A MINIATURIZED DIELECTRIC MONOBLOCK BAND-PASS FILTER FOR 800MHz BAND CORDLESS TELEPHONE SYSTEM.

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ABSTRACT

A miniaturized dielectric monoblock band-pass filter is realized by using unique coupling method in a ceramic block of high permittivity. The filter only consists of one dielectric monoblock and electrodes. The RF leakage is suppressed without other shield housing because the whole outside wall of the filter is covered with plated copper electrode except I/O ports useful for surface mount. The dimensions of dielectric monoblock and its electrodes are decided from the elements of an equivalent circuit by 3D-FEM. The volume of the filter made as a trial for 800 MHz cordless telephone is less than 300 mm^3 in insertion loss of 2.1dB.

1. INTRODUCTION

Many constructions of small-sized dielectric filter for mobile communication equipment have been reported. Their typical constructions are dielectric monoblock type using coupling hole[1], coaxial resonator type[2] and balanced double layer stripline type[3]. The monoblock type has useless space for the open surface of resonators, and there is a limit to the miniaturization. The coaxial resonator type has many numbers of constituent parts, so productivity is not improved sufficiently. The balanced double layer stripline type has a less unloaded Q, so it is difficult to obtain high attenuation characteristics.

The band-pass filter which has simple construction, high attenuation characteristics and high density mount ability is required for a portable telephone in enlarged market size. One of the solution is that only one dielectric monoblock performs the filter characteristics.

Newly developed filter is a dielectric monoblock whose all surface is covered with metal electrode except I/O ports. The coupling between two resonators which construct on the inside of the dielectric monoblock produces the filter characteristics, and the leakage of resonant energy including the coupling is suppressed completely. Therefore, it shows that this filter is able to be mounted with high density in the close position of other components. The construction of this filter is able to be analyzed in principle, and the filter is produced with ease by utilization of the design charts made with 3D-FEM analysis.

2. CONSTRUCTION

The filter only consists of one dielectric monoblock which has plural cylindrical holes for inner conductors of resonators. These resonators are a quarter wave length TEM mode transmission lines. All surface is metalized except surrounding of I/O ports and circumferential gaps inside of the end of the cylindrical holes. The shape of this construction is shown in Fig. 1. This is the simple case of two-section filter to explain the basic principle of it. It operates as gap capacitance and becomes the open end of the resonator. Two resonators are coupled by the influence of the gap capacitance. The I/O ports are capacitively coupled with the inner conductors.

The RF signal is scarcely leaked because there is no hot potential part on the surface of

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the filter. The filter is surface mountable because I/O ports are arranged on each corner between bottom and side planes.

The ceramic material is BaO-PbO-Nd_2O_3-TiO_2, its permittivity is 90[4].

3. DESIGN

3.1 Equivalent circuit

The coupling method of the filter is the same as comb-line filter circuit using TEM mode transmission lines[5]. The equivalent circuit of two-section filter is shown in Fig. 2. Each element of this circuit is related the construction as shown in Fig. 1.

3.2 Coupling coefficient

As shown in Fig. 3, TEM mode electromagnetic field is disturbed nearby the open end by addition to gap capacitance . It generates quasi-TM mode, then the resonators are coupled magnetically, that is inductive coupling.

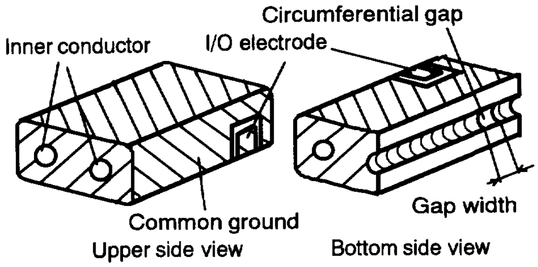


Fig. 1 Shape of two-section filter

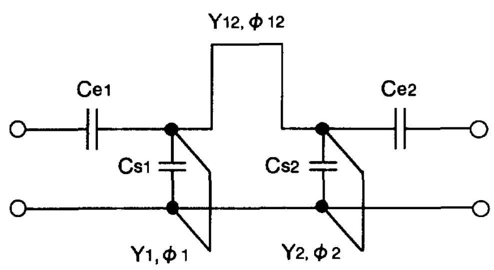


Fig. 2 Equivalent circuit

It is possible to analyze these complicated electromagnetic field by 3D-FEM analysis. The 3D-FEM is the method which calculates the distribution of electromagnetic field, resonant frequency and the capacitance between each electrode from cubic dimensions of analyzed object, and useful design charts are obtained by the results of the 3D-FEM analysis on various conditions.

The coupling coefficient and the gap capacitance are calculated from required filter characteristics[5]. The relation of the gap capacitance and the gap width are calculated by using 3D-FEM, and the relation of the gap width and the coupling coefficient are measured.

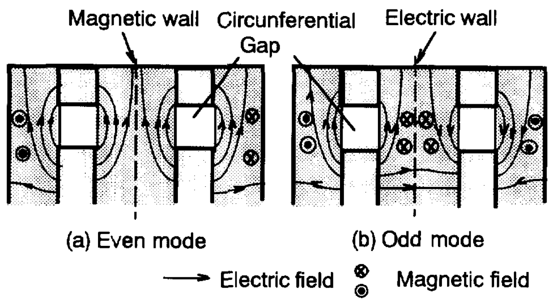


Fig. 3 Electromagnetic field near by gap

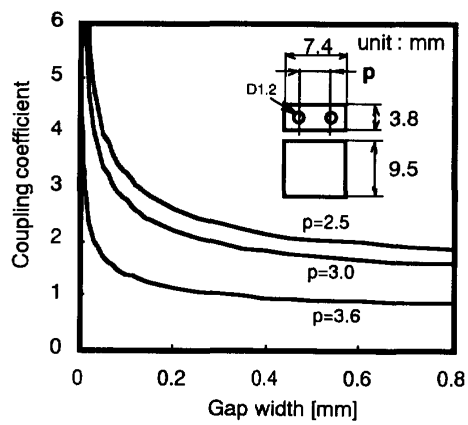


Fig. 4 Relation of coupling coefficient and gap width versus gap capacitance

These relation are shown in Fig. 4. These results agrée with results of measurement within 5%. Hence, the coupling coefficient can be controlled by the gap width even if the dimensions of the monoblock size and pitch are provided, then bandwidth of the filter is controlled too. By using this coupling method, the filters which have different center frequency and bandwidth are able to manufacture from the same dimensional dielectric monoblock. The range of the center frequency and the bandwidth are shown in Fig. 5.

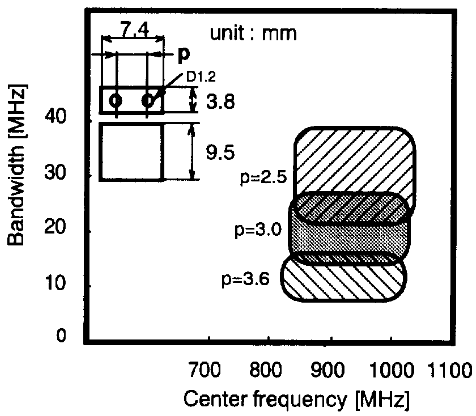


Fig. 5 Range of center frequency and bandwidth

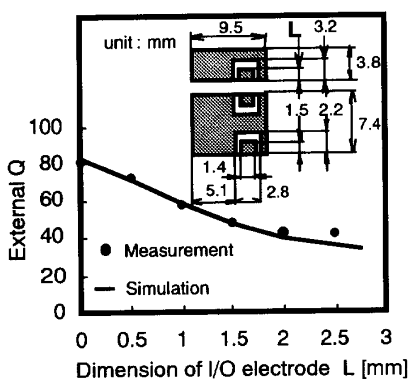


Fig. 6 External Q versus dimesion of I/O electrode

3.3 External Q

The I/O electrode are directly coupled the resonators by the external coupling capacitances. The external Q and the external coupling capacitance are calculated from required filter characteristics[5]. The relation of the external coupling capacitance and dimension of I/O electrode are calculated by using 3D-FEM, and the relation of dimension of I/O electrode and external Q are measured. These relation are shown in Fig. 6.

4. TRIAL MANUFACTURING AND PERFORMANCE

4.1 Requirements

The important requirements are shown in Table 1. The electrical requirements are typical characteristics for European cordless telephone system. The physical size requirements are required to miniaturize the radio terminal equipment.

Table 1. Requirements

Items	Requirements
Center frequency(f_0)	886.0 MHz/931.0 MHz
Pass band width	2.0 MHz
Insertion loss	3.0 dB MAX.
Attenuation at $f_0 \pm$ 44 MHz	24 dB MIN.
Height	4.0 mm MAX.
Volume	300 mm^3 MAX.

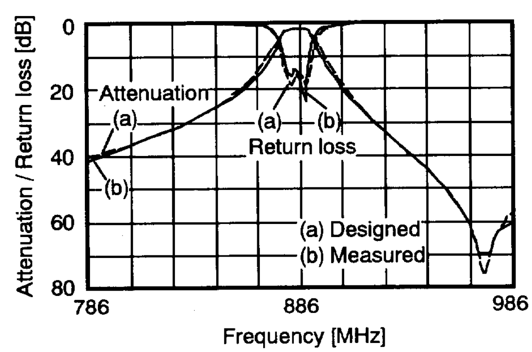


Fig. 7 Characteristics of attenuation and return loss

4.2 Simulation of characteristics

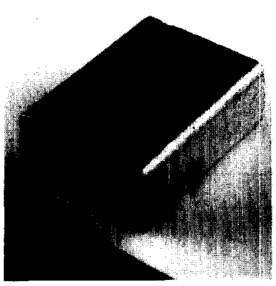
The elements of the equivalent circuit are calculated on Tchebyscheff type band-pass filter[5]. The design characteristics of attenuation and return loss are simulated, and these are shown in Fig. 7(a).

4.3 Performance

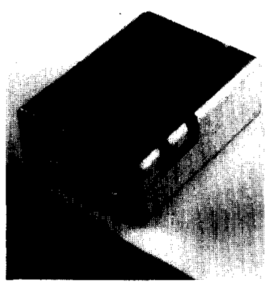
The trial samples of two-section filters for European cordless telephone system are manufactured, the size is width 7.4 x height 3.8 x depth 9.5 mm (267mm^3 in volume).Measured characteristics of attenuation and return loss are shown in Fig. 7(b). The insertion loss is 2.1 dB on center frequency of the filter. This measured results agree with the simulation results. Other performances are examined, and the results are shown in Table 2. The outside view of this filter is shown in Fig. 8.

Table 2. Performance

Items	Test conditions	Results
Temperature characteristics	-35 °C (Low), +85°C (High)	-1.5 ppm/°C(Low), +3.9 ppm/°C(High)
Vibration	10 - 50 Hz p-p 2 mm, 50 - 500 Hz 10 G, 3 directions, 2 hr/each direction	No varied
Shock	3000 G, 0.3 msec, half sine curve, 6 times, 3 directions	No varied
Fixed strength to PCB	2 directions	More than 15.0 kgf
Soldering heat resistance	230 °C MAX., 2 rounds	No varied



(a) Upper side



(b) Bottom side

Fig. 8 Outside view

5. CONCLUSION

A miniaturized dielectric monoblock band-pass filter was developed. This filter was a surface mount device using high permittivity monoblock ceramics. The resonators were coupled magnetically by disturbing TEM mode electromagnetic field nearby the open end of the resonators, then the construction of one dielectric monoblock resonator performed filter characteristics by itself. All surface of this filter was covered with ground electrode, so RF leakage was suppressed. The trial samples for European cordless telephone system were manufactured, the effectiveness of the design method of the filter was confirmed by the measurement of them. The insertion loss was 2.1 dB. Its volume was 267 mm^3, it was 60 percents of the volume of the conventional filter which had same insertion loss. This filter was useful to the cordless telephone and various mobile communication systems. And an antenna duplexer can be made by using these techniques of this filter.

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