800 MHz LOW LOSS SAW FILTER USING NEW PHASE WEIGHTING

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Summary

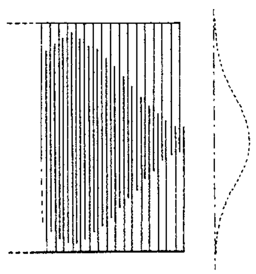
A new high performance SAW filter for a mobile telephone is presented here. New technologies - - low loss weighting in an IDT, and a new resonant filter configuration - - are described. Experimental results with 3.5~4.0 dB insertion loss at 830 MHz are presented.

Introduction

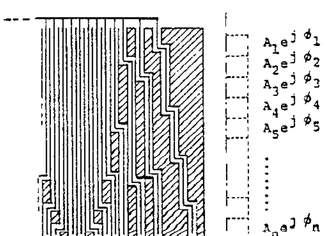
SAW filters offer advantages in that thay are small, do not need adjustment, and are highly reproducibile. They have been widely used for TV-IF circuits. However, their applications have been limited due to their large insertion losses.

Recently, high performance SAW filters with (1) low insertion loss, (2) a sharp-cutoff frequency response, and (3) high-sidelobe suppression have come to be needed for RF circuit integration in such communication equipment, as mobile telephone transceivers, and cable TV repeaters and converters.

This paper describes a new high performance SAW filter for an 800 MHz mobile telephone achieved by means of several new technologies.



(a) Apodization

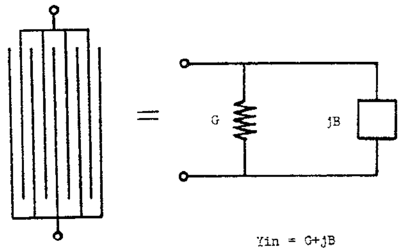


$A_1 \simeq A_2 \simeq A_3 \simeq \cdots\cdots \simeq A_n$
$\phi_1 \simeq \phi_2 \simeq \phi_3 \simeq \cdots\cdots \simeq \phi_n$: pass band

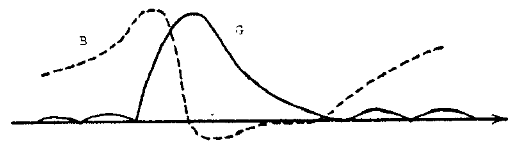
$A_1 \simeq A_2 \simeq A_3 \simeq \cdots\cdots \simeq A_n$
$\phi_1 \neq \phi_2 \neq \phi_3 \neq \cdots\cdots \neq \phi_n$: off band

(b) New Phase Weighting

Fig.1 Conparision between conventional weighting and New Phase Weighting



(a) Electric equivalent circuit of an IDT



(b) Admittance Yin of an IDT with an optimum number of fingers

Fig.2 Frequency characteristics of an IDT

New Configurations

To realize low loss SAW filters, low loss frequency response synthesis[5] as well as low loss filter configulation must be developed.[(1)~(4)]

Apodization of IDTs is widely used to provide a desired frequency response.[6] However, this procedure essentially allows a weighting loss, because the excited SAW from an apodized IDT has wave front distortion, as shown in Fig.1(a). We have developed a new low loss weighting technique named New Phase Weighting.[5] As shown in Fig.1(b), this procedure is based on conventional apodization and has nearly equivalent performance. However, there is negligible loss increase in this weighting. This is because, in the pass band, SAW transversal amplitudes over an IDT are synchronously added in phase to form an almost plane wave. In the stop band, the transversal amplitudes are added in various phases.

To realize a sharp-cutoff frequency response, a new filter configuration that uses the impedance characteristics of an IDT was developed. A well known electric equivalent circuit of an IDT is shown in Fig.2(a). If the number of fingers in an IDT is optimum, a wide frequency range exists. Over this range the susceptance of the electric input admittance, Yin becomes very small due to the cancellation of acoustic and electric reactance components. This is shown in Fig.2(b).

The new filter configuration is shown in Fig.3(a). One pair of electrically connected IDTs with an optimum number of fingers is introduced, and input and output IDTs with a broader frequency response are arranged beside it. With Fig.3(a)'s

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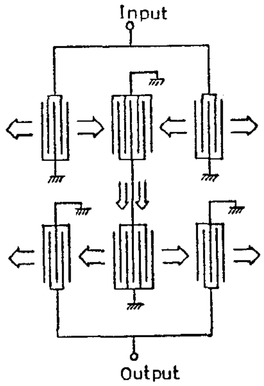
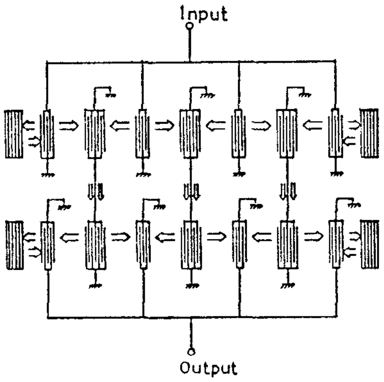
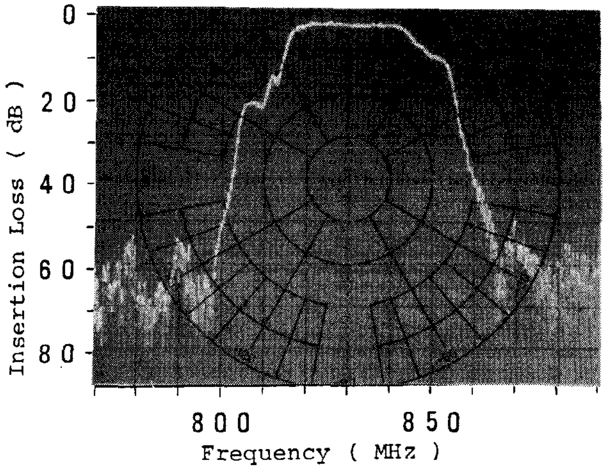


(a) Realization of a sharp-cutoff frequency response

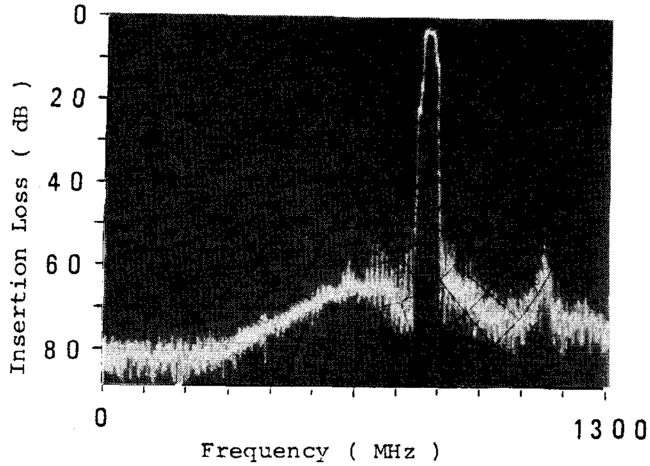


(b) Lateral repetitions of (a) as a basic unit

Fig.3 Filter configuration with low loss and a sharp-cutoff frequency response



(a) Pass band characteristics



(b) Out-of-band characteristics

Fig.5 Experimental results of the filter for a mobile telephone

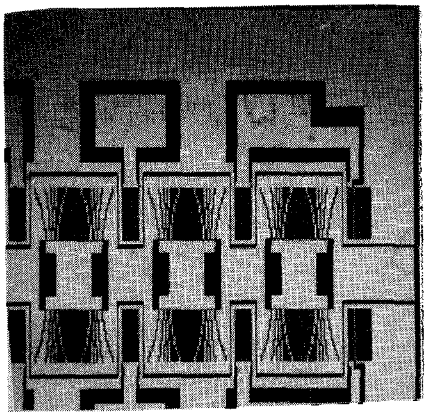


Fig.4 Fiter pattern employed in the experiment

weighting-less simple configuration, a sharp-cutoff frequency response, where the susceptance cancelled frequency range is a pass band, can be realized. However, this configuration has an inherent bidirectionality 6 dB loss. To overcome this loss, an energy trap resonant structure containing lateral repetitions of Fig.3(a) as a basic unit, as well as SAW reflectors, has been introduced. This is shown in Fig.3(b).

Experiment

A photograph of the aluminum electrode pattern on the filter chip used in the experiment is shown in Fig.4. A four repetition structure is used, and to achieve high sidelobe suppression, New Phase Weighting is introduced to electrically connected IDTs. A Hamming function is employed as a weighting function.

This pattern has been designed using 36° rotated Y cut X propagation $LiTaO_3$ as a substrate[7] because the surface shear wave mode propagating on it has a rather large electro-mechanical coupling coefficient($2\Delta v/v \simeq 5$ %), as well as a good temperature coefficient(-28~-32ppm/^{o}C).

Experimental results are shown in Fig.5. Pass band characteristics at 770 to 890 MHz are given in Fig.5(a). Out-of-band characteristics at 0 to 1300 MHz are given in Fig.5(b). Low insertion loss(3.5~4.0 dB), a sharp-cutoff frequency response and high sidelobe suppression(above 50 dB) have been achieved. All characteristics in the experiment are summed up in Table 1. The results of computer simulation used in the design of this filter are shown in Fig.6. Fairly good agreement between experimental and simulation results is noticable.

This high performance SAW filter can satisfy all the frequency response requirements for a mobile telephone over a wide temperature range of -32^{o}~+80^{o}C. The minimum finger width is 1.2μm and so it is possible to utilize the same standard photographic techniques as with silicon ICs, that is, optical exposure (contact or projection) and chemical eching processes. Thus, this filter offers not only high performance, but also very high mass-producibility and reliability.

Table 1. Characteristics of the filter for a mobile telephone

Center Frequency	830 MHz
Band Width (-1 dB)	25~27 MHz
Insertion Loss	3.5~4.0 dB
Pass Band Ripple	±0.3 dB
Sidelobe Suppression	> 50 dB
Pattern Size	1.5×1.6 mm
Minimum Finger Width	1.2μm
Al Thickness	0.1μm
Substrate	36°Y-X $LiTaO_3$ ($k^2 \simeq 5$ %)
Temperature Coefficient	-28~-32 ppm/°C
Temperature Range	-36°~+80° C

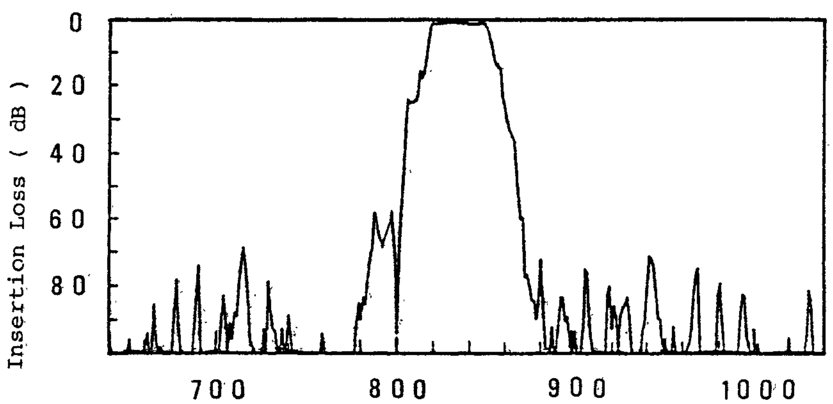


Fig.6 Computer simulation results

Conclusion

A new low loss weighting technique in an IDT and a new resonant filter configuration were developed. By these new technologies, 800 MHz high performance SAW filter with loss as low as 3.5~4.0 dB, a sharp-cutoff frequency response and high sidelobe suppression(above 50 dB) has been achieved. This filter offers not only the required frequency response for a mobile telephone, but also the wider applicabilities to the RF circuit integration in communication equipments.

References

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