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Wide Bandstop Filter using Interdigital Capacitor and Frequency Selective Coupling Structure

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Abstract: In this study, we propose a microstrip Ultra-Wideband (UWB) Bandstop Filter (BSF) using Dual Interdigital Capacitor Frequency Selective Coupling Structure (DIDC-FSCS). The proposed UWB BSF is designed based on lossless FSCS with transverse wave form. The designed BSF used two $\lambda/4$ lengths to make an interdigital capacitor and then make it dual FSCS. And one Shunt Open Circuit Resonator (SOCR) with an additional $\lambda/4$ length. The SOCR is composed of meander lines. The input and output ports were terminated to 50 Ω for the system application. The designed BSF was simulated using the Sonnet simulator. The measured center frequency is 6.3 GHz, the BSF 3 dB bandwidth is 4.2 GHz and the maximum transmission coefficient and the reflection coefficient are 35.0 and 0.43 dB, respectively. The actual size of the BSF is 10.0×12.57 mm.

Key words: Interdigital capacitor, micro-strip line, ultra-wideband band-stop filter, C-band, meander line, bandwidth

INTRODUCTION

Recently, ultra-high frequency communication has been performing UWB communication between LTE-A, wireless data LAN, satellite communication stations and communication between satellite communication units and earth stations. Then, UWB radio wave interference occurs in the system and during transmitting and receiving of radio waves. Various RF filters have emerged to eliminate and reduce radio interference as much as possible. Among them, UWB BSF is used effectively. It should have wide bandwidth, small size and high selectivity (Ren *et al*., 2015). In this study, we proposed a novel small bandstop filter with a frequency selective coupling structure in the form of left and right symmetry and it is designed to have a frequency bandwidth of 4.2-8.4 GHz. The microstrip line UWB BSF for center frequency and bandwidth control uses two FSCSs of $\lambda/4$ length and one SOCR of $\lambda/4$ lengths (Kim *et al*., 2017a, b). Adding FSCS or increasing the length of the SOCR is used to improve performance but also causes size problems (Shrestha and Kim, 2015). A method for improving bandstop characteristics by applying interdigital between two FSCSs has been introduced (Sanchez-Soriano *et al*., 2010; Hsieh and Wang, 2005). To improve the BSF performance, two FSCSs were combined into two IDCs. In addition, the SOCR was designed as a meander line, which is a quarter wave resonator to increase the transmission zero. This is an effective way to improve the stopband performance by using a shunt stub type FSCS load at the input and output terminals. Transmission zeros can be obtained by interfering signals between two transmission paths (Kim *et al*., 2017a, b). In this study, the broadband BSF is realized by arranging the IDC as the dual FSCS and the SOCR as the meander line. The performance of BSF is greatly improved and it is small and easy to manufacture. Many design techniques have been used to minimize the size of the microstrip line filter and to improve the performance (Li *et al*., 2014; Kumar and Chauhan, 2016). And UWBSF is designed to reduce the complexity of structure and fabrication. EM (Electro-Magnetic) simulation was performed using Sonnet simulator based on EM theory of transmission line.

MATERIALS AND METHODS

Design and simulation OF UWB BSF: The proposed dual IDC FSCS filter combines two electrically coupled FSCS

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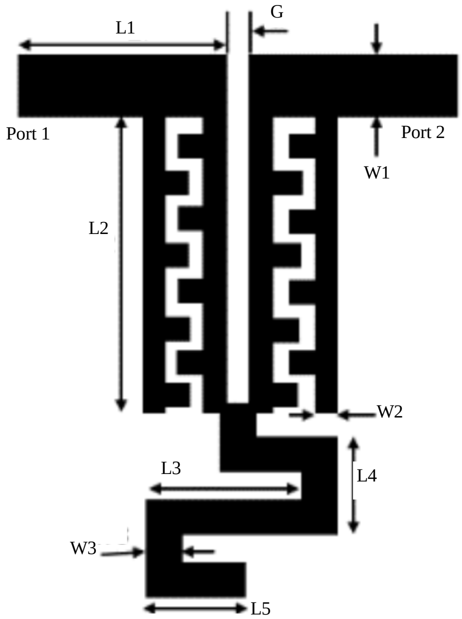

Fig. 1: Structure of dual IDC FSCS filter

and one meander line SOCR. In addition, the electrical length of FSCS and SOCR is $\lambda r/4$ ($\pi/2$) which is largely designed to be 3 and is completed by combining with left-right symmetry. Figure 1a is the structure of the designed dual IDC FSCS filter. The proposed BSF is based on the EM field theory and the load impedance at both ends has the same characteristic in the vicinity of $\omega = \omega_0$ in both Eq. 1 and 2. The load impedance is solved as follows:

Here, $\omega = \omega_0 \pm \Delta\omega$

$$Z_L = j\omega_0 L\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right) \approx \pm j2L\Delta\omega \quad (1)$$

$$Z_L = \frac{jZ_r\pi}{4}\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right) \approx \pm\frac{jZ_r\pi}{4}\frac{\Delta\omega}{\omega_0} \quad (2)$$

Here, the band-stop filter structure of Fig. 1 is analyzed by the even and odd mode excitation method. In one band reject filter, the input admittances of the even and odd modes are given by the following Eq. 3 and 4:

$$Y_{ine} = Y_{0e}\frac{Y_{Ls} + jY_{0e}\tan\theta}{Y_{0e} + jY_{Ls}\tan\theta} \quad (3)$$

$$Y_{ino} = -jY_{0o}\cot\theta \quad (4)$$

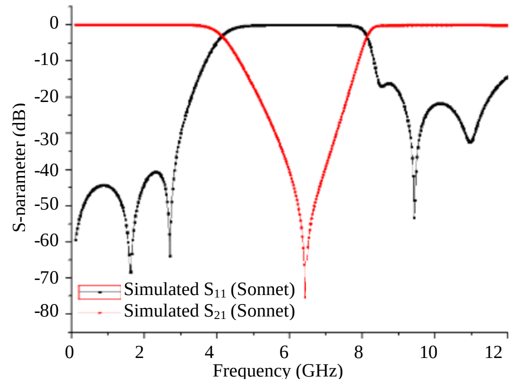

Fig. 2: Simulated frequency response of DIDC FSCS filter

Y_{1e} which is an even load admittance is obtained by the following Eq. 5:

$$Y_{Le} = \frac{1}{Z_{Le}} = \frac{1}{(2Z_L)} = \frac{jY_r\tan\theta}{2} \quad (5)$$

The condition of the transmission zero (S21 = 0) is $Y_{ine} = Y_{ino}$

The proposed left right dual IDC FSCS UWB BSF is a form of single FSCS structure. Its length is tuned to the center frequency 6.0 GHz. Using a coupling gap as IDC to improve the performance, Transmission Zero (TZ) is generated near the center of the band and the sharpness of bandstop appears and the selectivity is increased. The proposed BSF uses an electrically coupled FSCS that is DIDC FSCS loaded. BSF is designed on a substrate with a thickness (h) = 0.54 mm and has a relative permittivity of 2.54 and a loss rate of 0.002. Terminate both ends of the filter with 50 Ω. The size of the filter is 10.0×15.0 mm^2 and the actual size of the filter is 10.0×12.57 mm^2. The detailed dimensions of the designed BSF are as follows. L1 = 4.8 mm, L2 = 7.4 mm, L3 = 4.0 mm, L4 = 2.4 mm, L5 = 2.0 mm, L6 = 2.4 mm, W1 = 1.4 mm, W2 = 0.5 mm, W3 = 0.8 mm and G = 0.4 mm . The simulation results for DIDC FSCS UWBSF as shown in Fig. 2 are as follows: The lower side of the 3 dB stopband is 4.0 GHz and the upper side is 8.0 GHz. The center frequency Fo is 6.0 GHz and the bandwidth is 4.0 GHz. The transmission coefficient maximum is 72.9 dB at 6.45 GHz where the reflection coefficient is 0.044 dB. The peak reflection coefficient points are 4 and represent 68 dB at 1.6 GHz, 45 at 2.7, 64 at 9.45 and 33 dB at 10.95 GHz. The transmission loss outside the stop band is 0.01 dB at the lower 2.0 GHz and 1.0 dB at the upper 10.0 GHz. The transmission zero point is 1 which is equal to the maximum transmission point and is 72.9 dB at 6.45 GHz.

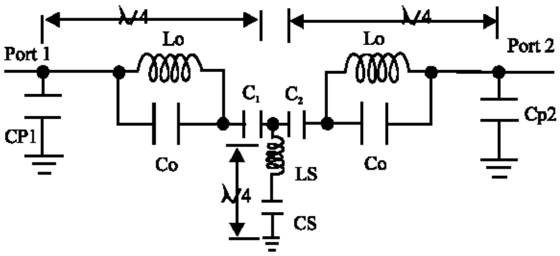

Fig. 3: Equivalent circuit of DIDC FSCS filter

Figure 3 shows the equivalent circuit of DIDC FSCS BSF. Lo and Co serve as an LC tank circuit that generates an ultra-wideband band stop filter response. Lo, Co and C1 which are composed of two layers are composed of a microstrip transmission line of about λ/4 and are responsible for half of the filters. In the equivalent circuit, Lo, Co and C1 have a length of about λ/4.

The meander line microstrip line formed at the lower side of the filter is drawn in the middle of the Interdigital Capacitor (IDC) and is represented by the series inductance Ls and the capacitance Cs. The effect of the incoming meander line has a length of λ/4, widening the stop band of the pass band and sharpening the slope. The center frequency can also be shifted. When the length becomes longer, the lower side of the center frequency and the lowering frequency is further lowered and when the length becomes shorter, the upper side of the center frequency and the lowering frequency moves upward. It also has a great effect at high frequencies. These characteristics were verified by EM simulation.

In the parallel filter structure, the uppermost interdigital capacitor line can reduce the length of the microstrip line. It can adjust the frequency bandwidth and makes it easier to move the center frequency down. The spacing between the interdigital capacitor lines is small and does not have a valid capacitance value but it maintains the minimum gap required for fabrication, so that, the effect can be maximized. The effect appears large across the band stop frequency. The interval is indicated by C1 and C2. Cp1 and Cp2 in the equivalent circuit represent the terminal capacitance and Input/Output 1 and 2 are combined into 50 Ω for system applications.

RESULTS AND DISCUSSION

The measurement instrument is the Agilent (HP) 8719ES Vector Network Analyzer (VNA) and measured with this instrument. The fabricated DIDC FSCS UWBSF is shown in Fig. 4.

The filter was fabricated using SONET simulator. The Teflon PCB used for the fabricated filter is TACONICS

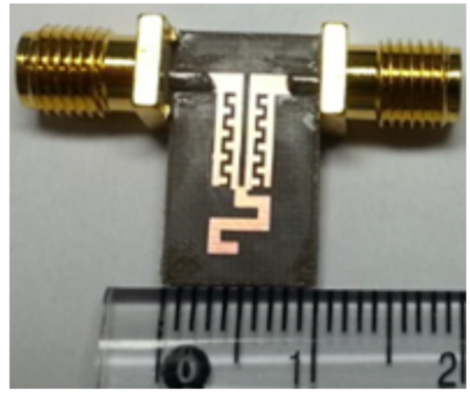

Fig. 4: Fabricated DIDC FSCS UWBSF

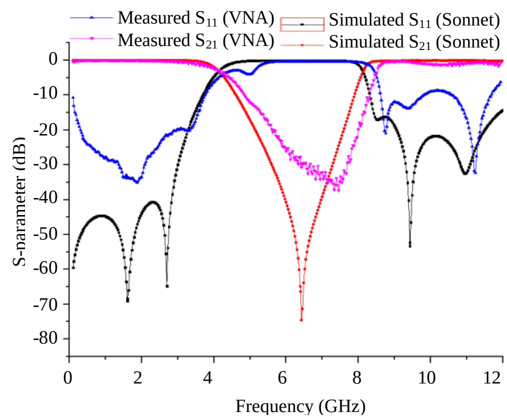

Fig. 5: The simulation and measurement results

TLX-8 Teflon and the thickness of the copper plate is 18 μm. The simulation results of the DIDC FSCS UWB BSF and the actual measurement results were compared as follows which is shown in Fig. 5. The 3 dB frequency start of the UWB BSF shifted from 4.0-4.2 GHz and the end point shifted from 8.0-8.4 GHz. The center frequency shifted from 6.0-6.3 GHz and the bandwidth widened from 4.0-4.2 GHz.

The maximum value of the transmission coefficient (S_{21}) was changed from 6.45-7.3 GHz and from 72.9-35 dB. The insertion loss on the lower and upper sides of the stopband was changed from 0.01, 0.10 -0.5 dB and 1.2 dB, respectively. In addition, the maximum transmission zero point is 1 and there is no change and it is changed from 6.45-7.3 GHz and from 72.9-35.0 dB. The maximum reflection coefficient and the pole point were 4-3 maximum points. 3 are 35, 21 and 31.0 dB at 1.7, 8.6 and 11.2 GHz, respectively.

CONCLUSION

In this study, we proposed a microstrip line DIDC FSCS UWBBSF using DIDC FSCS and meander line SOCR. The UWB BSF design for center frequency and bandwidth control has two λ/4 lengths as interdigital capacitors. In addition, FSCS was used as a doublet and a shunt open circuit resonator (SOCR) of λ/4 length was added to it. The SOCR is composed of meander lines. In addition, the FSCS portion coupled with dual IDC could enhance frequency regulation and stopband characteristics. In this study, we analyzed the characteristics of UWBSF using DIDC FSCS structure by design, simulation and fabrication. The center frequency of the measured UWBSF is 6.3 GHz and the bandwidth is 4.2 GHz. The maximum value of the transmission coefficient (S_{21}) is 72.9 dB at 6.45 GHz and the reflection coefficient (S_{11}) is 0.41 dB. Insertion loss outside the stopband was 0.5 dB and 1.2 dB on the lower and upper sides. In addition, the transmission zero point is equal to the transmission coefficient maximum point and is 1 and there is no change, it becomes 35.0 dB at 7.3 GHz. The external size is 10×20 mm^2 but the actual filter size is 10×12.57 mm^2. The substrate is teflon which has excellent high-frequency characteristics with a loss ratio of 0.002 and a dielectric constant of 2.54. It has good high-frequency characteristics and small size and it is easy to fabricate with a simple structure. UWB BSF can be applied to C-band (4-8 GHz) radio relay communication system, inter-satellite communication, satellite and station interstation, terrestrial microwave relay system, radar system and EMI suppression device in RF system.

REFERENCES

Hsieh, M.Y. and S.M. Wang, 2005. Compact and wideband microstrip bandstop filter. IEEE. Microwave Wireless Compon. Lett., 15: 472-474.

Kim, C., T.H. Lee, B. Shrestha and K.C. Son, 2017b. Miniaturized dual-band bandpass filter based on stepped impedance resonators. Microwave Opt. Technol. Lett., 59: 1116-1119.

Kim, C.S., T.H. Lee, K.S. Shin, B. Shrestha and K.C. Son, 2017a. SIR based symmetric hairpin bandstop filter. Far East J. Electron. Commun., 17: 839-844.

Kumar, J. and R.K. Chauhan, 2016. Microstrip wideband band stop filter with IDC loaded open loop resonator. Intl. J. Sci. Technol. Eng., 3: 167-169.

Li, L., Q.H. Wu, K.Y. Zhao, J. Li and Y.M. Wang, 2014. Sharp-rejection and ultra-wide bandstop filter with five transmission zero frequencies. IET. Microwaves Antennas Propag., 8: 80-85.

Ren, S.W., L.S. Wu, H.L. Peng and J.F. Mao, 2015. Quasi-elliptic wideband bandstop filter using stepped-impedance coupled line. IEEE. Microwave Wirel. Lett., 25: 364-366.

Sanchez-Soriano, M.A., G. Torregrosa-Penalva and E. Bronchalo, 2010. Compact wideband bandstop filter with four transmission zeros. IEEE. Microwave Wirel. Compon. Lett., 20: 313-315.

Shrestha, B. and N.Y. Kim, 2015. Microstrip wideband bandstop filter with open stubs for UWB applications. Microwave Opt. Technol. Lett., 57: 1003-1006.