A MINIATURIZED END-COUPLED BANDPASS FILTER USING λ/4 HAIR-PIN COPLANAR RESONATORS

Tatsuya TSUJIGUCHI, Haruo MATSUMOTO and Toshio NISHIKAWA

Murata Manufacturing Co., Ltd.
Nagaokakyo,Kyoto,Japan

ABSTRACT

A miniaturized end-coupled bandpass filter is realized by λ/4 hair-pin coplanar resonators. Attenuation poles at both-side of the passband are generated by resonators arrangement to make multi-pass circuit. The trial filter has 590MHz 3dB-bandwidth at 5.8GHz and the insertion loss is 3.8dB. The size is $3.5x3.75x0.4mm^3$. It is applicable to MCM(multi-chip-module) by bare-chip mount.

1. INTRODUCTION

Microstrip line structure has been widely used in planar microwave circuits, however there is the productivity problem which is the necessity a short circuit to make a λ/4 resonator. Coplanar waveguide(CPW) line[1] is superior in productivity, because the short circuit part is able to be constructed in the uni-plane. CPW bandpass filter using series coupling of λ/2 resonators has been already reported[2][3][4], however it has the limitation of miniaturization and it is difficult to generate the attenuation pole. We realized four sections filter of λ/4 series coupling resonators by using the capacitive and the unique inductive coupling. High attenuation is obtained by the attenuation poles at both-side of the passband of the filter. Those poles are generated by the resonators arrangement to make multi-pass circuit. This paper reports the construction and the performance of newly developed bandpass filter for ISM5.8 application.

2. CONSTRUCTION

The layout of this filter is shown in Fig.1. The physical dimensions of the filter are shown in Table 1.

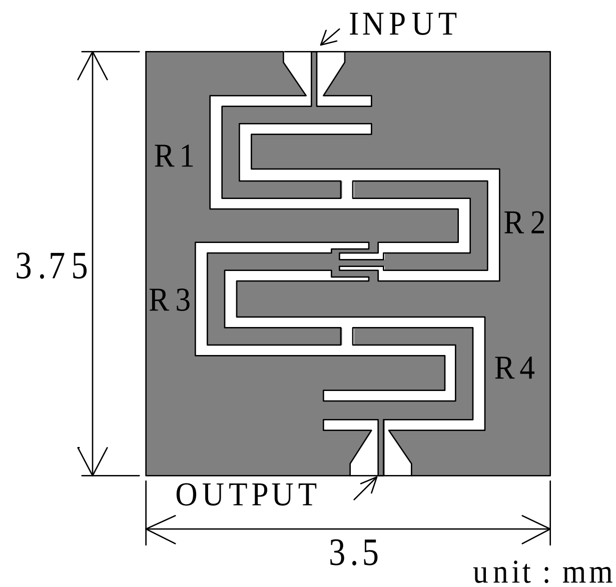

Fig.1 The layout of the developed filter

The electrode of Au is formed on the temperature stable substrate with high dielectric constant(εr=39 [5]). The resonators are a quarter wavelength of CPW line. The electrode is constructed by three layers. Ti and Pd layers(respectively 80nm and 150nm) are formed by evaporation. Moreover, 5.5μm thickness Au layer is formed by electrical plating on Ti and Pd. The circuit patterns are transcribed by photolithography and semi-additive method. The four λ/4 resonators are connected in series, and each resonator has hair-pin structure. The width of center conductor and the spacing between the conductor and the ground plane are decided to obtain maximum Q. A gap of coplanar line causes Capacitive coupling, and the relatively strong coupling is obtained by high dielectric constant substrate. A shunt inductive line causes inductive coupling, and the strength of the coupling is able to control this inductive line length. External coupling is obtained by tapped line, and the distance from the tapped line to short circuit part controls the strength of the external coupling.

The interactions between R1 and R3(the same as R2 and R4) and between R1 and R4 generate attenuation poles at both side of the passband, therefore high attenuation near the passband is obtained. And the frequency of the attenuation poles are controllable by changing the resonators arrangement. This filter characteristics is accurately reproducible because of the technology of photolithography, therefore it has good productivity.

Table1. The physical dimensions of the filter

Parameter	Dimension
Center conductor width	150μm
Spacing between conductor and ground plane	100μm
Ti/Pd/Au thickness	80nm/150nm/5.5 μm
Substrate thickness	400μm
Dielectric constant of substrate	39

3. EQUIVALENT CIRCUIT AND DESIGN

The equivalent circuits of the filter is shown in Fig.2. The interactions between R1 and R3(the same as R2 and R4) and between R1 and R4 are represented, as well as the coupling between the resonators in series. The coupling between each resonators is obtained by three dimensional FEM analysis and the equivalent circuit model. The interactions values obtained by FEM are corrected by the experimental results. The relationship between the gap width(W) of the coplanar line in the capacitive coupling part and the coupling coefficient(K) is shown in Fig.3

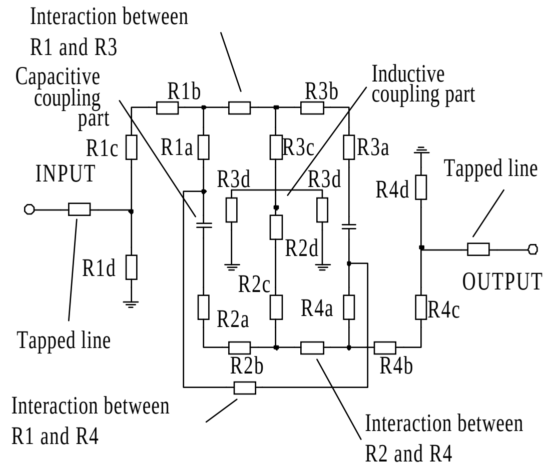

Fig.2 Equivalent circuit

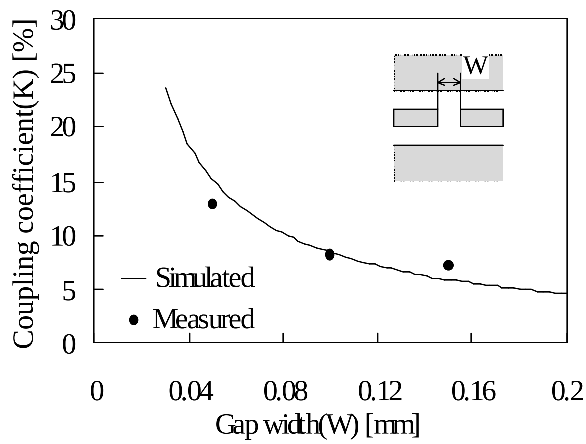

Fig.3 Gap width(W) vs. Coupling coefficient(K)

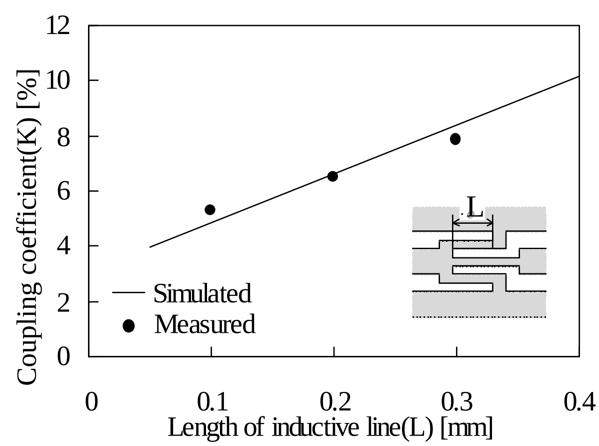

Fig.4 Length of inductive line(L) vs. Coupling coefficient

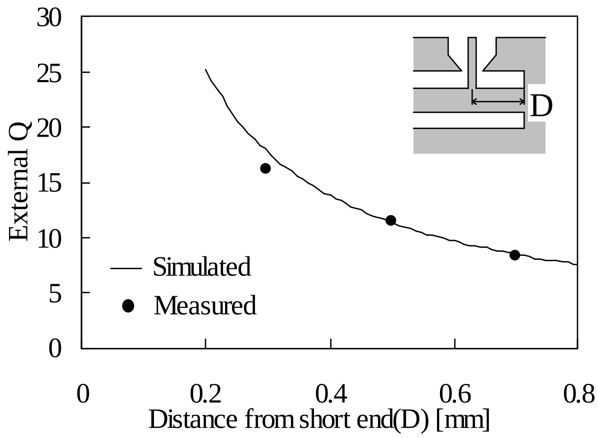

Fig.5 Distance from short end(D) vs. External Q

The relationship between the length(L) of the inductive line in the inductive coupling part and the coupling coefficient(K) is shown in Fig.4. And the relationship between the distance(D) from the tapped line to the short circuit part and the external Q is shown in Fig.5. The simulation and experimental results is shown in each figures.

The relationship between the attenuation pole frequency and the resonators arrangement is discussed. Two filters having different layouts are shown in Fig.6. R1 and R4 have bent at different positions and the spacing(S) between R1 and R3 in the filterB is larger than the filterA, therefore the interaction between R1 and R3(the same as R2 and R4) in the filterB is weaker than the filterA.

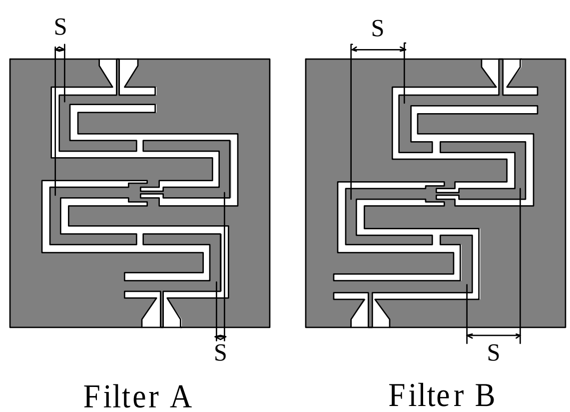

Fig.6 Two different layout filters

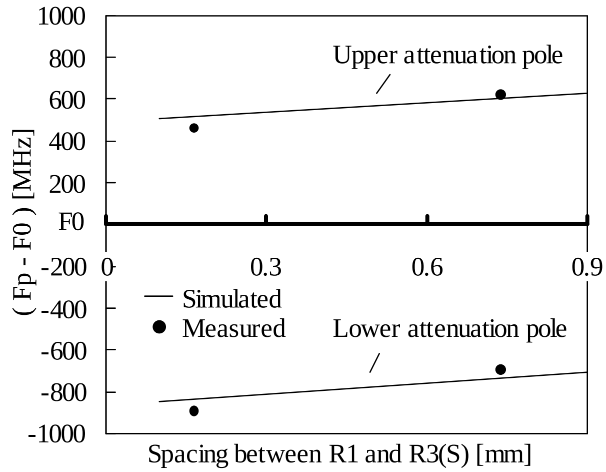

Fig.7 Spacing between R1 and R3(S) vs. Attenuation pole frequency

The relationship between the spacing(S) and the deviation of the attenuation pole frequency(Fp) from the center frequency(F0) are shown in Fig.7. As the spacing is wider, both lower and upper attenuation poles shift higher. In this way, the interaction of each resonators are determined by changing the resonators arrangement, therefore it is possible to control the frequency of the attenuation poles.

4.EXPERIMENTAL RESULTS

The trial sample of the four-sections filter is discussed. The size is 3.5x3.75x0.4mm^3, the volume is 5.25mm^3. The characteristics of the trial sample is shown in Table 2.

Table2. The characteristics of the filter

Center frequency F0	5780MHz
3dB-bandwidth	590MHz
Insertion loss	3.8dB
Lower attenuation pole frequency	4880MHz
Upper attenuation pole frequency	6240MHz

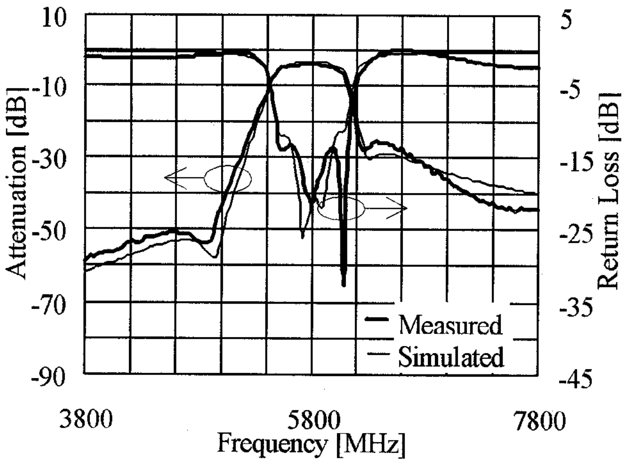

Fig.8 The characteristics of the filter

The measured and simulated transmission and return loss characteristics of the filter are shown in Fig.8. The measured results almost agree with the simulated one. The trial filter has 5780MHz center frequency and 590MHz 3dB-bandwidth. And the minimum insertion loss at passband is 3.8dB. It has the attenuation poles at both side of the passband and obtains the high attenuation near the passband. The photograph of the filter is shown in Fig.9.

5. CONCLUSION

We developed a miniaturized end-coupled bandpass filter by using $\lambda/4$ hair-pin coplanar resonators.

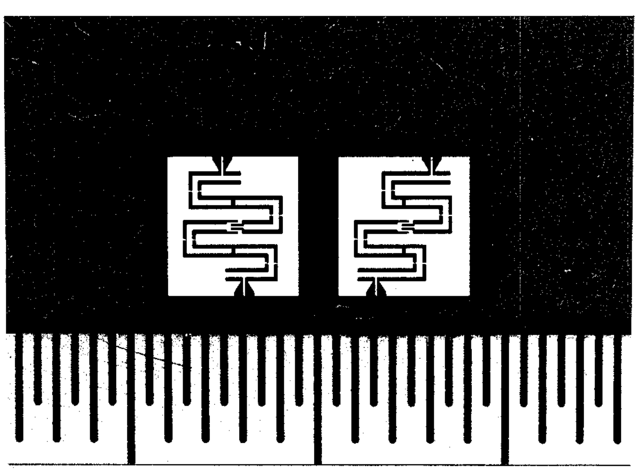

Fig.9 The photograph of the filter

The attenuation poles at both-side of the passband of the filter are generated by the resonators arrangement.

The trial filter has 590MHz 3dB-bandwidth at 5.8GHz and the insertion loss is 3.8dB. The size of it is 3.5x3.75x0.4mm^3. This filter characteristics is accurately reproducible because of the technology of photolithography, therefore it has good productivity. It is applicable to MCM for ISM5.8 application by bare-chip mount.

REFERENCE

[1] K.C.Gupta, R.Garg, I.Bahl, and P.Bhartia, “Microstrip Lines and Slotlines ”, Artech House, London, 1996(second edition)

[2] J.K.A.Everard, K.K.M.Cheng, ”High Performance Direct Coupled Bandpass Filter on Coplanar Waveguide”, IEEE Trans. Microwave Theory Tech., Vol. 41, No.9, Sep. 1993

[3] Daniel G.Swanson,Jr., Roger J.Forse, ”An HTS End-coupled CPW Filter at 35GHz”, IEEE Int. Microwave symposium Digest, June 1994, pp199-202.

[4] Andreas Vogt and Wilhelm Jutzi, “An HTS Narrow Bandwidth Coplanar Shunt Inductively Coupled Microwave Bandpass Filter on $LaAlO_3$”, IEEE Trans. Microwave Theory Tech., Vol. 45, No.4, April 1997

[5] K.Wakino, T.Nishikawa, S.Tamura, and Y.Ishikawa, “Microwave Bandpass Filters Containing Dielectric Resonators with Improved Temperature Stability and Sprious Response”, IEEE MTT-S IEEE Cat. No.75 CH0955-5, p63 1975