Intermodulation Characteristics of High-Power Bandpass Filter Using Dielectric Rod Resonators Loaded in a High-Tc Superconducting Cylinder

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ABSTRACT

A narrow-bandwidth bandpass filter with a bandwidth of 36MHz at a center frequency of 12GHz, is constructed by orienting a pair of $TM_{01\delta}$-mode dielectric rod resonators in the center of a YBCO high-Tc superconducting bulk cylinder. The high-power and intermodulation characteristics of this filter is compared with those for a similar filter structure using a Cu cylinder in place of the YBCO cylinder. This filter realizes the low-loss characteristic below 0.2dB upto 5W, the high power-handling capability over 10W and the third-order intermodulation intercept of 100dBm at 77K.

INTRODUCTION

High power-handling high-Tc superconducting microstrip filters have recently been developed for cellular base-station applications by Liang et al.[1],[2]. In some of these filters, the power-handling capability over 27W at 10K and the third order intercept in intermodulation about 64dBm at 56K are realized. Also, it has been verified that a temperature-stable bandpass filter constructed by orienting a pair of $TM_{01\delta}$-mode dielectric rod resonators in the center of a YBCO bulk cylinder withstands high power input of 10W with an insertion loss I.L. below 1dB at 77K and 12GHz[3],[4]. This high power-handling capability can be realized by the fact that the electromagnetic energy concentrates in the dielectric rods and the current flowing on the surface of the superconducting cylinder decreases.

In this paper high-power and intermodulation characteristics of this filter is discussed in comparison with those for a similar filter structure using a Cu cylinder in place of the YBCO cylinder.

FILTER FABRICATION

Figure 1 shows a structure of a two-stage YBCO BPF used in experiment, with a center frequency 11.935GHz and a 3dB bandwidth 36MHz for channel 11 of Japan broadcasting satellite[4]. A pair of BMT ceramic rods having diameter D, length L, relative permittivity ε_r=24, and loss tangent $\tan\delta=1.6\times10^{-5}$ at 77K, is supported with foamed polystyrene of relative permittivity ε_2=1.031 in a YBCO bulk cylinder of surface resistance R_s=20mΩ, operating as a TM_{01}-mode cutoff circular waveguide. The $TM_{01\delta}$ resonant mode is exited by a monopole antenna. A filter housing is fabricated from Cu. Figure 2 shows a similar structure with a Cu cylinder (Cu BPF) in place of the YBCO cylinder in Fig.1. The detail of the filter design is given in [5]. Comparison of two BPFs are performed for high-power and intermodulation characteristics.

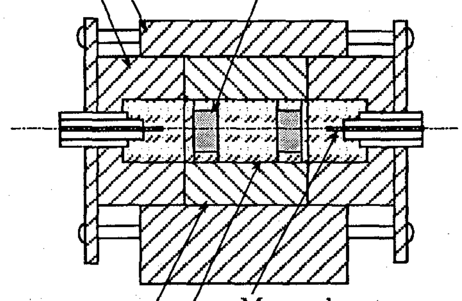

Fig.1. Structure of a 2-stage YBCO BPF.

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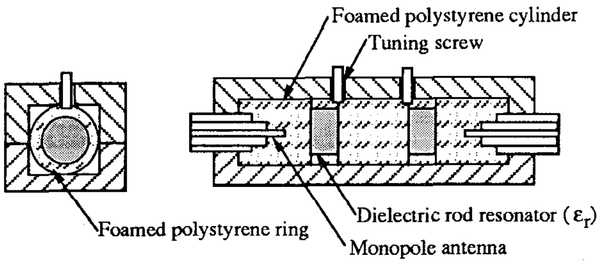


Fig.2. Structure of a 2-stage Cu BPF.

CALCULATION OF POWER LOSS

Table1 shows the values of $Q_d\tan\delta$ and $Q_c\delta_s/\lambda_0$ calculated for four resonators, where Q_d and Q_c are quality factors due to the dielectric and conductor losses, δ_s the skin depth, and λ_0 the resonant wavelength[4]. It is important to realize high-Q_c value by reducing a magnetic field on the cylinder surface to obtain high power-handling capability. Thus it is seen from Table 1 that a $TM_{01\delta}$-mode dielectric rod resonator realizes the highest Q_c values of these resonators ($TM_{01\delta}$ high-Q DRR).

For two $TM_{01\delta}$ high-Q DRRs, where one is with a YBCO cylinder and the other is with a Cu cylinder, the temperature dependences of Q_d, Q_c, and unloaded quality factor Q_u were calculated by using measured results of $\tan\delta$ and R_s for Cu and YBCO bulks shown in Fig.3. The results are shown in Fig.4. The $TM_{01\delta}$ resonator with YBCO cylinder has rather lower Q_u value at 77K than one with a Cu cylinder. Furthermore, for the YBCO and Cu BPFs in Figs.1 and 2 the temperature dependences of I.L. and of the dielectric loss P_d and the conductor loss P_c of the filter to the input power P_{in}=100W were calculated by using the results in Fig.4[4], provided these values are independent of the input power. The results are shown in Fig.5. The influence of P_d on I.L. is much greater than one of P_c. This means that thermal diffusion from dielectric rods is important to high-power application.

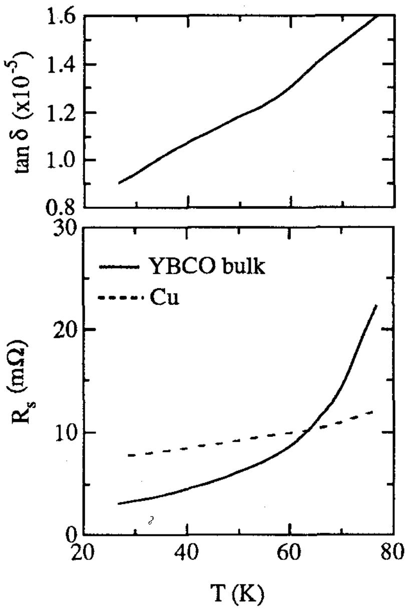
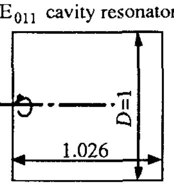
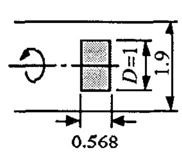
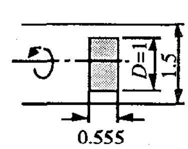
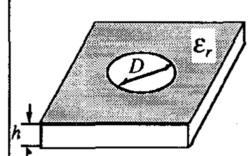


Fig.3. Temperature dependences of $\tan\delta$ for BMT ceramics(ε_r=24.6) and R_s for Cu and YBCO bulks measured at 12GHz.

Table 1 Comparison of four resonators.

	TE_{011} cavity resonator	$TE_{01\delta}$ $F_r$max DRR	$TM_{01\delta}$ high-Q DRR	TM_{110} disk resonator
Aspect ratio to D=1				
Diameter D(mm) ($22<\varepsilon_r<26$)	$\frac{393.8}{f_0(\mathrm{GHz})}$	$\frac{63.20}{f_0(\mathrm{GHz})}\sqrt{\frac{24}{\varepsilon_r}}$	$\frac{86.94}{f_0(\mathrm{GHz})}\sqrt{\frac{24}{\varepsilon_r}}$	$\frac{175.7}{f_0(\mathrm{GHz})\sqrt{\varepsilon_r}}$
Frequency ratio F_r	1.05	1.14	1.14	1.66
$Q_d\tan\delta$	-----	1.03	1.24	1.00
$Q_c\delta_s/\lambda_0$	0.66	1.35	2.73	h/λ_0

$\delta_s = R_s/(\pi f_0\mu_0)$, $\mu_0 = 4\pi\times10^{-7}$ H/m, $\lambda_0=c/f_0$ c:light velocity

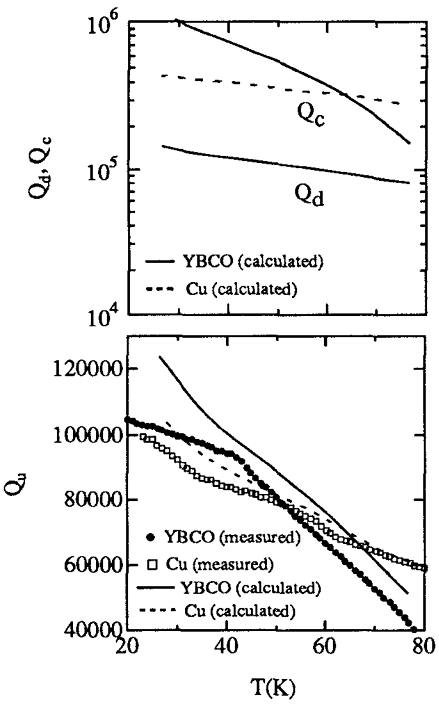


Fig.4. Calculated and measured results of temperature dependences of Q-factors for two $TM_{01\delta}$ high-Q DRRs with YBCO and Cu cylinders.

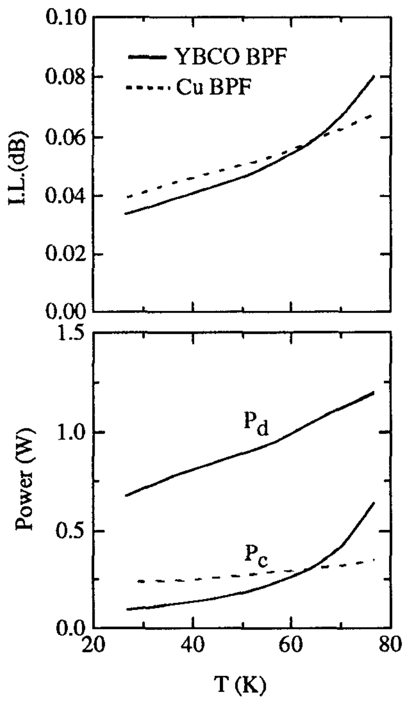


Fig.5. Calculated and measured temperature characteristics of I.L., P_d, and P_c to P_{in}=100W for the 2-stage YBCO and Cu BPFs.

HIGH-POWER MEASUREMENTS

Figure 6 shows a measurement system of transmission and reflection responses . Figure 7 shows I.L. measured at 77K as a function of P_{in} for both YBCO and Cu BPFs. Figure 8 shows transmission and reflection responses of the YBCO filter at 77K.The apparent increase of I.L. observed below 1W for the YBCO BPF appears to be the measurement error depending on the noise output from the TWTA.

As is expected from Fig.5, the I.L. of both BPF is

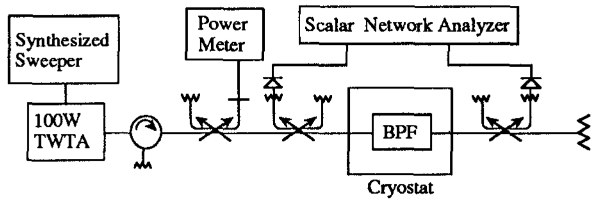


Fig.6. Measurement system of transmission and reflection responses.

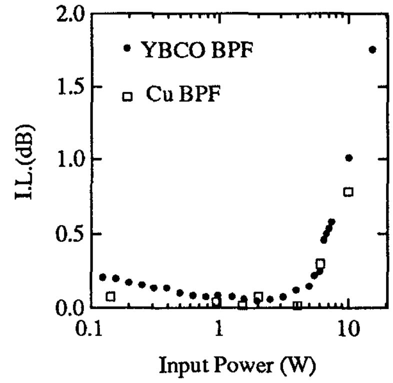


Fig.7. Insertion loss versus input power for 2-stage YBCO and Cu BPFs measured at 77K.

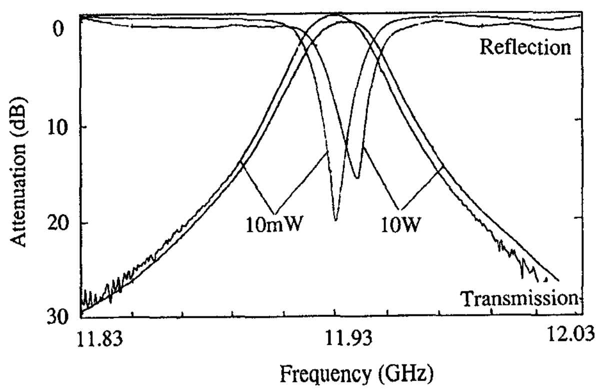


Fig.8. Transmission and reflection responses of the YBCO BPF.

about 0.1dB below P_{in}=3W. As P_{in} increases over 7W, I.L.s for both BPFs increases abruptly because of the Q_d degradation due to temperature rising of dielectric rods.

INTERMODULATION MEASUREMENTS

Figure 9 shows an intermodulation measurement system. Figure 10 shows the results of third-order intermodulation measured at 12GHz at 77K as a function of P_{in} (2W to 40W) for both YBCO and Cu BPFs. The third-order intermodulations for the YBCO BPF are almost the same as the ones for the Cu BPF and are on a straight line of slope 2. The third-order intercept is 100dBm which is much higher than 64dBm at 56K for HTS microstrip filters presented by Liang et al. [1].

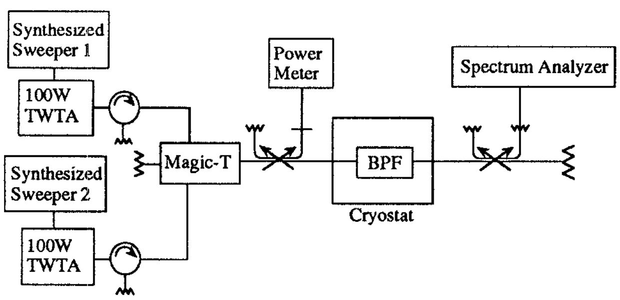


Fig.9. Intermodulation Measurement System.

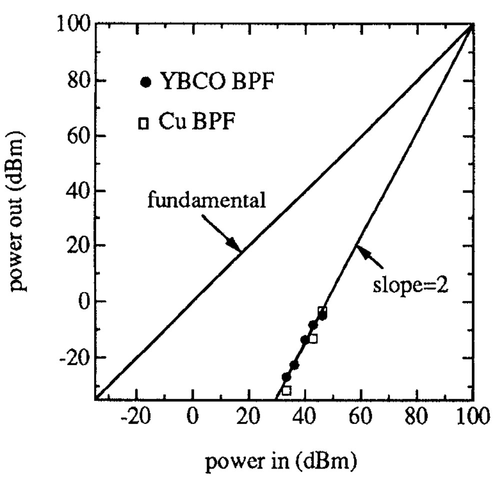


Fig.10. Intermodulation measurements of two-stage YBCO and Cu BPFs performed with input powers of 11,935+/-1MHz and 11,930+/-1MHz at 77K, respectively.

CONCLUSIONS

The YBCO BPF was compared with the Cu BPF experimentally for I.L., power handling capability, and intermodulation. As a result we can not conclude that the YBCO BPF is superior to the Cu BPF under the temperature condition 77K. Also, it was verified that BPFs of this type realize excellent high power-handling capability, compared with planar type BPFs. It is planned presently to improve low thermal conductivity for these filter structures and to make experiment for realizing higher power-handling capability.

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