A MINIATURIZED DIELECTRIC MONOBLOCK DUPLEXER MATCHED BY THE BURIED IMPEDANCE TRANSFORMING CIRCUIT

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ABSTRACT

A dielectric monoblock duplexer as surface mount device is realized by using the stepped impedance resonators and the buried impedance transforming circuit. The RF leakage is suppressed because the whole outside wall of the filter is covered with plating electrode. The volume of the trial filter for 800MHz mobile telephone terminal is less than 3.9cm^3 . The insertion loss and attenuation of transmitting filter are 1.6dB and 53dB, and these of receiving filter are 2.3dB and 56dB.

1. INTRODUCTION

Several types of miniaturized dielectric antenna filter and duplexer for cellular mobile communication equipments have been reported [1]-[3]. The monoblock type [1] has useless space such as the open surface of resonators, and the miniaturization is limited inevitably. The discrete coaxial resonator type [2] and its stepped impedance resonator type [3] have many numbers of constituent parts, so productivity is not improved sufficiently.

Recently, the dielectric monoblock band-pass filter using comb-line coupling has been reported [4]. However, as attenuation poles of the monoblock filter have no more than upper side of the pass band, it is difficult to realize effectively filter of higher frequency side in duplexer.

We succeeded to realize reasonably the miniaturized and high performance monoblock duplexer by applying the stepped impedance resonators and the buried impedance transforming circuit. This paper reports on the construction and the performance of newly developed duplexer for 800MHz band cellular mobile telephone systems.

2. CONSTRUCTION

The construction of this duplexer is shown in Fig.1. The high permittivity ceramic (K=90 [5]) monoblock element has a plurality of cylindrical holes that form the inner conductors of resonators. These resonators are a quarter wavelength TEM mode transmission lines.

All surfaces of the monoblock are metalized by copper plating except the area surrounding of I/O ports and the circumferential inside gaps of the end of each cylindrical holes. These gaps have stray capacitance and become open ends of the resonators. The RF signal is scarcely leaked to outside because there is no hot potential part on the surface of the filter.

It is able to control widely the coupling coefficient (k) and attenuation pole frequency by using the stepped impedance resonators that the inner diameter of the open end is larger than one of the short end. The boundary of the stepped impedance locates the center of an axial length.

The I/O ports of this duplexer is the driving conductor coupled electromagnetically to each filter, and the buried impedance transforming circuit consists of the driving conductor and the grounded hole installed to obstruct needless coupling in the upper side of the driving conductor. The impedance transforming circuits in TX and RX port are coupled to their band-pass filter (BPF) and band-elimination filter (BEF). The impedance transforming circuit of ANT port is coupled to TX filter and RX filter. Each external

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Q is determined by space between the inner conductor of resonator of the filter and the driving conductor, and impedance matching is determined by a characteristic impedance and a length of the driving conductor, however, the characteristic impedance is affected by the grounded hole.

No additional conductive housing and pin terminal are required, making the device especially suitable for high integration surface mounting technology applications. And it is very reliable against thermal shock and high temperature storage because it has no soldering point. As characteristics of this filter are determined by trimming only the gap width, it is feasible to manufacture by automatic process.

3. EQUIVALENT CIRCUIT AND DESIGN

3.1 EQUIVALENT CIRCUIT

The equivalent circuit of duplexer is shown in Fig.2. The coupling method of the filter resembles comb-line filter circuit using TEM mode transmission lines [6]. The TX filter consists of a band-pass filter with 3 stages and a band-elimination filter with a mono-pole, and the RX filter consists of a band-pass filter with 4 stages and a band-elimination filter with a mono-pole. The impedance transforming circuit is expressed as an interdigital parallel coupled line.

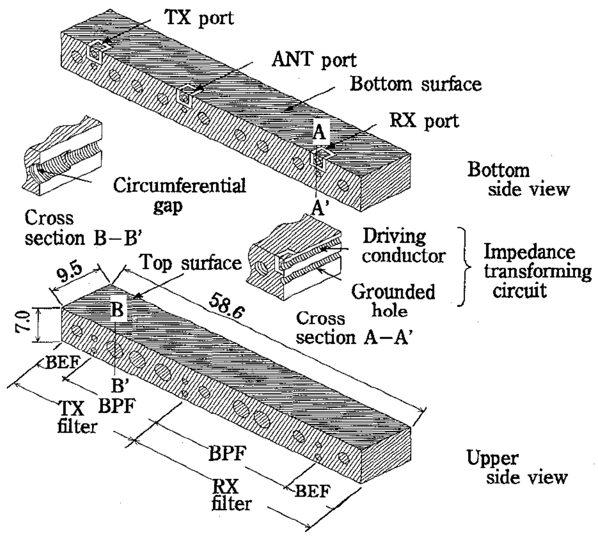


Fig.1 Out and inside view

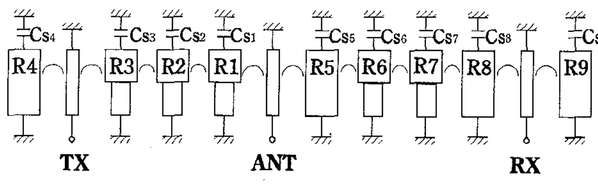
3.2 DESIGN

The resonant frequency of the filter is determined by position of the gap. The attenuation pole frequency can be analytically calculated as variables of the step ratio of the inner diameters in constant coupling coefficient (refer to Fig.3). In this case, the separation (p1) between the coaxial holes is selected by the design of the filter. It is able to have attenuation poles at both side of pass band keeping the pass band width by changing the step ratio of the inner diameters, so TX and RX filter in monoblock are realized. The external Q is determined by space between the inner conductor of resonator of the filter and the driving conductor, p2 , as shown in Fig.4.

These dimensions of this duplexer are obtained by the 3D-FEM analysis.

4. EXPERIMENTAL RESULTS

The trial sample of the duplexer for mobile telephone terminals of E-AMPS is discussed.



Transmitting filter (BPF 3+BEF 1) **Receiving filter (BPF 4+BEF 1)**

Fig.2 Equivalent circuit

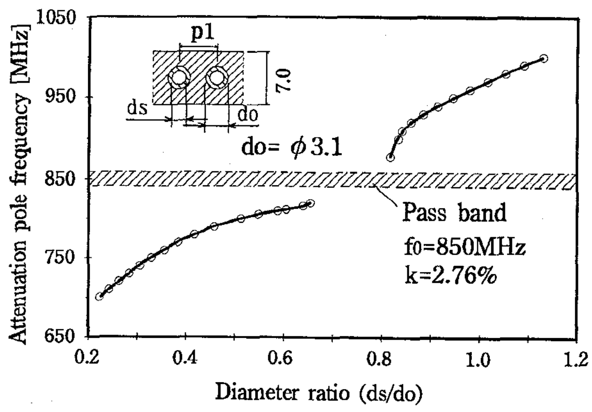


Fig.3 Diameter ratio vs. Pole frequenc

4.1 TX FILTER

In the TX filter, the electrical charcteristics of target value and measured one of the trial sample are shown in Table 1. An insertion loss and an attenuation are 1.6 dB and 53 dB, respectively. The measured and simulated transmission characteristics of the TX filter are shown in Fig.5. This measured results agree with the simulated one. Spurious response characteristic is shown in Fig.6. A spurious mode at 1590MHz is TE_{101}. This mode is excited by the outline dimension of the monoblock duplexer.

4.2 RX FILTER

In the RX filter, the electrical charcteristics of target value and measured one of the trial sample are shown in Table 2. These are 2.3 dB and 56 dB, respectively. The measured and simulated transmission characteristics of the RX filter are shown in Fig.7. This measured results agree with the simulated one, too. Spurious response characteristic is shown in Fig.8. Spurious response of the RX filter is similar to the TX one.

4.3 COMPARISON WITH A CONVENTIONAL DUPLEXER

The comparison with conventional filter for 800MHz mobile telephone is shown in Table 3, the developed duplexer is smaller (width 58.6 x height 7.0 x depth 9.5 mm^3) and simple construction than conventional one as similar

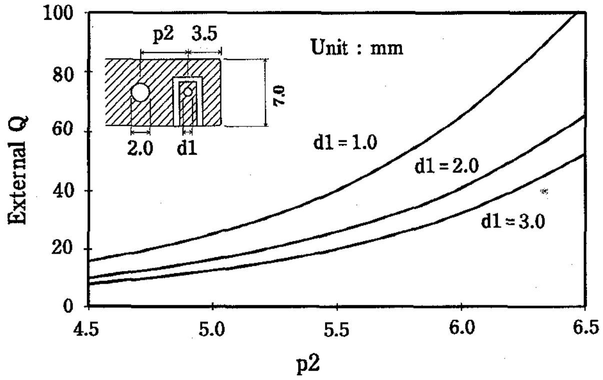


Fig.4 Separation between inner and driving conductor, p2, vs. External Q

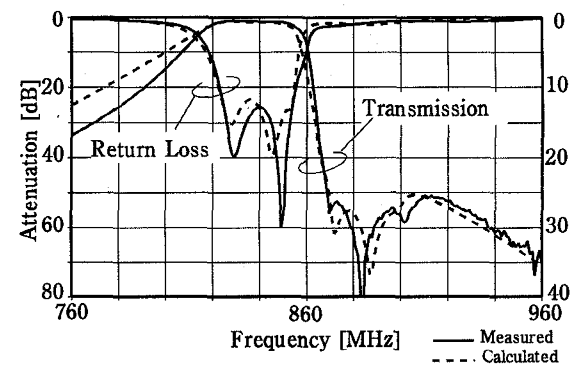


Fig.5 Transmission characteristics of the TX filter

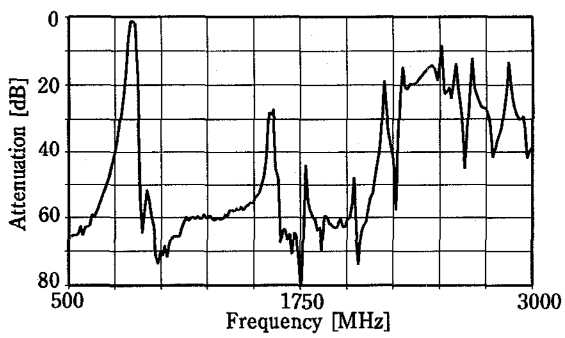


Fig.6 Spurious response of the TX filter

Table 1. Performance of the TX filter

Items	Condition	Target	Measured
Insertion loss		2.2 dB max.	1.64 dB
Ripple	824–849MHz	1.0 dB max.	0.59 dB
V.S.W.R	(Bandwidth)	2.0 max.	1.67
Attenuation	869–894MHz	50 dB min.	53.1 dB
	779–804MHz	10 dB min.	11.8 dB
	1648–1698MHz	30 dB min.	49.5 dB
	2472–2547MHz	5 dB min.	8.2 dB

Table 2. Performance of the RX filter

Items	Condition	Target	Measured
Insertion loss		3.2 dB max.	2.32 dB
Ripple	869–894MHz	2.0 dB max.	0.70 dB
V.S.W.R	(Bandwidth)	2.0 max.	1.62
Attenuation	824–849MHz	54 dB min.	56.3 dB
	914–939MHz	19 dB min.	21.6 dB
	959–984MHz	55 dB min.	59.2 dB

electrical characteristics.

5. CONCLUSION

A miniaturized and high performance monoblock duplexer with specified attenuation poles at both side of a pass band was developed by the stepped impedance resonators and the buried impedance transforming circuit.

It is made by only one part of dielectric ceramic monoblock, and has so good productivity and high reliability. All surfaces of this duplexer are metalized with ground electrode, and the RF leakage is suppressed. So this duplexer is suitable for high integration surface mounting technology applications. The duplexer made as a trial sample for mobile telephone terminals of E-AMPS is 3.9 cm^3 in volume which is 62 % of a conventional duplexer. In the TX filter, an insertion loss and an attenuation are 1.5 dB and 52 dB, respectively. In the RX filter, these are 2.6 dB and 57 dB, respectively.

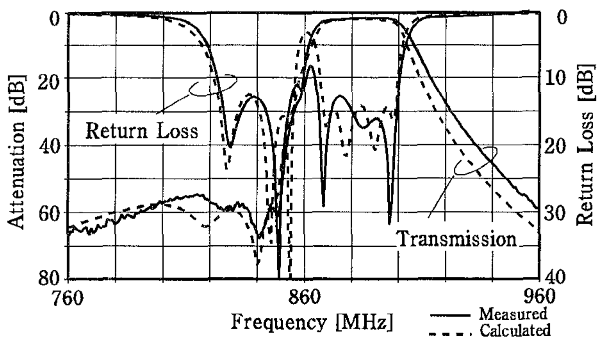


Fig.7 Transmission characteristics of the RX filter

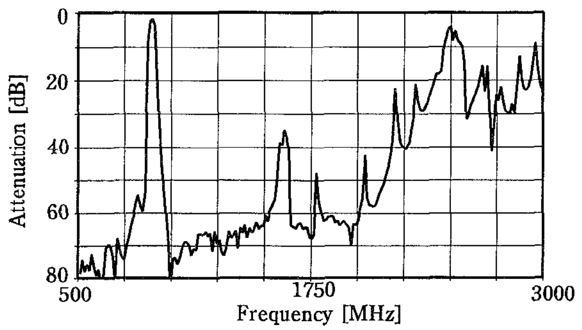


Fig.8 Spurious response of the RX filter

Table 3. Comparison with a conventional duplexer for 800MHz mobile telephone

Items	Developed	Conventional
Type	Monoblock	Two blocks
Size(mm^3)	7×9.5×58.6	7.8×13.8×61.6
Volume(cm^3)	3.9	6.6
Weight(g)	20	23
Stage	9	9
Tx (dB) Insertion loss	1.64	1.67
Attenuation (dB) (869–894MHz)	53.1	58.4
Rx (dB) Insertion loss	2.32	2.61
Attenuation (dB) (824–849MHz)	56.3	60.0
Number of parts	1	13

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