Journal of the Korean Institute of Illuminating and Electrical Installation Engineers Vol. 20, No.9, pp. 40~44 November 2006

논문 20-9-6

Implementation of Tuneable Filter Using CPW Coupled Line and Varactor Diode

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Abstract

This study investigated a new tuneable bandpass filter based on coplanar waveguide coupled line structure, and using the varactor diode for tuning the center frequency of the filter. The filter was designed by a commercial simulator and had a tuning range of 180[MHz] from 0.95[GHz] to 1.13[GHz]. The filter acceptable values regarding the insertion loss was less than 3[dB] and its return loss greater than 12[dB]. The figure of merit of the implemented tuneable filter increased with the reverse bias voltage up to 14[V] on the varactor diode. The proposed filter has a promising future as it can be used in integration processes and in various materials as substrate.

Key Words : CPW(Coplanar Waveguide), Coupled Line, Varactor Diode, Tuneable Filter, Figure of Merit

1. Introduction

In modern electronic communication systems, tuneable filters capable to adjust frequencies are needed for diverse applications. In order to meet those needs, the use of varactor diodes and ferroelectric materials has been suggested [1-4].

A tuneable filter using a varactor diode on the base of the conventional microstrip circuit, can quickly adjust its frequency, and may present the advantage of having suitable Q values. However, such tuneable filter carries can be source of problems; The manufacturing process becomes complicated due to holes that must be formed on the circuit board when implementing the shunt element in the microstrip, and problems with the blazing. Furthermore, it is difficult to apply it to integrated process.

In the present study, a filter passing the tuneable band on the base of the Coplanar Waveguide (CPW) structure was proposed. The CPW has a flatness figure suitable to the process of integrated circuit using ultra high MMIC (or RFIC) frequencies. Therefore, the CPW may help solve the problems discussed above, operate at low frequencies, and in the future may be suitable for communication equipments using a variety of materials for ubiquitous computing.

Although many studies have been performed with tuneable filters having CPW(Coplanar Waveguide) slot line structure [5], it entails a more complicated manufacturing process, and requires a

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Date of submit : 2006. 5. 2
First assessment : 2006. 5. 9
Completion of assessment : 2006. 8. 3

structure able to convert the microstip into slot line for input and output purposes. In the present study, a broad band pass filter coupled with a varactor diode was designed, in order to be able to adjust the frequency by using the line coupled with the CPW, which can be applied to various materials. Furthermore, the manufacturing of the present system is simple, and its characteristics can be estimated.

2. Filter Design and Implementation

2.1 Varactor Diode

A YIG(Yittrium-Iron-Garnet) with a high quality coefficient capable of tuning the frequency in the wide range was selected to adjust the frequency electrically.

However, the YIG can cause magnetic hysteresis which can decrease the tuning speed. In addition, the YIG is very big and expensive.

In recent years, the varactor diode has generally been used for tuning high speed frequencies. As the varactor diode is used with varying capacitance, in the depletion of PN connection by the voltage applied in reverse, it is possible to actuate it into high speed. The varactor diode is widely used despite having a coefficient of quality lowered than the YIG, an insertion loss higher. Furthermore, it is limited in the adjustable range because it has no hysteresis property.

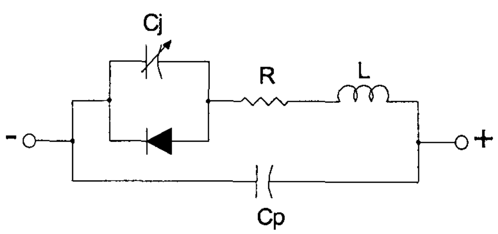


Fig. 1. Equivalent circuit of the varactor diode

The equivalent circuit is shown in fig.1, where C_j is the junction capacitance, C_p the package capacitance, R the resistive component of the varactor diode, and L the component of the inductance.

The capacitance of the voltage applied reversely is expressed according to the following Equation (1).

$$C(V) = \frac{C_j(0)}{(1 + V/V_j)^M} + C_p \qquad (1)$$

Where $C_j(0)$ is the capacitance of zero potential, V the bias voltage applied in reverse, V_j the built up voltage, and M the grading coefficient according to the element.

If the package capacitance in Equation (1) is neglected, then the equivalent circuit may be considered a serial circuit composed of R and $C_j(V)$, as it was assumed in this study.

2.2 Design of band pass filter

The varactor diode used in the present study was a 1SV287 with the following characteristics: Rs=1.9[Ω], C_j(2V)=4.2[pF], C_j(25V)=0.53[pF], M=0.5. [6].

A single side board made of FR4 Epoxy (εr=4.2, t=1.58[mm]) was used to make the CPW filter.

A real band pass filter, not equipped with a varactor diode of CPW structure was designed as described in Figure 2, using a commercial simulator.

The input/output terminals were used with a 50 [Ω] SMA connector, and the impedance for the input/output of the filter was fixed at 50[Ω]. As shown in Figure 3, the circuit pattern was formed using milling machine.

The DC bias was applied with the 1~20[V] voltage of direct current to be biased against the varactor diode by drawing the wires into the center of the central line as shown in Figure 3.

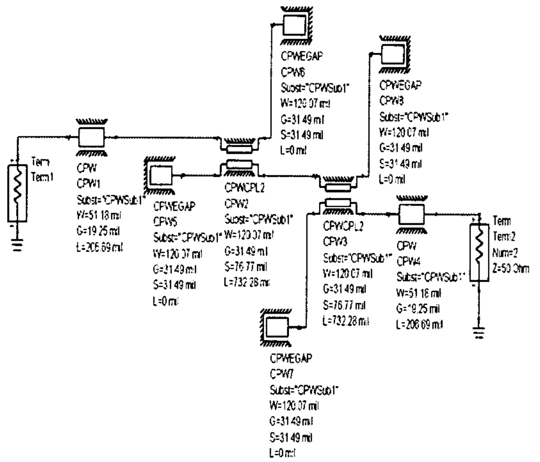
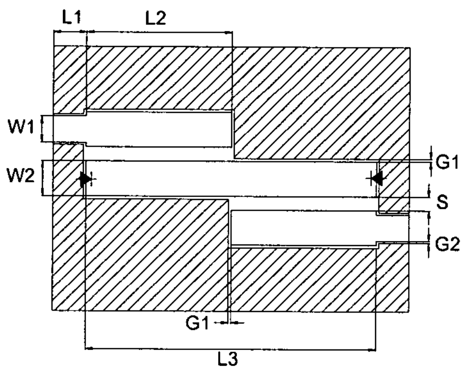
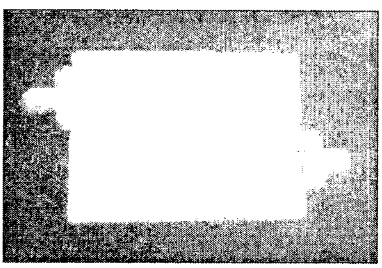


Fig. 2. The design of the CPW bandpass filter using commercial simulator



(a) The figure of the designed CPW filter



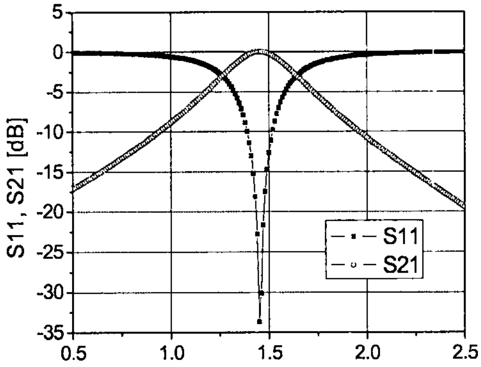
(b) The fabricated CPW bandpass filter

Fig. 3. The implement of the designed filter

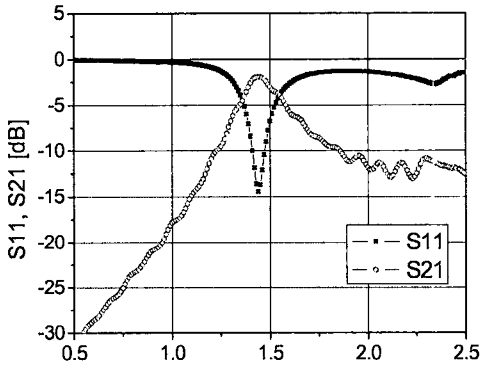
3. Test Result

The simulation values and measured data of the S11 and S21 over the filter made are shown in Figure 4. At the time of the measurement, the character of the filter was estimated by measuring the S parameter using an Agilent 8722ES Vector Network Analyser. When compared the simulation results with the measurement values of the filter, and designed by the simulator, the center frequency was 1.45[GHz], and coincided well with the design value. The values of the following parameters were determined: The insertion loss was 2[dB] within the band pass, and the reflection loss was 14.5[dB]. The cutoff's property outside the passband was different from the simulation value, appearing the tendency of brazing so that to improve such characteristics, even though an improvement is expected through applying with a number of couple line, it is anticipated that letting the insertion loss be increased within the passband.

Figure 5 shows the variation of the filter characteristics with the voltage when a dc voltage was applied to tune the frequency. The center frequency (0.5[GHz]) shifted from its initial value due to the junction capacitance of the varactor diode. When the applied voltage of dc voltage varied from 1[V] to 20[V], the center frequency changed from 1.13[GHz] to 0.95[GHz] so that it became possible to tune the center frequency around 180[MHz]. The following data were obtained: The band width of 3[dB] was 220 [MHz], the insertion loss was less than 3[dB], and the reflection loss was more than 12[dB]. The more the applied voltage increases, the more the reflection loss and insertion loss improve. The study also found that the bandwidth at 3[dB] becomes wider.



(a) simulated data



(b) measured data

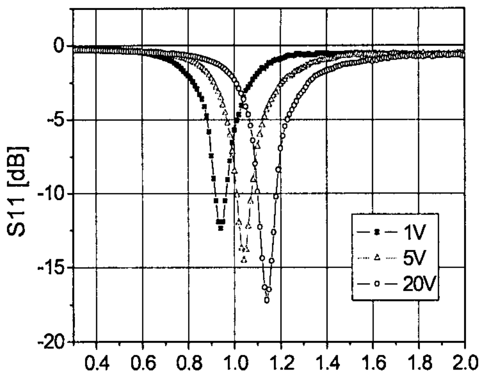
Fig. 4. Characteristics of bandpass filter before mounting the varactor diode for the tuning

4. Consideration

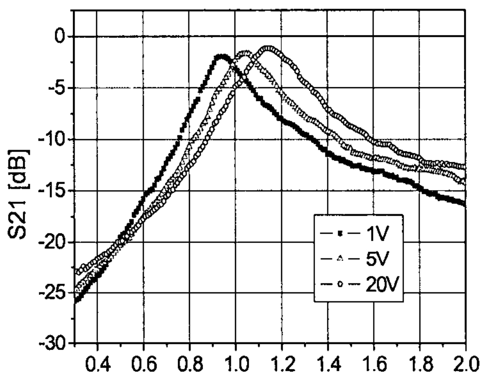
Diverse concepts have been introduced to estimate the performance of tuneable elements. In this paper, the estimation is shown as figure of merit, and is expressed by the equation of performance index of tuneable filter of Vendik (Equation (2)).

$$F = \frac{\omega_{02} - \omega_{01}}{\sqrt{\Delta\omega_1 \cdot \Delta\omega_2}} \cdot \frac{1}{\sqrt{L_1 \cdot L_2}} \ [\mathrm{dB}^{1}] \qquad (2)$$

Where $\omega_{01,02}$ is the center frequency of the filter, $\Delta\omega_{1,2}$ the width of the band pass of the filter, and L_1 and L_2 the insertion loss of the filter.



(a) S11



(b) S21

Fig 5. The change of filter characteristics with bias voltage after mounting varactor diode

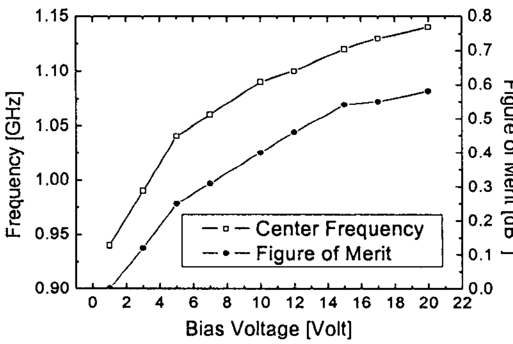


Fig. 6. The change of center frequency and Figure of Merit with bias voltage to tuneable filter

Figure 6 shows the variation of the center frequency and the figure of merit when the voltage of direct current applied was varied between 1~

20[V]. It appears that the figure of merit increased with the applied voltage up to 14[V], however, for the applied voltage to be used for tuneable frequency it is recommended that it remains as small as possible. In the present study, the figure of merit of the filter could be obtained as 0.55 under 14[V] of the applied voltage.

5. Conclusion

The present study designed a tuneable band pass filter using a varactor diode according to electrical lines coupled with a Coplanar Waveguide (CPW), constructed it, and estimated its characteristics. With the bias voltage applied to the varactor diode, the junction capacitance was varied in an applied voltage range of 1~20[V], and it became possible to tune in the range of 180 [MHz} as its center frequency 0.95~1.13[GHz]

We could obtain the characteristics of the insertion loss less than 3[dB,], reflection loss more than 12[dB], and though the reflection loss and insertion loss may be improved in their characteristics, it showed the tendency to wide the band width. The figure of merit displaying the tuneable ability of filter frequency could be obtained the approximate 0.55 under 14[V] of applied voltage, and more than 0.5 for application in practice could be obtained.

By applying the line coupled of multistage structure, the skirt characteristics of cut off region seems to be improved but it is expected that the insertion loss within band pass is increased so that we decided as that this study shall be dealt later

Since the band pass filter of the structure of lines coupled with CPW proposed in the present study has the flat structure, it is expected that will have wide application for respect to the circuit board made of variety material or to integration of circuit.

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