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Compact Ultra-wideband Bandpass Filter Using DUC-EBG Cell

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1. Introduction

The Federal Communications Commission (FCC) in the U. S. has released the unlicensed use of ultra-wideband (UWB) in February 2002 [1]. The significant research activities and interests on UWB techniques have been increased in both academic and industrial aspects since the FCC requires that the UWB bandwidth must be strictly contained between 3.1 and 10.6 GHz for the indoor and hand-held UWB systems. As the UWB bandpass filter (BPF) is one of the main issues, it has been considered and developed to make up the whole UWB passband. In recent years, several approaches have been reported, e. g., open stub loading [2], composite lowpass-highpass [3]-[4], broadband coupling structure between microstrip line to coplanar waveguide structure [5], microstrip MMR [6]. First of all, the UWB BPF based on the microstrip MMR can be easily achieved UWB passband without adding any complicated structure. However, the filter size of the conventional UWB BPF based on the microstrip MMR can not be reduced since the length of the conventional microstrip MMR is one-half wavelength at the center frequency 6.85 GHz. The DUC-EBG structure reported in [7] is very suitable in the size reduction of UWB BPF because the DUC-EBG cell has many distributed L-C components. In this paper, the UWB BPF using distorted uniplanar compact electromagnetic bandgap cell (DUC-EBG) is presented for size reduction. A DUC-EBG cell modelled with many L-C distributed components is operated as MMR in the whole UWB passband of 3.1-10.6 GHz. The proposed filter is experimentally verified and analyzed using an equivalent circuit of the EBG cell. In section 2, the equivalent circuit of DUC-EBG cell are introduced. And experimental results are shown in section 3.

2. Filter Design

Fig. 1 shows the proposed UWB BPF using DUC-EBG cell. The designed UWB filter is composed of a DUC-EBG cell acted as MMR and two capacitive-ended coupled lines placed at two sides with coupling peak at the center frequency of 6.85 GHz. The total length except 50 Ω feed line is 10.86 mm and size reduction is 32% than the conventional UWB BPF based on one-half wavelength microstrip MMR presented in [6]. And the length of the coupled line is set to be a quarter-wavelength at the center frequency for broadband coupling in the UWB passband. The proposed filter is fabricated on RT/Duroid 6010 substrate with dielectric constant of 10.2, loss tangent of 0.0023, and thickness of 1.27 mm. The transmission zero at out of UWB passband can be achieved from the capacitive-ended coupled line [6]. The distributed L-C components of the DUC-EBG cell are depicted as an L-C equivalent circuit in Fig. 2. The capacitance C_0 is due to an arrow-shaped strip. C_1 is the gap capacitance between arrow-shaped strips. C_2 is the gap capacitance between transverse strip and an arrow-shaped strip. The inductances L_1 and L_2 are corresponding to the transverse and diagonal strip. The inductance L_3 is the headlike part of an arrow-shaped strip.

3. Experimental Results and Analysis

The parameters of the proposed UWB BPF shown in Fig. 1 are w_1=0.18 mm, w_2=0.28 mm, w_3=0.08 mm, w_4=0.18 mm, w_5 =0.16 mm, l_1=4.68 mm, l_2=1.5 mm, g_1=0.1 mm, g_2=0.1 mm, and g_3=0.2 mm. The curve-fitting method with the measured s-parameters is utilized to find each value

ISBN: 978-4-88552-223-9 C3055©IEICE

of the distributed L-C components at the equivalent circuit shown in Fig. 2. Each value obtained from this process is C_0=0.065 pF, C_1=0.3 pF, C_2=0.12 pF, L_1=0.57 nH, L_2=0.087 nH, and L_3=0.1 nH. S_{11} and S_{21} of the full filter circuit are calculated from these parameters and shown in Fig. 3. It can be seen that the full circuit model with this equivalent DUC-EBG circuit is pretty accurate especially for the four resonances at 3.4, 5.7, 8.6, and 10.1 GHz. In Fig. 4, the measured group delay is varied within less than 0.18 ns. The two and three-stage filter shown in Fig. 5 is fabricated in order to further improve the skirt at the outband performances in both lower and upper stopbands. Between the DUC-EBG cells the modified interdigital coupled line with a center slot is used to improve coupling degree at the center frequency of 6.85 GHz. All parameters are the same those of the one-stage filter except g_4=0.05 mm, w_6=0.28 mm, and w_7=0.54 mm. The total lengths except 50 Ω feed line of two and three-stage are 17.17 mm and 23.48 mm, respectively. Fig. 6 and 7 show the performances of the two and three-stage filter. The skirt performance at the outband is much sharper in accordance with the increase of the stage. The variation of the group delay is less than 0.35 ns in two-stage BPF, while the variation is less than 0.48 ns in three-stage. An increase in delay time with the increase of one stage is 0.095 ns at the center frequency of 6.85 GHz. The total length except 50 Ω feed line of three-stage filter is 23.48 mm, which is less than that of two-stage UWB filter presented in [6].

4. Conclusion

In this paper, the design and analysis of the UWB BPF using DUC-EBG single cell is demonstrated. Since a DUC-EBG cell is considered to many distributed L-C components, it is suitable for substitution of the conventional MMR for size reduction. The distributed L-C component values of the DUC-EBG cell can be derived using curve-fitting with the measured s-parameters. In additionally, two and three-stage DUC-EBG filters are designed and fabricated to improve the skirt performance. These proposed filters are useful for UWB application as the compactness is needed.

5. Figures

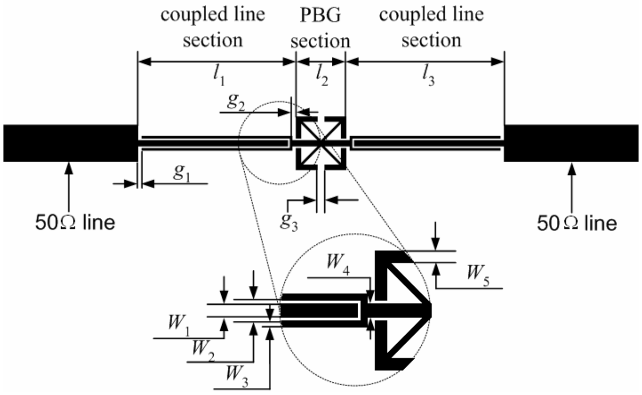

Figure 1: The layout of the proposed one-stage UWB BPF

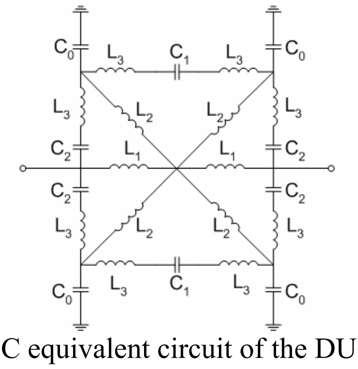

Figure 2: L-C equivalent circuit of the DUC-EBG cell

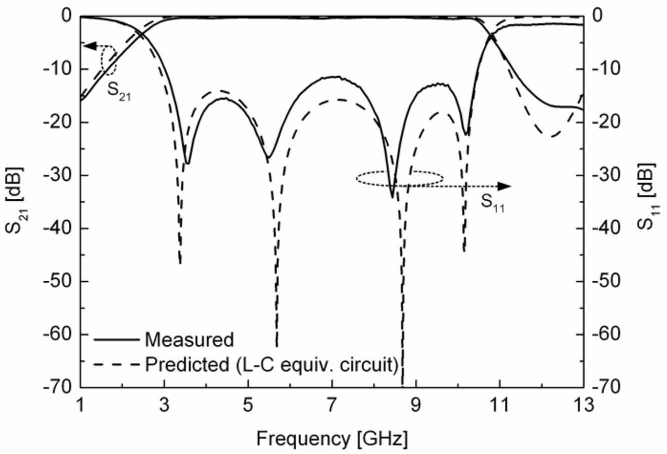

Figure 3: Measured and predicted s-parameters of one-stage BPF with the L-C equivalent circuit shown in Fig. 2

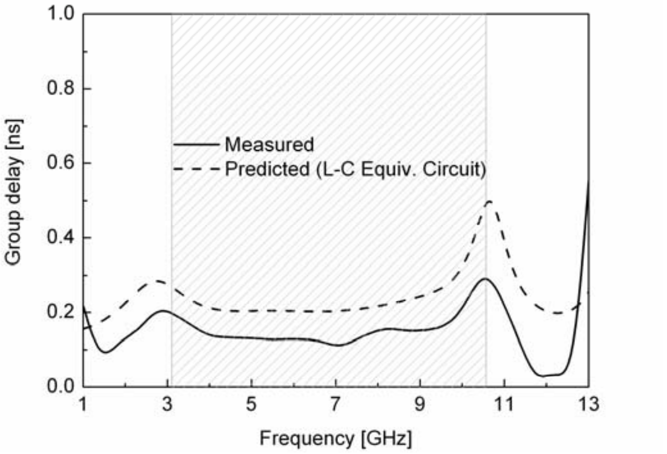

Figure 4: Measured and predicted group delay of one-stage UWB BPF

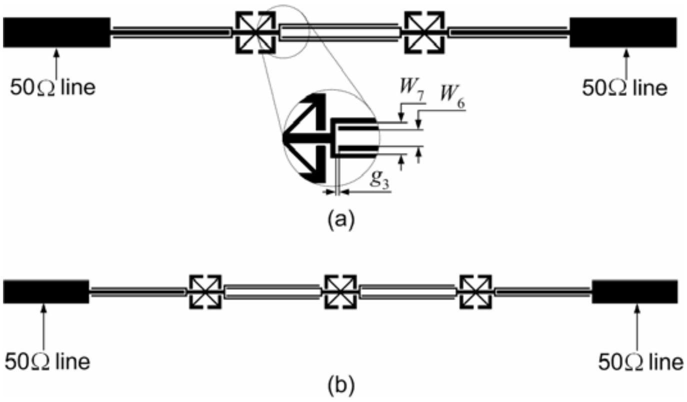

Figure 5: Schematic of (a) two and (b) three-stage UWB BPF

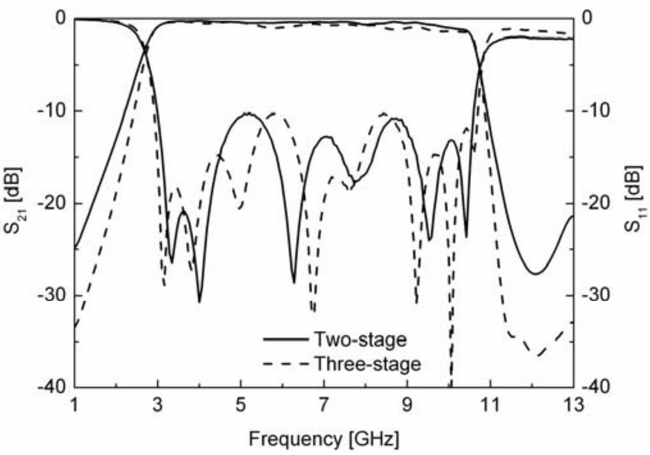

Figure 6: Measured s-parameters of two and three-stage BPF

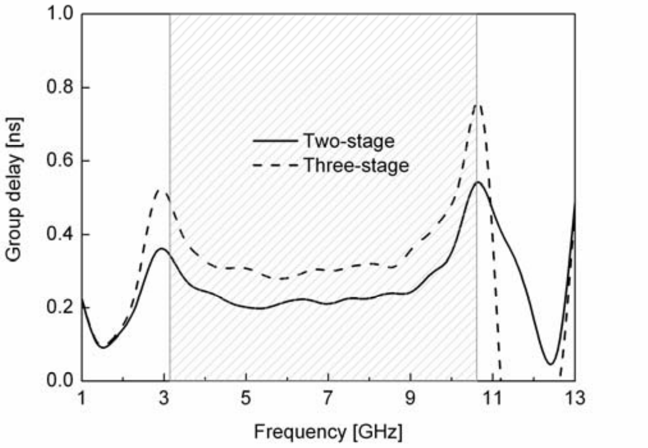

Figure 7: Measured group delay of two and three-stage BPF

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