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28GHz BAND BANDPASS FILTER USING HIGH Q DIELECTRIC RESONATORS

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ABSTRACT

A 28GHz band bandpass filter using high Q dielectric resonators has been developed. High Q dielectric ceramics $Ba(Sn,Mg,Ta)O_3$ was applied to a new configuration for symmetrically circular filter. Direct eigen mode expansion method is applied to multi-pole bandpass filter design and is effective for determination of construction parameters. The overall size of the filter is 10 × 10 × 20 mm and the volume is one fourth of dielectric resonator filters of conventional parallel structure. Insertion loss of the filter is 0.74 dB at 190 MHz bandwidth and attenuation is 33 dB at fo ± 300 MHz. The filter is suitable for K-band communication equipment.

INTRODUCTION

Millimeter waves offer an exciting new oppotunity for delivering multichannel information. Usually millimeter wave communication equipment contain high performance cavity type filters. However the size and weight of cavity type filters are still larger than other component of the equipment utilizing MIC technology.

Microwave filters using dielectric resonators were proposed[1, 2] and miniaturized bandpass filters using multimode dielectric resonators in 12 GHz band were reported[3]. Dielectric bandpass filters of parallel structures were reported in millimeter wave region[4]. However dielectric filters of axisymmetric structure have not been reported in millimeter wave region because the method to fix resonators stably have not been proposed. We applied the axisymmetric construction to millimeter wave filter to realize small size and low loss performance. Dielectric resonators and spacers of the same diameter are aligned and mounted to assure temperature stability of the filter. We succeeded in exact design procedure in calculation appling direct eigen mode expansion method to multi-pole dielectric resonator filter. Calculated characteristics of the filter agree well with experimental results. The design procedure is confirmed to be effective to design of millimeter wave filter.

A 28 GHz band bandpass filter using high Q dielectric resonators was developed. In this paper practical design and performance aspects associated with implementation are discussed.

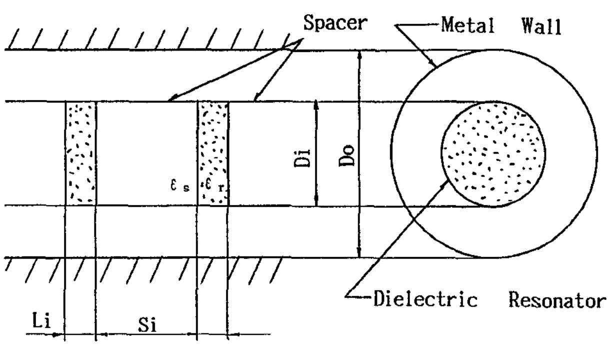


Figure 1 Basic construction of the filter

CONSTRUCTION

At present, high Q dielectric ceramics Ba(Sn,Mg,Ta)O_3 have been developed for millimeter wave applications. Dielectric properties of Ba(Sn,Mg,Ta)O_3 and conventional ceramics are shown in Table 1. Ba(Sn,Mg,Ta)O_3 has one half the dielectric loss compared with the conventional material, Ba(Zr,Zn,Ta)O_3. We applied these Ba(Sn,Mg,Ta)O_3 dielectric resonators to K-band filters. The dielectric resonators are mounted in the center of a circular, evanescent mode, metal cavity which is made of brass plated with silver . The basic construction of the axisymmetric dielectric filter is shown in Figure 1. A new configuration using spacers with epoxy bond is necessary to support these dielectric resonators. The dielectric resonators and the spacers make a circular dielectric wave guide which has discontinuities of dielectric constant. The mounting has to be mechanically stable to assure temperature stability and good vibration performance. Available materials for such spacers have to meet specific criteria such as low loss, low dielectric constant, and excellent mechanical properties. Fused quartz, which is found to give satisfactory performance, is applied to spacers of the filter. The construction of a four-pole filter is shown in Figure 2. Input-Output terminals are 3.5 mm connectors and external Q was obtained magnetically using loop probes. The size of the filter is 10 × 10 × 21 mm and the volume is one fourth of conventional dielectric resonator filters because the field distribution of the filter is axisymmetrically circular.

Table 1. Dielectric materials

Materials	K	Q	τ_f (ppm/℃)	f_0 (GHz)
Ba(Sn,Mg,Ta)O_3	25	30000	≒ 0	10
Ba(Zr,Zn,Ta)O_3	30	15000	≒ 0	10
(Zr,Sn)TiO_4	38	6000	≒ 0	10

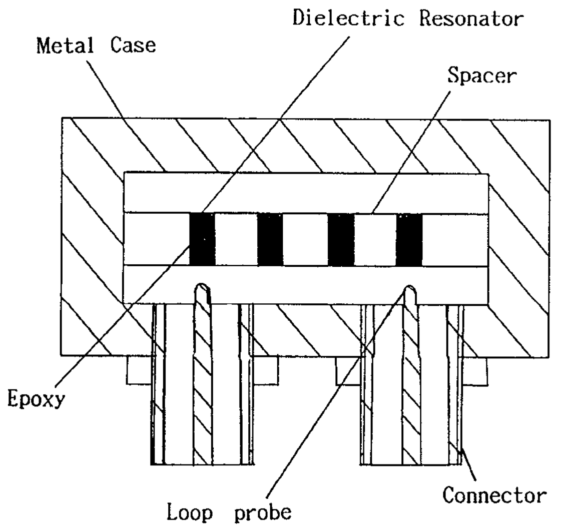


Figure 2 Construction of four-pole filter

Table 2. Outline of required characteristics

Center frequency (fo)	28.72 GHz
Bandwith (BW)	190 MHz
Attenuation(at fo±300MHz)	30 dB min.
Insertion loss (at BW)	0.8 dB max.
V.S.W.R. (at BW)	1.5 max.
Volume	2.5 cm^3

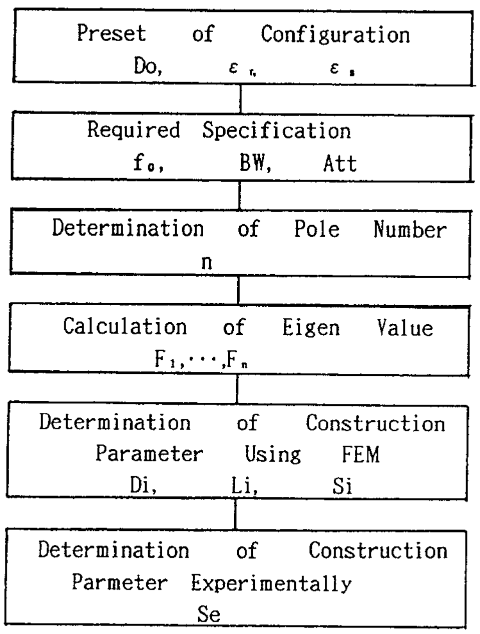
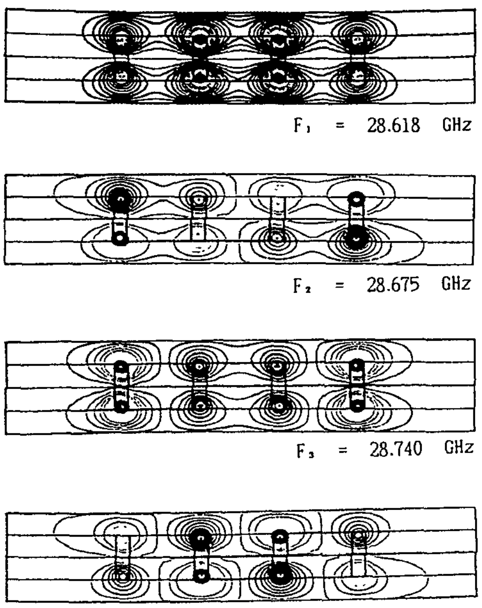


Figure 3 Design procedure

FILTER DESIGN

The required characteristics of the bandpass filter used for 28GHz multichannel data delivering systems are listed in table 2. Design procedure of the in-line filter is shown in Figure 3. In order to determine the construction parameters, we newly apply eigen mode expansion method using finite element method (FEM). As for axisymmetric dielectric filter design, coupling coefficients of two dielectric resonators have been calculated using series expansion method [5]. However resonant modes frequencies of multi-pole filter have not been calculated because the spatial division of series expansion method is so complex. We applied FEM to design of multi-pole filters. The eigen value of resonant mode were calculated using FEM. The new configuration of the axisymmetric filter fits FEM analysis. Figure 4 shows field distributions and resonant frequencies of each resonant modes.



Do = 5.0 mm ε_r = 24.2
Di = 2.5 mm ε_s = 3.8
Li = 0.75 mm
Si = 3.5 mm

Figure 4 Resonant modes of four-pole filter

Construction parameters of resonators and spacers were optimized by resonant mode frequencies. The frequency characteristics of the filter were calculated with resonant frequencies and external Q of each resonant modes. Separation between loop probe and resonator was determined experimentally.

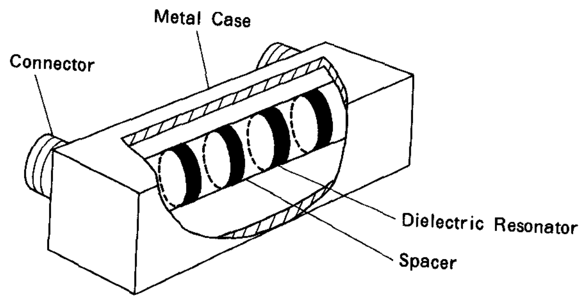


Figure 5 28 GHz band bandpass filter

EXPERIMENTAL RESULTS

An in-line filter with a $TE_{01\delta}$ mode dielectric resonator configuration was built and tested. Input-Output terminals were coaxial connectors as shown in Figure 5. Inner diameter of the cavity was 5.0 mm and diameter of the resonators was 2.5 mm.A four-pole filter with center frequency (fo) of 28.72 GHz was realized and tested. The transmission and reflection response are shown in Figure 6. The measured

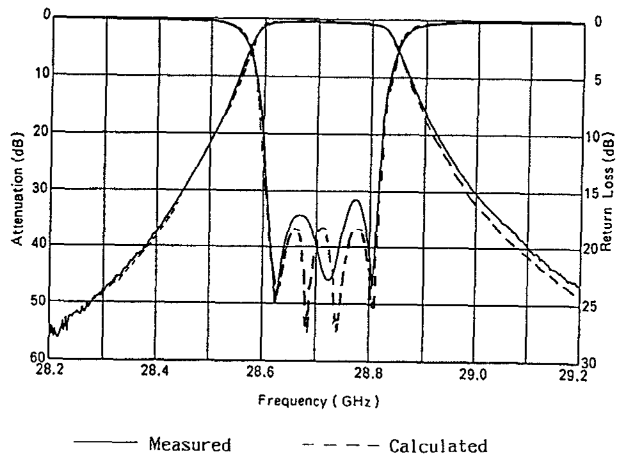


Figure 6 Electrical performance of the filter

characteristics agree well with the calculated curve. The measured value of unloaded Q, Qo=6700 gives a midband insertion loss of 0.57 dB, while the measured insertion loss of 0.65 dB corresponds to Qo=5900. This degradation is due to the conductor loss of the coupling structure. Insertion loss of the filter is 0.74dB at 190 MHz bandwidth. Attenuation is 33dB at fo ± 300 MHz. The insertion loss is less than that of dielectric resonator filter with conventional parallel structure. The performance of the filter is shown in Table 3. This performance sufficiently satisfies the required characteristics shown in Table 2. The spurious response characteristics of the filter is shown in Figure 7. The temperature coefficient of the filter is 2 ppm/℃.

Table 3. Performance of the filter

Center frequency (fo)	28.72 GHz
Bandwith (BW)	190 MHz
Attenuation(at fo±300MHz)	33 dB
Insertion loss (at BW)	0.74 dB
V.S.W.R. (at BW)	1.40
Size	10×10×21 mm (2.1 cm^3)

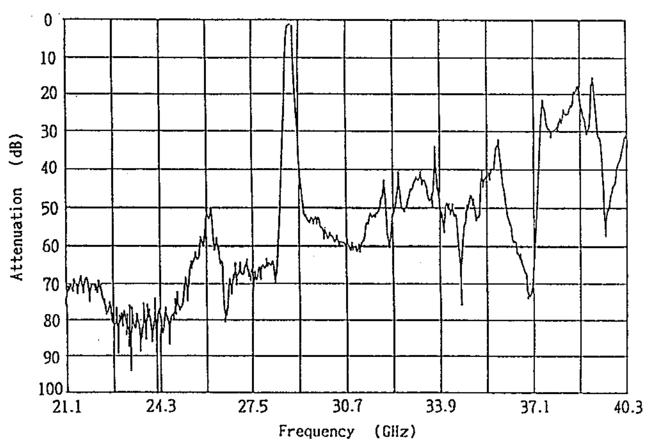


Figure 7 Wideband frequency sweep of the filter

CONCLUSION

A 28 GHz band dielectric bandpass filter was developed. Low dielectric loss material for millimeter wave is applied to the filter. A new configuration of symmetrically circular filter fits design under FEM. A photograph of the filter is shown in Figure 8. The size of the filter is 10 × 10 × 21 mm. Low insertion loss of 0.74 dB is obtained by high unloaded Q of 5900. Calculated frequency characteristics agree well with measured results. The filter is suitable for millimeter wave communication equipment.

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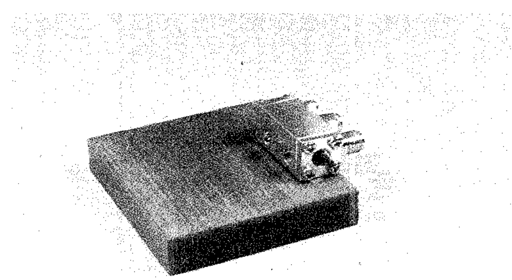

Figure 8 Photograph of the filter