_i$ are width, separation between coupled-lines, and length of the $i$th section, respectively.
Fig. 1. Configuration of unit cell CSSR-DMS and transmission coefficients for different length \( L_O \). \( W_e = 1 \text{ mm}, \quad L_e = 1 \text{ mm}, \quad g = 1 \text{ mm}, \quad c = 1 \) 

Fig. 2. Image of the fabricated filter (a) Geometry of proposed bandpass filter defining its physical parameters (b) (dimensions in mm).

The dimensions of coupled line are: \( W_1 = W_4 = 1.85 \text{ mm}, \quad W_2 = W_3 = 2.49 \text{ mm}, \quad S_1 = S_4 = 0.23 \text{ mm}, \quad S_2 = S_3 = 0.68 \text{ mm}, \quad L_1 = L_4 = 9.1 \text{ mm}, \quad L_2 = L_3 = 8.9 \text{ mm}, \quad L_{O1} = 5.5 \text{ mm}, \quad L_{O2} = 4.53 \text{ mm}, \quad L_{O3} = 4.545 \text{ mm}, \quad L_{O4} = 6 \text{ mm}, \quad c_1 = c_2 = c_4 = c_3 = 0.2 \text{ mm}, \quad L_{e1} = 1.8 \text{ mm}, \quad L_{e2} = L_{e3} = 1.2 \text{ mm}, \quad L_{e4} = 1.5 \text{ mm}, \quad g_1 = g_2 = g_3 = g_4 = 0.7 \text{ mm}, \quad W_{e1} = W_{e4} = 0.9 \text{ mm}, \quad W_{e2} = 0.65 \text{ mm}, \quad W_{e3} = 0.675 \text{ mm}, \quad W_{r1} = W_{r4} = 1.3 \text{ mm}, \quad W_{r2} = W_{r3} = 1.2 \text{ mm}. \)

The input and output port strip width are \( W_0 = 3.55 \text{ mm}, \) corresponding to 50 \( \Omega \).
DMS resonators perform a serious $LC$ resonance property in certain frequency. The proposed hairpin structure uses the rejection properties of DMSs merged in filter structure to reject specific frequencies while having the least effect on the filter pass band response. Thus, it is more reasonable to use multiple DMSs to make a wide reject band without meaningful effect on main response. This technique eliminates the first harmonic response and makes better sharpness level of transition from passband to stopband region.

Figure 3 (a) shows the comparison between the full-wave simulation results of the conventional and DMS-integrated PCML bandpass filter. As it is seen, the DMSs work as band-reject elements with almost no effect on filter

![Figure 3](image_url)

**Fig. 3.** (a) Comparison between the full-wave simulated $S$-parameters of the conventional and DMS-integrated PCML bandpass filter (b) Measured and simulated results of DMS-integrated PCML bandpass filter.
performance and therefore could be designed independently. The first spurious passband is suppressed by more than 30 dB at twice the centre frequency and 50 dB suppression at 6.5 GHz. Figure 3 (b) provides a comparison measured and full-wave simulated results. Good agreement between simulations and experimental data has been obtained.

3 Conclusion

This paper introduces a new simple and effective application of the CSSR-DMS to suppress the first spurious response of the PCML bandpass filter. The filter structure has great advantages because of the achievable bandwidth, minimization of radiation from the defects and broad stopband because of effective inductance of the DMSs, etched on the microstrip line. In the high frequency applications, the board area is seriously limited, so using this filter; the circuit area is minimized. These structures can be integrated more easily with other microwave circuits and very suitable for applications of global wireless communication and sensitive military systems. The measured results show a satisfactory rejection level more than 30 dB at first spurious harmonic without affecting the passband response.