A Stepped Cavity Resonator with Optimized Spurious Performance and its Applications to BPFs

Kenichi Konno, Michiyo Kubota

Antenna Giken co., ltd., 4-72 Miyagayatou, Saitama, Saitama, 330-0011, Japan

Abstract — **To improve spurious characteristics of the dual-mode cavity resonator, the stepped cavity resonator is proposed, and the difference between the fundamental resonant and the spurious resonant frequencies is a 200MHz improvement seen in the case of stepped cylindrical fundamental band of 1.8GHz against the conventional cylindrical cavity. These are used in a two-stage BPF, showing an improvement in spurious characteristics.**

I. Introduction

In recent years, the development and proliferation of PCS telephony, cellular phones, and other wireless systems has been remarkable. With the Band Pass Filter (BPF) used in these systems, still greater performance can be expected. The BPFs used in these systems ' base stations, especially, need to have superior low insertion loss and band rejection characteristics. Used in these BPFs are high Q resonators such as dielectric and cavity resonators.

The Q_0 value for these resonators' 1.8GHz band (PCS system) is about 24,000 for the dielectric resonator, about 27,000(Cu) for the cavity resonator. The cavity resonator is superior, but it is large, and generally used in conventional dual-mode or multi-mode operation to realize smaller size of BPFs.

When using the cylindrical cavity resonator in dual-mode, TE_{111} mode is used as fundamental mode, but with TM_{011} mode as spurious mode, comparisons become closer. When TE_{111} mode's resonant frequency uses the 1.8GHz band, TM_{011} mode becomes 2.1-2.2GHz at the upper end of 300-400MHz.

This paper proposes the Stepped Cavity Resonator for improvement of the dual-mode cavity resonator's spurious characteristics, and discusses the results of the improvement. These characteristics, when applied to BPF in the 1.8GHz band, are compared to BPF characteristics using an ordinary cavity resonator.

II. Basic Consideration Of Cavity Resonators

Fig. 1 shows the theoretical value of resonant frequency fe111 and fm011 of TE_{111} mode and TM_{011} mode vs. the length L of the cylindrical cavity resonator. Radius D is fixed at 6cm. This figure shows if the length L is longer, the difference between the fundamental mode frequency fe111 and spurious mode frequency fm011 grows wider. To make this relationship still clearer, Fig. 2 shows fe111-fm011=Δf for L/D. In this figure, as L/D gets bigger, Δf gets bigger, but even if L/D increases to 3 or more, further improvement in separation effects cannot be obtained. Fig. 3 shows the theoretical value of the cylindrical cavity resonator's Q_0 value. With Q_0 value, too, as L/D gets bigger, Q_0 value becomes greater, but whereas L/D is around 2.5, the Q_0 value is the maximum. From this result, the cylindrical cavity resonator's optimum L/D can be considered about 3, considering the size of the cavity. If L/D=3, d=6cm, then the theoretical values of fe111, fm011, and Q_0 are as follows:

TE_{111} mode resonant frequency = 1.68545GHz
TM_{011} mode resonant frequency = 2.08740GHz
Frequency gap Δf = 402MHz
Q_0 = 27,878(Cu)

Fig. 4 shows the electric field within the cavity. Around the upper and lower wall areas of the cavity, in TE_{111} mode the magnetic energy is strong and electric field energy is weak, and in TM_{011} mode magnetic energy is weak and electric field energy is strong. With a small change of volume ΔS in the upper and lower wall surfaces, the change in each mode's resonant frequencies shows the following equation of perturbation theory [1]:

$$\frac{\delta\omega}{\omega} = \frac{\Delta W_e - \Delta W_m}{W_T} \quad (1)$$

Here $\delta\omega$ is the change in the resonant frequency, ω is the resonant frequency, ΔW_e is the electric field energy within the small volume ΔS, ΔW_m is the magnetic field energy within the small volume ΔS, and W_T is the total electromagnetic energy within the cavity.

In TE_{111} mode, for $\Delta W_e < \Delta W_m$, $\delta\omega < 0$
In TM_{011} mode, for $\Delta W_e > \Delta W_m$, $\delta\omega > 0$

This means that the change in the resonant frequency in TE_{111} mode and TM_{011} mode against the change in the small volume ΔS the former gets lower but the latter gets higher. That is to say, the frequency numerical difference,

$$\Delta f = fm011 - fe111 \quad (2)$$

is showing that it tends to expand as ΔS increases.

0-7803-7239-5/02/\$10.00 © 2002 IEEE

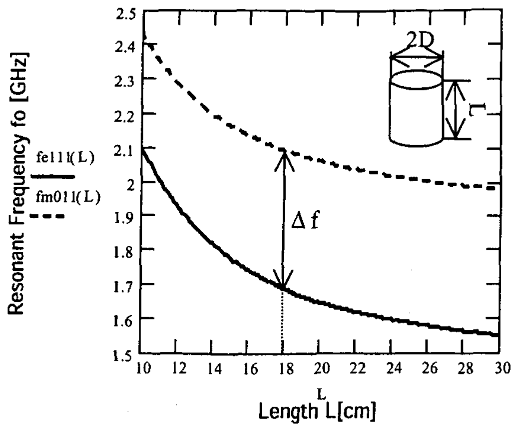


Fig. 1. Resonant frequency of each mode of cylindrical resonators (D=6cm).

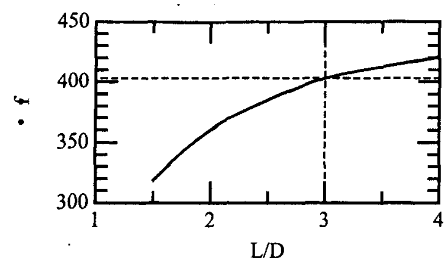


Fig. 2. Difference of resonant frequency of TE_{111} and TM_{011} mode.

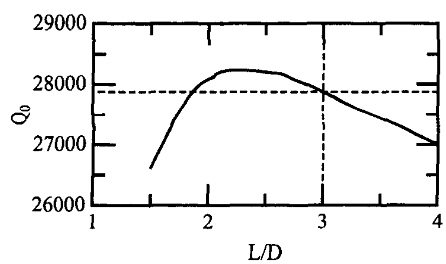


Fig. 3. Q_0 value of cylindrical cavity resonators.

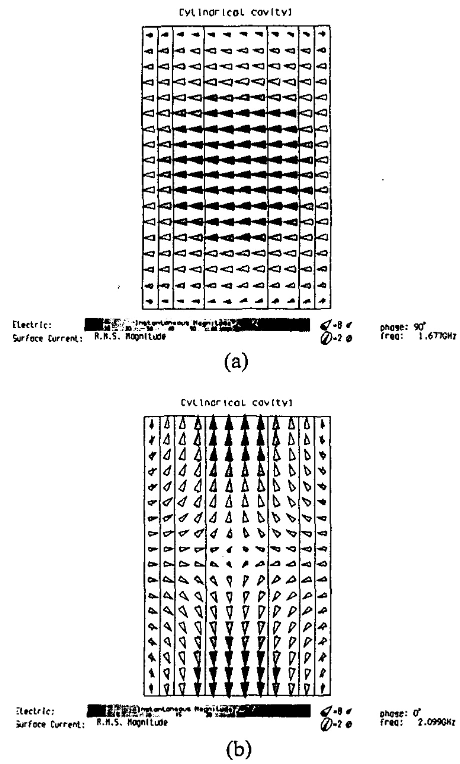


Fig. 4. Electric Field of the cylindrical cavity resonator.(a) TE_{111} mode.(b) TM_{011} mode.

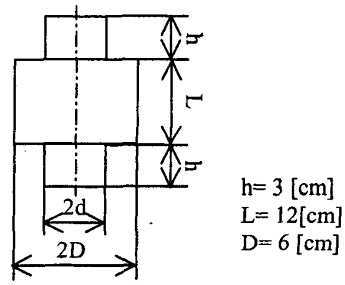


Fig. 5. A stepped cylindrical cavity resonator.

It follows that, using this feature, we can aim to improve the spurious characteristics. Here we will state the improvement methods and their effects.

III. Stepped Cylindrical Cavity Resonators

As mentioned above, we propose the stepped cavity as the cavity structure (shown in Fig. 5) that achieves spurious improvement results. In order to show the effects of these improvements, in the case of change in the step area diameter 2d, the difference between TE_{111} mode and TM_{011} mode resonant frequency (Δf = fe111-fm011) and the Q_0 value of simulated results are shown in Table I. Here the length of the cylinder (L) is 12cm, and the length of the step area (h) is fixed at 3cm. This table shows the greatest value of frequency difference Δf when d=4cm or thereabouts, and shows the value Δf_{max} at about 600MHz. The improvement is about 200MHz.

Further, in this table, conventional cylindrical cavity D is fixed at 6cm, and when L changed from 12cm to18cm,

TABLE I

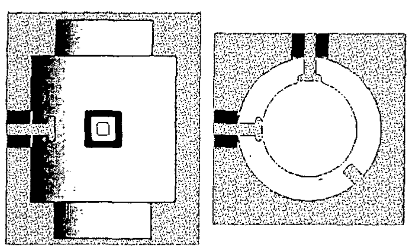
THE STEPPED CAVITY RESONATOR'S RESONANT FREQUENCY AND Q_0 OF TE_{111} AND TM_{011} MODE.

Stepped Cylindrical Cavity resonator L=12cm, D=6cm, h=3cm (Simulated value)					Cylindrical Cavity Resonator D=6cm (Theoretical value)				
d[cm]	TE_{111} mode		TM_{011} mode	Δf [MHz]	L[cm]	TE_{111} mode		TM_{011} mode	Δf [MHz]
	Q_0	fe111 [GHz]	fm011 [GHz]			Q_0	fe111 [GHz]	fm011 [GHz]	
0	27,815	1.92720	2.28849	361.29	12	28,087	1.92582	2.28589	360.07
2	26,853	1.90754	2.32028	412.74	12.3	28,142	1.90617	2.26936	363.19
3	26,082	1.86141	2.37475	513.34	13.08	28,231	1.86049	2.23112	370.63
4	26,045	1.79399	2.40511	611.12	15.4	28,190	1.75927	2.14744	388.17
5	26,750	1.73036	2.29492	564.56	16.3	28,100	1.73007	2.12359	393.52
6	27,682	1.68747	2.09059	403.12	18	27,878	1.68545	2.08740	401.95

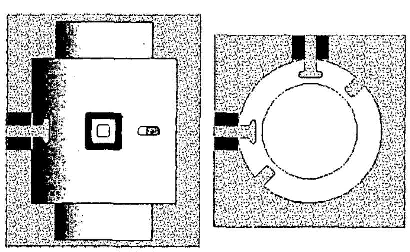
the resonant frequency difference Δf and theoretical value Q_0 were shown. For L=12cm, and 18cm, the simulated value and theoretical value are seen to be very similar. The stepped cavity Q_0 value achieves around 26,000 for d=4cm. The following explains applications for the stepped cavity two-stage BPF.

IV. APPLICATION TO BPFS

Fig. 6 shows the structure of the two-stage stepped dual-mode cavity resonator BPF, (a) is with transmission zero and (b) is without transmission zero. The transmission zero appears when the phase difference of capacitive coupling signal between input and output port and resonator coupling signal become 180 degrees.



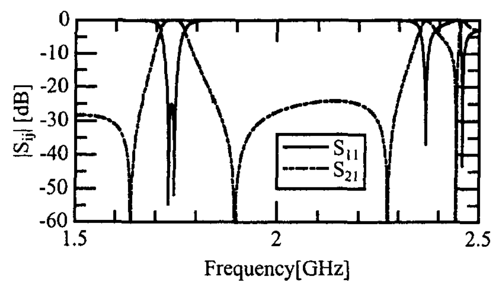
(a)



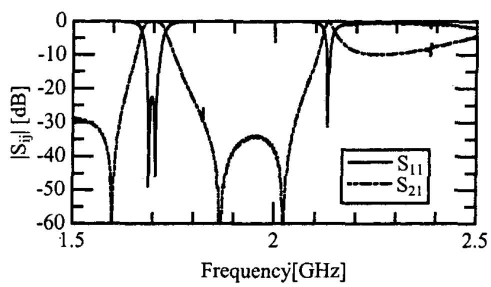
(b)

Fig. 6. Structure of two-stage dual-mode BPF.(a) With transmission zero.(b) Without transmission zero.

Fig. 7 shows the characteristics of BPF's S_{11} and S_{21}. At the center frequency of 1.738GHz, R. L. is –20dB or less and 3dB bandwidth is 58MHz. The spurious frequency is 2.367GHz and Δf is 629MHz. The same figure (b) shows BPF characteristics using a no stepped cavity, and the difference Δf is 430MHz. The stepped cavity BPF has a 200MHz improvement.



(a)



(b)

Fig. 7. The performance of the BPFs with transmission zero.(a) S_{11} and S_{21} of the BPF using the stepped cavity resonator.(b) S_{11} and S_{21} of the BPF using a no stepped cavity resonator.

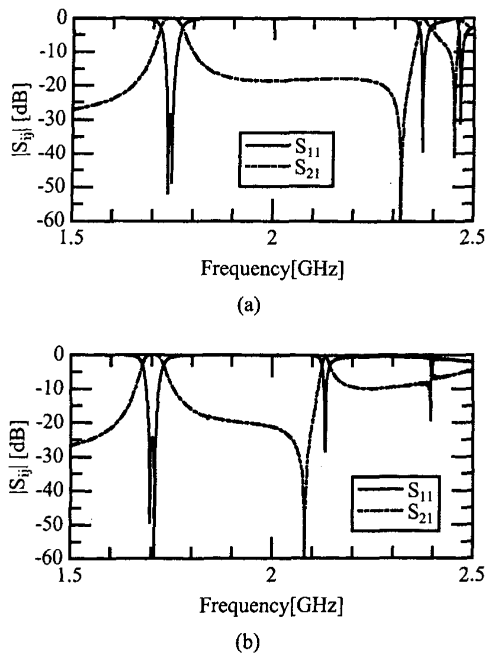


Fig. 8. The performance of the BPFs without transmission zero. (a) S_{11} and S_{21} of the BPF using the stepped cavity resonator.(b) S_{11} and S_{21} of the BPF using a no stepped cavity resonator.

Fig. 8 shows the characteristics when there is no transmission zero. The attenuation characteristics of outside of the pass-band are deteriorating more than in Fig. 7. Concerning spurious characteristics, for no stepped cavity BPF's Δf = 457MHz, stepped cavity BPF is 653 MHz, an improvement of about 200MHz.

Fig. 9 shows wide-band characteristics of the 3dB bandwidth of 100MHz or more. As for stepped cavity BPF, spurious improved by about 200MHz. For no stepped cavity BPF, especially, the pass-band's higher side attenuated characteristics are added to the spurious frequency's lower side attenuated characteristics, and its rejection characteristics deteriorate greatly. Stepped cavity's effects are clearly significant.

V. Conclusion

To improve spurious characteristics of the Dual-Mode Cavity Resonator, the stepped cavity resonator is proposed, and the difference between the fundamental resonant and the spurious resonant frequencies is a 200MHz improvement seen in the case of stepped cylindrical fundamental band of 1.8GHz against the conventional cylindrical cavity. These are used in a two-stage BPF, showing an improvement in spurious characteristics. They have been analyzed through simulation, but prototype BPF is currently at the testing stage and is yet to be released.

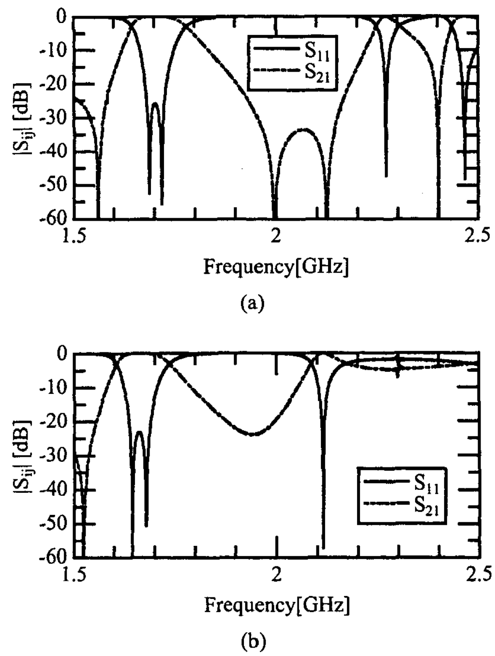


Fig. 9. The performance of the wideband BPFs with transmission zero.(a) S_{11} and S_{21} of the BPF using the stepped cavity resonator. (b) S_{11} and S_{21} of the BPF using a no stepped cavity resonator.

Further, concerning 1.3GHz band BPF, testing of prototype two-stage dual-mode BPF using a conventional cavity is over, and it is being confirmed that the results of the features simulation and measurement findings agree very closely [2].

References

[1] Y. Konishi, *Basic and Application of Microwave Circuit*, Tokyo, Japan: Sohgoh Denshi, 1990.

[2] K. Konno and M. Kubota, " A Narrow-bandwidth Two-Stage BPF with Two Transmission Zeros Using One Dual-mode Cavity," *Proc. IEICE Conf. 'CS*, C-2-53, Sep. 2001.