800 MHz Band Channel Dropping Filter Using TM_{010} mode Dielectric Resonator

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ABSTRACT

High Power "Channel Bandpass Filter" for Base station was miniaturized to 1/5 to 1/10 in dimension by using high K dielectric ceramics. The resonant mode is dielectric TM_{010} and its unloaded Q is over 8,000 at 800 MHz. The frequency temperature stability of the filter is less than 0.5ppm/°c.

Introduction

Recently, in mobile communication systems, cellular systems have been put into practical use, and the number of the base stations has increased. Channel filters are used for transmission multiplexers in the base station, and their technical requirements are increasing to high levels. The characteristics requested for these filters are as follows; low transmission loss, high power capability, small size, high stability, high isolation between channels, and low cost and high productivity.

The original filters were constructed of cavity resonators made of invar, and the volume was more than 2,000 cubic cm. After that $TE_{01\delta}$ mode dielectric resonator shielded by metal cases were used in order to miniaturize the filter.(1) But it is necessary to adjust the temperature coefficient of the dielectric material, considering those of other construction parts in order to control the center frequency of the filter within a small allowance.

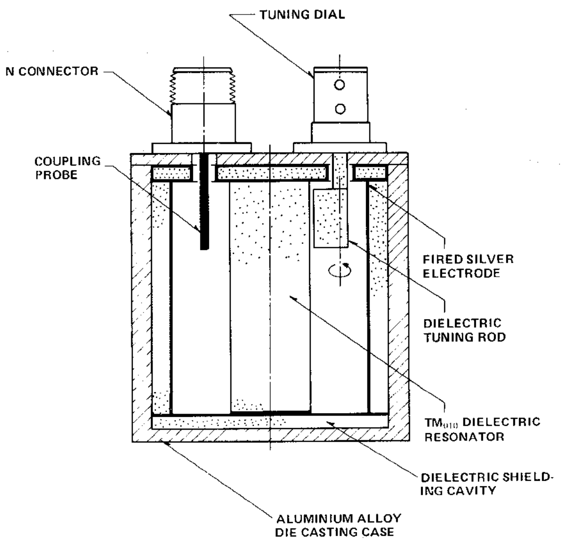

Fig 1. The construction of dielectric "Channel Dropping Filter"

Recently, TM_{010} mode dielectric resonators and filters with metal cavity have been reported.(2) These resonators are much smaller than $TE_{01\delta}$ mode resonators. However, the essential problem of the frequency stability is not solved. Now, we newly succeeded in developing 800 MHz band dielectric channel dropping filters with high stability. The measured values of unloaded Q and temperature coefficient of the center frequency well coincided with design values.

Construction

A cross sectional view of the filter is shown in Figure 1. The dielectric circular rod (with K of 37.5) is fixed in the center of a cylindrical cavity. The outside walls are used for electromagnetic shielding and are made of ceramic material with the same thermal expansion coefficient as the rod resonator. The electrode of the cavity is the thin film of fired silver. The surface resistance of the electrode is about 10% bigger than the theoretical value of silver. The small dielectric rod in the cavity is used for tuning frequency of the center frequency. The resonant frequency is perturbed by moving ceramic dielectrics in the electric

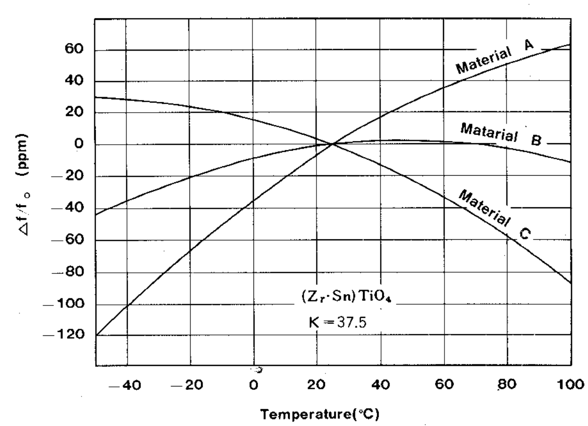

Fig 2. The change of resonant frequency of high K material versus temperature (Materials A, B and C have different compound ratios from each other in the same material system)

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Part	Material	K	(ppm/°C)	1/tanδ
Resonator	$(Zr \cdot Sn)TiO_4$	37.5	6.5	23000
Tuning Rod	$(Zr \cdot Sn)TiO_4$	37.5	6.5	23000
Shielding Cavity	$2MgO \cdot SiO_2 - ZrO_2 \cdot SiO_2$		6.5	

Table 1. Properties of the ceramic materials

field gradient. The dielectric cavity resonator is electrically coupled to the load by coupling probe, and coupling strength is controlled by the length of the probe.

Dielectric materials of the filter

The ceramic materials used for the filter are listed in Table 1. The changes of the resonant frequency of the high K material versus temperature are shown in Figure 2. The frequency temperature coefficient (η_{f_0}) of the dielectric material is defined as the following equation,

$$\eta_{f_0} \equiv -\frac{1}{2}\,\eta_K - \alpha = \frac{1}{f_o}\frac{\partial f_o}{\partial T} \qquad (1)$$

where η_K is the temperature coefficient of K, and α is the thermal expansion coefficient. The second equal sign of the equation is realized when the electro-magnetic energy is perfectly confined in the dielectric material. Therefore value of η_{f_0} is independent of the shape of ceramics and its resonant mode.

Unloaded Q and the temperature coefficient (η_f)

The TM_{010} mode analysis and its unloaded Q was reported by Kobayashi et al.[2] In the special case we used, the unloaded Q versus outside cavity dimension is shown in Figure 3. The dush in the same figure is the normalized lateral conduction Q. The theoretical and experimental unloaded Q are 8,400 and 8,200 respectively when D is 58mm.

The change of the K constant causes the change

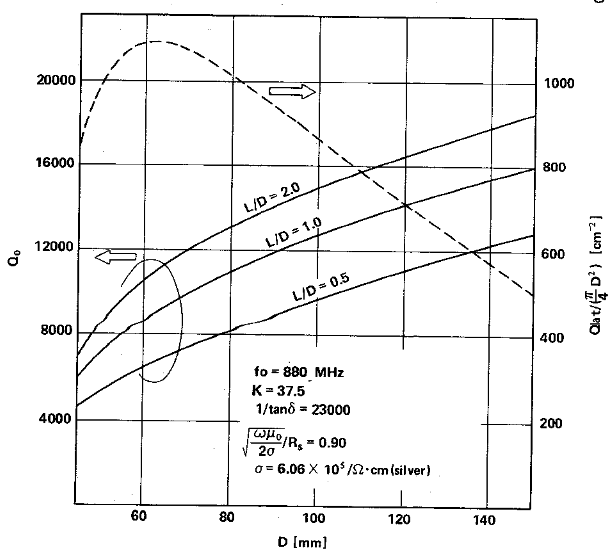

Fig 3. Unloaded Q of TM_{010} dielectric resonator

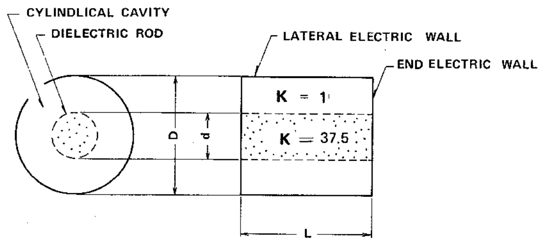

Fig 4. Cross section of TM_{010} dielectric resonator cavity

in the distribution of electro-magnetic energy. On the other hand, the thermal expansion with similar figure of field space in the cavity resonator does not effect the field distribution. Therefore the contribution of the thermal expansion coefficient of the ceramics is the same as the equation (1). Considering these effect, the temperature coefficient of the TM_{010} resonant frequency is expressed by the modified equation using correction factor A as follows.

$$\eta_f \equiv \frac{1}{f_o}\frac{\partial f}{\partial T} = -\frac{1}{2}A\,\eta_K - \alpha \qquad (2)$$

When A is almost 1 as shown in Figure 5, the difference in the temperature coefficient between equation (1) and equation (2) is given as follows.

$$\Delta\eta_f = \eta_f - \eta_{f_0} = \frac{1}{2}(1-A)\eta_K \simeq 0 \qquad (3)$$

Electrical design

The design parameters of the filter are shown in Table (2).

(1)Physical size of the dielectric rod resonator.

The diameter of the dielectric rod resonator (d) is determined by the resonant condition as follows,

$$\frac{K}{u}\frac{J_o'(u)}{J_o(u)} - \frac{1}{v}\frac{J_o'(v)Y_o(vS) - J_o(vS)Y_o'(v)}{J_o(v)Y_o(vS) - J_o(vS)Y_o(v)} = 0 \qquad (4)$$

where $u = \frac{\pi d}{\lambda_o}\sqrt{K}$, $v = \frac{u}{\sqrt{K}}$ and $S = \frac{D}{d}$. (5),(6),(7)

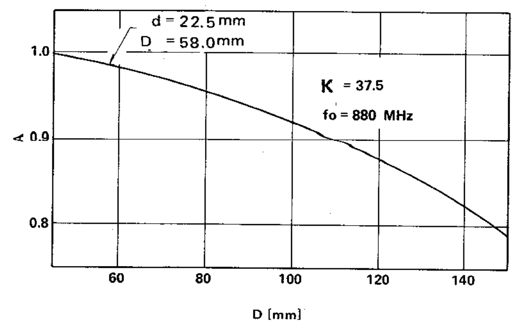

Fig 5. The ratio of the electric energy stored in the dielectric rod in proportion to the total electric energy in the cavity

Center frequency	880MHz
Frequency adjustable range	from 875MHz to 885MHz
Attenuation at fo±0.6MHz	8.5dB (at 25°C)
Operating power	30 W min.
Operating temperature	from -30°C to +80°C
Outer dimension (volume)	69×69×68 (mm) (324cc)

Table 2. Design parameters of the TM_{010} dielectric filter

When D is 58mm, K constant is 37.5, and fo is 880 MHz, the diameter (d) of 22.5mm satisfies the resonant condition. The length of the rod resonator (L) affects to only unloaded Q. The dielectric resonator of 58mm length gives the 8400 unloaded Q as show in Figure 3.

(2)External Q (Qex)

The attenuation characteristics determine the loaded Q (Q). Then unloaded Q (Qo) and loaded Q give the Qex as follows.

$$\frac{2}{Q_{ex}} = \frac{1}{Q_L} - \frac{1}{Q_o} \qquad (8)$$

Performance

The attenuation characteristics of the filter we made as a trial are shown in figure 6. The attenuation at fo +0.6 MHz is 8.9dB. The insertion loss at the center frequency was 1.75dB at room temperature. The deviation of the center frequency of the filter is shown in figure 7. The frequency deviation of the filter using material B is minimum. The temperature coefficient of the resonant frequency of the filter shows good agreement with that of the material. The mean temperature rise of the resonator caused by applied power of 30 watts to input port was about 25°C from room temperature.

Conclusion

A small sized channel dropping filter using TM_{010} dielectric resonator was developed. The outer dimension is 69×69×68mm (324cc). The unloaded Q of the resonator was about 8,200 and insertion loss at the center frequency was 1.75 dB when loaded Q is 1,500. As the temperature coefficient of the filter is almost the same as that of the material, the high stability of the center frequency is easily obtained. This stable and reduced size channel dropping filter is suitable for smaller sized mobile telecommunication equipment.

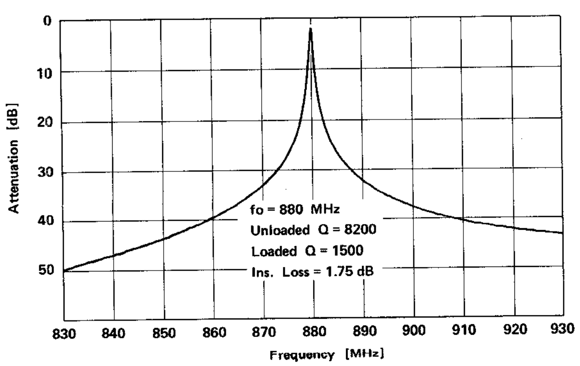

Fig 6. Measured frequency response of the TM_{010} dielectric filter

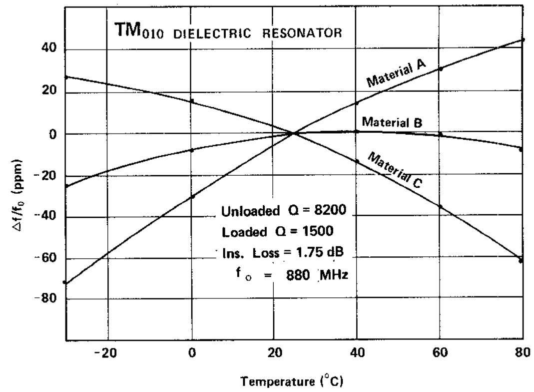

Fig 7. Measured frequency deviation of the TM_{010} dielectric resonator filter

Acknowledgement

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Reference

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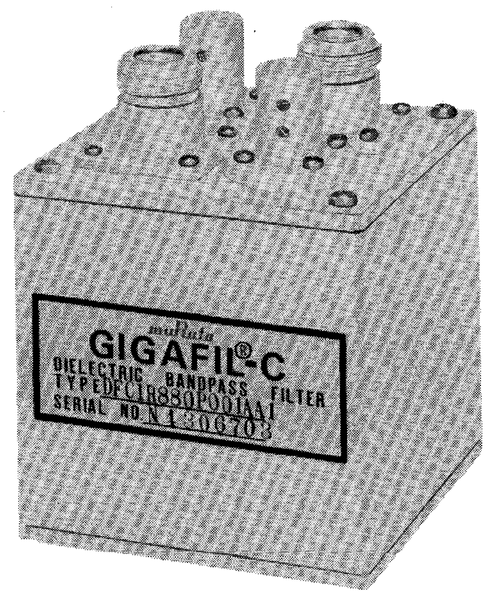

Fig 8. Channel Dropping Filter