A miniaturized band rejection filter with new compact PBG (photonic band gap) cell employing T-type microstrip line

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***Abstract*—A new type of compact microstrip line photonic band gap(PBG) structure employing T-type microstrip line for filter is presented. A miniature band rejection filter with four cells is simulated, fabricated, and measured. The filter with four proposed PBG structure exhibits band rejection characteristics (lower than -10dB from 23GHz~32GHz). The center frequency of stop-band is at 28GHz. The period of the PBG lattice is about 0.15λ_e. The line length of the filter with PBG cell employing T-type micorstrip line was reduced to about 10.4mm, and its size was 14% of the conventional band rejection filter. The filter is very compact and much easier for fabrication and realization in MIC and MMIC.**

Key words: microstrip, photonic band-gap (PBG), T-type microstrip line, band-stop filter, MMIC.

I. INTRODUCTION

RF components dealing with high frequency signals are most important in wireless communication system and the performance of the system depends on them. In RFIC device such as PA and Mixer, Filters such as LPF or BPF is required for its operation. Filter is one of the passive components widely used in order to get wanted frequency or get rid of unwanted frequency. However, conventional bulky Filters such as LPF or BPF highly increase the circuit size and manufacturing cost. The development of miniaturized on-chip filters will especially greatly reduce the size of MMICs. A structure of PBG is proposed in order to solve problem of size of bulky filters. The idea of employing photonic band-gap (PBG) was first proposed by Yabnolovitch in 1987[1]. A PBG device is a periodic structure where electromagnetic waves in a certain frequency band cannot propagate or are strongly attenuated. Therefore they are used widely for electromagnetic wave propagation control. The size of devices can be reduced with PBG.

Several PBG structures etching in the ground plane have been presented[2]. But, disadvantage of these kinds of structure comes from the packaging problem and realization of MMIC. A sandwich structure of PBG is proposed[3]. This structure can avoid the packaging problem, but realization in MMIC is still very difficult. For this reason, Nesic has proposed a novel PBG microstrip structure without etching in the ground plane for filter[4].

In this work, we propose a new miniaturized microstrip PBG structure employing T-type microstrip line for filters. The filter adopting the proposed PBG structure exhibits wider, deeper and steeper stop-band characteristics. A miniature PBG employing T-type line based structure band-stop filter with four cells is simulated, fabricated, and measured. The period length of the PBG lattice is about 0.15λe where λe is the guiding wavelength at center frequency of stop-band. Its size was 14% of conventional band rejection filter[5]. The simulation was performed using Advanced Design SYSTEM (ADS).

II. Design of The New PBG Cell Employing T-Type Microstrip Line

The proposed conventional PBG cell by W. Zhang[6] is shown in Fig 1. It was used for the fabrication of conventional PBG cell filter, which resulted in deep band rejection characteristics of the filter and its size reduction. In this work, we propose a new type PBG cell for a filter reduction of the filter size. Concretely, we propose PBG cell employing T-type microstrip line for size reduction.

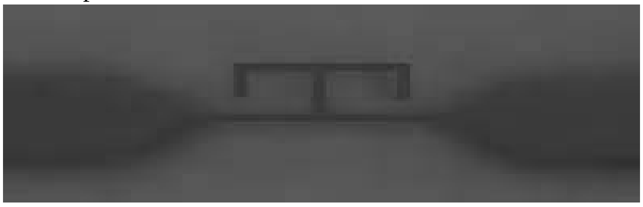


Fig. 1. The proposed conventional PBG cell.

Fig 2-(a) and (b) show a quarter-wavelength line and conventional T-type microstrip line structure equivalent to the quarter-wavelength line, respectively. The Eq. (1) and (2) are ABCD parameters of Fig. 2. (a) and (b), respectively. The Eqs. (3)-(4) should be satisfied in order that the conventional T-type microstrip line may be equivalent with the quarter-wavelength line[7].

$$\begin{pmatrix} \cos\theta' & jZ'\sin\theta' \\ j\dfrac{\sin\theta}{Z'} & \cos\theta' \end{pmatrix} \tag{1}$$

$$\begin{pmatrix} \cos\theta & jZ\sin\theta \\ j\dfrac{\sin\theta}{Z} & \cos\theta \end{pmatrix}\begin{pmatrix} 1 & 0 \\ j\omega C & 1 \end{pmatrix}\begin{pmatrix} \cos\theta & jZ\sin\theta \\ j\dfrac{\sin\theta}{Z} & \cos\theta \end{pmatrix} \tag{2}$$

$$Z\omega C = t \tag{3}$$

$$t = \frac{2(\cos 2\theta - \cos\theta')}{\sin 2\theta} \tag{4}$$

From Eqs. (1)-(4), we can see that, the conventional T-type microstrip line may be equivalent with the quarter-wavelength line. In addition, we can see that, as the line length of the T-type microstrip line becomes shorter, a shunt capacitor C and characteristic impedance Z become larger. In this work, we propose a new miniaturized microstrip PBG structure employing T-type microstrip line in order to reduce size of conventional PBG cell. The designed PBG cell employing T-type microstrip line is shown in Fig. 3. The propagation constant of the microstrip line without loss is $\beta=2\pi f_0\sqrt{LC}$, where f_0, L, C are center frequency, inductance, capacitance of the line, respectively. By the way, if the value of L and C are increased, keeping constant value for the ratio of L and C, the propagation constant β can be increased. For this reason, PBG cell reduces passive circuit size.

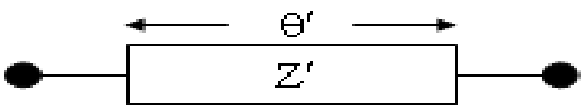
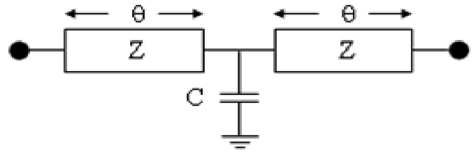


Fig. 2. (a) A quarter-wavelength line.



(b) Conventional T-type single microstrip line

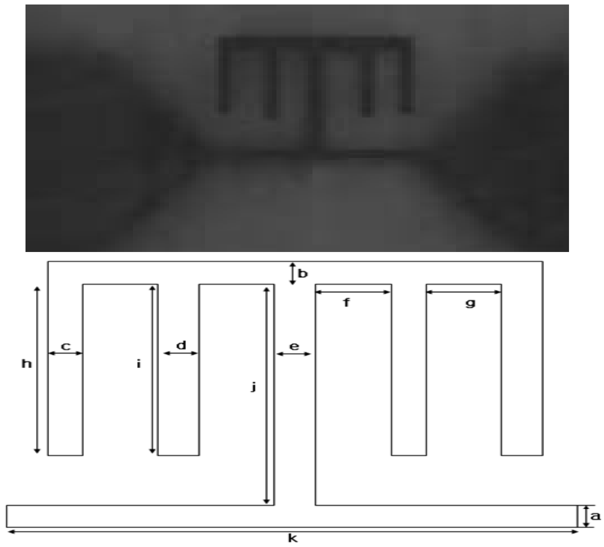


Fig. 3. The proposed microstrip PBG cell employing T-type microstrip line ($1.1\times0.73\text{mm}^2$).

In this work, a=b=c=d=e is assumed for simple design. By connecting identical cells, in series, the periodic structure will exhibit typical band-stop characteristics of PBG.

III. Measurement Results

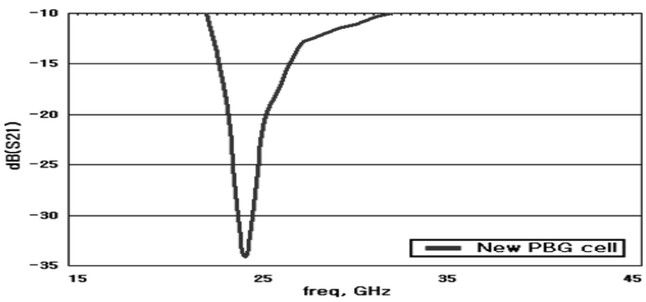


Fig. 4 S_{21} characteristics for the simulated PBG cell employing T-type microstrip line.

The characterization of the proposed PBG cell employing T-type microstrip line is simulated, and the insertion loss (S_{21}) or the simulated new PBG cell employing T-type microstrip line is shown in Fig. 4. From the Fig .4, we can see that the proposed PBG cell is a kind of resonant circuit. By connecting identical cells in series, the periodic structure will exhibit typical band-stop characteristics of PBG. The center frequency of stop-band approaches to resonance frequency of PBG cell, also relies on the period k. The center frequency of stop-band is at 30GHz. The guiding wavelength λe at 28GHz is 6.95mm. The length of PBG employing T-type microstrip line is 1.1mm, amounting to 0.15(e. The size of proposed PBG cell employing T-type micro strip line was reduced compared with conventional PBG cell (The length of conventional PBG cell is 0.23(e)[5].

According to the above statement, a filter with two and four PBG cells was fabricated and its stop-band characteristics was investigated. The used substrate is Teflon with a dielectric constant of 3.5 and thickness of 0.508mm. Fig. 5 is band-stop filter with two PBG cells employing T-type microstrip line and Fig. 6 is band-stop filter with four PBG cells employing T-type microstrip line. The cell parameters are a=b=c=d=e=0.1mm, f=0.12mm, g=0.12mm, h=0.41mm, i=0.41mm, j=0.53mm, and k=1.1mm. The measured insertion loss(S_{21}) of filter with two PBG cells and four PBG cells are shown in Fig. 7 and Fig. 8, respectively. The filter with two PBG cells employing T-type microstrip line exhibits band rejection characteristics(lower than -10dB from 25 GHz~ 31 GHz). The center frequency of stop -band is at 28 GHz.

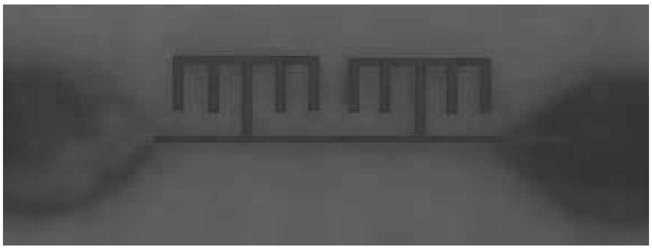


Fig. 5 Realized Filter with two PBG cells employing T-type microstrip line($2.2\times0.73mm^2$).

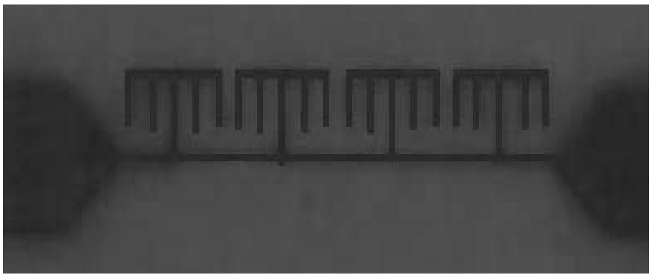


Fig. 6 Realized Filter with four PBG cells employing T-type microstrip line($4.4\times0.73mm^2$).

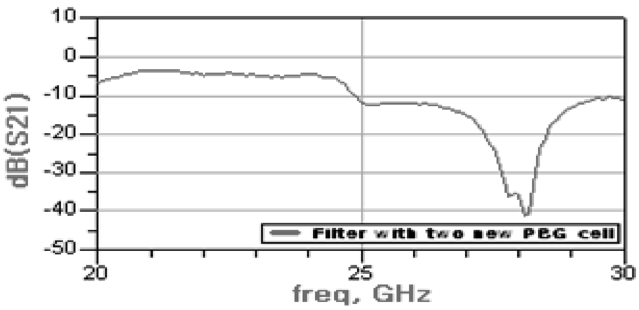


Fig. 7 S_{21} characteristics for the realized filter with two PBG cells employing T-type microstrip line.

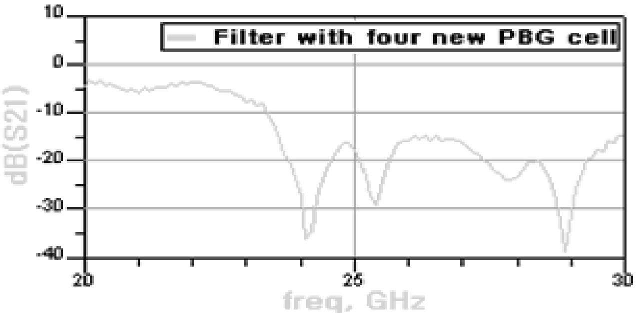


Fig. 8 S_{21} characteristics for the realized filter with four PBG cells employing T-type microstrip line.

The length of PBG structure is 2.2mm, corresponding to 0.316λe. The filter with four PBG cells employing T-type microstrip line exhibits band rejection characteristics (lower than -10dB from 23GHz ~ 32GHz). The center frequency of stop-band is at 28GHz. The total length of the realized structure with four PBG cells employing T-type microstrip line is only 4.4mm, about $0.632\lambda_e$. Its size is $3.2mm^2$, which is 14% of the conventional filter[5]. Fig. 9 shows the dependency of band rejection characteristics on the number of cells. As shown in Fig. 9, we can see, as the number of cells is increased, the bandwidth becomes wider compare with conventional PBG filter.

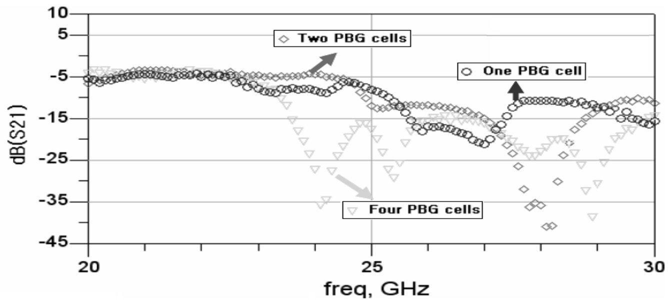


Fig. 9 Dependency of Band rejection characteristics on the number of cells.

IV. CONCLUSION

In this paper, we proposed a new type of compact PBG filter employing T-type microstrip line in MMIC. The center frequency of stop-band is 28 GHz. The length of the PBG cell is 1.1mm, corresponding to 0.15λe. The size of the proposed PBG cell was highly reduced by using T-type microstrip line. We fabricated band rejection filter by used the new PBG cells. Its size is 14% of the conventional filter. The filter with proposed new PBG cells employing T-type microstrip line is very compact and much easier for fabrication and integration with other circuits and can be applied in MIC and MMIC directly.

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