CHARACTERISTICS OF λ/4 CPW RESONATORS WITH TAP-EXCITATION AND THEIR APPLICATION TO BANDPASS FILTERS

Kouji Wada, Ikuo Awai and Yasuo Yamashita

Department of Electrical and Electronic Engineering,
Faculty of Engineering, Yamaguchi University
2557 Tokiwadai, Ube City, Yamaguchi 755, Japan.

ABSTRACT

The basic characteristics of λ/4 coplanar waveguide (CPW) resonators are verified by a theoretical analysis using an improved equivalent circuit and a laboratory test. We propose new types of combline BPFs using these resonators and examine their transmission characteristics.

INTRODUCTION

The filters for radio communications demand the following features : reduction of a circuit size, compatibility to monolithic microwave integrated circuits (MMICs) and applicability to millimeter-wave equipments. Realization of filters based on "planar transmission lines" are strongly expected because of suitability to the requirements. In this paper, we investigate the basic characteristics of λ/4 CPW resonators with a tap-excitation. The transmission characteristics of combline BPFs using these resonators are examined theoretically and experimentally as well. We also propose a number of combline BPFs using L type resonators. We obtain the transmission characteristics with attenuation poles close to passband.

λ/4 CPW RESONATOR WITH TAP-EXCITATION

Fig.1 shows a printed circuit board (PCB) of the λ/4 CPW resonator with a tap-excitation. The copper clad laminate has relative permittivity ε_r=10.5, thickness h=1.6mm and $\tan\delta$=0.0055 around 2.0GHz. The dimension of the PCB is 20×30mm. The dimensions of the CPW resonator are as follows: a center strip width w=0.8mm, a slot width s=0.4mm and a resonator length ℓ=15.6mm. For suppressing spurious modes, we use air bridges between the two ground planes. The external quality factor(Q_e) is controlled by shifting an excitation position and the discontinuities between a resonator and a feed line. The equivalent circuit of the resonator with a tap-excitation was usually expressed as shown in F 2[1][2]. But the effects of discontinuities between a res nator and a feed line are not included in the circuit e pression. In fact, a resonance frequency and Q_e are infl enced by the effect of these discontinuities. We propo an improved expression of the equivalent circuit shown in Fig.3 which considers the effects of discon nuities by a parallel LC circuit (jX) . Each value of L components is evaluated by the self parallel resonance bridged tapping wires.

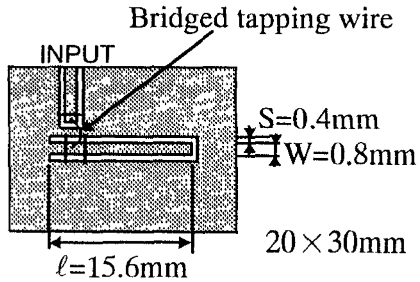
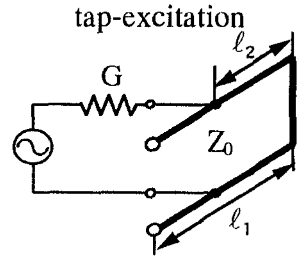
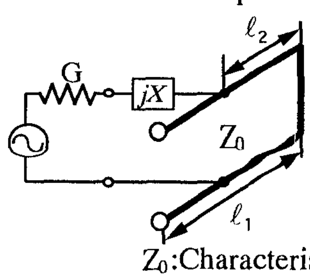


Fig.1 λ/4 CPW resonator with tap-excitation



Z_0:Characteristic impedance

Fig.2 Conventional equivalent circuit



Z_0:Characteristic impedance

Fig.3 Improved equivalent circuit

The resonance condition of this resonator can be described by the following equation

$$\frac{\tan\frac{\omega}{v}(\ell_1-\ell_2)\cdot\tan\frac{\omega}{v}\ell_2-1}{Z_0\tan\frac{\omega}{v}\ell_2}-\frac{G^2X}{1+G^2X^2}=0\,,\; X=\frac{\omega L}{1-\omega^2LC} \qquad (1)$$

The Q_e of the resonator can be given by

$$Q_e=\frac{\omega_0}{2G_g}\frac{\mathrm{d}}{\mathrm{d}\omega}\left\{\frac{\tan\frac{\omega}{v}(\ell_1-\ell_2)\cdot\tan\frac{\omega}{v}\ell_2-1}{Z_0\tan\frac{\omega}{v}\ell_2}-\frac{G^2X}{1+G^2X^2}\right\}\Bigg|_{\omega=\omega_0} \qquad (2)$$

$$G_g=\frac{G}{1+G^2X^2}\,,\; X=\frac{\omega L}{1-\omega^2LC}$$

Fig.4 shows the calculated Q_e of a conventional and an improved equivalent circuits (length of a bridged tapping wire : 5 mm, L=2.22nH and C=0.076pF; 6 mm, L=2.77 nH and C=0.072 pF). Fig. 5 shows the theoretical and experimental results of a fundamental resonance frequency of this CPW resonator. These experimental results are measured by a VNA HP-8719C. The theoretical and experimental results of Q_e is shown in Fig.6, whereas Fig .7 shows that the experimental result of Q_0 of the resonator is around 95 irrespective of the excitation position.

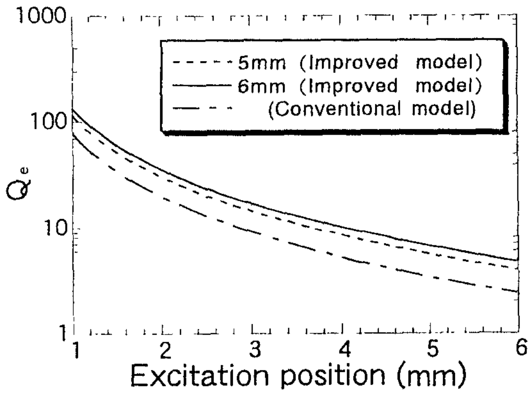


Fig.4 Q_e versus excitation position

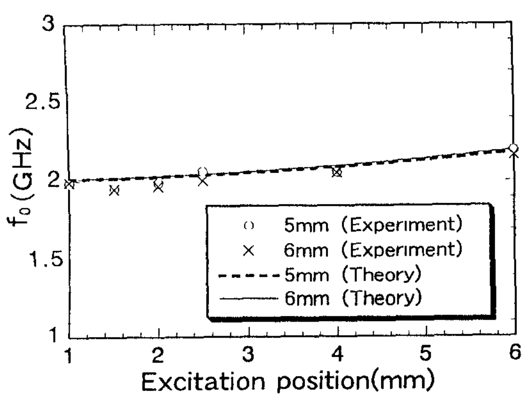


Fig.5 Fundamental resonance frequency versus excitation position

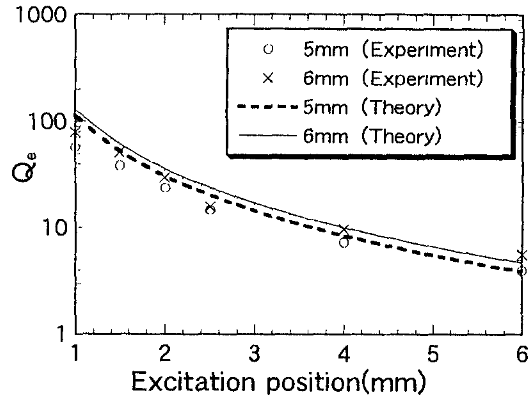


Fig.6 Q_e versus excitation position

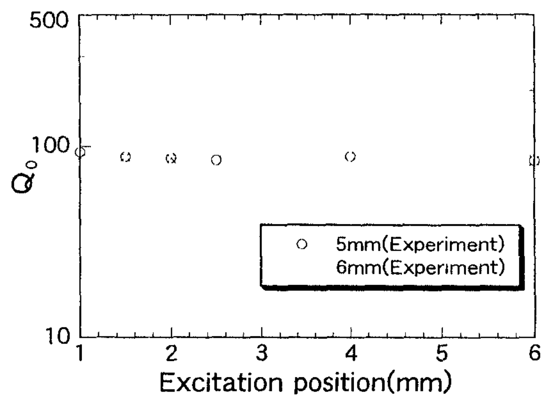
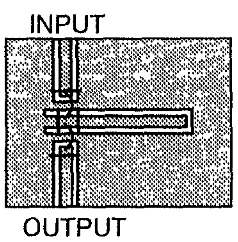
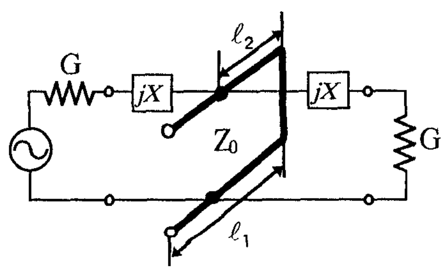


Fig.7 Q_0 versus excitation position



20×30mm

Fig.8 λ/4CPW resonator with I/O terminals



Z_0:Characteristic impedance

Fig.9 Equivalent circuit of λ/4 CPW resonator with I/O terminals

Fig.8 shows a $\lambda/4$ CPW resonator with I/O terminals (PCB size :20×30mm). A fundamental matrix **K** of this resonator can be expressed by

$$\mathbf{K}=\begin{bmatrix}1 & j\dfrac{\omega L}{1-\omega^2 LC}\\ 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0\\ j\dfrac{\tan\dfrac{\omega}{v}(\ell_1-\ell_2)\cdot\tan\dfrac{\omega}{v}\ell_2-1}{Z_0\tan\dfrac{\omega}{v}\ell_2} & 1\end{bmatrix}\begin{bmatrix}1 & j\dfrac{\omega L}{1-\omega^2 LC}\\ 0 & 1\end{bmatrix} \quad (3)$$

Its equivalent circuit and simulated characteristics is shown in Figs.9 and 10, respectively, where the harmonic responses appear at the odd integral multiple of the fundamental resonance frequency. The experimental result is shown in Fig. 11, in which the harmonic responses appear at the predicted frequencies.

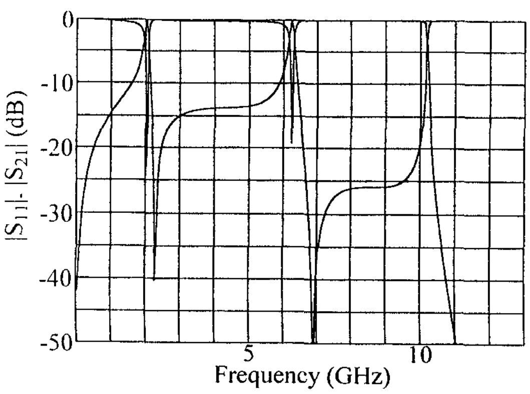


Fig.10 Simulated result of Fig.9

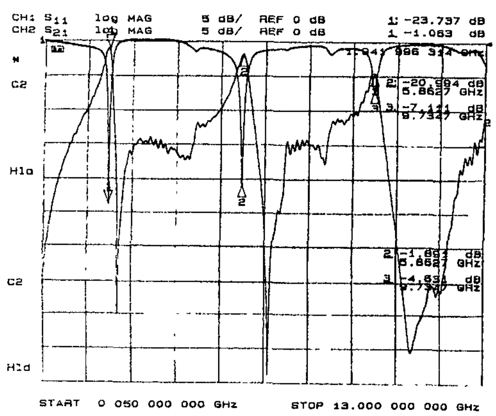


Fig.11 Experimental result of Fig.8

COMBLINE BANDPASS FILTERS

We present the new types of combline BPFs with CPW resonators mentioned above. Fig.12 shows a PCB of a new type of BPF. This configuration has the ground conductor (width : 0.2mm) between the center strips and a wire bridge (length : 3.0mm) between two resonators. For suppressing coupled slotline modes, we use air bridges between the ground plates. The transmission characteristics of the BPF is shown in Fig.13, where the harmonic responses appear at the odd integral multiple of the center frequency.

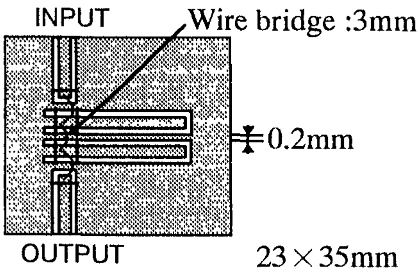


Fig.12 Combline BPF

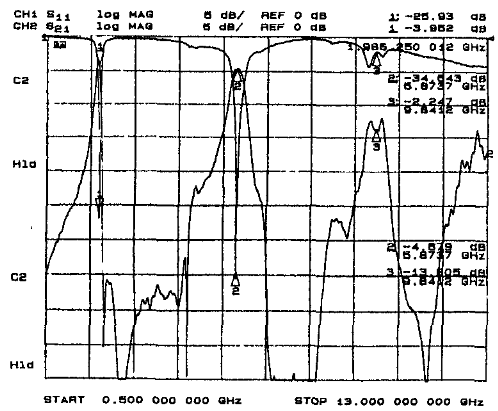


Fig.13 Experimental result of Fig.12

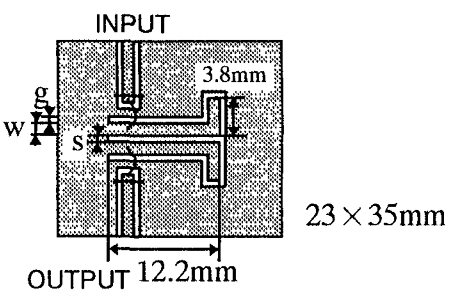


Fig.14 Combline BPF using L type resonator (Type 1)

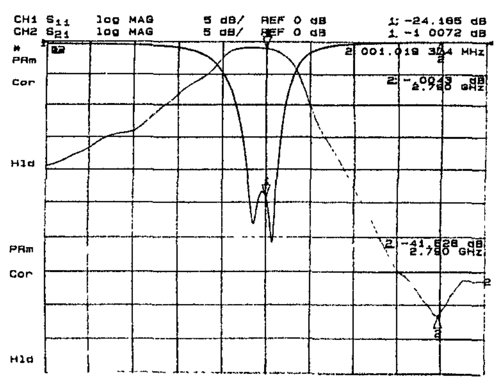


Fig.15 Experimental result of Fig.14

Fig.8 shows a $\lambda/4$ CPW resonator with I/O terminals (PCB size :20×30mm). A fundamental matrix **K** of this resonator can be expressed by

$$\mathbf{K}=\begin{bmatrix}1 & j\dfrac{\omega L}{1-\omega^2 LC}\\ 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0\\ j\dfrac{\tan\frac{\omega}{v}(\ell_1-\ell_2)\cdot\tan\frac{\omega}{v}\ell_2-1}{Z_0\tan\frac{\omega}{v}\ell_2} & 1\end{bmatrix}\begin{bmatrix}1 & j\dfrac{\omega L}{1-\omega^2 LC}\\ 0 & 1\end{bmatrix} \tag{3}$$

Its equivalent circuit and simulated characteristics is shown in Figs.9 and 10, respectively, where the harmonic responses appear at the odd integral multiple of the fundamental resonance frequency. The experimental result is shown in Fig. 11, in which the harmonic responses appear at the predicted frequencies.

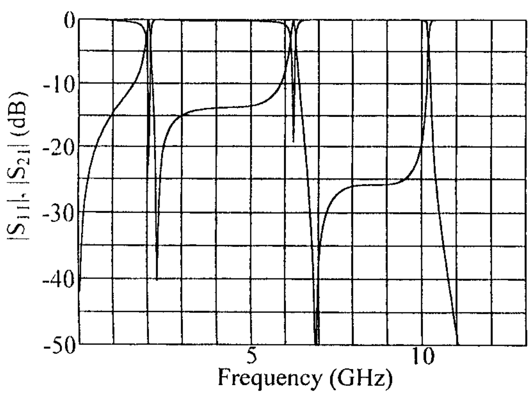


Fig.10 Simulated result of Fig.9

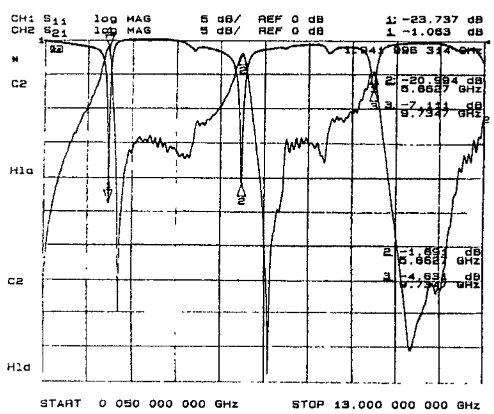


Fig.11 Experimental result of Fig.8

COMBLINE BANDPASS FILTERS

We present the new types of combline BPFs with CPW resonators mentioned above. Fig.12 shows a PCB of a new type of BPF. This configuration has the ground conductor (width : 0.2mm) between the center strips and a wire bridge (length : 3.0mm) between two resonators. For suppressing coupled slotline modes, we use air bridges between the ground plates. The transmission characteristics of the BPF is shown in Fig.13, where the harmonic responses appear at the odd integral multiple of the center frequency.

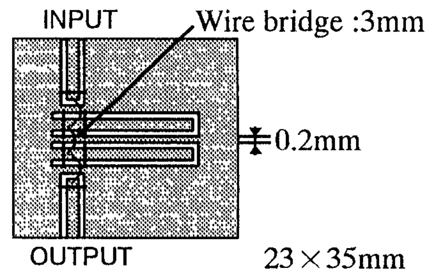


Fig.12 Combline BPF

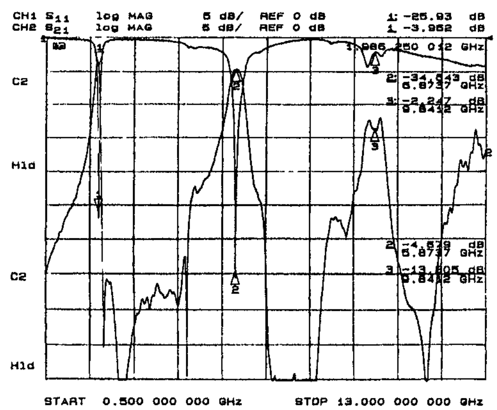


Fig.13 Experimental result of Fig.12

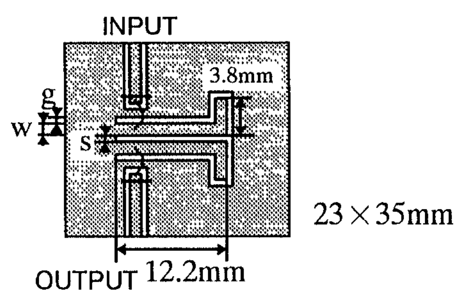


Fig.14 Combline BPF using
L type resonator (Type 1)

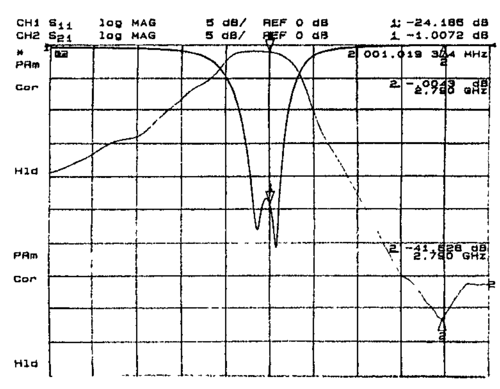


Fig.15 Experimental result of Fig.14

0-7803-4603-6/97/$5.00 (c) IEEE

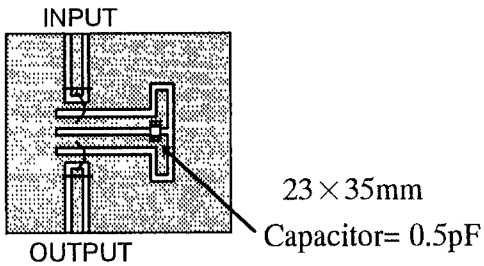


Fig.16 Combline BPF using
L type resonator (Type2)

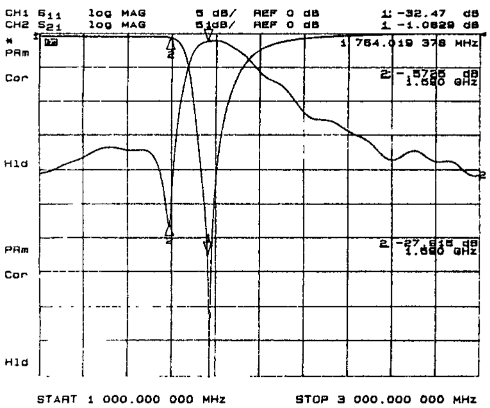


Fig.17 Experimental result of Fig.16

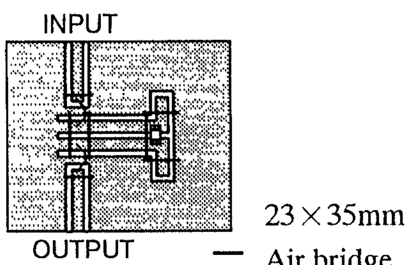


Fig.18 Combline BPF using
L type resonator (Type 3)

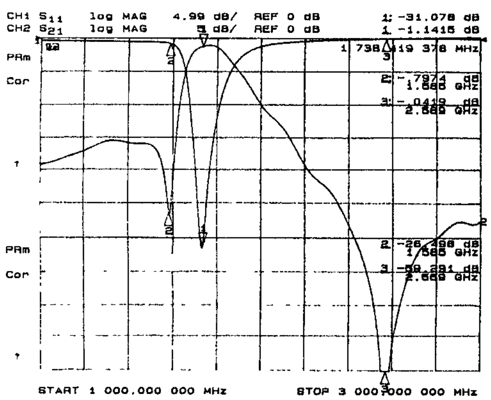


Fig.19 Experimental result of Fig.18

Fig.14 shows the combline BPF made of L type resonators, the airbridges being removed. The dimensions of PCB are as follows; size 23×35mm, a center strip width w=0.8mm, a width between center strips: s=0.4mm and a center strip to ground spacing : g=0.4mm. The passband characteristics of this BPF is shown in Fig.15. In this figure, the attenuation pole appears at the higher side of the passband(f_H=2.79GHz and f_0=2.00GHz). Fig.16 shows the PCB of the the combline BPF using L type resonators with a loading capacitor (chip ceramic capacitor : 0.5pF). The passband characteristics of this filter is shown in Fig.17. The attenuation pole appears at the lower side of the passband (f_L=1.59GHz and f_0=1.76GHz). Fig.18 show the combline BPF using L type resonator with a loading capacitor (chip ceramic capacitor : 0.5pF) where the airbridges are attached near the resonators. The passband characteristics is shown in Fig.19, where the attenuation poles appear at the both sides of the passband (f_L=1.59GHz, f_H=2.57GHz and f_0=1.74GHz).

CONCLUSION

We have investigated $\lambda/4$ CPW resonators with a tap-excitation and their application to BPFs. The basic characteristics of these resonators were verified by theoretical analysis using an improved equivalent circuit and a laboratory test. We have presented new types of combline BPFs and examined their transmission characteristics. We have also proposed combline BPFs using L type resonators. These filters are characterized by attenuation poles located at either or both side of the passband.

REFERENCES

[1] G.L.Matthaei," Comb-line band-pass filters of narrow or moderate bandwidth" ,Microwave-Journal, vol.6, pp.82- 91, Aug.1963.

[2]E.G.Cristal, " Tapped line coupled transmission lines with application to interdigital and combline filters", IEEE Trans. Microwave Theory and Techniques, Vol. MTT-23, pp.1007-1012, Dec., 1975.

[3]K.Wada et al.," Tapped-Feed Combline-Type Coplanar Waveguide Resonator Bandpass Filters", IEEE MTT-S Symposium on Technologies for Wireless Applications Digest, pp.141-146,Feb. 1995.