MINIATURE SAW ANTENNA DUPLEXER MODULE FOR 1.9 GHz PCN SYSTEMS USING SAW-RESONATOR-COUPLED FILTERS

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Abstract

Surface Acoustic Wave (SAW) filters has been widely applied to radio personal communication to reduce size and volume of the radio terminals. In this paper, we discuss the application of SAW filters used in 1.8-GHz band antenna duplexer module for Personal Communications Network (PCN) systems. The module consisting of a receiver top filter (R1), a transmitter final stage filter (T1), lumped matching-circuit elements and lumped phase-shift circuits has been developed.

The duplexer module has an insertion loss of less than 1.6 dB (1710-1785 MHz) in the Tx-to-antenna path and of less than 3.3 dB (1805-1880 MHz) in the antenna-to-Rx path, respectively. It also has the size of 14 x 8 x 1.8 mm^3 and the weight of 0.4g, which achieved about one-fifth reduction compared with the conventional dielectric-resonator filter duplexers.

1. Introduction

In radio personal communications, such as cellular telephones and cordless telephones, miniature and light devices are strongly required to reduce size and weight of the radio terminals. Furthermore, in a general trend the demand for increasing frequency bandwidth has resulted in using higher frequencies, such as 1.5-2.0 GHz.

In this paper, we focus on design procedures of antenna duplexer module [1][2] for PCN (1.8-GHz band) system. PCN system requires not only extremely wide pass-band but also severe blocking characteristics and low-level spurious emission characteristics. Using SAW duplexer module is one of the solution to achieve small and light radio terminals for PCN systems. We have designed two types of SAW-resonator-coupled filter, the transmitter final stage filter (T1) and the receiver top filter (R1), fabricated on a 36°YX-$LiTaO_3$ substrate for use in a PCN antenna duplexer module. Modeling for frequency characteristics of SAW resonator used in filter design was discussed. Some techniques to achieve sufficient suppression characteristics for the duplexer module and experimental results were also described.

2. Antenna duplexers for cellular telephones

As shown in Fig.1 (a), an antenna duplexer consists of two filters (T1 and R1) connected in parallel with phase-shift elements between the antenna and two filters. The frequency allocation of the PCN system is shown in Fig.1 (b). The transmitter band (f_T) is from 1710 to 1785 MHz, the receiver band (f_R) is from 1805 to 1880 MHz. Each bandwidth and guard band are 75 MHz and 20 MHz, respectively. Relative band width is much wider and relative guard band is much narrower than the conventional 800-MHz band systems, such as GSM and EAMPS. Therefore, the T1 filter must have extremely sharp cut-off frequency characteristics at the upper edge of the f_T band. The harmonic spurious emissions from high power amplifier must be severely suppressed at the second- and third-harmonics bands. The R1 filter must not only protect the receiver from the transmitter signal but also attenuate external interfering signals such as image frequency and blocking-band signals. Antenna side impedance of T1 and R1 should be open at the mutual bands, f_T for R1 and f_R for T1, to minimize the loss increase due to the parallel connection at the antenna terminal.

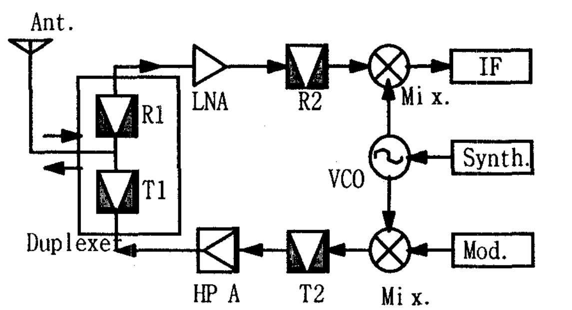

Fig.1(a) RF block diagram for cellular phone

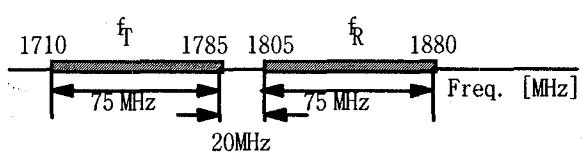

Fig.1(b) Frequency allocation for PCN system

3. SAW resonator and filter design

We used 36°YX-$LiTaO_3$ [3] as a substrate due to its high electromechanical coupling coefficient and its rather small temperature coefficient of delay. Fig.2 (a), (b) shows typical measurement result and simulated behavior of frequency characteristics of SAW resonator. Excellent reactance characteristics near resonance and anti-resonance frequencies was observed in imaginary part of impedance. In real part of the impedance, we can see small peak due to bulk-wave radiation as indicated in Fig.2 (b). Precise modeling of the frequency characteristics of the SAW resonator is a mater of vital importance in filter design. Our simulation [4] take into account of the bulk-wave radiation characteristics, Al-electrode thickness dependence, propagation loss of leaky SAW and several parasitical factor, such as bonding-wire

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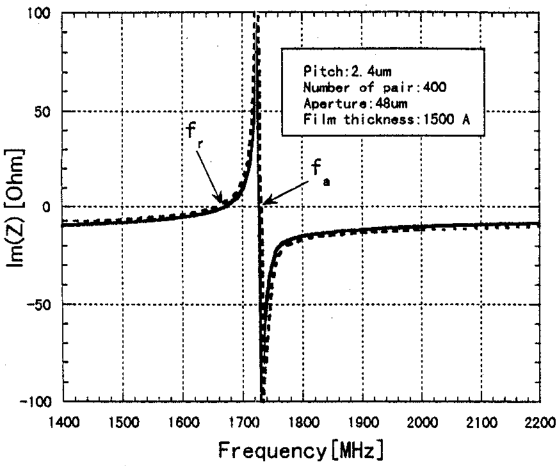

Fig.2 (a) Measured frequency characteristics for SAW resonator (Imaginary part)
The broken line indicate simulation result

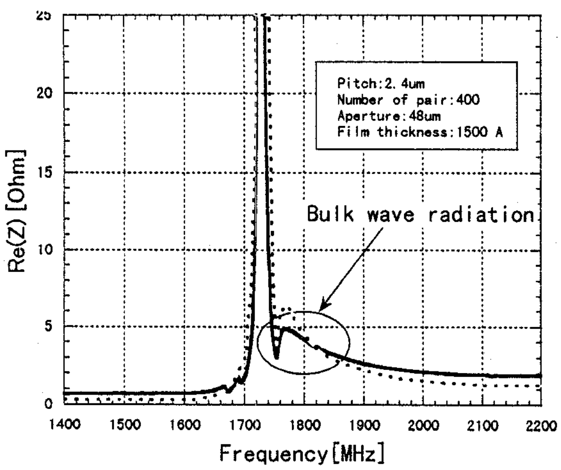

Fig.2 (b) Measured frequency characteristics for SAW resonator(Real part)
The broken line indicate simulation result

inductance and fringing capacitance of IDTs. Fairly good agreement between measured result and simulation result are obtained. We used a cascade connected SAW-resonator-coupled-filter as the final stage filter T1 to achieve a low insertion loss and high power handling capability. A π-connected SAW-resonator-coupled-filter is used for the receiver top filter R1. Equivalent circuits for T1, R1 and the duplexer module are shown in Fig.3. Lumped matching circuits and phase-shift circuits are made from conventional 1608 size chip capacitors and chip inductors. The SAW filters, whose chip size was 2.5 x 1.5 mm, were mounted in conventional 3.5 x 3.5 mm SMD packages. These packages, the chip inductors and chip capacitors were fixed onto a 14 x 8 x 0.4 mm epoxy substrate.

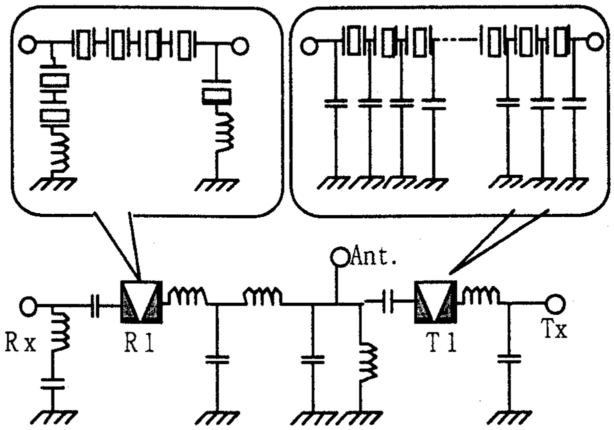

Fig.3 Equivalent circuit for T1, R1 and duplexer

4. Experimental results of SAW duplexer

Maximum height of 1.8 mm was achieved using our new configuration of the duplexer module.

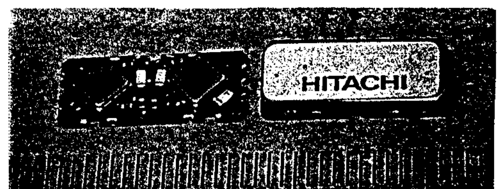

Fig.4 Photograph of the antenna duplexer module

Fig.4 shows the photograph of the duplexer module. The photo on the left shows the internal configuration, while the photo on the right shows external appearance with the metal casing. Fig. 5 and 6 respectively show the measured frequency characteristics of Tx path and Rx path for the duplexer module. In the Tx path, the maximum insertion loss at the f_T band, 1710 to 1785 MHz, was 1.6 dB, and the minimum attenuation at the f_R band, 1805 to 1880 MHz, was 12 dB. In the Rx path, the maximum insertion loss at the f_R band was 3.3 dB, and the minimum attenuation at the f_T and minimum attenuation at over 1920 MHz , i.e. blocking band, are 16 dB and 14 dB, respectively. Loss increases due to parallel connection were 0.5 dB and 0.3 dB in Tx and Rx paths, respectively.

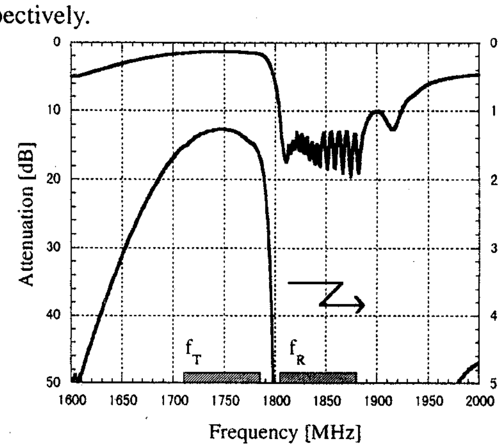

Fig.5 Frequency characteristics of Tx path

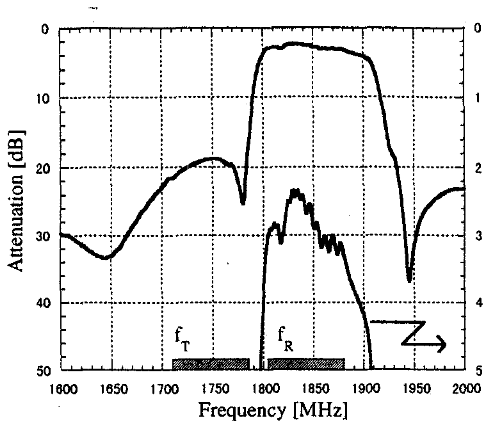

Fig.6 Frequency characteristics of Rx path

Generally, attenuation of SAW-resonator-coupled filter at off-band are not large, because each SAW resonator essentially operates as a simple capacitor in the off-band frequencies, e.g. harmonics and image frequencies, etc. Because of realizing sufficient attenuation at these frequency bands, we introduced lumped matching and phase-shift circuit elements. The image frequency band allocate around 1300 MHz, because the intermediate frequency of about 250 MHz are used in general PCN receiver design. We introduce series connected C and L in shunt arm matching circuit for R1 filter to improve suppression in image frequency band.

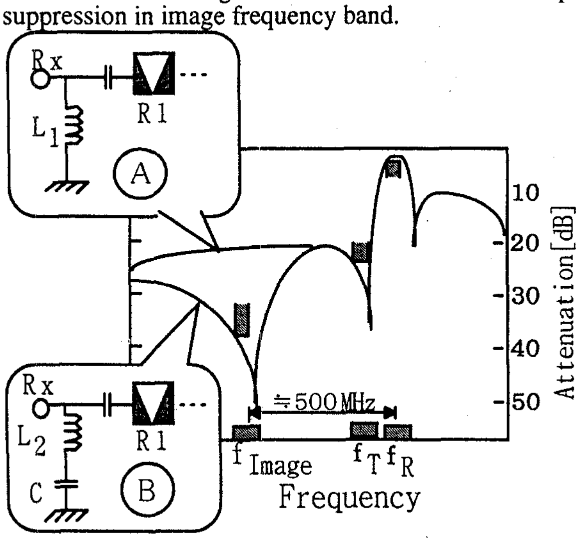

Fig.7 Schematic drawing for suppression at image frequencies in Rx path

Fig.7 schematically shows the matching circuits together with its response. Matching circuit A is conventional type and L1 simply operates as a matching element at f_R. On the other hand, matching circuit B consists of L2 and C operates as a matching element at f_R as well as rejection filter at f_{IM} due to series resonant. Fig. 8 and 9 respectively show the measured wide-band frequency characteristics of the Tx and Rx-paths of the duplexer module. Attenuation more than 35 dB at the image-frequency band was

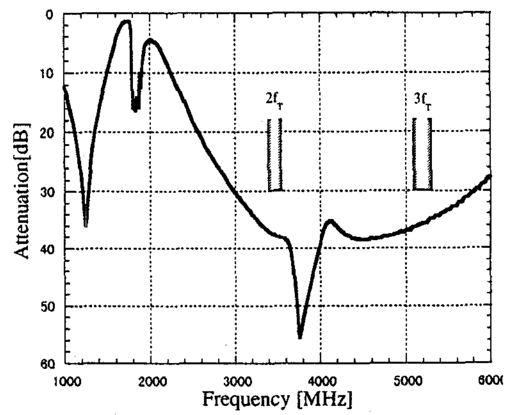

Fig.8 Wide-band characteristics of Tx path

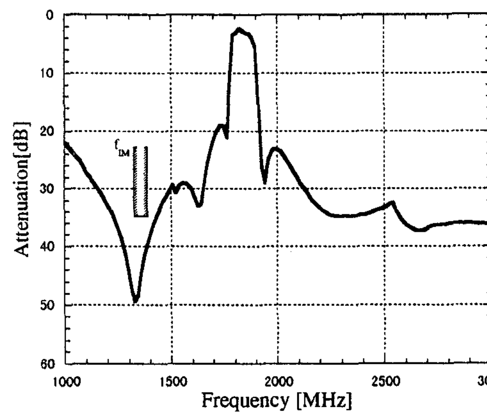

Fig.9 Wide-band characteristics of Rx path

achieved using new configuration in the Rx path. In the Tx path, attenuation more than 30 dB at the second- and third-harmonics were also achieved. Sufficient suppression characteristics for duplexer were achieved by combination of SAW filters and lumped elements circuits.

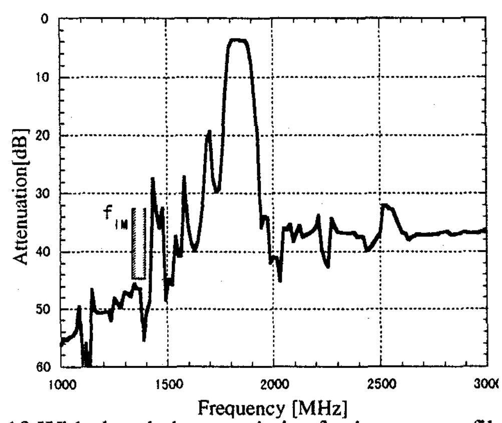

Fig.10 Wide-band characteristics for inter-stage filter

We have also developed inter-stage receiver filter (R2) [5] for PCN system using IIDT type SAW technology. Frequency characteristics of the R2 filter is shown in Fig.10. Suppression more than 45 dB was achieved in the image frequency band. We have demonstrated total

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receiver characteristics using the duplexer module, the new R2 and standard LNA (G≈10 dB). We measured frequency characteristics from antenna terminal to output port of R2 filter as shown in Fig.11. Fig. 12 shows measurement result for total receiver characteristics. Sufficient selectivity was achieved with combination of the duplexer module and inter-stage filter R2.

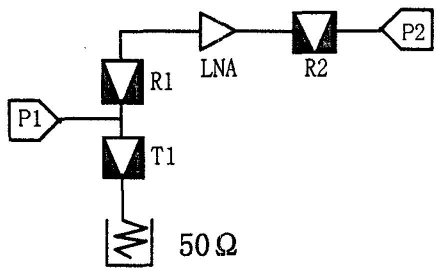

Fig.11 Measurement block diagram for total receiver performance

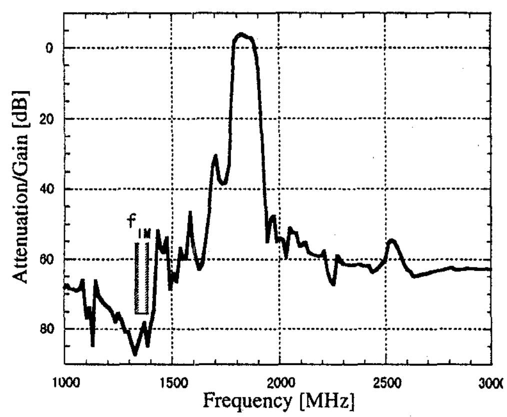

Fig.12 Total receiver performance with the duplexer, LNA and inter-stage filter (R2)

5. Conclusion

We have demonstrated the feasibility of a SAW duplexer module for 1.8 GHz PCN system. Two types of filter, the T1 and R1 filters, that use SAW resonator as basic elements have been developed. The duplexer module consisting of T1, R1, and lumped matching / phase-shift circuits achieves sufficient attenuation at the harmonics bands, image-frequency band, etc. The developed duplexer module has an insertion loss of less than 1.6 dB in the Tx path and of less than 3.3 dB in the Rx path. The size of the duplexer module is 14 x 8 x 1.8 mm and it weighs 0.4g, which shows sufficient size and weight reduction for PCN duplexer.

References

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