Tunable Duplexer Having Multilayer Structure Using LTCC

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Abstract — A tunable duplexer has been designed for GSM1800/1900 digital cellular system. The tunable duplexer has been fabricated with LTCC (Low Temperature Co-fired Ceramics) multilayer technologies assisted by varactor diodes. To accomplish higher attenuation for each system, multi-tuning method, which enables to control the passband and the stopband independently, is applied. Size is designed as 5.7x5.7x1.8mm. Insertion losses are less than 3.5dB. Attenuation is more than 25dB at Fo+200MHz in Tx, and is more than 10dB at F0-150MHz in Rx.

I. INTRODUCTION

Recently, cellular phone systems have been widely spread, and developed in several systems such as GSM, DCS, and PCS around the world. The demands on a multiband cellular phone have been increased due to its higher convenience. Furthermore, the third generation system of cellular phone is coming into a practical use. In the fourth generation system, it is needed to cover all of these systems with a single handy phone. Software defined radio [1] is discussed to get a handy terminal for cellular system of the fourth generation. In such a software radio system, one appropriate radio band is activated with downloading software among several cellular bands in accordance with the situation.

A tunable device has been discussed to realize the higher flexibility of RF front-end in the radio system. For example, voltage-controlled oscillators (VCOs) are well known as a tunable device. We have developed tunable band-pass filters (BPF) with LTCC technology [2,3]. These tunable filters have a multilayer structure. Many passives are embedded in LTCC substrate, and two varactor diodes are mounted on the top of the surface. Since resonator in tunable band-pass filter consist of these varactor diodes, the passband frequency is tuned to the chosen frequency by applying the voltage to varactor diodes.

LTCC technology is well known to be suitable to build a multilayer structure in which many passives are embedded. The LTCC process is a useful technology for microwave application since high-conductivity metal, such as pure silver, can be used for an internal conductor material, and contributes to low loss at microwave frequency.

In this paper, design and fabrication of the tunable duplexer at 1800-1900MHz is discussed. Tunable duplexer has a multilayer structure in which more than ten passives are embedded with LTCC technology, and has a function to tune both the passband and the stopband to desired frequency independently. Size is designed as 5.7x5.7x1.8mm. Insertion losses are less than 3.5dB. Attenuation is more than 25dB at Fo+200MHz in Tx, and is also more than 10dB at F0-100MHz in Rx.

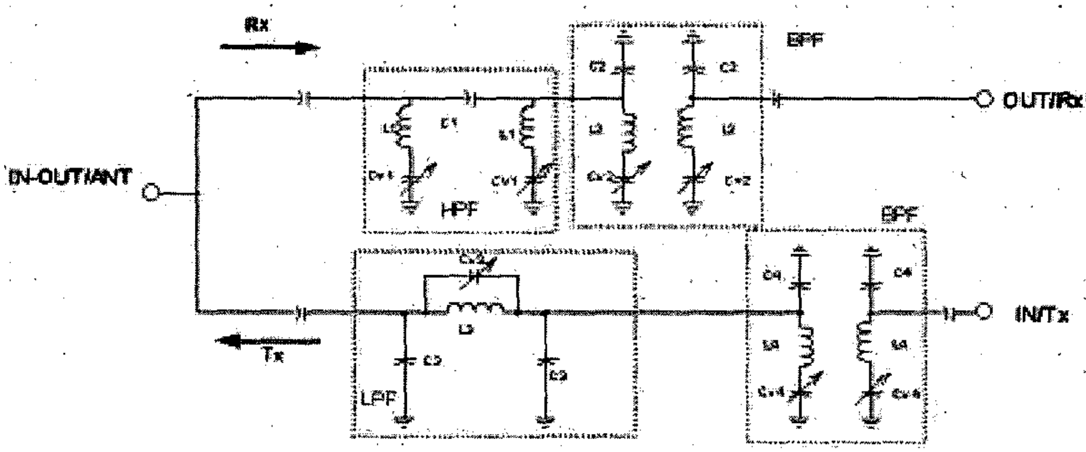

Figure 1. Equivalent Circuit of tunable duplexer

Table 1. Design Parameter of tunable duplexer

Tx		Rx	
LPF	BPF	HPF	BPF
C1 = 0.95pF	C2 = 5.0pF	C3 = 0.67pF	C4 = 4.5pF
L1 = 7.58nH	L2 = 2.6nH	L3 = 2.94nH	L4 = 3.0nH
Cv1 = 1.2-1.5pF	Cv2 =4.0-5.5pF	Cv3 = 2.0-2.5pF	Cv4 =3.5-4.0pF

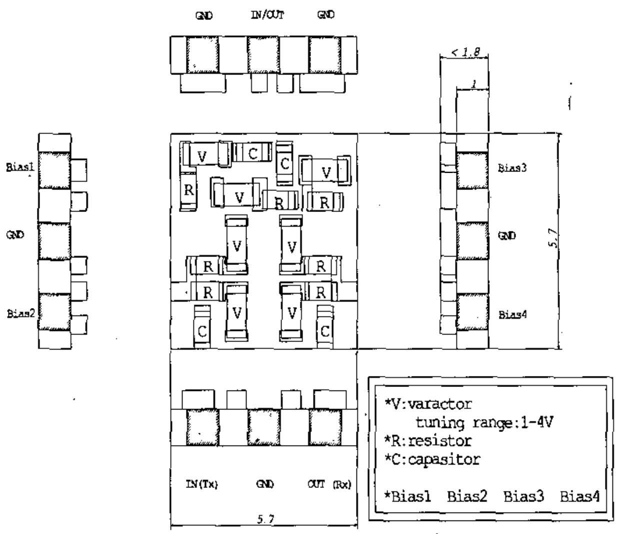

Figure 2. Appearance of tunable duplexer

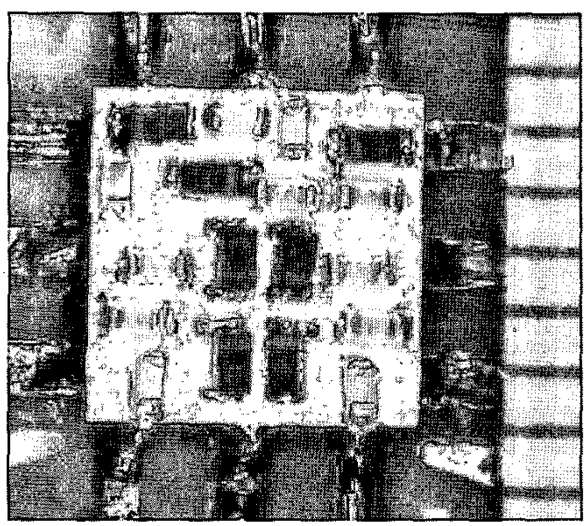

Figure 3. Photograph of tunable duplexer

II. Circuit Design and Fabrication

The lumped equivalent circuit of tunable duplexer is shown in Figure 1. The detailed design parameters are listed in Table1. Since the interval between the passband and the stopband differs in GSM1800 and GSM1900, it is needed to tune both the passband and the stopband to desired frequency independently. In order to realize such flexibility, High Pass Filter (HPF) in Tx and Low Pass Filter (LPF) in Rx are designed to be combined to each BPF respectively. The stopband is required at higher side of passband for Tx, and is also required at lower side for Rx.

Four bias terminals are designed on LTCC substrate to separately control each four filters, which have each varactor respectively. All varactor diodes (Toshiba, 1SV313 for BPF, JDV2S17E for HPF, JDV2S10E for LPF) are mounted on the top surface of tunable duplexer. The tuning voltage is between 1 to 4V. The responses of tunable duplexer are simulated by using a Liner Simulator (ADS) and a Finite Element Method (FEM).

Figure 2 shows the appearances of tunable duplexer. Size is 5.7x5.7x1.8mm (including the varactor diode's height). Figure 3 presents photograph of the tunable duplexer. The LTCC material has $CaO\text{-}Al_2O_3\text{-}SiO_2\text{-}B_2O_3$ composition and dielectric constant of LTCC is 7.7[4]. In Figure 1, passive components except for both varactor diodes and resistors are embedded in LTCC substrate. These LTCC materials are sheet-casted to 0.07mm and 0.1mm thick tape. Electrode patterns are formed by screen-printing method. Pure silver is applied to internal and external electrodes.

After stacking the printed sheets, the stacked blank is cut into pieces, and then co-fired in the furnace around 900 degree-C for 1hour in air.

Table 2. Target value and simulated response

	GSM1800				GSM1900			
	Tx		Rx		Tx		Rx	
Passband	1710-1785MHz		1805-1880MHz		1850-1910MHz		1930-1990MHz	
I.L.	> -3.5dB	> -1.7dB	> -3.5dB	> -3.3dB	> -3.5dB	> -1.7dB	> -3.5dB	>-3.4dB
Attenuation (stopband)								
F0-150MHz			< -10dB	-10.5dB			< -10dB	-11.5dB
F0+200MHz	< -20dB	-29.2dB						
F0+250MHz					< -20dB	-39.4dB		
	Target	Simulated	Target	Simulated	Target	Simulated	Target	Simulated

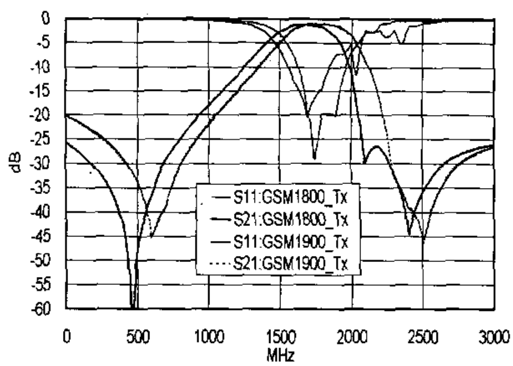

Figure 3. Simulated response of Tx

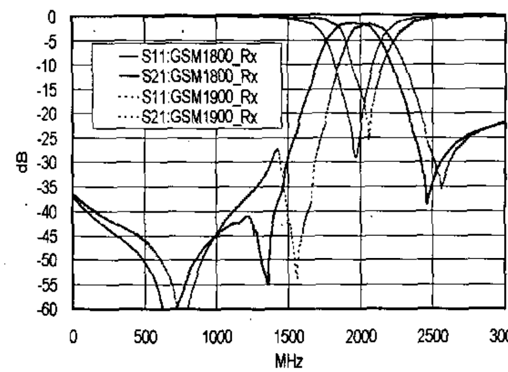

Figure 4. Simulated Response of Rx

Table 3. Bias voltage and Capacitance in Figure 3 and 4

	Tx		Rx	
	GSM1800	GSM1900	GSM1800	GSM1900
Cv1	1.5V: 1.5pF	2.5V: 1.2pF		
Cv2	1.0V: 4.0pF	1.5V: 5.5pF		
Cv3			1.5V: 2.5pF	3.5V: 1.75pF
Cv4			1.8V: 4.0pF	2.5V: 3.5pF

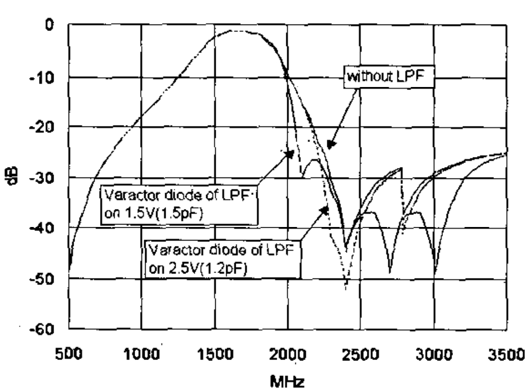

Figure 5. Dependability of Bias voltage of stopband attenuation in Tx

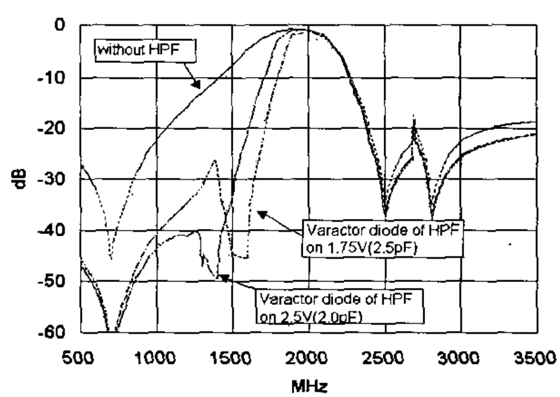

Figure 6. Dependability of Bias voltage of stopband attenuation in Rx

V. RESULTS AND DISCUSSION

Figure 3 and Figure 4 show the simulated results for Tx and Rx of GSM1800/1900 respectively. Table 2 shows the tuned voltage shown in Figure 3 and Figure 4. These results are obtained by Electro-Magnetic Analysis, which simulate the structure as shown in Figure 2. The passband frequency of Tx is tuned from 1710 MHz to 1910 MHz, and that of Rx is tuned from 1805MHz to 1990MHz. As shown in table 2, insertion loss is less than 3.5dB. And attenuation is more than 20dB at f0+200MHz in Tx, and is more than 10dB at f0-150MHz in Rx. Figure 5 and Figure 6 show the tunability of stopband for TX and Rx respectively. In Figure 5 and Figure 6, 1V of bias voltage is applied to BPF of Tx and Rx. In Figure 5, when applied voltage to LPF is increased from 1 to 4V, the notch on the higher side of passband moves toward lower frequency. Contrarily, the notch on the lower side of passband in Figure 6 moves higher frequency according to the increase in applied voltage. After the passband is fixed, the stopband is tuned by controlling voltages to BPF so that the notch of HPF and LPF is adjusted to desired frequency range for Tx and Rx respectively. Therefore the desired responses are attained with tuning the passband and the stopband independently.

The measured responses of actual tunable duplexer are shown in figure.8 and 9. In Tx, insertion losses are less than 5.5dB and atteneuation at Fo+150MHz are more than 20dB. In Rx, insertion losses are less than 3.5dB and attenuation at Fo-100MHz are more than 10dB. Pass band of Tx/Rx of GSM1800/1900 are tuned with a tunning voltage of 1.0-4.0V. It turned out that the trial product acts as a tunable duplexer. Further efforts have been made to improve responses of Tx and Rx with adjusting embedded elements in LTCC.

VI CONCLUSION

Tunable duplexer having multilayer structure using LTCC has been designed. The duplexer has the circuit combining HPF or LPF to BPF in order to tune the passband and the stopband independently. Size of the designed duplexer is 5.7x5.7x1.8mm. In Tx/Rx of GSM1800/1900, Insertion loss is less than 5.5dB at the passband. Attenuation of stopband is more than 20dB at Fo+200MHz in Tx, the other attenuation is more than 10dB at F0-100MHz in Rx. The frequency characteristic has been found to be enough for practical use.

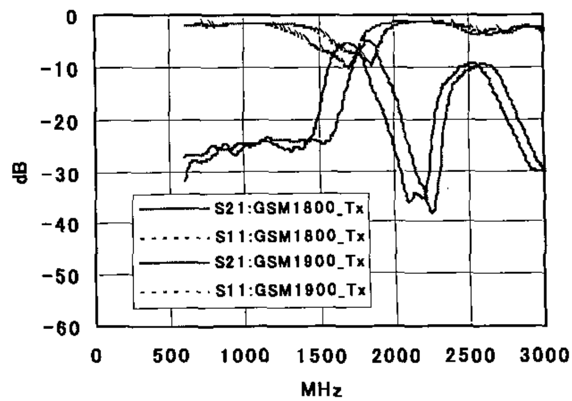

Figure 8. Measured response of Tx

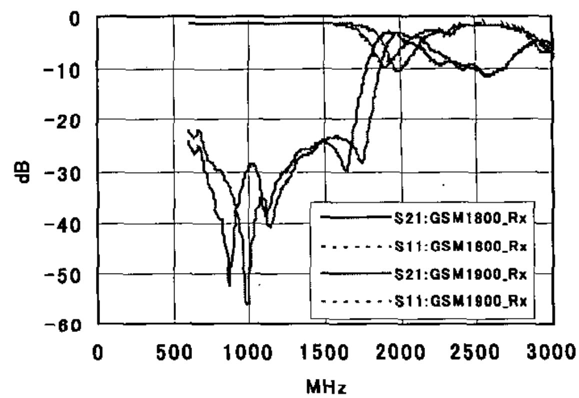

Figure 9. Measured response of Rx

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