K-band Planar Type Dielectric Resonator Filter with High-ε Ceramic Substrate

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Abstract

A new planar type dielectric resonator filter, named TE_{010} mode dielectric filter, is proposed for high-speed data communication systems. The filter was manufactured with precise photolithography process on the high-ε (high-dielectric-constant) ceramic substrate. The small filter with low loss and high selectivity characteristics has been realized at 19 GHz.

1. INTRODUCTION

The wireless communication systems have been quickly expanding and require new frequency band. Moreover, very wide frequency range is required for high-speed data communication in the future. The frequencies higher than 10 GHz are suitable for future communication systems. Therefore demands for the filter for such communication systems are increasing in recent years.

The required characteristics of the filters are, (1) small size, (2) low insertion loss, (3) high selectivity, (4) high productivity, and (5) high temperature stability. Moreover, in order to connect the filters to MMICs or MICs, they must be easily integrated into planar circuits. Several types of the filters have been reported at frequencies higher than 10 GHz. However, they don't completely satisfy the above requirements

This paper describes a K-band filter which satisfies those requirements by using new planar type dielectric resonators.

2. TE_{010} MODE DIELECTRIC RESONATOR

2.1. Configuration

Fig. 1 shows the configuration of a TE_{010} mode dielectric resonator we have proposed[1]. The resonator consists of a dielectric substrate and upper metal plate and lower one. The dielectric substrate, which has thin-film electrodes on its both surfaces, is placed between the both metal plates. The thin-film electrodes have hollow patches of the same diameter with each other. The electrodes divide the resonator into three layers (Ⅰ, Ⅱ, Ⅲ) which form cut-off waveguides for cylindrical TE mode waves propagating outwardly. Therefore the electromagnetic field is confined within the circular hollow patches.

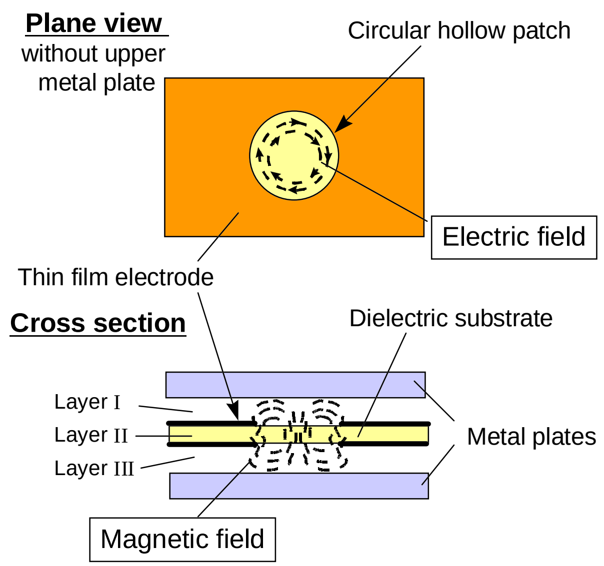

Fig. 1 TE_{010} mode dielectric resonator

2.2. Characteristics of the resonator

In order to analyze the characteristics of the resonator, a two-dimensional finite element method for rotationally symmetrical structure[2] is used.

Electromagnetic field distribution

The electromagnetic field distribution is similar to that of a $TE_{01\delta}$ mode dielectric resonator. However, outside the resonator, it has a very strong cutoff region compared to the $TE_{01\delta}$ dielectric resonator. Fig. 2 shows magnetic field intensity in $TE_{01\delta}$ and TE_{010} mode (the dashed lines in the figure indicate the position for calculation of the magnetic field intensity). This signifies that electromagnetic energy is concentrated in the dielectric substrate, compared with other resonators. Thus, mutual interference among circuit elements are negligible and a highly integrated circuit construction will be expected

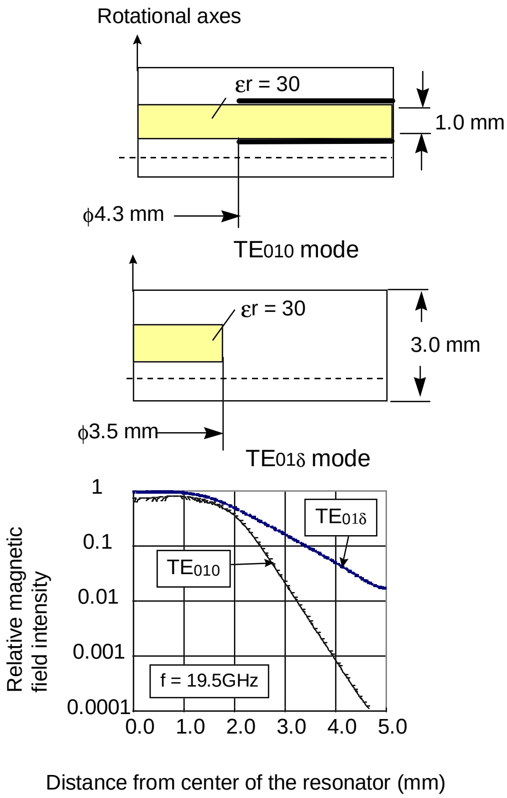

Fig.2 Magnetic field intensity in resonator

Resonant frequency

Fig. 3 shows the relationship between the diameter of the resonator and the resonant frequency. In case of using the high-dielectric-constant substrate ($\varepsilon r = 30$), the diameter is 4.3 mm for 19.5 GHz resonator. Consequently we expect that the small size resonator will be realized. Moreover, it indicates that the resonant frequency depends upon the diameter of the hollow patches. Therefore high-precision photolithography process will be applicable effectively.

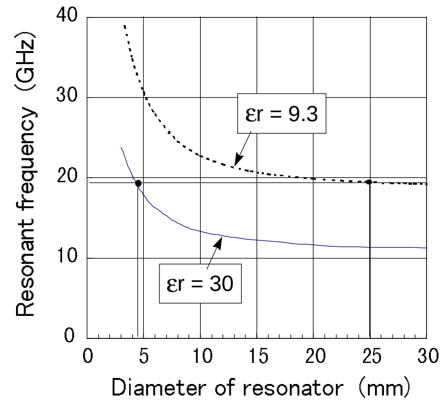

Fig. 3 Relationship between the diameter of resonator and the resonant frequency

Unloaded Q

In order to calculate the unloaded Q (*Qu*) of TE_{010} mode dielectric resonator, it is necessary to calculate conductor Q (*Qc*) exactly. The metal surface of the model shown in Fig. 4 is divided into four regions, and *Qc* of these regions, i.e., *Qc(up)* : thin-film electrode upper surface, *Qc(low)* : thin-film electrode lower portion , boundary between the thin-film electrode and the dielectric substrate, *Qc(ed)* : thin-film electrode edge section, and *Qc(cav)* : upper and lower metal plates, are calculated.

$$1/Qc(total)$$
$$= 1/Qc(up) + 1/Qc(low) + 1/Qc(ed) + 1/Qc(cav)$$

Qc of the TE mode resonator, in which no vertical electric field exists about a conductor, can be calculated by perturbation method[3]. It is necessary to consider the convergence of current density at the edge of the electrode for the calculation. Calculated and measured Q values are listed in Table I. The measured unloaded Q is very close to the calculated value.

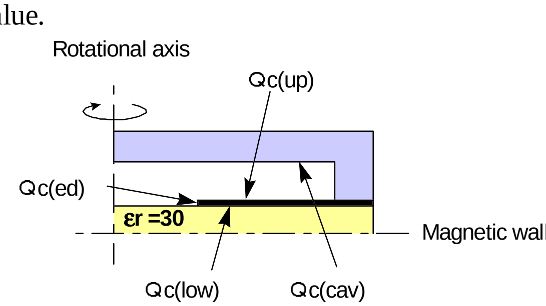

Fig. 4 Analytical model

TABLE I Q value of the resonator	
Qc(up)	9230
Qc(low)	4300
Qc(ed)	7400
Qc(cav)	36500
Qc(total)	1980
Qd	7600
Qu (calculated)	**1570**
Qu (measured)	**1550**

Coupling coefficient

The resonator has multilayer structure, therefore, electromagnetic simulator for multilayer substrate is available for physical design. The coupling coefficient of the resonators is calculated by HP-MOMENTUM. Fig. 5 shows the relationship of the gap between the two resonators with the coupling coefficient. Measured values agree well with calculated values

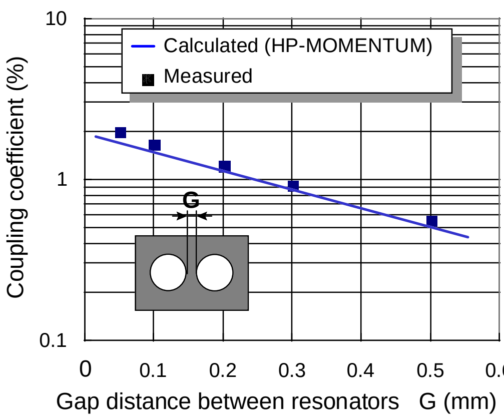

Fig. 5 Relationship of gap distance between resonators and coupling coefficient

2.3 FABRICATION

A K-band resonator was fabricated with the photolithography technique. A ceramic substrate with high-dielectric-constant ($\varepsilon r = 30$, $\tan\delta = 7 \times 10^{-5}$ at 10GHz, thickness = 1.0 mm) was mirror-polished so precisely to enable photolithography process. High unloaded-Q of 1550 was obtained. Measured temperature coefficient of the resonant frequency is less than 1×10^{-6} /ºC.

3. TE_{010} MODE DIELECTRIC FILTER

3.1 Configuration

A three-pole filter was designed using TE_{010} mode dielectric resonators. The configuration and equivalent circuit of the filter are shown in Fig. 6 and Fig.7 respectively. Three resonators are fabricated on the same substrate and magnetically coupled with one another. The coupling line for K13 is formed on the base substrate to improve the attenuation characteristics. The input and output ports are connected to the microstrip lines. The microstrip line is magnetically coupled to the TE_{010} mode of the resonator to obtain the desired external Q. Since plural resonators can be fabricated on the same substrate, the advantages of photolithography technology are fully utilized to realize a high precision process and a highly accurate relative position between resonators.

3.2 Electrical design

Target characteristics of the filter to be fabricated are shown in Table Ⅱ. The relative pass bandwidth is approximately 0.3 %. The unloaded-Q of the resonator is required to be larger than 1200. Filter structure parameters are derived from the analytical results of the resonator described above.

Table Ⅱ Target characteristics of the filter	
Center frequency (fo)	19.5 GHz
Pass bandwidth (BW)	60 MHz
Insertion loss (IL)	3.0 dB
Return loss (RL)	12 dB
Attenuation (at f_0 -250 MHz)	40 dB

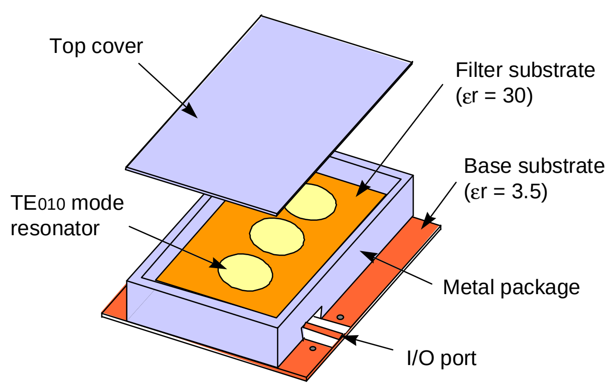

Fig. 6 Filter configuration

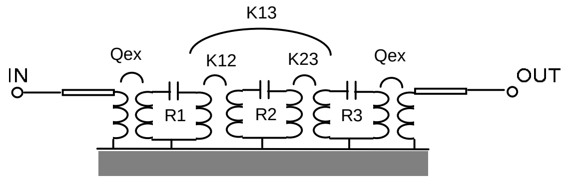

Fig. 7 Equivalent circuit

3.3 Results

Fig. 8 shows the photograph of the filter we fabricated. The size of the filter is 19 mm(W) × 10 mm(D) × 3.5 mm(H). The volume of the filter is less than 1/5 of that of the $TE_{01\delta}$ mode dielectric filter. Small and low profile construction has been realized owing to the TE_{010} mode dielectric resonators. The measured filter characteristics are shown in Fig. 9 and Table Ⅲ Low insertion loss and high attenuation characteristics are realized. Temperature characteristics of the filter is shown as Fig. 10. High temperature stability is obtained.

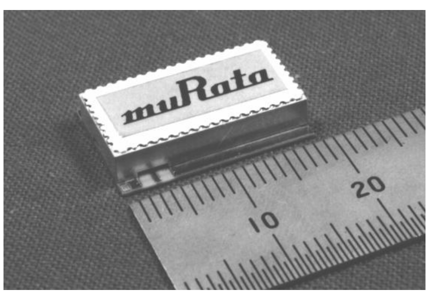

Fig. 8 Photograph of the filter

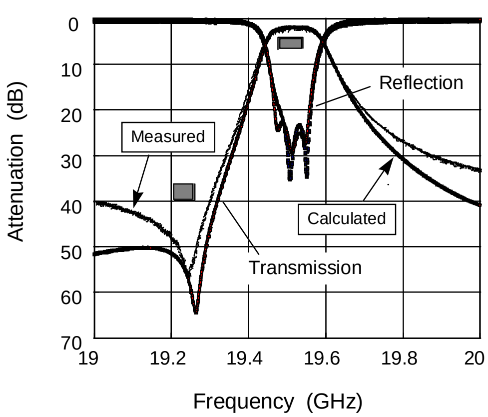

Fig. 9 Filter response

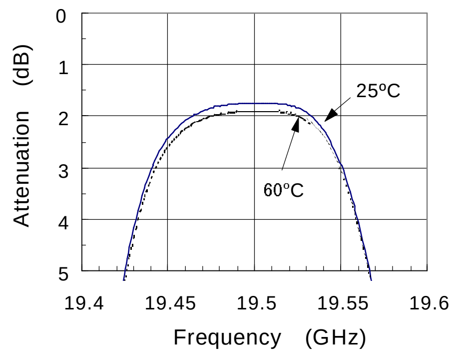

Fig. 10 Temperature characteristics

Table Ⅲ Measured results

Center frequency (fo)	19.5 GHz
Pass bandwidth (BW)	60 MHz
Insertion loss (IL)	2.0 dB
Return loss (RL)	18 dB
Attenuation (at f_0 -250 MHz)	55 dB

4. CONCLUSION

A planar type dielectric filter, named TE_{010} mode dielectric resonator filter is proposed to realize a K-band filter. A three-pole filter was manufactured with precise photolithography process on the high-dielectric-constant ceramic substrate. Low insertion loss and high attenuation characteristics are realized. The filter can be easily integrated into planar circuits, therefore it is expected to be applicable to future high-speed data communication systems.

ACKNOWLEDGMENT

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