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IMPROVED SPIRAL COMPACT MICROSTRIP RESONANT CELL WITH OPEN STUB LINES

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Abstract: An improved spiral compact microstrip resonant cell (SCMRC) was presented. The improved SCMRC with microstrip open stub lines was designed to achieve 50Ω port impedance in the low-pass band. Also, the microstrip open stub liens are resonant at the stop-band of the SCMRC resulting in the stronger slow-wave effect and wider stop-band. The proposed improved SCMRC was designed, fabricated, and measured. It shows the lower insertion loss, improved return loss in the low-pass band, and wider stop-band with compact size.

Key words: microstrip open stub line; spiral compact microstrip resonant cell (SCMRC); slow-wave; stop-band
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一种使用开路并联线的改进型螺旋微带谐振单元

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摘要:提出了一种改进型螺旋微带谐振单元(SCMRC)的结构.该改进型螺旋微带谐振单元具有微带并联开路线,在低频通带内通过设计达到50Ω的端口阻抗.同时,并联的微带开路线在SCMRC结构的禁带中谐振,来实现更强的慢波效应和更宽的禁带.实际设计、制作和测试了该改进型螺旋微带谐振单元,该滤波器在低频通带内具有低插入损耗、改善的回波损耗,以及在较小面积下的宽禁带.

关 键 词:微带并联开路线;螺旋微带谐振单元;慢波;禁带

Introduction

Photonic bandgap (PBG)[1] structures emerged to control electromagnetic wave propagation by constructing artificial periodic discontinuities, which were periodical cells composed of dielectric or metallic elements and satisfying Bragg condition. The PBG structures were developed for use at optical frequencies. It also can be applied to microwave and millimeter-wave circuits. In recent years, many electromagnetic bandgap (EBG) structures have been reported and widely used in microwave circuits for harmonic suppression or efficiency improvement etc.

Previously, two-dimensional (2—D) EBG structures were proposed for antennas and microstrip circuits applications consisting of periodical air holes, which were micromachined or drilled through the substrate in order to get stop-band in microwave and millimeter-

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wave frequency. However, it is difficult to fabricate in hybrid microwave integrated circuits (HMIC) and monolithic microwave integrated circuits (MMIC) process. The uniplanar compact PBG (UC-PBG) structure has been realized by etching in the ground plane and connected with narrow lines [2~3]. Thus holes on substrate are not required. The defected ground structurs (DGS) were reported in references [4—6]. DGS has good stop-band performance with compact circuit area. The UC-PBG and DGS structures are easy to manufacture and more frequently used in microwave and millimeter-wave circuits and antennas. However, the components with UC-PBG or DGS structure must be suspended from ground plane avoiding the invalidation of EBG function.

In 2 000, Q. Xue published a compact microstrip resonant cell (CMRC) structure [7], which can be realized by etching specific patterns inside microstrip line in order to obtain EBG function without etching on the ground plane. The spiral compact microstrip resonant cell (SCMRC) [8] can further enhance the slow-wave effect and enlarge the stop-band bandwidth for better performance. Consequently, it has been incorporated into microwave and millimeter-wave circuits for purpose of minimization and harmonic rejection.

Compared with the previous SCMRC, an improved SCMRC with compensated open stub microstrip lines is proposed in this paper. The improved SCMRC exhibits wider stop-band and stronger slow-wave effect. In order to verify the improved performances, the original SCMRC and the improved one are designed, fabricated, and measured. Both filters are fabricated on a substrate

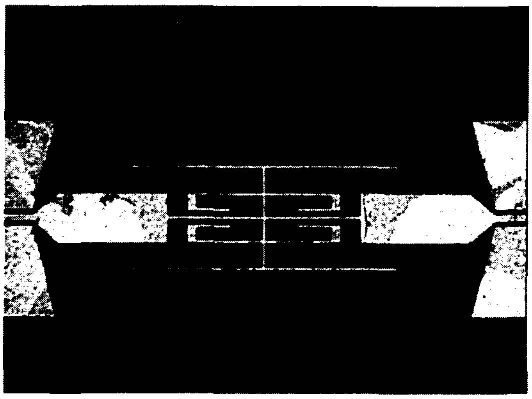

Fig. 1 Top view photograph of an improved SCMRC.

with a relative dielectric constant of 9.8, a loss tangent of 0.003, and a thickness (h) of 0.635mm.

1 Design

According to transmission line theory, the propagation constant of a lossless line is:

$$\beta = \omega_0 \sqrt{LC} \quad , \tag{1}$$

where L and C are the per-unit-length series inductance and shunt capacitance, respectively. According to the SCMRC structure, both series inductance and shunt capacitance are increased in order to achieve the desired slow-wave and stop-band performance. However, a high reflection coefficient results in high insertion loss when this SCMRC is used as a low-pass filter. The characteristic impedance of a lossless transmission line is:

$$Z_0 = \sqrt{L/C} \quad . \tag{2}$$

The series inductance is increased more than the shunt capacitance in the original SCMRC according to the simulated results. According to equation (2), the value of L and C should be tuned in order to change the characteristic impedance of microstrip transmission line.

In this paper, microstrip open stub lines are added at the center of the SCMRC to compensate the unbalanced change of inductance and capacitance. Fig. 1 is a photograph of the improved SCMRC structure. In this way, the transmission performance of the SCMRC is improved at the low-pass band. Moreover, SCMRC with open stub microstrip lines has stronger slow-wave effect and is better for size reduction. The pattern is etched inside the 50Ω microstrip line. The line width between SCMRC is chosen to realize 50Ω characteristic impedance.

Four compensated microstrip open stub lines are designed as $\frac{\lambda}{4}$ resonator according for the center frequency of stop-band. Four microstrip open stub lines also show the capacitive loading effect in the low-pass band to compensate the unbalanced port impedance. Fig. 2 shows the simulated input impedance of the original SCMRC and the improved SCMRC with four microstrip open stub lines. The port impedance of the original SCMRC is near 100Ω. In order to match this

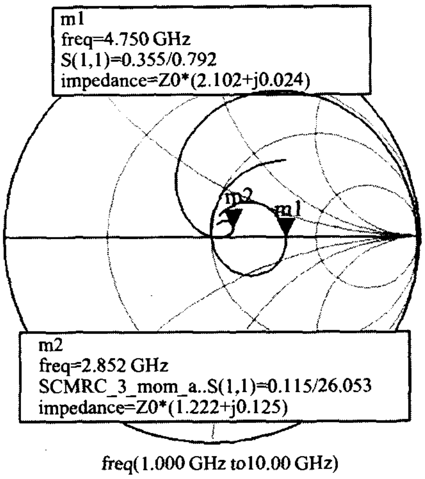

Fig. 2 Simulated input impedance in the low-pass band of the SCMRC (m1) and the improved SCMRC (m2).

port impedance to 50Ω, four parallel microstrip stub lines are connected at the center of the SCMRC. Thus the port impedance of the new SCMRC is decreased to 60Ω, which locates near the center of the Smith chart. Thus, the low insertion loss, low reflection coefficient in the low-pass band and wide stop-band as well as compact circuit area are achieved with this structure. A via-less coplanar waveguide to microstrip transition[9] for cascade probes measurement system is also designed for measurement.

2 Measured results

The layouts of the original SCMRC and the improved SCMRC are shown in Fig. 3. The width of 50Ω microstrip line is 0. 63mm. The width of the compensated microstrip open stub lines is 0. 04mm, which is the

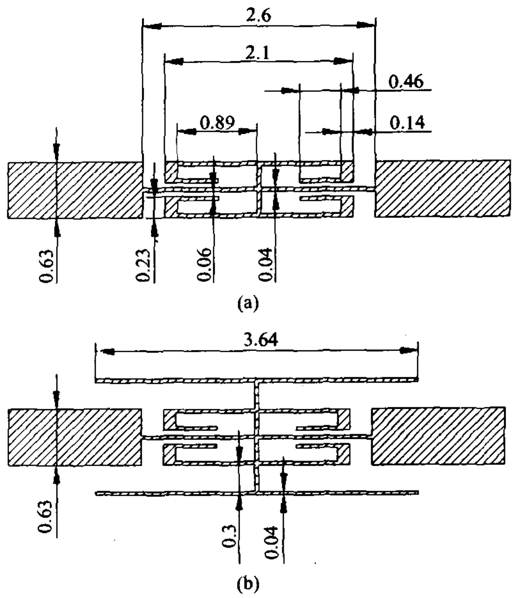

Fig. 3 Layout of the original SCMRC and the improved SCMRC. (a) the original SCMRC, (b) the improved SCMRC. (unit: mm)

thinnest line in our fabrication process. The length is 1. 8mm so that the resonant frequency of the open stub lines is at 18GHz. To demonstrate the improved performance, the other dimensions of the SCMRC structures are remain unchanged. The both two kinds of SCMRCs were measured with a vector network analyzer (HP8722D) and cascade probes measurement system. Measured results are shown in Fig. 4.

As can be seen in Fig. 4, the -10dB stop-band width for the original SCMRC is from 10. 8GHz to 22. 4GHz, while the proposed one is from 8. 0GHz to 22. 8GHz. The maximal attenuation pole, shifting from 14. 4GHz to 10. 5GHz, demonstrates the stronger slow-wave effect. Four compensated microstrip open

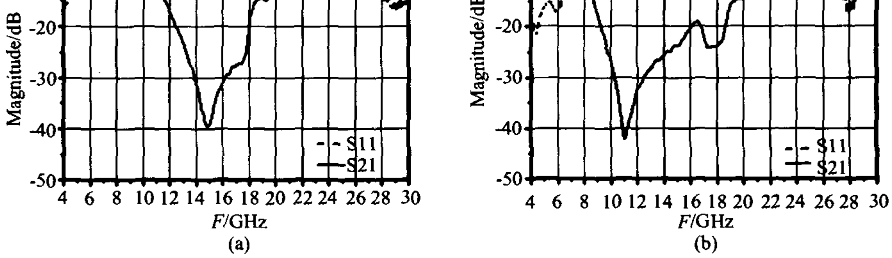

Fig. 4 Measured S-parameters of the orginal SCMRC and the improved SCMRC: (a) the original SCMRC, (b) the improved SCMRC.

stub lines, resonanting at 18GHz, enlarge the stop-band. Moreover, the peak return loss of the improved SCMRC is below-15dB in the low-pass region. The insertion loss of the improved SCMRC is below 1dB including the insertion loss of two via-less coplanar waveguide to microstrip transitions.

3 Conclusion

In this paper, an improved SCMRC is presented with compensated microstrip open stub lines at the center. The measured results of the proposed SCMRC indicate lower insertion loss in low-pass band, an enlarged stop-band, and a stronger slow-wave effect are over the previously reported SCMRC structure. The newly uniplanar SCMRC will be very useful for various HMICs and MMICs without any additional process.

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