Asymmetric Coplanar Waveguide Filter with Defected Ground Structure

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Abstract

Proposed novel asymmetric coplanar waveguide filter with defected ground structure, discussed its performance with different dimensions employing conformal mapping techniques and commercial EM software CST Microwave Studio. Several filter circuits were fabricated and measured, the results showed good agreement with analysis, while the structure was proven to have good performance and design flexibilities.

1. Introduction

Coplanar waveguide (CPW) is an important planar transmission line proposed by C. P. Wen in 1969 [1]. Profit from the character of single conductor plane, CPW has several advantages, such like easy on fabrication, convenient on connection with other circuit components, etc. Asymmetric coplanar waveguide (ACPW) [2] is a transmission line developed from CPW. As the name implies, ACPW has different slot width in compare with traditional CPW. CPW can be treated as special case of ACPW, and ACPW is supposed to have more design flexibilities. In recent years, ACPW got more and more attentions. Many researchers analyzed ACPW characters and studies on various ACPW applications [3-5].

Defected ground structure (DGS) [6] is a kind of slow wave structure, which is developed from photonic band-gap (PBG) [7-8] structures proposed by Yablonovitch and John S.Strong in 1987. DGS also exhibited distinguished frequency selectivity, while no extra circuit size occupied. This character is always desirable in filter applications.

2. ACPW and Asymmetric Characters

The structure and parameters of ACPW is illustrated in Fig. 1. The width of center strip is w_c, two slots are w_{s1} and w_{s2}, respectively, the substrate has dielectric constant ε_r and thickness h, while the thickness of metal is t. in this paper, t is always supposed to be zero for simplify the problem.

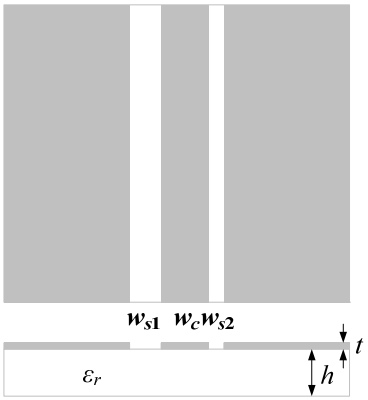

Fig.1 Illustration of ACPW

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Characters of ACPW have been studied for several years, closed form formulas for effective dielectric constant, characteristic impedance, and phase velocities are available [9]. Commercial EM software like HFSS can also employed to compute these characters, which is convenient, fast, and accurate enough for practical applications.

In C. P. Wen's paper [1], CPW was supposed to have infinite substrate thickness, which is a reasonable approximation for many applications. Effective dielectric constant ε_{eff} and phase velocity υ_{ph} are expressed in expression (1) and (2), it is obviously that both ε_{eff} and υ_{ph} are only related with dielectric constant ε_r. Worth mentioning, for the case of ACPW with infinite substrate, same expressions are derived. That is, ACPW with same dielectric constant but different dimensions will have equal effective dielectric constant and phase velocity.

$$\varepsilon_{eff} = (\varepsilon_r + 1)/2 \tag{1}$$

$$\upsilon_{ph} = \frac{c}{\sqrt{\varepsilon_{eff}}} = \left(\frac{2}{\varepsilon_r + 1}\right)^{1/2} c \tag{2}$$

When thickness of substrate is considered, ε_{eff} is no longer only related with ε_r. ε_{eff} with finite substrate can be computed by expression (3), where C_{sub} is the unit capacitance of transmission line and C_{air} is the unit capacitance when substrate material replaced by air.

$$\varepsilon_{eff} = C_{sub} / C_{air} \tag{3}$$

Both capacitances mentioned are determined by ε_r and other parameters together. As a result, electromagnetic wave will traveled in different phase velocities for CPW/ACPW with different dimensions. Since CPW can be seemed as a combination of two slot lines, it is a reasonable assumption that in ACPW, different phase velocities exist in two slots and can be estimated by corresponding CPWs. We compute Z_0 and ε_{eff} for ACPW with different dimensions and list the results in Tab.1. In row 2, 3, and 4, s_1=s_2, it can be seen as a special case of ACPW.

Tab. 1 Characters of different ACPWs

ε_r	h	w_c	s_1	s_2	Z_0	ε_{eff}
10.2	1.2	0.8	0.3	0.4	50.1	5.32
10.2	1.2	0.8	0.3	0.3	48.0	5.34
10.2	1.2	0.8	0.35	0.35	50.3	5.31
10.2	1.2	0.8	0.4	0.4	52.5	5.28

The ε_{eff} ratio of row 2 and row 4 is about 1.01, and the velocity difference between two slots can be estimate as 0.57%, that would made a 2° phase difference between two CPWs with 360° electrical length. To verify the assumption mentioned before, a time domain simulation of ACPW is made by commercial software CST Microwave Studio (v2012). The simulation model is illustrated in Fig. 2. Two probes are placed on the two slots of ACPW, 9.9 mm away from port1, which is the reference exciting port for following analysis.

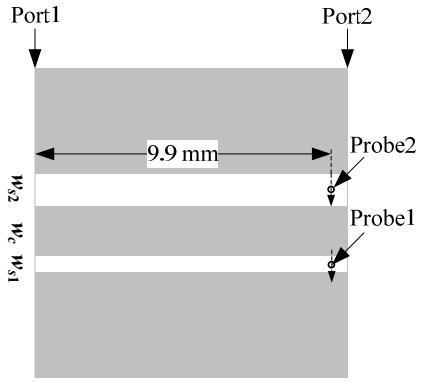

Fig. 2 Simulation model of ACPW

Dimensions of simulated ACPW are as follows: ε_r=10.2, h=1.2 mm, w_c=0.8 mm, w_{s1}=0.3 mm, w_{s2}=0.4 mm. The simulated time delay between port1 and probe1 is 82.9 ps, while between port1 and probe2 is 81.76ps, then we can easily compute the difference between velocities of the two slots is about 1.39%, 2.4 times of estimated number. Velocity difference is always harmful for signal transmission, odd mode would be excited even the feed port provide pure QTEM mode exciting. But in some case, for example, the right angle bend, the phase difference is inherently exist, so this character of ACPW can be used to improve the situation by carefully design.

3. Description of proposed Structures

Proposed ACPW DGS filter is illustrated in Fig. 3. Dumbbell shaped DGSs etched on both ground planes with different dimensions. For convenience, the two grounds are numbered as ground1 and ground2. DGS on ground1 has width of A_1, distance from the ground border l1, and coupled slot width g_1, while dimensions for DGS on ground2 are A_2, l_2, and g_2 respectively. Traditional CPW DGS filter provide band-stop character while the DGS act as a resonator. When employing different DGS dimensions on both side, two resonant frequencies would be obtained. Moreover, if the two frequencies are near to each other, the stop-band would be expanded. But different DGS also yield different ground current path, which would degrade the transmission character via pass-band.

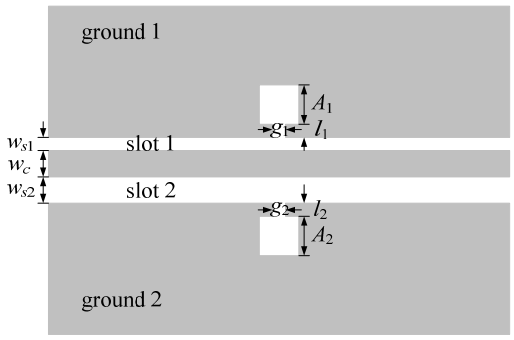

Fig. 3 Proposed ACPW DGS filter

As mentioned in section II, different slot widths caused phase differences between two slots in ACPW, which would degrade transmission characters. But in the case of asymmetrical DGS, this character can be used to compensate the phase difference caused by asymmetrical structure itself. Several ACPW DGS filter dimensions are given in Tab. 2. Row 1 is more likely to be named as CPW-DGS, but it can be seen as a special case of ACPW-DGS also.

Tab. 2 Dimensions of proposed filters

	w_c	s_1	s_2	A_1	A_2
CPW-DGS	0.8	0.35	0.35	3	3
ACPW-DGS	0.8	0.3	0.4	3	3
ACPW-ADGS	0.8	0.3	0.4	2.9	3

4. Fabrications and Measurements

Three circuits were fabricated and measured for validation, that is: CPW-DGS filter, ACPW-DGS filter, and ACPW-ADGS filter. All filters are manufactured on substrate with dielectric constant 10.2 and thickness 1.2 mm. Dimensions of ACPW-DGS filter are as follows: width of center conductor w_c=0.8mm, two slots are w_{s1}=0.3mm and w_{s2}=0.4mm respectively; characteristic impedance is about 50.1 Ω, which is obtained by the method of conformal mapping [9]; g_1=g_2=0.4 mm; l_1=l_2=1 mm; A_1=A_2=3 mm. In the case of CPW-DGS, dimensions are as same as ACPW-DGS, unless w_{s1}=w_{s2}=0.35 mm, which would provide similar characteristic impedance compared with former ACPW. ACPW-ADGS filter has a smaller DGS, while keep other dimensions. The photograph of proposed filter is given in Fig. 4.

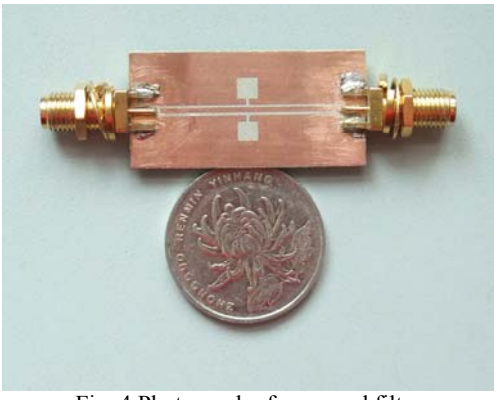

Fig. 4 Photograph of proposed filter

The filters are measured by Agilent vector network analyzer N5230A, which is calibrated by 85052D economic calibration kit. It can be observed that ACPW-ADGS provided the best stop-band rejection, as analyzed before.

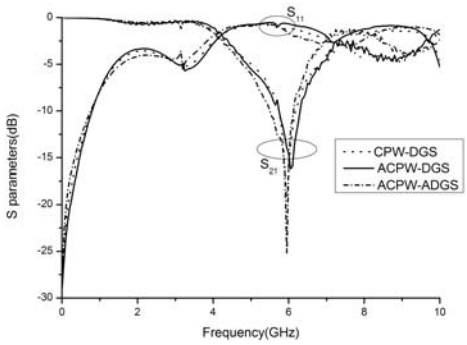

Fig. 5 Measurement of proposed filters

5. Conclusion

In this paper, a novel ACPW-DGS filter is proposed and shown good performance and design flexibilities. An assumption of different velocities in two slots of ACPW is made here for analyzing, while the measurements of proposed filter also validate this assumption. Velocity difference of ACPW is exemplified here for improving circuit performance, and other applications using this character can be expected.

References

[1]. C. P. Wen. Coplanar waveguide: A surface strip transmission line suitable for nonreciprocal gyro-magnetic device applications [J]. IEEE Trans. on Microwave Theory and Techniques, 1969, vol. 17(12): 1087-1090.

[2]. V. Fouad Hanna, D. Thebault. Analysis of asymmetrical coplanar waveguides [J], INT. J. Electronics, 1981, vol. 50(3): 221-224.