Design of CFD Structured Microstrip Line Bandpass Filter

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CFD 구조의 마이크로스트립 라인 가변 대역통과필터 설계

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요 약

본 논문에서는 CFD 구조에 기반한 마이크로스트립 라인을 이용하여 커플링 개수가 3개인 가변 대역통과 필터를 제안한다. 바이어스 전압을 증가시키면 강유전체의 실효 유전율(εeff)이 감소하고, 감소된 실효 유전율은 중심 주파수를 높은 값으로 이동시킨다. 설계된 필터는 εeff이 13~10에 걸쳐, 반사 손실이 10 dB 이상, 삽입손실이 3.5 dB 이하, 3-dB 대역폭이 1.18 GHz 이하, 중심 주파수는 25.4 GHz에서 28.8 GHz까지 이동하므로 가변성은 3.4 GHz에 달하는 특성을 보인다. 필터의 크기는 7.0 mm × 5.0 mm × 0.5 mm이다.

ABSTRACT

In this paper, a 3-coupled microstrip line tunable bandpass filter has been designed on the basis of a Conductor/Ferroelectric/Dielectric (CFD) structure. This tunable filter basically exploits the fact that the increase in the bias voltage leads to the reduction of the effective dielectric constant (εeff). This reduced εeff shifts the center frequency (fc) to the higher value. The characteristics of designed filter are as follows; Return loss (RL) is larger than 10 dB; Insertion loss (IL) is less than 3.5 dB; 3-dB bandwidth (BW) is less than 1.18 GHz; fc can be tuned from 25.4 GHz to 28.8 GHz over the variation of εeff, from 10 to 13. Therefore, the tunability comes up to 3.4 GHz. The dimension of the filter designed is 7.0 mm × 5.0 mm × 0.5 mm.

키워드

Ferroelectric, bandpass filter, coupling, insertion loss, return loss

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Ⅰ. Introduction

Recently, there have been intensive studies on the wireless communication systems particularly to make the elements into smaller size, lighter weight with even lower power loss than ever. It is inevitably needed to implement a narrow bandwidth filter to allocate more frequency band in a limited frequency resources. Transmission line can be divided into 3 structures, namely, microstrip line, CPW, CBCPW. Among these structures, both CPW and CBCPW have good performances in TEM mode mainly because signal line and ground plane coexist in upper plane. However, in high frequency beyond C-band, the upper ground plane can function as an undesired signal line. Thus, there becomes a signal distortion between the signal line and the ground plane, which makes it difficult to design a desirable filter. Whereas, if microstrip lines are used instead, the ground plane is at the bottom of filter and thus the signal distortion can be significantly suppressed. In addition, there are many skills reported to significantly reduce the filter size. For example, there are the use of the high dielectric materials, the use of meandering microstrip line resonator, the reduction of the propagation velocity by increasing the internal inductance, the use of the slow wave transmission line, etc. In particular, the technique of meandering the microstrip line is mainly used for smaller size RF components. The increase in the applied bias voltage tends to decrease the relative dielectric constant of ferroelectrics. Thus, the tunability of the bandpass filter can be controlled. Both STO and BSTO are the typical high dielectric constant ferroelectric materials used to obtain the tunability [1][2][3]. The STO is usually used in low temperature like 100 K, and shows good performances such as low loss and low power consumption. But in room temperature, it does not show such a good performance any more. To overcome this temperature limit, the BSTO is used. Just below the BSTO layer, the MgO substrate is positioned to stabilize the total dielectric multilayers. In consequence, the MgO substrate can prohibit the BSTO layer from being broken from the abrupt bias voltage applied. The BSTO/MgO composite layers offer some advantages over other available field-tunable technologies such as pure BST ceramics, BST thin films, strontium titanate and high-temperature superconductors. In other words, the BSTO/MgO composite layers show a relatively lower dielectric constant, allowing for an easier impedance matching to air for high frequency antenna applications, a higher tunability, lower dielectric losses at microwave frequencies, and a wide range of possible operating temperature. In this paper, a 3-coupled tunable bandpass filter using microstrip line has been designed and its simulation result is demonstrated.

Ⅱ. Basic concept of tunable bandpass filter

Equations (1), (2) explain how the capacitance and center frequency (fc) can be changed in thin dielectric film structure. Fig. 1 shows the variation of dielectric constant of ferroelectrics according to the electric field [4]. As the bias voltage increases, the effective dielectric constant (εeff) decreases and the reduced εeff moves the fc to the higher value. Like this way, fc can be adjusted by controlling the bias voltage.

$$f_c = \frac{1}{2\pi\sqrt{LC}} \qquad (1)$$

$$C = \frac{\varepsilon_0 \varepsilon_r S}{d} \qquad (2)$$

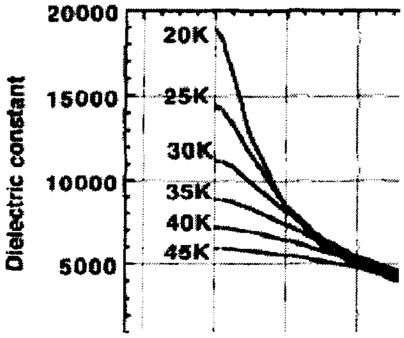

Fig. 1. Variation of dielectric constant of ferroelectrics according to the electric field [4]

Fig. 2 shows the side-view of designed filter. The thickness of the bottom ground plane is 2 um, the MgO thickness is 500 um, the BSTO thickness is 0.5 um, and the thickness of the upper signal line is 1 um. The relative dielectric constant of MgO layer is 10 and that of BSTO varies widely according to the applied bias voltage. The width of the signal line for 50 Ω matching is determined by equations (3) and (4) [5].

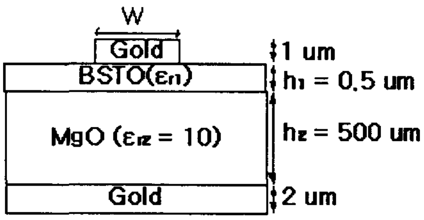

Fig. 2. Side-view of proposed filter

$$Z_0 = \frac{377}{\sqrt{\varepsilon_{eff}}\left(1.393 + \frac{W}{h} + \frac{2}{3}\ln\left(\frac{W}{h} + 1.444\right)\right)} \quad (3)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-0.5} \quad (4)$$

Fig. 3 shows the top-view of the designed filter where W is 500 um for 50 Ω matching, S1 is 120 um, S2 is 1300 um, and the other dimensions are described in Fig. 3.

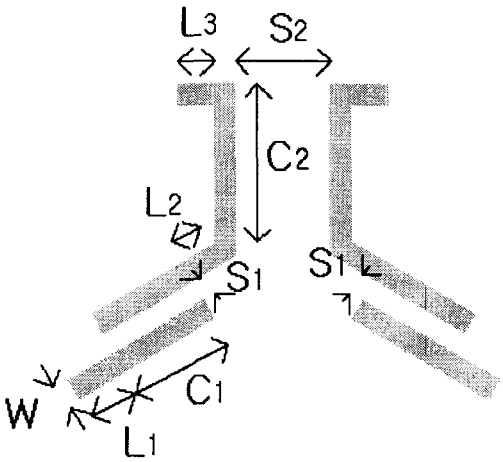

Fig. 3. Top-view of proposed filter where W = 500 um, L1 = 500 um, L2 = 1000 um, L3 =500 um, C1 = 1500 um, C2 = 2300 um, S1 = 120um, S2 = 1300 um

III. Simulation result

Fig. 4 shows the return loss (RL) characteristics of the proposed tunable bandpass filter for the variations of effective dielectric constant (εeff) from 10 to 13 with step of 1. When the εeff is 13, fc is 25.4 GHz and RL is 16 dB while as the εeff decreases up to 10, the fc shifts to the higher value, and RL characteristic gets worse.

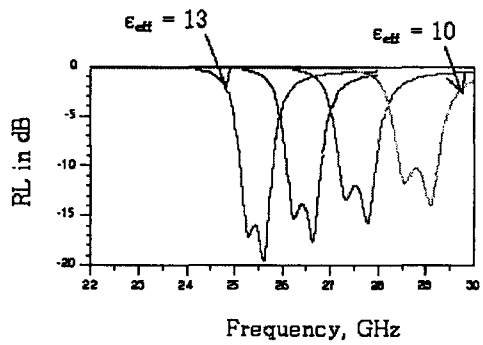

Fig. 4. RL characteristics of proposed filter for the variations of εeff, 13∼10 with step of 1

Fig. 5 shows the insertion loss (IL) characteristics of the proposed tunable bandpass filter for the variation of εeff, from 10 to 13 with step of 1. As the εeff decreases from 13 to 10, the IL characteristic becomes worse and the bandwidth (BW) gets widended from 0.95 GHz to 1.18 GHz.

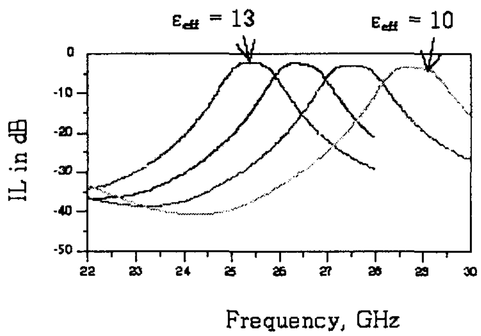

Fig. 5. IL characteristics of proposed filter for the variations of εeff, 13~10 with step of 1

The details of RL, IL, fc, and BW with the variations of εeff are shown in Table 1. Here, the values of RL and IL are measured at fc. As the ε eff decreases, RL and IL characteristic becomes worse and fc moves to the higher frequency side, and the BW becomes wider. Table 2 shows the details of RL, IL, fc, and BW with the different lengths of L3. As the L3 increases, the RL characteristic gets improved more, the IL characteristic becomes worse, the fc moves to the lower value side and the BW becomes narrower.

Table 1. Details of RL, IL, fc, and BW for different effective dielectric constant (εeff).

ε_{eff}	13	12	11	10
RL (dB)	16	13	11	10
IL (dB)	2.3	2.6	3.0	3.5
f_c (GHz)	25.4	26.4	27.5	28.8
BW (GHz)	0.95	0.99	1.07	1.18

Table 2. Details of RL, IL, fc, and BW for the different length of L3.

L_3 (um)	300	500	700
RL (dB)	12	16	22
IL (dB)	2.4	2.3	2.6
f_c (GHz)	25.9	25.4	24.6
BW (GHz)	1.06	0.95	0.85

IV. Conclusion

In this paper, we designed a 3-coupled tunable bandpass filter using 2 microstrip line resonators based on the BSTO/MgO structure. When the εeff is 13, fc is 25.4 GHz, RL is 16 dB and IL is 2.3 dB. Whereas, as the εeff decreases up to 10, the fc moves to 28.8 GHz; RL changes to 10 dB; IL changes to 3.5 dB. Therefore, the tuning range comes up to 3.4 GHz. The proposed bandpass filter seems highly promising for future wireless communication applications.

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