A Novel Stepped-Patch Loaded CPW and Its Application to a Low-Pass Filter

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Abstract

A novel stepped-patch loaded coplanar waveguide(SPLCPW) structure is proposed and applied to the design of a low-pass filter(LPF). The stepped-patch loaded on the opposite side of the CPW plane is shown to provide a shunt-connected series L-C resonance, which is dual to that of a conventional CPW defected ground structure(DGS). As a simple example of the proposed SPLCPW circuit, a 3-pole SPLCPW LPF is designed and good results are obtained.

Key words: Stepped-Patch Loaded Coplanar Waveguide(SPLCPW), Low-Pass Filter(LPF).

I. Introduction

Among the numerous studies that have explored the band-stop property provided by periodic bandgap(PBG) structures, a defected ground structure(DGS) can be considered as one of the most useful approaches due to its simple equivalent circuit[1]. As shown widely, a conventional DGS unit section in a microstrip line[1] or a coplanar waveguide(CPW)[2] is represented as a series-connection of L-C band stop resonator. As another kind of a band-stop resonator, there exists a shunt-connected resonator which is dual to the former one. If both types of resonators are properly utilized, a higher performance microwave component can be designed such as a harmonic-suppressed low-pass filter(LPF) with a very wide rejection band[3]. In case of microstrip lines, a step-impedance shunt stub[3,4] is a good example of the latter one. For the slotines, a patch loaded slotline(PLS) was proposed as a shunt-connected series resonator[5]. In this paper, a novel stepped-patch loaded CPW(SPLCPW) is proposed as a CPW shunt connected series resonator. A patch loaded CPW(PLCPW) structure was first proposed in [6]. However, its equivalent circuit is somewhat complex and difficult to represent as a simple resonator. Thus, it is hard to use for the design of conventional planar circuits. Undoubtedly besides the PLCPW structure, there have been various types of series resonators for CPW[7]. Compared with them, the proposed SPLCPW has no discontinuities in the main CPW plane, and there is no need to use an air-bridge. Also, it is easy to implement various L and C values necessary for the circuit design by adjusting various geometrical parameters of a stepped-patch instead of a plain patch. Especially, the proposed SPLCPW is able to provide the relatively large capacitance value due to the broadside coupling between a loaded patch and a CPW line.

II. Equivalent Circuit of a SPLCPW Unit Section

Fig. 1 shows the configuration of the proposed SPLCPW unit section. A conventional CPW is placed on the one side of a substrate and a stepped-patch is loaded on the other side. As another configuration, the stepped-patch could be loaded on the superstrate of a conventional CPW, but only the first case is considered in this paper.

As shown in Fig. 1, several dimensional parameters

![Fig. 1. Configuration of a proposed SPLCPW.](image-url)
of a stepped-patch determine the resonant characteristics. In this paper, for simplicity, some assumptions are made concerning the dimensions of the patch. First, the sub-patch A should be placed on the opposite side of the CPW signal line only, while each sub-patch B should only be mounted on the opposite side of each CPW ground. In other words, $W_A$ should not be larger than $W_C$, and $L_S$ should be large enough to keep the sub-patch B from overlapping the CPW gap. Another important assumption is that the stepped-patch should be symmetrical along the CPW center line, which can be considered a magnetic wall. Based on these assumptions, the sub-patches A and B provide capacitance like parallel plates and two narrow strips connecting these sub-patches provide series inductance since the magnetic fields in the CPW gap turn around the narrow strips. Therefore, the equivalent circuit can be represented as shown in Fig. 2. This is identical to that of a unit PLS section [5] since the field distribution in the half section along the magnetic wall is very similar to that in the slotline. In order to show its validity, a SPLCPW is designed and its equivalent circuit parameters are extracted from the EM simulation results. Then the equivalent circuit S-parameters are calculated and compared with those of the full-wave EM simulation. The substrate is Roger’s Duroid 6010LM with a thickness of 25 mil and a dielectric constant of 10.2. The dimensions of the designed stepped-patch and the 50 Ohm CPW line are given as follows: $W_B=L_B=L_A=4$ mm, $W_C=W_G=3$ mm, $G_C=0.63$ mm, $W_G=0.2$ mm, $L_G=0.9$ mm.

In Fig. 2, note that the S-parameters of the SPLCPW only are obtained by deembedding those of the 50 Ohm uniform lines from both simulation ports to the center of the stepped-patch along the z-direction. From these S-parameters, the equivalent inductance and capacitance values are extracted into 0.648 nH and 1.204 pF, respectively. Fig. 2 shows that the proposed equivalent circuit is valid since the $S_{11}$ traces in the Smith chart represent the typical shunt-connected series L-C resonance and the two S-parameters are in good agreement as well.

III. Design of a 3-Pole Low-Pass Filter

As a simple example of a SPLCPW circuit, a 3-pole LPF with a cut-off frequency of 2.0 GHz and a ripple

![Fig. 2. Equivalent circuit model and simulated S-parameters of a SPLCPW unit section.](image)

![Fig. 3. (a) Configuration of the designed LPF with its dimensions(unit: mm), (b) Simulated and measured frequency responses of the designed LPF.](image)
level of 0.01 dB is designed according to the well-known procedure provided in [1] and fabricated on the same substrate as one used in the section II above.

Fig. 3(a) depicts the configuration of the designed LPF with its physical dimensions, and Fig. 3(b) represents the simulated and measured frequency responses. Since a shunt-connected series L-C resonator looks like a simple shunt capacitor in the low frequency region, the proposed SPLCPW is used as a shunt element of the LPF. On the other hand, a conventional high-impedance line is employed for the LPF series inductance. The measured results in Fig. 3(b) show the validity of the proposed SPLCPW and its equivalent circuit model since they are in good agreement with the results obtained from EM simulations using Ansoft ENSEMBLE and CST MWS. Also, it is notable that, as expected, the SPLCPW provides the deep nulls in the stop-band region due to its resonance.

IV. Conclusions

A novel SPLCPW structure is proposed and applied to the design of an LPF. It is shown that the SPLCPW equivalent circuit can be simply represented as a shunt-connected series L-C resonator. Since it is easy to implement the necessary L and C values simply by varying the dimensions of a loaded stepped-patch without introducing any air bridges or discontinuities in a main CPW, this is expected to be useful for the design of various CPW circuits.

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