800MHz BAND HIGH-POWER BANDPASS FILTER USING TM_{110} MODE DIELECTRIC RESONATORS FOR CELLULAR BASE STATIONS

Toshio Nishikawa, Kikuo Wakino, Toshiro Hiratsuka, and Youhei Ishikawa

Murata Manufacturing Company Limited
Kyoto, Japan

ABSTRACT

An 800 MHz band high-power filter using new type TM_{110} mode dielectric resonators has been developed. This filter has a low dissipation characteristics and excellent temperature stability. Under high-power operation, the changes of the filter characteristics are negligible. The size of the filter is 200×140×60mm (1700cc), about one fifth the volume of conventional high-power filters.

INTRODUCTION

In mobile communications systems, 800 MHz band cellular systems have increased rapidly in recent years. Transmitting high-power bandpass filters for their base stations are required to be compact and low cost.

As a means of miniaturizing the filter, use of dielectric resonators is expected. Especially, the filter using TM_{110} mode dielectric resonators reported by Y. Kobayashi (1) is considered to be suitable because of its compactness and low dissipation performance. This filter has basically good electric performance, however, the filter has a serious problem about temperature stability because of the air gap between the ceramics and metal housing. The ceramic cavity method of the TM_{010} single pole filter which we proposed before (2) is a powerful method to improve the temperature stability of the resonant frequency. But in order to apply this method to the multi-pole low dissipation filter, the simple coupling structure between resonators must be designed.

We solved this problem by developing the ceramic cavity resonator unit of trapped state TM_{110} resonance which has two full open coupling windows. A monoblock construction of the resonator unit, which works as a total resonance system was proposed to reduce cost and to improve mechanical reliability.

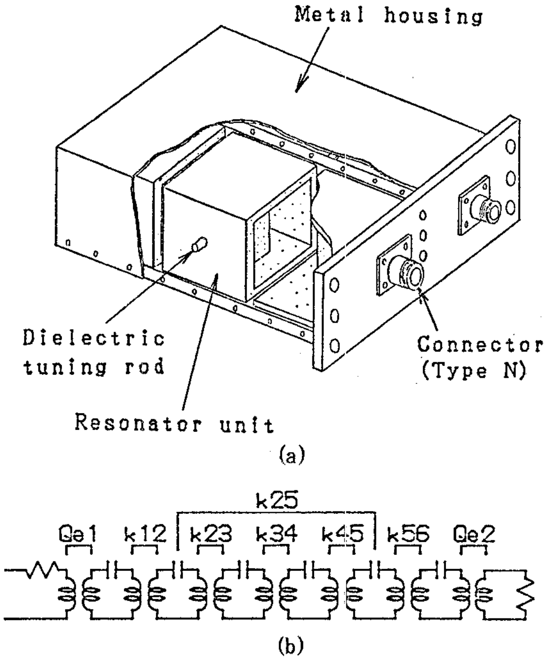

Fig. 1. Basic construction of the filter and its equivalent circuit

This paper describes the construction, design and consideration under high-power operation of the new type filter.

CONSTRUCTION

The construction of the filter using a discrete TM_{110} mode dielectric resonator unit is shown in Fig. 1. (a). Fig. 2 shows the cross sectional view of the resonator. This monoblock resonator unit is made of ceramics. The core dielectric works as a resonator, and the surrounding dielectric, which is silver-plated on the outside, works as a shielding cavity.

Resonant frequency is adjusted by the position of the dielectric tuning rod, which is made of the same material of the resonator, in the through hole of the core dielectric.

Resonators are inductively coupled to each other by the coupling windows. This filter is consisted of six resonator units and the elliptic function characteristics are obtained by a inductive coupling between the second and the fifth resonator. The equivalent circuit corresponding to this construction is shown in Fig.1.(b).

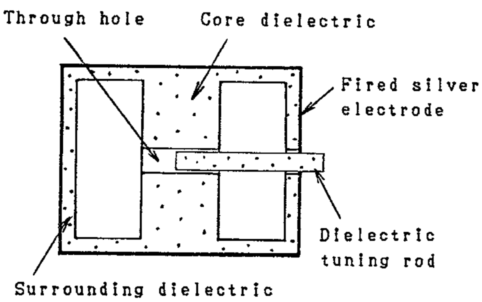

Fig. 2. Cross sectional view of the resonator

DESIGN

Required Characteristics

The required characteristics for the bandpass filter used for mobile communications systems at the 800 MHz band are listed in Table 1.

Table 1. Outline of required characteristics

Center frequency	881.5 MHz
Bandwidth (BW)	25 MHz
Insertion loss (at BW)	0.40 dB max
VSWR (at BW)	1.5 max
Attenuation (at f_0-32.5MHz)	60 dB min
Input power	500 watts
Size	200×150×70mm

Dielectric Materials

Dielectric materials of the resonator and the tuning rod are listed in Table 2.

Table 2. Dielectric materials

Material system	$(Zr,Sn)TiO_4$
Dielectric constant (εr)	37.5
Dissipation factor ($\tan\delta$)	2.5×10^{-5} at 800 MHz
$\frac{1}{\tan\delta}\ \frac{\Delta\tan\delta}{\Delta T}$	2%/10℃
Temperature coefficient(η_f)	2ppm/℃
Thermal conductivity(K)	0.02 Joule/cm·deg·sec

Resonant Frequency and Unloaded Q

Analysis of the resonant frequency and the unloaded Q of original TM_{110} mode dielectric resonator which has a surrounding metal cavity was reported by Y. Kobayashi (1). Unloaded Q in relation to the size of the resonator is shown in Fig. 3. In this figure the calculated unloaded Q is the value which the surrounding dielectric is ignored. When the dimensions of the resonator is 60×60×50mm, calculated and measured unloaded Q are 9600 and 9200 respectively. It shows that the effect of the surrounding dielectric is negligible.

The resonant frequency and the unloaded Q of the resonator in relation to inserted length of the dielectric tuning rod are shown in Fig. 4. This figure

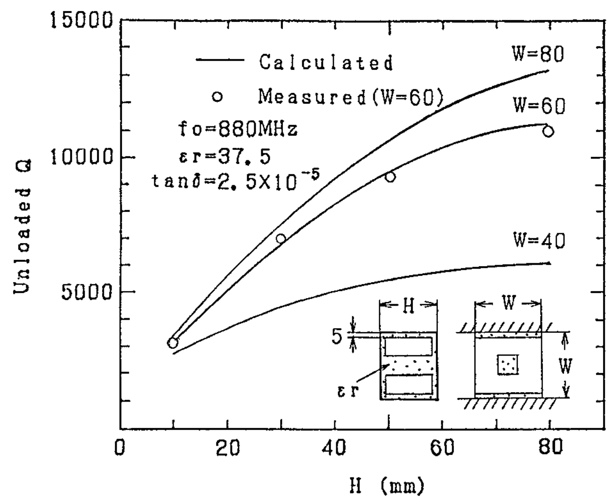

Fig. 3 Unloaded Q of TM_{110} mode dielectric resonator

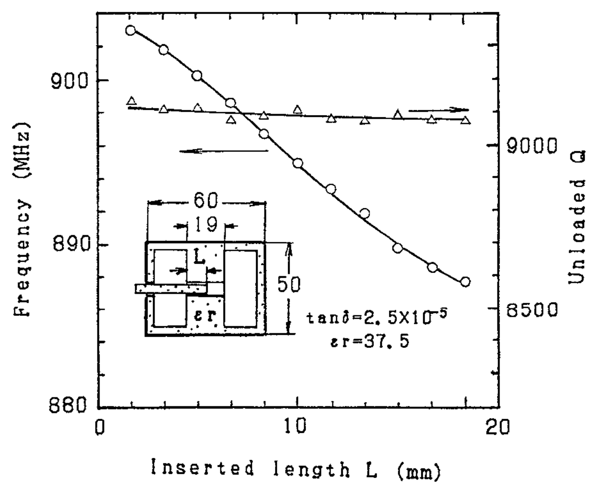

Fig. 4 Resonant frequency and unloaded Q for inserted length of dielectric tuning rod

electric tuning rod are shown in Fig. 4. This figure shows that the unloaded Q keeps constant, and the resonant frequency changes linearly for the inserted length of the tuning rod.

Coupling Coefficient

Coupling coefficient between the resonators is adjusted by the silver-plated ceramic fin added on the coupling window.

Fig. 5 shows the measured coupling cofficient in relation to size of the fin.

CONSIDERATION OF HIGH-POWER OPERATION

Electric Field Intensity in a Resonator

The electromagnetic energy stored in a resonator was reported by us (3). When input power to the filter is 500 watts, the maximum stored energy calculated by this method is 6.0×10^{-6} Joules in both of the third and fourth resonators at 869 MHz. The maximum field intensity in the core dielectric calculated by FEM field analysis is 17 V/mm.

The measured third-order intermodulation level of the resonator (3) at field intensity of 17 V/mm is less than -130 dBc which is the limit of sensitivity of the measurement system.

Temperature Rise

This resonator is effective to suppress the temperature rise because of constructing a continuous thermal diffusion path from the core dielectric to the metal housing through the surrounding dielectric.

Fig.6 shows the measured temperature distribution in the resonator when energy of 6.0×10^{-6} Joules is stored. The highest temperature point is the center of the core dielectric, and its measured value is 7℃ higher than heat sink.

The maximum temperature rise (ΔT_{MAX}) is generally proportional to RF power loss (P_{Loss}), and power loss is expressed by input power (P_{in}) and insertion loss (IL) of the filter.

Therefore, the equation is obtained.

$$\Delta T_{MAX} = \alpha \left(1-10^{-\frac{IL}{20}}\right) P_{in}$$

(α = 0.41 ℃/W ;experimental value)

where α is the thermal resistibilty constant between core resonator and sink of metal housing.

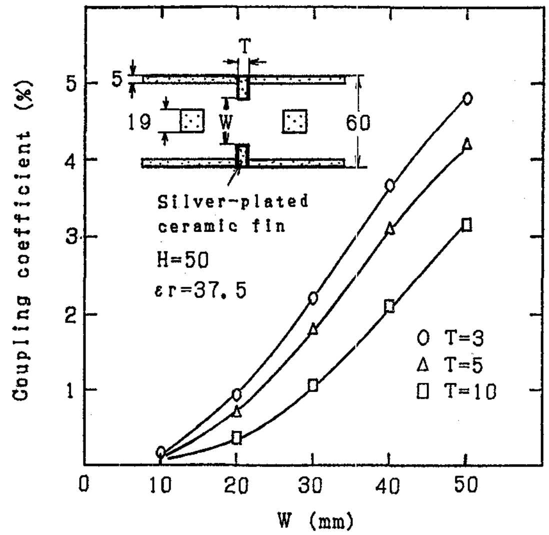

Fig. 5 Coupling coefficient versus the size of fin

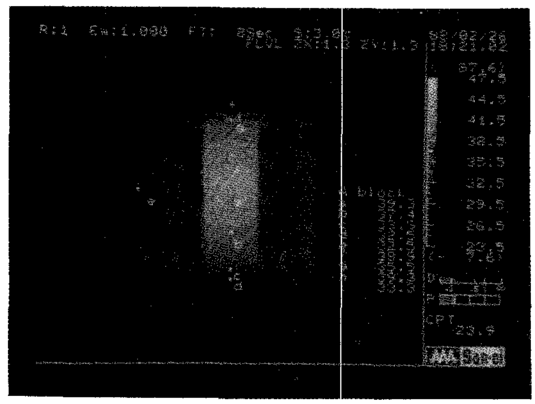

Fig. 6 Temperature distribution of the resonator

PERFORMANCE

The performance of the filter we made as a trial is shown in Table 3, Fig. 7 and Fig. 8. This performance sufficiently satisfies the requirements shown in Table 1. Transmission characteristics agree well with the simulation by the equivalent circuit. Temperature coefficient of center frequency is about 1 ppm/℃. Fig. 9 shows the spurious response. The adjacent harmonics responses at 1670 MHz (1.9 times of center frequency).

Actually, when RF power of 500W (31W×16channels) was input to the filter, temperature rise of the filter case was 15℃. So maximum temperature rise in the core dielectric was estimated about 22 ℃. At this time, the increase of insertion loss of the filter was 0.03 dB, and the changes of attenuation level and

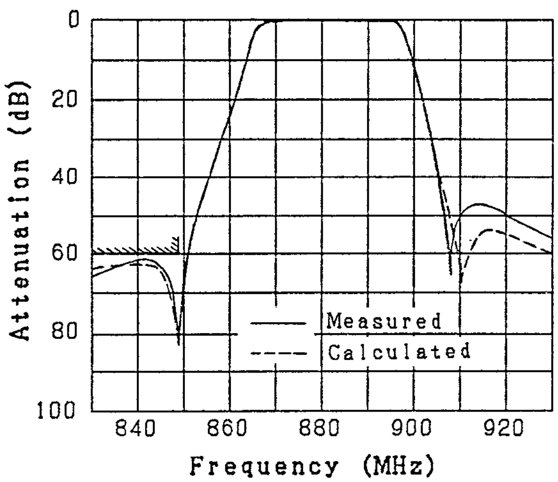

Fig. 7 Transmission characteristics

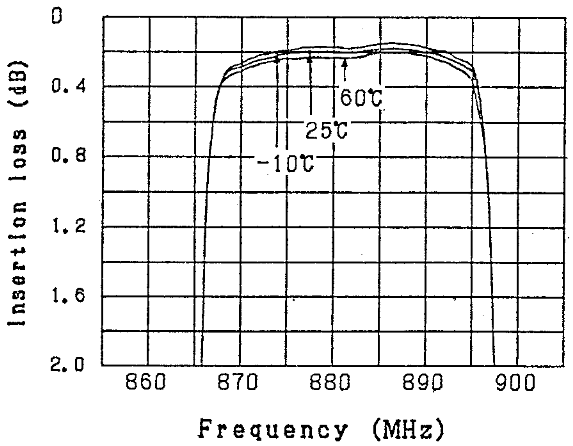

Fig. 8 Temperature characteristics

VSWR were negligible. The measured third-order intermodulation level was less than -140 dBc, it was the limit of sensitivity of the measurement system.

CONCLUSION

We have developed an 800 MHz band high-power bandpass filter with 25MHz bandwidth using new type TM_{110} mode dielectric resonators.

The static filter characteristics satisfied the requirements by 6-pole elliptic function type. High stable temperature characteristics were obtained by monoblock type ceramic resonators.

Under high-power operation, temperature rise was lower, and the third-order intermodulation level was negligible.

The dimensions of the filter are 200×140×60mm, about one fifth the size of conventional high-power filters.

Table 3. Performance of the filter

Center frequency	881.5 MHz
Bandwidth (BW)	25 MHz
Insertion Loss (at BW)	0.29 dB
VSWR	1.20
Attenuation (at f_0-32.5 MHz)	62 dB
Input power	over 500W
Size	200×140×60mm

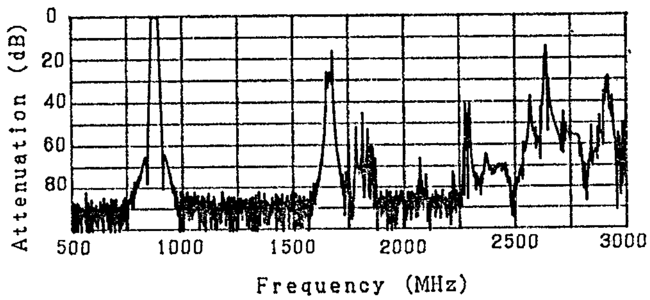

Fig. 9 Spurious response

This filter is expected to be applicable to use in 800MHz band cellular base station.

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3. T. Nishikawa et al., "Dielectric High-power Bandpass Filter Using Quarter-cut $TE_{01\delta}$ Image Resonator for Cellular Base Stations," IEEE Trans. Microwave Theory Tech. vol. MTT-35, pp. 1150-1155, Dec. 1987.

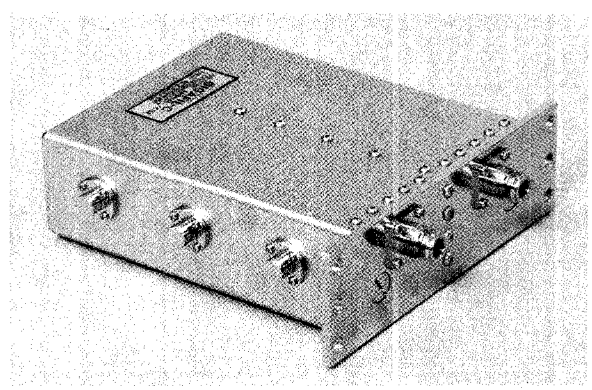

Fig.10 Photograph of the new filter