BANDPASS AND BANDSTOP FILTERS USING DOMINANT $TM_{01\delta}$ MODE DIELECTRIC ROD RESONATORS

Y. Kobayashi and C. Inoue

Saitama Univ., Dept. of Electrical and Electronic Engineering
Urawa, Saitama, 338, Japan

ABSTRACT

A dielectric rod resonator with the dominant $TM_{01\delta}$ mode proposed realizes a strong coupling between the resonator and a waveguide. The design is performed to obtain the best separation from the other higher modes. Bandpass and bandstop filters with excellent spurious characteristics are designed by using these resonators.

INTRODUCTION

The high-Q $TM_{01\delta}$ mode in a dielectric rod resonator has been used to construct a compact bandpass filter, where the resonators are placed in the center of a conducting cylinder and are excited axially symmetrically by coaxial monopoles [1]. In this structure, the strong excitation between the $TM_{01\delta}$ mode and the monopole can not only be obtained, but also the excitations of undesired modes except the TM_0 mode can be suppressed; thus the good spurious characteristic can be realized although this mode is the fourth higher resonant mode. Some detailed discussions have been presented for the inter-resonator coupling and for a coupling between the resonator and the coaxial monopole; thus we can use precise calculation approachs to design these filters [2]-[6]. For high-power applications of these filters, it is necesary to excite this resonator by a waveguide. However, it is difficult to obtain the good response, because an aperture on the waveguide excites all the modes.

In this paper, a new resonator structure characterized by the dominant $TM_{01\delta}$ mode with the lowest resonant frequency is proposed and is designed to obtain the best separation from the other higher modes. Experiment shows that a stronger coupling between a resonant mode and a waveguide can be realized for the dominant $TM_{01\delta}$ mode, compared with two cases of the high-Q $TM_{01\delta}$ mode[7] and the $TE_{01\delta}$ mode [8, 9]. It is verified that bandpass and bandstop filters using these resonators realize excellent spurious characteristics even for waveguide excitations.

DOMINANT $TM_{01\delta}$ MODE RESONATOR

Fig. 1 shows configuration of a dielectric rod resonator, where a dielectric rod having relative permittivity ε_r, diameter D, and length L is placed symmetrically in the center of a cylindrical conductor cavity of diameter d and height h. For this structure, the rigorous field analysis of all resonant modes has been already performed by the mode matching technique[1]. From the computation, it was found that the $TM_{01\delta}$ mode becomes dominant when L is considerably longer than D. For this dominant $TM_{01\delta}$ mode resonator with ε_r=24, optimum values of S=d/D, X=D/L, and G=t/D were determined to obtain the maximum value F_{rmax} of a frequency ratio $F_r=f_r/f_0$, where f_0 and f_r are resonant frequencies of the $TM_{01\delta}$ mode and of the other higher modes, respectively. Fig. 2 shows the mode charts to calculate easily resonant frequencies and normalized Q values, $Q_d \tan\delta$ and $Q_c\delta_s/\lambda_0$ for this resonator, computed around the optimum dimension ratios (S=4.0, X=0.17, and G=1.0 for F_{rmax}=1.5). The unloaded Q-factor of this

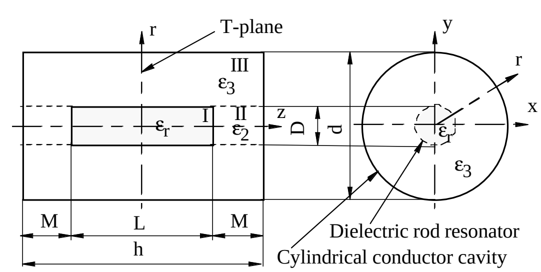


Fig. 1 Configuration of a dielectric resonator

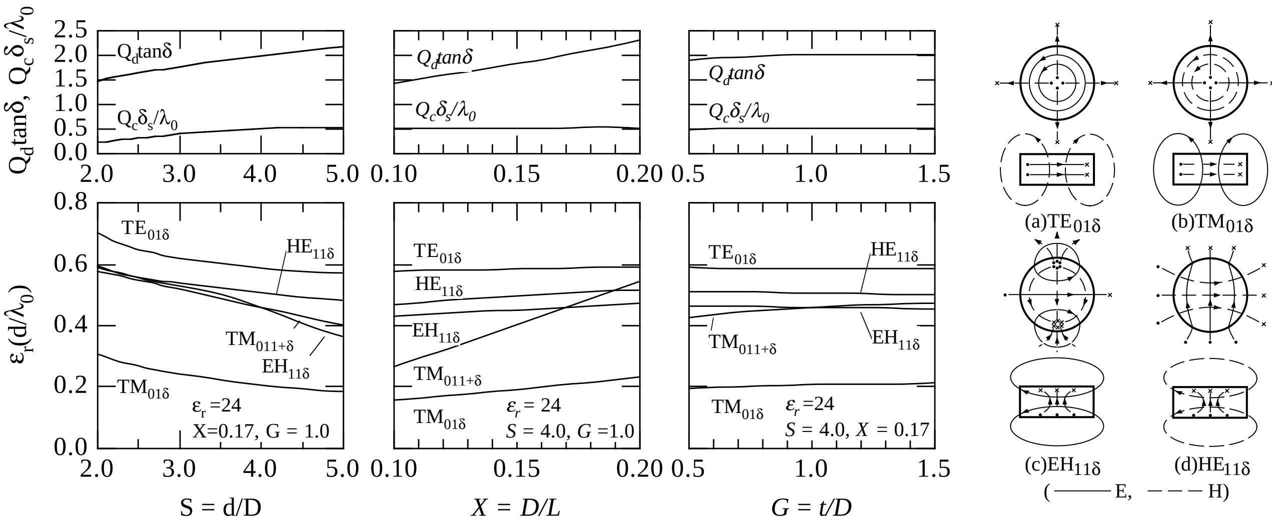


Fig. 2 Mode charts of the dominant $TM_{01\delta}$ dielectric rod resonator and field plots of the principal modes for the rod resonator

resonator Q_u can be calculated by using the relation $1/Q_u=1/Q_d+1/Q_c$, where Q_d is one due to the dielectric loss, Q_c is one due to the conductor loss, $\tan\delta$ is the loss tangent, $\delta_s=(2/\omega\mu\sigma)^{1/2}$ is the skin depth, λ_0 is the resonant wavelength, and σ is the conductivity of conductor.

We measured the external Q, Q_e as a function of a space between a rod end and a waveguide wall *l* for each of three resonators; the dominant $TM_{01\delta}$ mode and the high-Q $TM_{01\delta}$ mode[7] and the $TE_{01\delta}$ mode[8, 9], constructing reaction type resonators shown in Fig. 3. These measured results are shown in Fig. 4. The dominant $TM_{01\delta}$ mode can realize the lowest measured Q_e valueof three modes. For the $TE_{01\delta}$ mode, the resonator must be inserted in a waveguide to obtain a strong coupling[8, 9]. On the other hand, for the dominant $TM_{01\delta}$ mode, the same Q_e value can be obtained without insertion of a rod into waveguide; thus, we can avoid the undesired inter-resonator coupling in this case.

BANDPASS AND BANDSTOP FILTERS

Three bandpass filters (BPF) and a bandstop filter (BSF) with waveguide excitations were designed by using $Ba(Mg,Ta)O_3$ ceramic rods (ε_r=24, $\tan\delta=4\times10^{-5}$ at 12GHz) at a center frequency 12GHz with a 3dB bandwidth 36MHz.

Fig. 5(a) shows a structure of a four-stage BPF, constructed by using the high-Q $TM_{01\delta}$ mode resonators. Four ceramic rods are placed coaxially in a copper

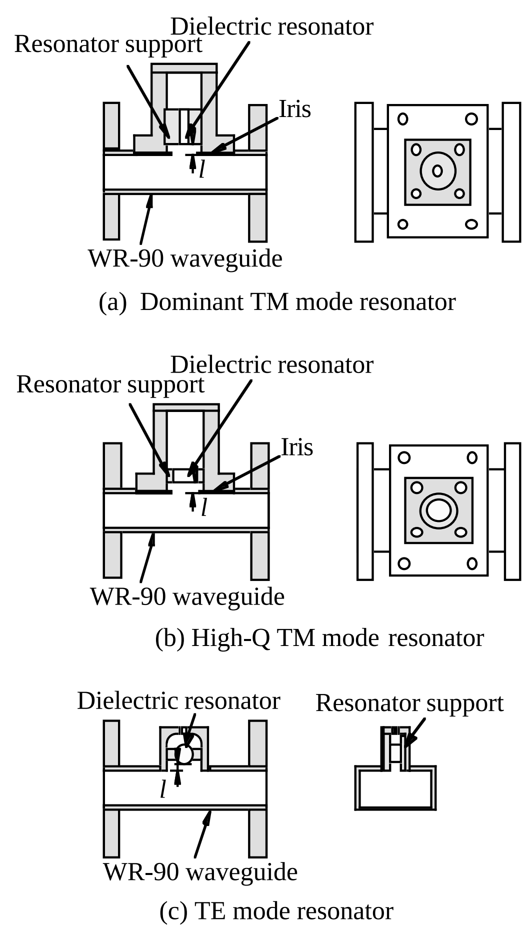


Fig. 3 Configuration of reaction type resonators with aperture coupling

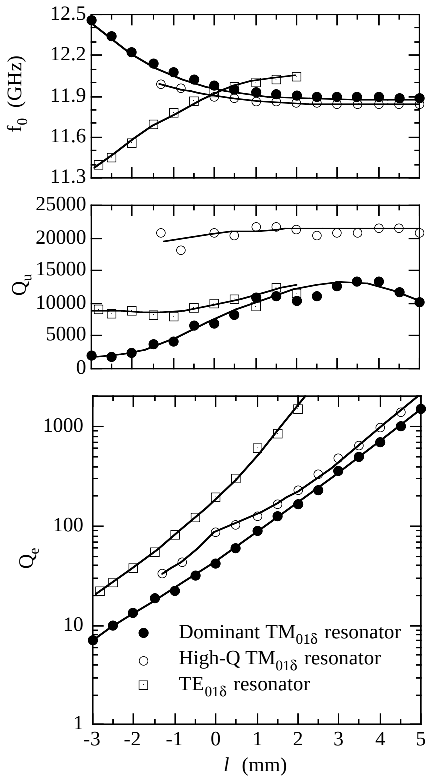
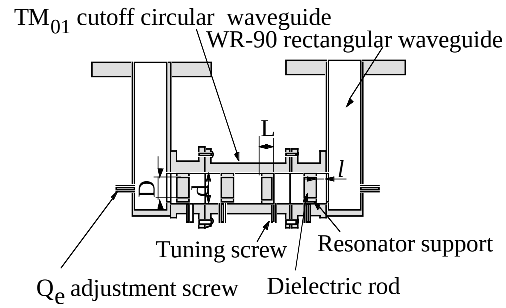


Fig. 4 Measured results for three resonators with aperture coupling

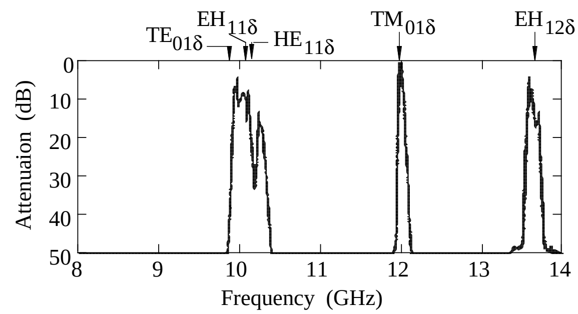
cylindrical cavity and are supported by foamed polystyrene. Fig. 5(b) shows the measured frequency response. Three spurious modes appear under the $TM_{01\delta}$ mode.

Fig. 6(a) shows the filter using four dominant $TM_{01\delta}$ mode resonators. Fig. 6(b) shows the measured frequency response. The spurious response is improved, compared with the case of Fig. 5.

To improve the insertion loss of the filter shown in Fig. 6(a), we designed a structure shown in Fig. 7(a), in which the second and third dominant $TM_{01\delta}$ mode resonators (Q_u=9,000) were replaced by the high-Q $TM_{01\delta}$ mode resonators (Q_u=22,000) shown in Fig. 5(a). A 3dB bandwidth is 133MHz only in this case. Fig. 7(b) shows the measured frequency response, where no spurious response appeares over the waveguide bandwidth, and the equivalent Q_u value calculated from the insertion loss is Q_u=14500, compared with Q_u=8200 for the filter in Fig. 6. For multiplexer applications, furthermore this structure is expected to be superior to the case of the $TE_{01\delta}$ mode resonators, because the strong

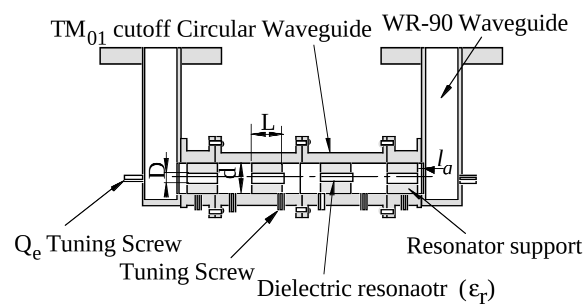


(a) Structure

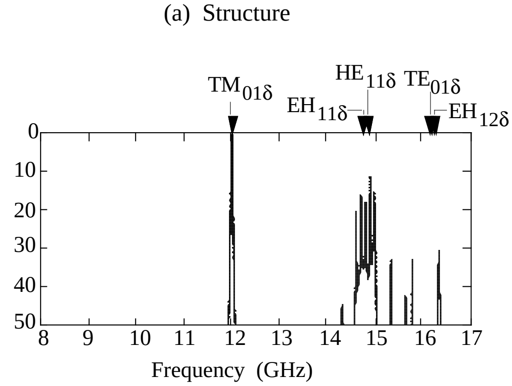


(b) Measured result

Fig. 5 A four-stage BPF using $TM_{01\delta}$ resonators excited by waveguide

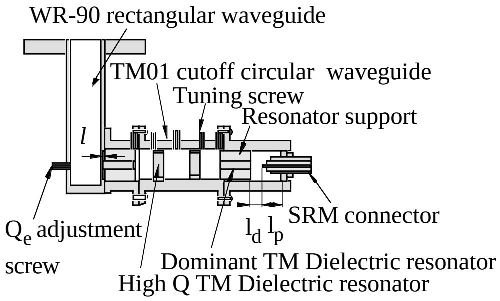


(a) Structure

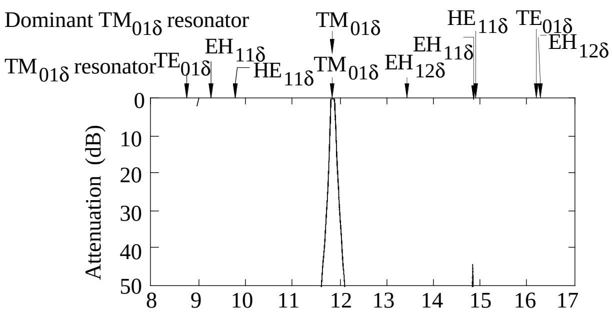


(b) Measured result

Fig. 6 A four-stage BPF using dominant $TM_{01\delta}$ resonators excited by waveguides

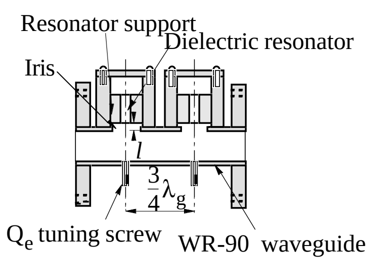


(a) Structure

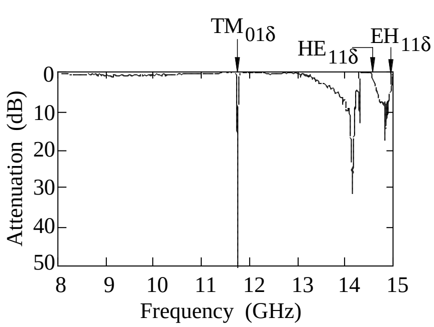


(b) Measured result

Fig. 7 A four-stage BPF using dominant $TM_{01\delta}$ resonators and $TM_{01\delta}$ resonators excited by waveguide



(a) Structure



(b) Measured result

Fig. 8 A two-stage BSF using dominant $TM_{01\delta}$ resonators excited by waveguide

coupling between the dominant $TM_{01\delta}$ mode resonator and a waveguide can realize the reflection characteristic.

Finally, a two-stage BSF was designed by using the dominant $TM_{01\delta}$ mode resonators. Fig. 8(a) shows the structure. Fig 8(b) shows the measured frequency response of this filter. This characteristic is comparable to the $TE_{01\delta}$ case.

CONCLUSION

It is concluded that the dominant $TM_{01\delta}$ mode dielectric resonators are useful to realize BPFs and BSFs with relatively wide bandwidth and excellent spurious calacteristics.

ACKNOWLEDGMENT

The authors would like to thank M. Katoh for filter fabrications and Y. Kogami and K. Hoshino for filter designs.

REFERENCES

[1] Y. Kobayashi and M. Minegishi, "A low-loss bandpass filter using electrically coupled high-Q $TM_{01\delta}$ dielectirc rod resonators," IEEE Trans. Microwave Theory Tech., Vol. 36, No. 12, pp. 1727-1732, Dec. 1988.
[2] A. Abramowicz, "Exact model of coupled dielectric resonators," 20th European Microwave Conf. Proc., pp. 1125-1130, Sept. 1990.
[3] A. Abramowicz, "Analysis of coupled dielectric resonators by means of eigenfrequency method," 24th European Microwave Conf. Proc., pp. 1197-1202, Sept. 1994.
[4] J.-P. Cousty, S. Verdeyme, M. Aubourg, and P. Guillon, "Finite elements for microwave device simulation: Application to microwave dielectric resonator filters," IEEE Trans. Microwave Theory Tech., Vol.40, No. 5, pp.925-932, May 1992.
[5] A. D. Lago, A. Lobina, and R. Urciuol, "A simple solution for high performance, cost-effective filtering: A new technique widens the tuning range of TM-mode dielectric resonator filters," 24th European Microwave Conf. Proc., pp. 1166-1172, Sept. 1994.
[6] G. Macchiarella and G. B. Stracca, "An accurate design approach for TM mode dielectric resonator filters in circular waveguide below cutoff," IEEE Trans. Microwave Theory Tech., Vol. 42, No. 7, pp.1321-1329, July 1994.
[7] Y. Kogami and Y. Kobayashi, " Micowave bandstop filter using $TM_{01\delta}$-mode dielectric rod resonators," Proc. 1990 Asia-Pacific Microwave Conf. , pp. 315-318, 1990.
[8] C.-L. Ren, "Waveguide bandstop filter utilizing $Ba_2Ti_9O_{20}$ resonators," IEEE MTT-S Int. Microwave Symp. Dig., pp.227-229, June 1978.
[9] P. Guillon, M.-P. Chong, and Y. Garault, "Dielectric resonators band pass filter with high attenuation rate," IEEE MTT-S Microwave Symp. Dig., pp.240-242, 1984.