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***Research paper***

# Effect of defected ground plane on the bandwidth of parallel line-coupled bandpass filter at 3.3 GHz

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## Abstract

The effect of a defected ground plane made up of photonic band-gap structure of circular slots or patches of the radii r on the bandwidth of a parallel line- coupled bandpass filter, realized on a dielectric substrate and of 3.3 GHz center, frequency is highlighted in this study. The use of defected ground plane increases the filter bandwidth and allows its use on a broad-band frequency.

***Keywords***: *Bandpass Filter, Photonic Structure, Parallel-Coupled Lines.*

## 1. Introduction

In microstrip technology, the structure with parallel-coupled lines, consisted of a succession of sections of parallel-coupled lines lengths equal to the quarter wavelength at the center frequency of the filter is most usually used to implement the bandpass filters because, it makes it possible to obtain good couplings and bandwidths adapted with a suitable spacing between the lines, contrary to the other configurations of filters [1]. However, frequency response of these filters suffers from the spurious response at twice the basic passband frequency ($2f_0$)) which reduces its stopband and which it is appropriate to eliminate if one wants to work with signals of wider spectrum. One finds in the literature several methods dedicated for this purpose [2], [3], [4], [5].
For certain applications, one wishes to have a broadband filter, from where the idea to explore methods allowing to widen the bandwidth of a filter [6].
In this paper, we propose to analyze the effect of the photonic defected ground plane on the bandwidth of a Chebyshev bandpass filter, using parallel-coupled resonators carried out in microstrip technology and having 3.3 GHz of center frequency.
Indeed, the use of defected ground made up of a photonic band-gap circular slots or circular patches regularly spaced with one period a along the length of the structure and one period b along its width has made it possible to reduce the coupling between resonators and thus to increase the bandwidth of the filter until approximately 20% in the case where the ground consists of metallic circular patches.

## 2. Filter design

The desired filter obeyed the following specifications:

- filter order: $n = 3$
- equal ripple in the passband: $A_p = 0.5$ dB
- center frequency: $f_0 = 3.3$ GHz
- fractional bandwidth: $\Delta = 10\%$
- characteristic impedance of the terminating lines: $Z_0 = 50\ \Omega$

With these specifications, the elements value of a ladder-type low-pass prototype normalized filter in Chebyshev approximation are given by:

$g_0 = 1$ ;$g_1 = 1.5963$ ; $g_2 = 1.0963$ ; $g_4 = 1$.

A bandpass filter consists of series resonators alternating with parallel resonators or conversely.
In microstrip technology, such a filter can be carried out using the admittance inverters J and the parallel resonators made up of the quarter-wavelength coupled lines of characteristic impedances $Z_{oe}$ for the even mode and $Z_{oo}$ for the odd mode [7],[8], as represented in Fig.1. These characteristic impedances are related to the admittance inverters of the sections of line by the following relations (1) and (2) [6].

$$Z_{oe\ i\ i+1} = Z_0[1 + Z_0 J_{i\ i+1} + (Z_0 J_{i\ i+1})^2] \quad (1)$$

$$Z_{oo\ i\ i+1} = Z_0[1 - Z_0 J_{i\ i+1} + (Z_0 J_{i\ i+1})^2] \quad (2)$$

The quantities $J_{i\ i+1}$ indicate the values of the characteristic admittances of the J-inverters separating two consecutive resonators i and i+1 of the filter. These characteristic admittances are related to the element values of the low-pass prototype normalized filter by [6]:

$$J_{0\ 1} Z_0 = \sqrt{\frac{\pi\Delta}{2g_0 g_1}} \quad (3)$$

$$J_{i\ i+1} Z_0 = \frac{\pi\Delta}{2\sqrt{g_i g_{i+1}}} \quad 1 \le i \le n \quad (4)$$

$$J_{n\ n+1} Z_0 = \sqrt{\frac{\pi\Delta}{2g_n g_{n+1}}} \quad (5)$$

The filter will be implemented with parallel coupled- lines on a duroid 1610 substrate of thickness h=0.635 mm, and a relative dielectric permittivity $\varepsilon_r$=10.5. The microstrip lines are out of copper with metallization thickness t=31μm and conductivity $\sigma$=5.710$^7$S/m.

From the relations (1), (2), (3), (4) and (5), one obtains the dimensions of each section of the three order half-wavelength resonators consigned in table 1 following.

**Table 1:** Dimensions of Microstrip Coupled-Line Bandpass Filter

| Section | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| J | 0.00627 | 0.00237 | 0.00237 | 0.00627 |
| $Z_{oe}(\Omega)$ | 70.60 | 56.64 | 56.64 | 70.60 |
| $Z_{oo}(\Omega)$ | 39.23 | 44.76 | 44.76 | 39.23 |
| w/h | 0.438 | 0.544 | 0.544 | 0.438 |
| s/h | 0.257 | 0.765 | 0.765 | 0.257 |
| L(mm) | 8.79 | 8.63 | 8.63 | 8.79 |

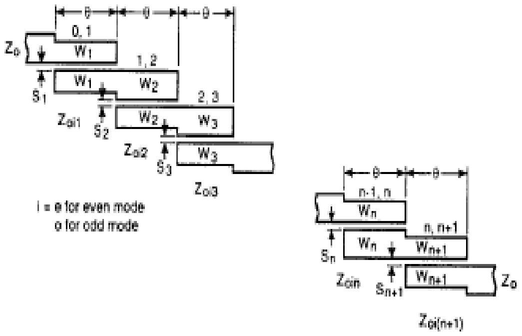


**Fig. 1:** Parallel-Coupled Transmission Line Resonator filter

## 3. Results and discussion

To highlight the effect of the defected ground on the widening of the filter bandwidth, we studied two structures of parallel-coupled half-wavelength resonator filters with a degraded ground. One with a ground plane containing of the circular holes (slots) of radius r regularly spaced with periods a and b, the other with a ground plane made up of metallic circulars patches of radii r, also regularly spaced with the same periods. The structures thus obtained using software ADS/MOMENTUM are represented on Fig.2.

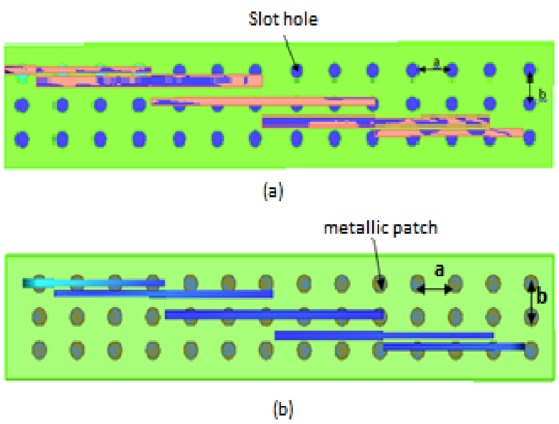


**Fig. 2:** Parallel-coupled line filter with defected ground plane:
a) Ground plane with slots
b) Ground plane with metallic patches

In Fig.3 we represented the transmission coefficient of parallel-coupled line filter with a ground plane made up of metallic patches for various radius r. As one could expect it, one observes on the one hand that bandwidth of Harmonic 2 decreases as the radius r of the

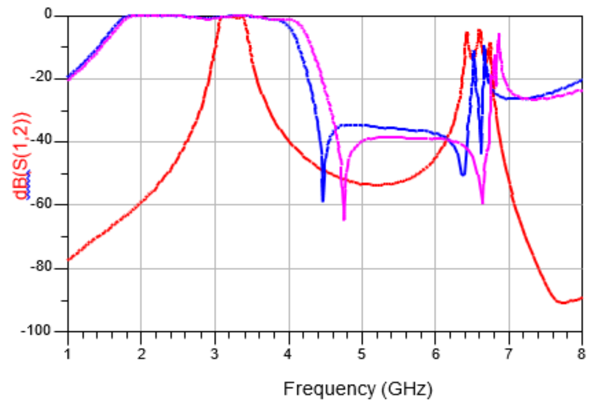


**Fig. 3:** Transmission Coefficient of Filter versus Frequency of Bandpass with Defected Ground Plane for Different Radii of Metallic Patches.

Red r=0; blue r=0.55 mm; pink r=1.1mm; a=3 mm; b=2.1 mm

patch grows and on the other hand that the bandwidth of the filter widened when r≥0.55 mm. The fractional bandwidth is of order 54.54% for r=0.55mm and of 68.18% for r=1.1mm. This can be interpreted by the fact that a defected ground plane made up of patches decreases the coupling between resonators, from where the widening of the bandwidth of the filter.

Fig.4 shows the variation of the transmission coefficient versus to the frequency of parallel-coupled line filter with a metallic ground plane on which circular holes (slots) of radius r are carried out. One notes that for r≤0.55 mm, there is no significant modification of the bandwidth of the filter. However one notes a light increase in the bandwidth for r=1.1mm. The fractional bandwidth remains equal to 10% for r≤0.55 mm and it is of order 16.55% for r=1.1mm.

One can thus note that the presence of the circular slots within metallic ground plane influences very little the busy bandwidth of the filter but it takes part in the reduction in the weight of the structure

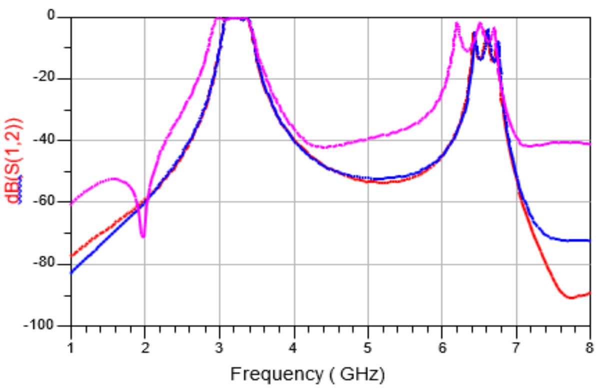


**Fig. 4:** Transmission Coefficient of Filter versus Frequency of Bandpass with Defected Ground Plane for Different Radii of Slots.

Red r=0; blue r=0.55mm; pink r=1.1mm; a=3mm; b=2.1mm.

## 4. Conclusion

This study showed us that the use of a ground defected plane makes it possible to increase to a significant degree the bandwidth of a parallel- coupled line bandpass filter and to reduce the busy bandwidth of the $2^{nd}$ harmonic, thus increasing its stop-passband. While exploiting the radius and the period of the metallic patch, this approach should make it possible to have a bandpass filter with an adjustable passband.

## References


[1] R. Levy, S. B. Cohn, "*A history of microwave filter research, design, and development*," IEEE Transactions on Microwave Theory and Techniques, vol. 32, no. 9, pp. 1055,1067, Sep 1984.

[2] J.-T. Kuo, W.-H. Hsu and W.-T. Huang, "*Parallel coupled microstrip filters with suppression of harmonic response*," IEEE Microwave Wireless Components Letters. vol. 12, no. 10, pp. 383-385, Oct. 2002. https://doi.org/10.1109/LMWC.2002.804559.

[3] Seungpyo Hong et al., "*A parallel-coupled microstrip bandpass filter with suppression of both the 2nd and the 3rd harmonic responses*," Microwave Symposium Digest, IEEE MTT-S international, pp. 365-368, 2006.

[4] D. Ahn, J. Park, C. Kim, J. Kim, Y. Qian, and T. Itoh, "*A design of the low-pass filter using the novel microstrip defected ground structure*," IEEE Transactions on Microwave Theory and Techniques, vol. 49, pp. 86–93, 2001. https://doi.org/10.1109/22.899965.

[5] Haiwen Liu,1 Zhengfan Li,1 Xiaowei Sun,2 and Junfa Ma, "*A novel photonic band-gap microstrip structures for lowpass filters of wide stop-band* ,'' Microwave and Optical Technology Letters , Vol. 37, No. 6, pp. 470- 471, June 2003 https://doi.org/10.1002/mop.10953.

[6] Aniket Gunjal, S.R.Gagare, R.P.Labade, "*Bandwidth enhancement in Bandpass filter (BPF) using Microstrip Coupled lines for WLAN (2.4GHZ) Applications,*''International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) – IEEE-2016

[7] David M. Pozar, Microwave Engineering 4th Edition Wiley 2011, chap.8.

[8] R. K. Mongia, I. J. Bahl, P. Bhartia, J. Hong8., RF and Microwave Coupled-Line Circuits, second edition Artech House, INC. 2007, chap.10.