A Tunable Bandstop Filter Design Using Parallel Coupled Line Resonator with Varactor

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Introduction

As wireless communication systems are rapidly developing, the compact design of high performance bandstop filters has been demanded. Many researches have been carried out on defected ground structure (DGS) for microwave circuit applications. The filters using DGS have been extensively researched [1]-[5]. Also, tunable bandstop filters which employ a shunt capacitor between the resonator and the ground plane have been developed in addition to the fundamental bandstop filters.

In this paper, we propose the new method of achieving a tunable bandstop filter. The tunable bandstop characteristic is obtained by inserting quarter-wavelength stubs with varactor diode.

Tunable Bandstop Filter Design

Fig. 1 shows the configurations of the $\lambda_g/4$ open stub resonator without varactor diode. The resonator is located under the microstrip line and connected to the microstrip line through a via hole. The energy stored in the resonant structure is mainly determined by the electromagnetic fields of the odd propagating mode. The energy and the bandwidth can be reduced by making the coupled lines close together, which means that the characteristic impedance for the odd mode is reduced [6]. The resonator is designed at fundamental resonant frequency of 4.7 GHz and fabricated without varactor. The operating frequency can be changed by the length (mm) of the resonator. Added microstrip lines are incorporated in the proposed bandstop filter so as to complement DGS which is realized by etching off the defected patterns from the ground plane.

Fig. 2 shows the geometry of the proposed tunable bandstop filter. The RF35/Taconic substrate with thickness $h$ (=0.5 mm) and the relative permittivity 3.5 are used. $L$ (=40 mm) and $W$ (=30 mm) denote the length and the width of dielectric substrate, respectively. The width of the microstrip line is 1 mm for 50 Ω line impedance. The dimensions of the added microstrip lines are as follows : $a = 0.55$ mm, $b = 11.46$ mm, $c = 2.15$ mm, and $d = 0.65$ mm. On the other side of the substrate, the resonator has a length ($e$) of 9.2 mm, width ($f$) of 1 mm.

In this study, we apply a varactor diode which has variable capacitance to change the electrical length. Consequently, the bandstop frequency can be tuned. A variable capacitance diode (KDV316E, KEC Corp.) is employed and its capacitance varies from 7.22 pF to 0.48 pF with respect to the reverse bias of 1 V to 25 V. Chip inductors of 10 nH are added to both sides of the varactor as RF chokes.

The conceptual equivalent circuit model for the proposed bandstop filter is given in Fig. 3. The entire resonator including the varactor and the stub can be represented with a variable capacitance diode in series with a transmission line.
Experimental Result

The bandstop filter fabricated by etching is shown in Fig. 4. As shown in this figure, a 50 Ω SMA connector is soldered to excite the signal. Simulations and measurements are performed to obtain the frequency response without varactor diode and chip inductors as shown in Fig. 5(a). In order to achieve the target resonant frequency of 4.7 GHz, the dimensions of the resonator are chosen using CST Microwave studio. The measured result agrees properly with the simulation result. The resonant frequency is measured 4.7 GHz and the stopband bandwidth with -10 dB reference level is 0.1 GHz (4.67-4.77 GHz). The measurements with a varactor diode are performed for the different bias voltage conditions and the measured results (|S11|, |S21|) are shown in Fig. 5(b) and (c). The resonant frequency and the percent bandwidth are summarized in Fig. 5(d). As reverse bias voltage decreases, the resonant frequency shifts to the lower frequencies. The resonant frequency is changed from 1.04 GHz to 3.13 GHz.

Conclusions

In this paper, a novel tunable bandstop filter has been proposed and fabricated. This filter is compact because the resonator is located under the microstrip line not to occupy much space. The equivalent circuit model of the proposed structure is proposed. By employing a varactor diode which has variable capacitance, the tunable bandstop characteristic is achieved. The fabricated bandstop filter shows good tunability (1.04-3.13 GHz).

References

Figure 1. Electric field for a bandstop filter with the proposed resonator

Figure 2. Geometry of the proposed bandstop filter

Figure 3. Conceptual equivalent circuit model for proposed filter
Figure 4. Fabricated bandstop filter

Figure 5. (a) Simulated and measured results without a varactor (b) Measured results ($|S_{21}|$) for different bias conditions (c) Measured results ($|S_{11}|$) for different bias conditions (d) Resonant frequency and percent bandwidth of the proposed bandstop filter