800 MHz BAND FACE-BONDING FILTER USING DIELECTRIC B.D.L.S.

Toshio Nishikawa, Kikuo Wakino, Jun Hattori, and Youhei Ishikawa

Murata Manufacturing Company Limited
Kyoto, Japan

ABSTRACT

A 800MHz band face-bonding bandpass filter using high K dielectric "Balanced Double Layered Stripline (B.D.L.S.)" construction was developed. This construction suppressed RF leakage almost completely. And excellent temperature stability as high as the dielectric material was obtained. The insertion loss was improved over 20% compared with the conventional microstripline filter. Outer dimensions of the 5-pole filter were 27×11×5mm.

INTRODUCTION

In mobile communication systems, cellular telephone at 800MHz band have been put into practical use, and recently the demand for hand held type cellular mobile communication sets has been increasing, and because of this, the requirement for low cost, small-sized RF components are also increasing. In terms of size and cost reduction, the antenna filter and RF stage filter are the most important RF passive components. The filter using the dielectric resonator has the biggest advantage for the reduction of cost and physical size, and we have reported on dielectric resonator filters and duplexers using coaxial TEM mode several times. [1] [2] [3] [4] Nevertheless due to the speed of technical progress of mobile communications, further size and cost reduction are required more than ever. We reported high K microstrip line resonator filter which is a great advantage to size and cost reduction [5]. But RF leakage and insertion loss are inferior to conventional dielectric resonator filters. Additionally for the high K microstrip combline filter, it is generally difficult to design the bandpass filter to be of both small and narrow band under 5% bandwidth ratio. Generally speaking, face-bonding techniques are required when a small component (with all dimensions under 1 inch or so) is mounted on a printed circuit board because it is needed to ease the assembly. In order to solve these problems, we proposed a new construction that has closed resonance space built up by two dielectric substrates, and we named it "Balanced Double Layered Stripline(B.D.L.S.)". Using this construction, we developed the 883MHz 5-pole bandpass filter (the fractional bandwidth ω is 2.6%). This paper shows the constrution and design method and performance of the B.D.L.S. resonator filter.

CONSTRUCTION

The construction of the dielectric B.D.L.S. resonator filter is shown in Figure 1. Its two dielectric substrates, above and below, are high K ceramics (K is 90). The electrodes of the ground and the stripline are fired silver, and the pattern of the stripline is constructed by photo-etching. A pair of striplines on the two substrates are arranged symmetrically, and the stripline sides of the two substrates face each other. The two outside ground planes stop the RF radiation. The low K resin plate is inserted between the two substrates. Short circuit pins are inserted vertically in suitable points of the resin plate, and by these pins the electromagnetic resonance on the striplines of above and below

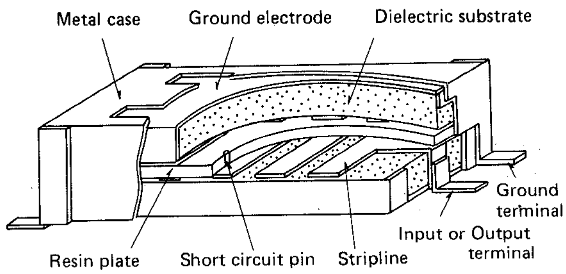

Fig. 1 Basic construction

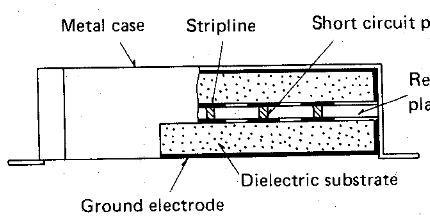

Fig. 2 Cross sectional view

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are excited at the same phase (namely even TEM mode). We can see that the even mode of the double striplines operates as a resonator. As this construction softens the current density concentration on the edge of the striplines, the unloaded Q of striplines can be improved. The cross sectional view which include short circuit pins is shown in Figure 2. As the effective dielectric constant of striplines is not so different from that of the dielectric substrates, the coupling constant between stripline resonators is small. This filter is packed by the metal case, and is soldered in several points. Input, output, and ground parts are designed to be suitable for face-bonding, and can be soldered easily on printed circuit boards.

MATERIALS

The high K (K is 90) ceramic and resin materials used for this filter are listed in Table 1. The dielectric dissipation factor is so small as not to affect the degradation of stripline resonators. And small temperature coefficient does not allow the center frequency of the filter to drift over 1.5% of the passband width. The material of the resin plate is PTFE.

Table 1. Materials of ceramic and resin

	ceramic	resin
Material	$BaO-Nd_2O_3-TiO_2$	PTFE
Dielectric constant	90	2.1
Dissipation factor	2.2×10^{-4}	7×10^{-4}
Temperature coefficient	3±1ppm/℃	

DESIGN

Outline of required characteristics

The required characteristics for the bandpass filter used for mobile communication systems at 800 MHz band are listed in Table 2.

Table 2. Outline of required characteristics

Size	≦30×12×5mm
Center frequency	883MHz
Bandwidth (BW)	26 MHz
Insertion loss (atBW)	≦3.5 dB
Return loss (atBW)	≧14 dB
Attenuation (at f_0±32 MHz)	≧30 dB
Operating power	5 Watt
Operating temperature range	-50~+85℃

Equivalent circuit

Equivalent circuit of B.D.L.S. is shown in Figure 3. R_J in the same figure shows a resonator of a pair of striplines which are shorted at open ends by a short circuit pin. In the conventional combline bandpass filter, $\varepsilon_{reff}^{even}$ is equal to ε_{reff}^{odd}, but in this case are not equal because of resin plate. This circuit expression shows that the coupling of resonators is due to the difference between $\varepsilon_{reff}^{even}$ and ε_{reff}^{odd}.

Coupling coefficient and resonant frequency

Electric field distributions of even and odd mode are shown in Figure 4. This figure shows that the electric energy of the even mode is concentrated more in the dielectric substrate than that of the odd mode, and $\varepsilon_{reff}^{even}$ is greater than ε_{reff}^{odd}. The coupling coefficient (k) is expressed by the following equation.

$$k=\frac{2(f_0^{odd}-f_0^{even})}{f_0^{odd}+f_0^{even}}=\frac{2(\sqrt{\varepsilon_{reff}^{even}}-\sqrt{\varepsilon_{reff}^{odd}})}{\sqrt{\varepsilon_{reff}^{even}}+\sqrt{\varepsilon_{reff}^{odd}}} \quad (1)$$

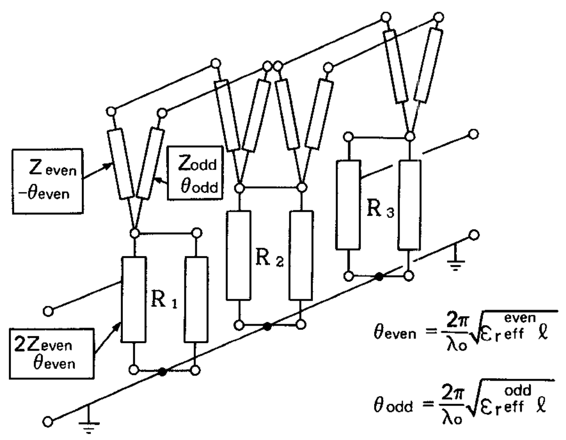
f_0^{even} and f_0^{odd} are resonant frequencies of even and odd mode respectively. f_0 is center frequency of the filter, and is expressed by the following equation.

$$f_0=\frac{c}{\lambda_0}=\frac{c}{4\ell\sqrt{\varepsilon_{reff}}} \quad (2)$$

$$\varepsilon_{reff}=\frac{\varepsilon_{reff}^{odd}+\varepsilon_{reff}^{even}}{2} \quad (3)$$

where c is the light velocity.

ε_{reff} versus the thickness of the resin plate (T) is shown in Figure 5. When T is under 0.5mm, we can obtain over 85% of the dielectric constant of the substrate (ε_r). Electric energy of B.D.L.S. is expected to be concentrated more in the dielectric substrate than that of the microstripline. ε_{reff} of B.D.L.S. is over 20% greater than that of the microstripline with



Z_{even}, Z_{odd} : characteristic impedance of even, odd mode
$\theta_{even}, \theta_{odd}$: electrical length of even, odd mode
$\varepsilon_{reff}^{even}, \varepsilon_{reff}^{odd}$: effective dielectric constant of even, odd mode
λ_o: wavelength in the air ℓ: axial length

Fig. 3 Equivalent circuit

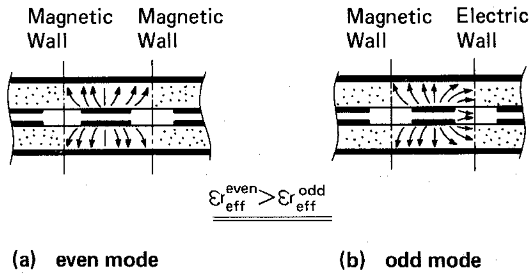


Fig. 4 Electric field distribution

the same dimensions. Therefore the axial length of B.D.L.S. filter is over 10% shorter than that of the microstripline filter, and the temperature stability of this filter, compared with the microstripline filter, is more similar to that of the dielectric substrate.

k versus the space between resonators (S) is shown in Figure 6. As S increases and T decreases, k decreases. We can have the needed k by cotrolling S and T. As the difference between $\varepsilon_{r\,eff}^{even}$ and $\varepsilon_{r\,eff}^{odd}$ in B.D.L.S. is much less than in the microstripline, k of B.D.L.S. is much smaller than that of the microstripline, We can design small sized narrow bandpass filter of which fractional band width is under 5% when T is under 0.5mm and S is over 1.5mm.

Unloaded Q of resonators

Unloaded Q (Q_0) of the resonator versus T is shown in Figure 5. Q_0 of the even mode is about 10% greater than that of the odd mode. Compared with the microstripline, this construction softens the current density concentration on the edge of the resonator, Q_0 is about 20% greater than that of the microstripline. Therefore, we can improve the insertion loss about 20%. As T increases, Q_0 decreases gradually; and when T increases infinitely, Q_0 approaches that of the microstripline.

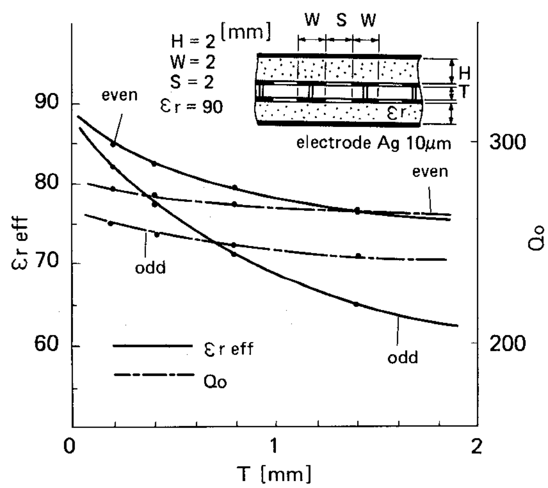


Fig. 5 Effective dielectric constant (ε_r eff) and unloaded Q (Q_0) versus T

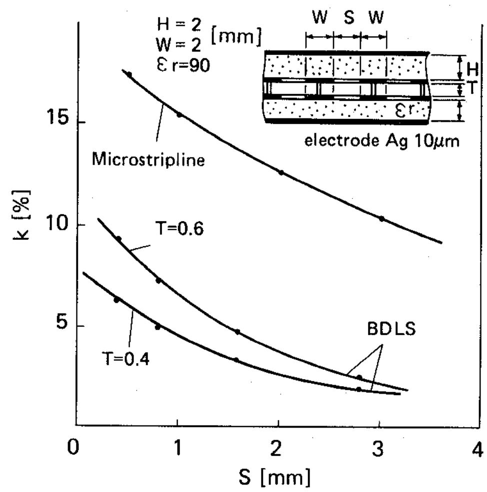


Fig. 6 Coupling coefficient (k) versus S

Filter design

We designed a B.D.L.S. bandpass filter which satisfies the required characteristics. The passband characteristics are approximated by 5-pole Chebysheff curve. The thickness of dielectric substrate (H) and the width of the stripline (W) are selected by considering the needed Q_0, S and T are selected by considering the needed k. l is calculated by equation (2). Input and output parts are coupled by the tapped stripline. In the first and the fifth resonator, the length between the tapped point and the open edge is ℓ_{ex}, and ℓ_{ex} is calculated by the following equation.

$$\ell_{ex} = \frac{c}{2\pi f_0 \sqrt{\varepsilon_{r\,eff}^{even}}} \tan^{-1} \frac{Q_e Z_{even}}{Z_0} \qquad (4)$$

where Q_e is the external Q, and Z_0 is the load impedance.

PERFORMANCE

The performance of this filter is shown in Table 3. By the narrow band design technique using B.D.L.S. construction outer dimensions are reduced to 27×11×5mm. The attenuation and return loss characteristics are shown in Figure 7. This performance satisfies the requirement shown in Table 2. The Q_0 of the resonators is about 240, and we have obtained insertion loss of 3.2dB. The attenuation curve at the lower frequency is slightly more gentle compared with that at the higher frequency. This tendency is also shown in the microtripline filter, and it is caused by the weak coupling between resonators that are not adjacent. Spurious response characteristics are shown in Figure 8. By two outside ground planes of B.D.L.S., RF leakage is suppressed almost completely, electrical influence to the neighbouring components need not be noticed. The performance is measured at -50℃~+85℃. The deviation of center frequency is within ±0.3MHz, and this result well agree with the temperature stability of the high K ceramic substrate.

Table 3 . Performance

Size	27×11×5 mm
Center frequency	883.2 MHz
Bandwidth (BW)	26.5 MHz
Insertion loss	3.2 dB
Return loss	15 dB
Attenuation: at f_0-32 MHz	31 dB
at f_0+32 MHz	38 dB
Temperature stability (f_0)	≦±0.3MHz

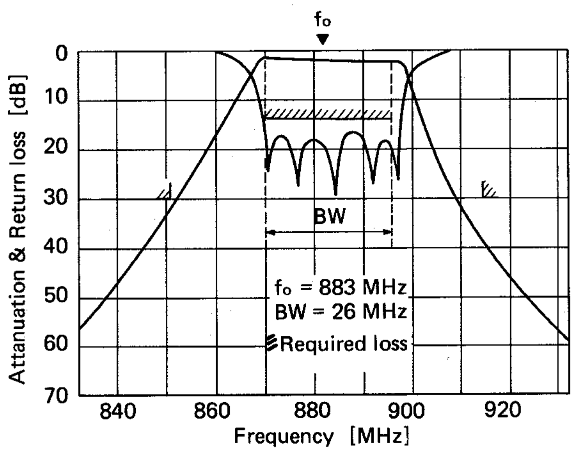


Fig. 7 Attenuation and return loss characteristics

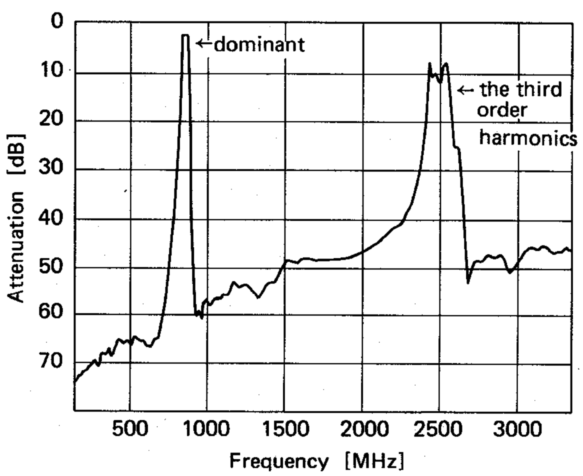


Fig. 8 Spurious response characteristics

CONCLUSION

A B.D.L.S. bandpass filter using high K ceramic substrates was developed. This filter is small, about 1/2 the size of conventional microstripline filter. Additionally this filter can be mounted on printed circuit boards by using face-bonding techniques. In electrical characteristics, compared with the microstripline filter, insertion loss is improved about 20%, and RF leakage is almost suppressed. This mass producable, cost reductive filter will be a very useful RF component for the cellular hand held type communication set.

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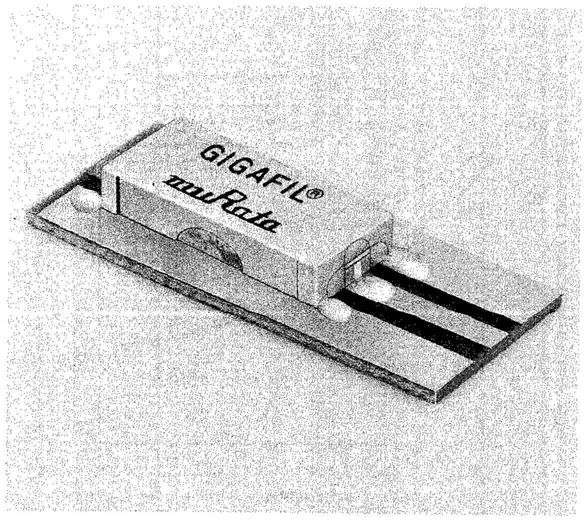

Fig 9. Face-bonding B.D.L.S. filter