2GHz Band Quadruple Mode Dielectric Resonator Filter For Cellular Base Station

Jun Hattori, Takaya Wada, Hiroyuki Kubo, Yohei Ishikawa

Murata Manufacturing Company Ltd., Nagaokakyo, Kyoto, 617-8555, Japan

Abstract **—— This paper describes a novel 2GHz bandpass filter using a novel quadruple mode dielectric resonator for compact cellular base station. We propose small high Q dielectric resonator technique using $TM_{11}\delta$-x, $TM_{11}\delta$-y, $TE_{01}\delta$-x and $TE_{01}\delta$-y modes. It has very high unloaded Q factor value of about 15000 at 2GHz band. We have designed and manufactured a 4-pole band filter using this resonator. Insertion loss is very low of less than 0.23 dB and high attenuation of 90dB. Outer dimensions are 48 x 48 x 42 mm.**

I. INTRODUCTION

Recently digital wireless mobile communication systems are growing more rapidly worldwide. Especially the third generation systems, for instance W-CDMA, are starting at 2GHz band. In this system, the filter for base stations have been more important and critical device in because of interference and high capacity problems. The serious demands for the filters are miniaturized size, high performance (low insertion loss and high attenuation), and low cost. To satisfy these demands we have previously developed monoblock type dual and triple mode dielectric resonator filter. [1]-[4] It has small size and good electrical performances and contributed to making compact tower top unit. But now more size reduction, on the other hand lower insertion loss, are requested strongly.

To solve this problem, we have newly developed a TM/TE quadruple mode dielectric resonator technique. It has the volume of about 1/4 of conventional TE and TM single mode resonator. And by using this resonator we have designed and manufactured a new compact bandpass filter at 2GHz band. It has the smallest size comparing with other conventional dielectric filters, and electrical performances are similar to these.

In this paper the construction and performance of this dielectric resonator, the filter design method, and the filter performances are discussed.

II. QUADRUPLE DIELECTRIC RESONATOR

The basic construction of a new quadruple mode dielectric resonator is shown in Figure 1. It consists of monoblock ceramic material. Its composition is based on (Zr Sr) TiO_4, dielectric constant K is 38, loss tanδ is $4.0x10^{-5}$ at 2GHz band and temperature coefficient is less than 2 ppm/deg.

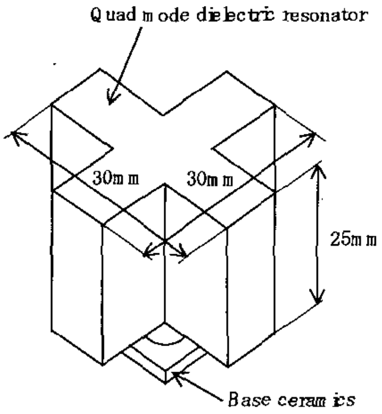


Fig. 1 Basic construction of quadruple mode resonator

It has a sort of thick crossing ceramic bulk shape. It is set on a cylindrical supporter made of low-K ceramic material and located at the center of a cubic metal cavity. Physical dimensions of ceramic are 30 x 30 x 25mm, and weight is about 80g. Unloaded Q at 2GHz band is about 15000 in average. Electric and magnetic field distributions of four modes ($TM_{01}\delta$-x, $TM_{01}\delta$-y, $TE_{01}\delta$-x, $TE_{01}\delta$-y) are shown in Figure 2. Figure 3 shows electromagnetic field simulation results by FEM numerical calculation. These modes are orthogonal with each other electromagnetically. By arranging x-y-z dimensions and shape factors, three modes are controlled into the same resonant frequency range. Electromagnetic coupling between each other modes is gained by asymmetrical grooves or gutters constructed in it directly. At temperature range of -20 to 60 deg, resonant frequency deviation is less than 2%, and sufficiently stable. Figure 4 shows the relationship between normalized unloaded Q and $(volume/pole)^{1/3}$ in some kinds of resonators including conventional dielectric and cavity type ones. This quadruple mode type has the highest performance for all types. Figure 4 shows a photograph of the external view of the resonator.

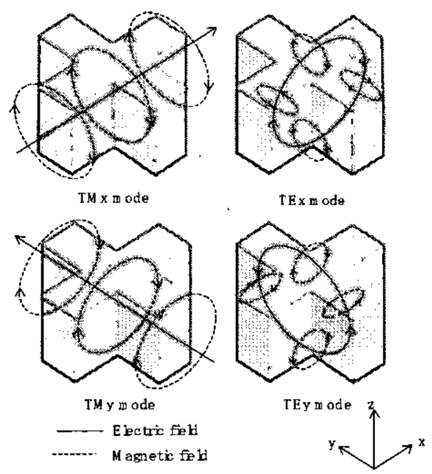


Fig. 2 E-M field distribution of quadruple mode

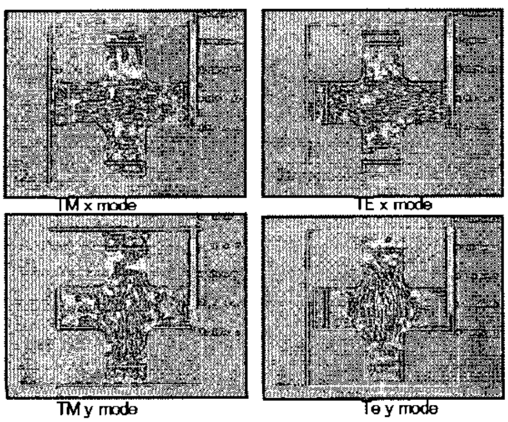
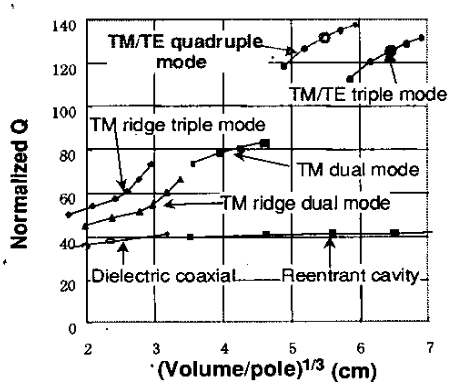


Fig. 3 E-M field simulation of quadruple mode



$$\text{Normalized Q (\%)} = \frac{Q_0 / V_0^{\ 1/3}}{Q_{TE011} / V_{TE011}^{\ 1/3}}$$

TE011=idealized (tand=0) cylindrical cavity

Fig.4 Relationship between normalized unloaded Q and $(\text{volume/pole})^{1/3}$

III. FILTER CONSTRUCTION AND DESIGN

A 4-pole dielectric bandpass filter can be organized by one quadruple mode dielectric resonator. Figure 5 shows basic structure of bandpass filter construction. A quadruple mode resonator is set in metal cavity, and whole cavity is constructed in monoblock and plated by silver electrode. External couplings with the resonator are realized by metal proves. Coupling amplitude is controlled by arranging probe's shape, angle and length. Figure 6 shows the coupling order in four resonant modes.

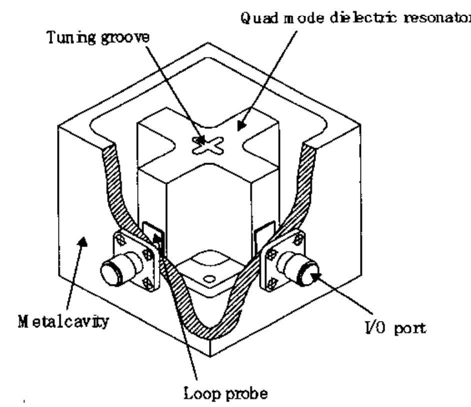


Fig. 5 Basic structure of bandpass filter construction

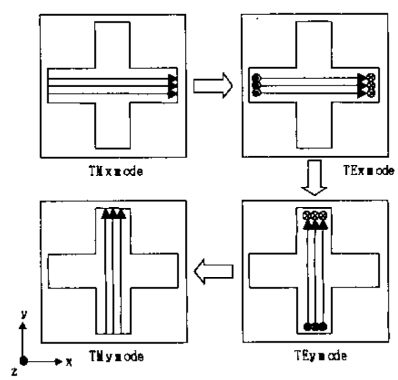


Fig. 6 Coupling order in four resonant modes

Figure 7(a) shows the unloaded Q factor and resonant frequency versus height of dielectric resonator. And as a example of coupling characteristic design, Figure 7(b) shows coupling coefficient between TEx and TEy mode depending on coupling groove depth. By using some data for electrical design like as these, physical design parameters can be determined. Design parameter values in the circuit (resonant frequency, coupling coefficient, etc.) are determined from required filter characteristics by Chebysheff based design calculation. In case of ordinal dielectric resonator filter, degradation of isolation characteristics between input and output port has become the problem. To solve this, we have developed plural cross coupling technique to be applied multimode resonator. Figure 8 shows the equivalent circuit of bandpass filter. In this case additional two attenuation poles that have close pole frequencies in lower frequency range can be arranged, that realize deeper attenuation curve comparing with conventional dielectric filters. Of course pole frequency ranges are controllable.

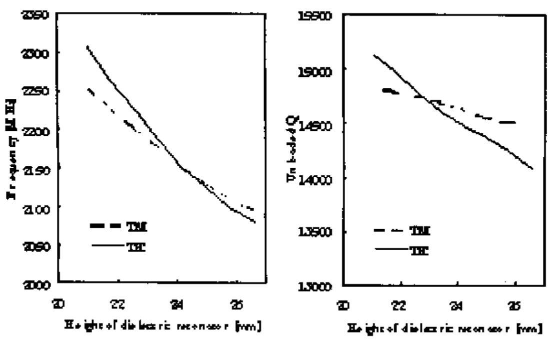


Fig.7(a) Unloaded Q factor and resonant frequency versus height of dielectric resonator of resonator

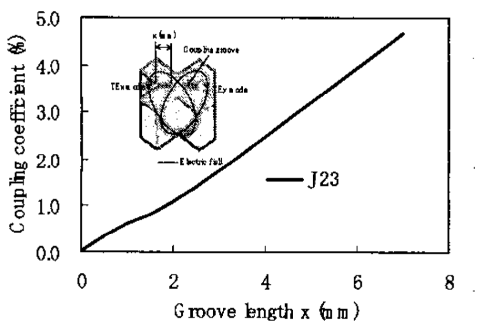


Fig.7(b) Coupling coefficient between TEx and TEy mode in quadruple resonator

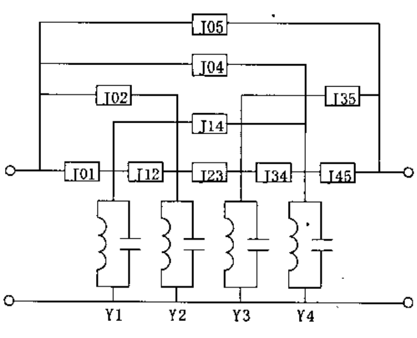
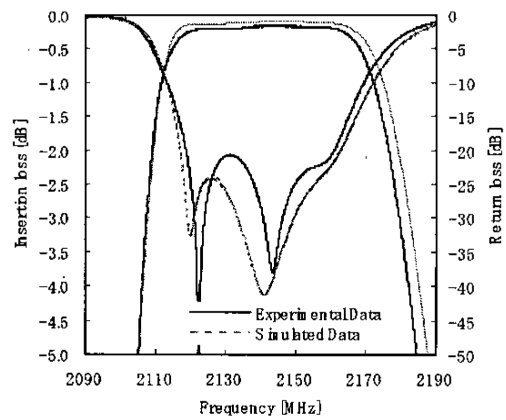


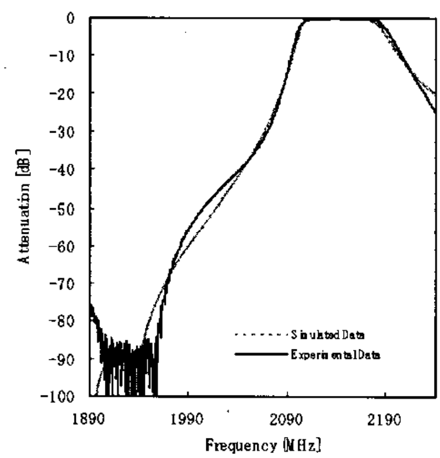
Fig.8 Equivalent circuit of designed bandpass filter

IV. BANDPASS FILTER CHARACTERISTICS

Table 1 show the 2GHz bandpass filter performance. The center frequency is 1950MHz, the band width is 40MHz, the insertion loss is less than 0.23dB, return loss is more than 20dB, and attenuation between 1940 and 1960 MHz is more than 86dB. The external dimensions are 48 x 48 x 42mm, volume is about 97cc, and weight is about 200g. Fig.9 shows the electrical characteristics. Simulated data and measured data agree very well. Maximum input power is 80W of CW, and intermodulation distortion power is less than –170 dBc at 30Wx2 tones. Operating temperature range is -20 to 60deg and humidity range is 20 to 95%. Figure 9 shows the external view of this bandpass filter.



Insertion loss and return loss performance



Attenuation performance

Fig.9 Electrical characteristics of 4-pole bandpass filter using a quadruple resonator

Pole Number	4
Center Frequency	2140 MHz
Passband Width	40 MHz
Insertion Loss	0.23 dB
Return Loss	20 dB
Attenuation at 1930-1950 MHz	86dB
Input Power	60 W
·Physical Dimensions	48×48×42 mm
Weight	200 g

Table 1 Bandpass filter performance

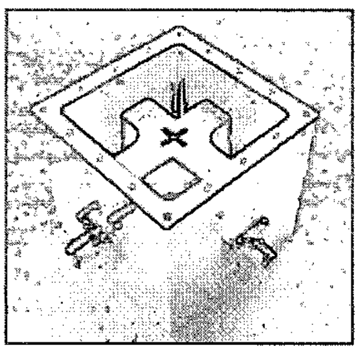


Fig. 10 Photograph of this bandpass filter

V. CONCLUSION

A novel 2GHz band compact and low-loss bandpass filter has been developed. The resonator is TM/TE quadruple mode dielectric one made by high K and low tangent loss ceramic material. This has bulky cross polar shape and very small volume of 97cc. And It has very high unloaded Q of about 15000 in average. By using this, we designed a bandpass filter with some attenuation poles. The manufactured 4-pole bandpass filter on trial has very low loss of 0.23 dB and high attenuation of more than 86dB by multi internal coupling. This is sufficiently useful as the high power filter for very compact base station tower top amplifier unit of next generation mobile communication system. And after now, we are designing and making a new compact duplexer.

REFFERENCES

[1] Y.Ishikawa,et al.,"800MHz High Power Duplexer Using TM Dual Mode Dielectric Resonators" 1992 IEEE MTT-S .

[2] J.Hattori,et al.,"Compact Transmitting Dielectric Resonator Filter using Capacitive Loaded Dual Mode Method for PCS Microcellular Base Station" 1996 IEEE MTT-S.

[3] J.Hattori,et al.,"A Small badpass filter for Cellular Base Station using 2GHz band dielectric triple mode resonator", 1999 IEICE(Japan), Fall Domestic Conf.

[4] J.Hattori,et al.,"2GHz Band Triple Mode Dielectric Resonator Duplexer For Digital Cellular Base Station " 2000 APMC