A Design of Planar Elliptic Bandpass Filter Using SMD Type Partially Metallized Rectangular Dielectric Resonators

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Abstract

In this paper, thin planar bandpass filter structures with elliptic, Chebychev, or notch filter response, using 2-D arrays of metallized rectangular dielectric waveguide type resonators on PCB are presented. Electrode pads on open-end surfaces (OEFs) of the resonator are used coupling ports to microstrip lines.

Because the resonant frequency of rectangular waveguide type resonator is not sensitive to height of the resonator, the filters can be used as planar or thin filter structure on PCB like other SMD chip devices.

A 4-pole elliptic function filter is designed and constructed. The measured frequency responses of the filter are agreed well with theoretical predictions.

1. Introduction

Dielectric materials with a high relative dielectric constant, high-Q values, as well as low temperature coefficients have been developed and widely adopted for many types of miniaturized resonators [1]-[6]. Using these materials, one can easily form small sized high-Q dielectric filled waveguide resonators or metallized rectangular ceramic resonators.

The TE_{101} or $TE_{10\delta}$ resonant frequency of the metallized dielectric rectangular resonator is not changed theoretically by the height or the dimension, b, which is very useful to build thin planar filter structure on PCB.

Two-dimensional (2-D) array of the planar rectangular resonator could give advantage to make compact filters with special responses, such as notch filter, duplexer, or Elliptic filter responses.

2. Resonator

A rectangular dielectric resonator is metallized except the left and right sides. On the each open-end surface (OEF), electrode pad is printed as suggested Konishi [1], which is used as connection port to microstrip line. According to the dimension of the electrode, the coupling strength from the resonator to microstrip line is determined. One measured result of the coupling coefficient using the definition of eq. (1) is given in Fig. 2. The used resonator dimension a×b×c is 20mm×10mm×5mm, and the dielectric constant is 38.4.

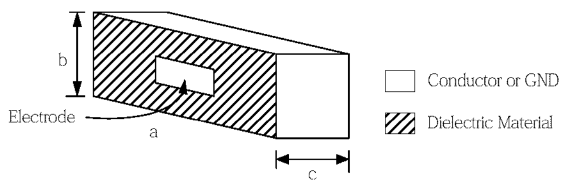

Fig. 1 A metallized rectangular ceramic resonator with electrodes on both OEFs.

As the electrode dimensions h and w is increased, the coupling coefficient k_{01} is normally increased, and the resonant frequency is decreased, but in the case of dimension w, there is an maximum point, as in Fig. 2. Using this property, we can choose proper resonant frequency and coupling coefficient k_{01}.

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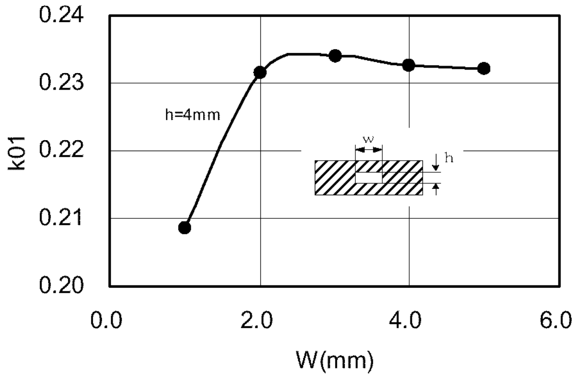

Fig. 2 Coupling of resonator to microstrip line

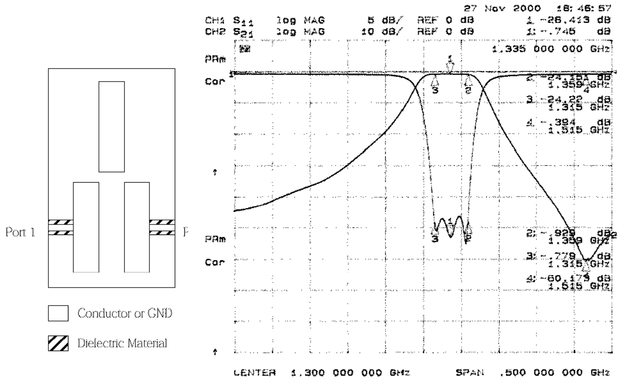

Fig.3 An example of 3-pole parallel array of the SMD type resonators and its response

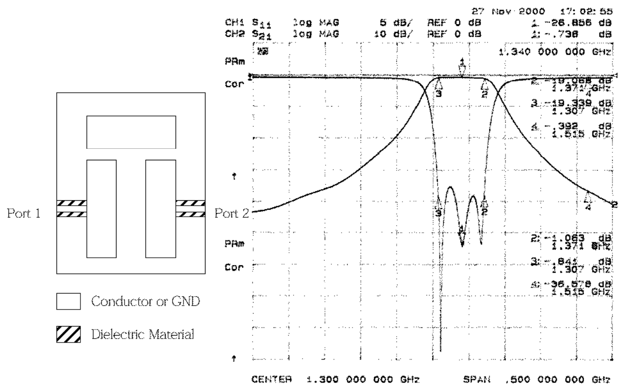

Fig. 4 An example of 3-pole mixed array of the SMD type resonators and its response

3. Bandpass filter structures

The SMD type resonators can be arranged as two-dimensional array for a Chebychev, notch or elliptic filter response. One is parallel array as example of 3-pole case as in Fig. 3. A mixed direction array is also possible for 2-D compact array as the example of Fig 4.

An elliptic filter response is obtained using the structure of Fig.5. For the negative closs-coupling values, chip capacitors or finger type microstrip coupling could be used. In the case of chip capacitor, by replacing the chip capacitors easily changes the cross-coupling values. In addition, the negative coupling values are so small that the loss by the chip capacitors is negligible.

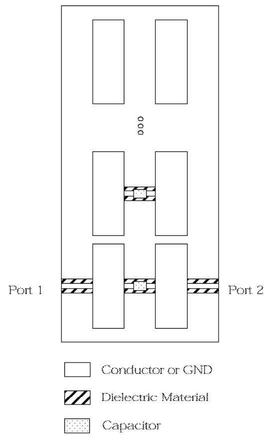

Fig.5 Elliptic function filter structure with even number of poles

4. Design of elliptic filter

Using conventional elliptic filter design procedure [8]-[12], a 4-pole elliptic function filter with center frequency of 1.35GHz, bandwidth of 54MHz (4%) and modulus k of 0.3333 is designed, built and tested. The angular pole frequencies are –0.36090 ±j1.34127 and –1.02095±j0.62426. The coupling matrix elements are as follows.

$$M = \begin{bmatrix} 0 & 1.0554 & 0 & -0.1109 \\ 1.0554 & 0 & 0.8279 & 0 \\ 0 & 0.8279 & 0 & 1.0554 \\ -0.1109 & 0 & 1.0554 & 0 \end{bmatrix}. \qquad (1)$$

Coupling coefficient k_{ij} can be defined as eq. (2), and (3)[13].

$$k_{01} = \frac{1}{\sqrt{Q_e}} = \frac{J_{01}}{\sqrt{Y_0 \bar{b}_1}} = \sqrt{\frac{W}{g_0 g_1 \omega_1'}} \quad (2)$$

$$k_{ij}\Big|_{j=1..n-1} = \frac{J_{j\,j+1}}{\sqrt{\bar{b}_j \bar{b}_{j+1}}} = \frac{W}{\omega_1' \sqrt{g_j g_{j+1}}} \quad (3)$$

The coupling coefficient k_{01} can be calculated by measured external quality factor Q_e or fractional bandwidth W, when a resonator is coupled to external circuit that has admittance Y_0. The inter-resonator coupling coefficient k_{ij} of eq. (3) also can be easily determined by measuring fractional bandwidth W or peak frequencies f_1 and f_2 under loose coupling condition of two identical resonators, and eq. (4) [7][8].

$$k_{ij}\Big|_{j=1..n-1} \approx \frac{f_2^2 - f_1^2}{f_2^2 + f_1^2} \approx \frac{f_2 - f_1}{f_0} \approx \frac{W}{\sqrt{2}} \quad (4)$$

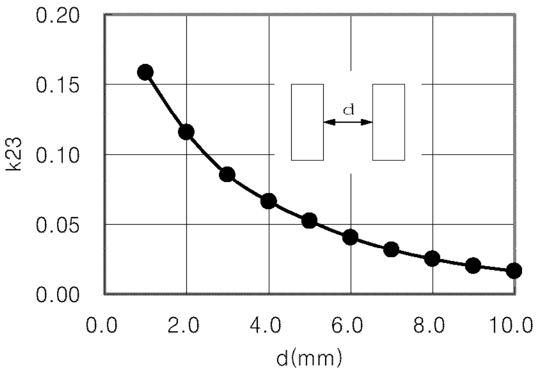

Fig. 6 Coupling coefficients of parallel array

The coupling coefficients needed to design elliptic filters are measured and shown in Fig. 6 to Fig. 8.

We used the electrode dimensions, w and h of 5.0 and 4.0 mm respectively, for k_{01} value of 0.234. The other coupling coefficient values of the elliptic filter are k_{12} of 0.0422, k_{23} of 0.033, and k_{14} of 0.0044(negative coupling). Using the graphs in Fig.6 to Fig. 8. the distances of resonators are determined.

The measured performance of the 4-pole elliptic filter is shown in Fig. 9. The result shows center frequency of 1.350GHz, insertion loss 0.999dB, bandwidth of 57MHz, and -20.1dB return loss in passband.. Which is agreed well with design specifications of the elliptic filter. Additional transmission zero at 1.120GHz is the parallel resonant frequency of the coupling of the 1st and 4th resonator. The inherent inductive coupling is canceled and changed to capacitive coupling by the capacitor. More symmetrical response is possible as increase the coupling distance of the 1st and 2nd resonators.

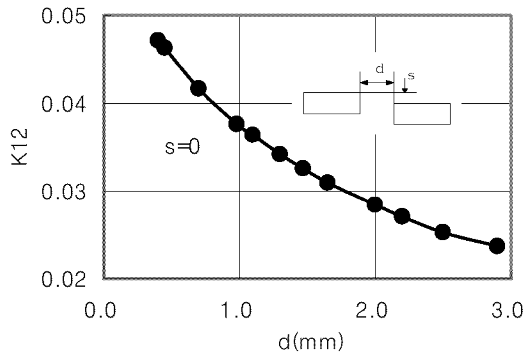

Fig. 7 Coupling coefficients of series array

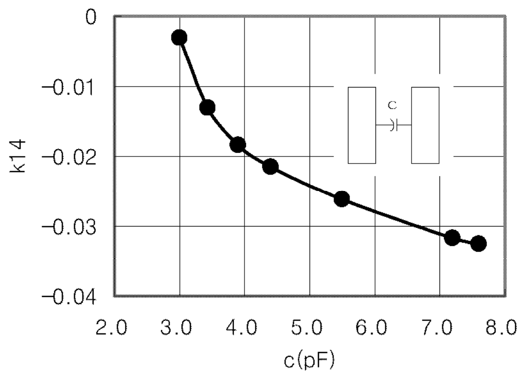

Fig. 8 Coupling coefficients of parallel array with an additional capacitor(distance of resonators = 7.0mm)

5. Conclusions

Using 2-D arrays of metal-coated dielectric rectangular resonators on PCB, an elliptic filter as well as Chebychev and notch filters, has been presented which has thin planar structure and easily connects to other SMD devices on the same PCB.

Using 2-D array of the resonator with the height of 5.0mm, a 4-pole elliptic filter with center frequency 1.35GHz, bandwidth of 54MHz (4%) has been designed for demonstrating the capability of generating elliptical response with typical finite transmission zeros.

The planar filter design can be easily accomplished with thinner resonator according to the need of thin device.

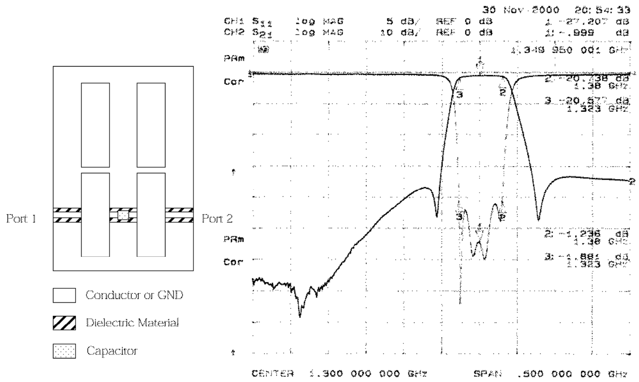

Fig. 9 Structure and performance of the 4-pole elliptic filter

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