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2014

Xu, S., Ma, K., & Yeo, K. S. (2014). A transformed radial stub low-pass filter using defected ground structure for stopband extension. 2014 International SoC Design Conference (ISOC), 82-83.

<https://hdl.handle.net/10356/79415>

<https://doi.org/10.1109/ISOC.2014.7087572>

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A Transformed Radial Stub Low-pass Filter Using Defected Ground Structure for Stopband Extension

Shanshan Xu¹, Kaixue Ma^{1,2}, Kiat Seng Yeo^{1,3}, Fanyi Meng¹

¹School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore

²University of Electronic Science and Technology of China (UESTC), Chengdu, China

³Singapore University of Technology and Design, Singapore

sxu2@e.ntu.edu.sg

Abstract

The paper presents a low-pass filter using defected ground structure for stopband enhancement. Face-to-face E shape defected ground structure is investigated using EM simulation, which are co-designed in transformed radial stub low-pass filter for stopband extension. The fabricated filter demonstrates a passband insertion loss of less than 1 dB, a wide stopband with more than 20 dB rejection up to $24f_c$ (f_c is the cut-off frequency of 1.6 GHz), a passband return loss of better than 20 dB, and a compact size of

Keywords - defected ground structure; low-pass filter; wide stopband

Introduction

Low-pass filters (LPF) are widely used in communication systems for noise and spurious filtering [1]. Advanced LPF designs have to accommodate for the modern mobile and portable ICs [2] and feature characteristics of low insertion loss, wide stopband, and small form-factor. Recently, LPF based on transformed radial stub (TRS) was investigated in [3]. LC structures were added at IN/OUT ports for stopband extension.

In this paper, defected ground structures (DGSs) [4] are investigated and implemented in the TRS LPF to enhance stopband rejection, with no additional space required. The fabricated filter features low insertion loss, ultra-wide stopband, and compact size.

Face-to-Face E shape DGS

The structure of the proposed DGS structure is depicted in Fig. 1. Two E shapes are defected on the ground plane in the face-to-face orientation. The middle defected slots of the two E shape are merged together.

The DGS is investigated using 3-D full-wave EM simulator ANSYS HFSS. Fig. 2 shows the simulated frequency response. Low-pass characteristic is obtained by placing the DGS under transmission line (TL), with two transmission zeros and stopband from 17 GHz to 34 GHz.

The electric field distribution is plotted in Fig. 3. At 17.1 GHz, the resonant is created by the resonance of the collective face-to-face E shape. At 32.1 GHz, the resonant is due to resonance property of each E shape.

Fig. 1 Proposed face-to-face E shape DGS. (Dash line is the signal line of transmission line; the area enclosed by the solid line is the defected area on the ground plane)

Fig. 2 Frequency response of the face-to-face E shape DGS in Fig. 1.

Fig. 3 Electric field distribution (a) signal line, (b) ground plane at first transmission zero (17.1 GHz), and (c) signal line, (d) ground

plane at second transmission zero (32.1 GHz).

Fig. 4 Single cell of the designed LPF: top plane (left); bottom plane (right). ($L_v = 231.07$ mil, $R_0 = 112.2$ mil, $W = 6$ mil, $S_1 = 6.12$ mil, $L_h = 11.59$ mil, $R_c = 70$ mil)

Fig. 5 EM simulated response of the TRS LPF and TRS LPF with DGS structures.

Fig. 6 Photograph of the fabricated four-cell LPF.

Design of the Four-Cell LPF

The proposed LPF is designed based on Rogers RT/duroid 5880 (substrate thickness = 10 mil, $\epsilon_r = 2.2$, $\tan(\delta) = 0.0009$).

The single cell of the designed LPF is shown in Fig. 4. Firstly, the frequency response of the TRS LPF is simulated and shown in Fig. 5. It features low-pass response with shape roll-off and f_c at 2 GHz. But the stopband is only to 14 GHz for 10 dB rejection. Then, the proposed face-to-face E shape DGS is defected on the ground plane. Its stopband rejection improves by more than 20 dB from 20 to 35 GHz. Another circular DGS shape is also defected under the coupled line to remove the undesired transmission pole at 17 GHz. Thus, the stopband is

extended from 14 GHz to 35 GHz, without increasing filter size. Finally, the four-cell LPF is designed by cascading the single cell and inserting via wall to reduce cross coupling between the four cells.

The fabricated filter is only 5×1.3 cm² including the testing structures, that is shown in Fig. 6. The scattering parameter of the filter is measured using Rohde & Schwarz VNA ZVA-67, after standard SOLT calibration. As shown in Fig. 7, the four-cell LPF achieves low-pass response with f_c at 1.6 GHz, and stopband rejection better than 20 dB up to 38.5 GHz, which is 24 times the f_c . The passband insertion loss is less than 1 dB and return loss is better than 20 dB.

Conclusion

This paper proposed the face-to-face E shape DGS structure. It is studied and investigated using EM simulation with assist of electric field distribution plots. The proposed structure was defected under the TRS to improve the stopband rejection, with no additional area occupation. The four-cell filter was designed and verified experimentally. Low insertion loss, shape roll-off, and ultra-wide stopband was achieved in the fabricated filter.

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