IF-FILTERS FOR MOBILE TELEPHONES

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Summary. Intermediate frequency (IF) filters for channel selection in mobile phone systems must offer narrow bandwidths togethег with very steep skirts and excellent stopband rejection. Surface acoustic wave (SAW) filters fulfill these requirements. But if conventional transversal design techniques are used chip sizes become too large.
We therefore folded the propagation path of the SAW in order to make better use of the total chip length. Using two slightly inclined reflectors to a Z-shaped filter which conserves the temperature stability of the quartz substrate.At a center frequency of 45 MHz we developed filteron small chips with good passband characteristics and an insertion loss better than 10 dB. A filter with signal suppression of 20 dB only 200 kHz from center frquency and an ultimate relative stopband rejection of 60 dB is shown.
Abstrakt. V práci je opísaná konštrukcia medzifervrnčného filtra s použitím povrchových akustických vĺn pre mobilný telefón. Mobilný telefón musí mať úzke priepustné pásmo, reflektory tvaru Z ktorý zachováva teplotnú stabilitu kremennej podložky.Stredný kmitočet je45 MHz.a vložené tlmenie v pásme nepriepustnosti je 60dB.

1. INTRODUCTION

The GSM recommandation define a Europe wide standard for a digital mobile telephone system. Networks according to it are now evolving in most European countries and the market for telephone sets is rapidly growing. GSM services have been allocated two 25 MHz bands in the 900 MHz range. Time and frequency multiplexing is used and the individual channels are separated by 200 kHz. SAW filters can be used for channel selection in the IF range. These filters must offer a number of particular features.

Obviously mobile telephones must work reliably over a large temperature range. The GSM recommendatios specify an ambient temperature of -25 °C to +80 °C. This requirement considerably reduces the choice of SAW materials and obviously qaurtz will be our first choice.

Secondly power consumption will play a major role when batteries are used as it is inevitably the case in handheld sets. Therefore we need a reasonably low loss solution. In addition low loss helps the system designer to control the noise level.

Channel selection in a GSM system means a fairly narow bandwidt and steep skirts. As mentioned above the individual chaaels are spaced by 200 kHz and the GSM standard demands considerable suppression already of the first and particularily of the second adjacent channel in order to keep these signals at an acceptable level for following amplifier stages. In addition good stopband rejection is needed only 600 kHz from the passband centre.

Finally mobile telephone sets must be small and light if they want to be attractive to the consumer. Components for mobile applications therefore underlie a strong competition in terms of their size and weight. This restriction is the most stringent one and it must be seen in context with the performance demanded.

High selectivity on a small chip means a problem for SAW designers. In transversal design techniques (as for example single phase unidirectional transducer (SPUDT) filters [1]) narrow bandwidths and steep skits inevitably lead to long filters. We tried A SPUDT design offering good selection already for the first adjacent channel demanded a chip length of 30 mm. At higher IF frequencies resonator filters [2] offer a worthwhile alternative. But of course higher frequencies also mean larger absolute temperature and fabrication tolerances. We therefore tried to fold the propagation path of the acoustic wave employing reflectors in order to use the available chip length more than once.

2. BASIC CONCEPTS OF Z-PATH FILTERS

Fig. 1 shows the basic concept of Z-path filters. A unidirectional input configuration (here simply a transducer and a reflector) serves to excite the SAW.

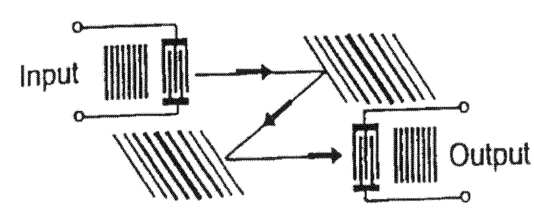

Fig. 1. Schematic layout of a Z-path filter: two weakly inclined reflectors couple the surface wave along a Z-shaped propagation path from the input transducer in the upper track to the output transducer in the lower track.

We then use a pair of weakly inclined reflectors (typically about 4°) into the lower one where it is detected by the output configuration. to couple the wave from the upper track On quartz only waves travelling along the main propagation axis offer temperature stability. Reflector filters using U-shaped propagation paths for example [3] suffer from considerable distortions of the reflection angle when operated over a large temperature range. Z-shaped propagation paths with weakly inclined reflactors, however, preserve temperature stability. The reason is that distortions of two opposite angles of reflection cancel and that we employ only propagation directions close to the main axis.

The way weakly inclined reflectors work is very similar to ordinare 180 ° reflectors. To some extend all the techniques known from inline reflector design can be readily transfered. In particular reflection from single metal strips add costructively across a large part of the aperture and losses due to a lack of total reflectively can be kept at a moderate level.

We use one dimensional analysis [4] and employ finger width weighting [5, 6] in order to design the reflector passband. No complicated new softwar had to be written. Of course the agreement between measurement and calculation is not as good as we are used to, yet this simple approach yields very satisfactory results.

We the selectivity of the inclined reflectors, where no rigorous simulation is currently available, to ensure stopband rejection. The passband and its upper skirts are formed by the input and output configurations, where our models are exact.

In order to design a Z-path filter all four elements are individually optimized, analysed and then cascaded. Due to the Z-shaped propagation path the length of the chip can be used up to three times. And the use of four filtering elements in succession leads to a particularily strong and stable stopband rejection.

The basic design technique remains transversal and no resonances are used. We achieve typical relative bandwidths of .5 to 1 % and can therefore remain in relatively low frequency ranges.

Yet we found one major problem with the configuration from fig. 1. Direct acoustic feed-through from input to output seriously disturbs in particular the upper stopband. Diffracted SAW, bulk waves and spurious signals from pads and finger tips travel directly from the upper to the lower track and unwanted sidelobes at a level of only 30 dB below the main signal appear.

3. TWIN Z-PATH FILTERS

The problem of unwanted direct feedthrough from input to output can be solved using a twin layout as sketched in Fig. 2.

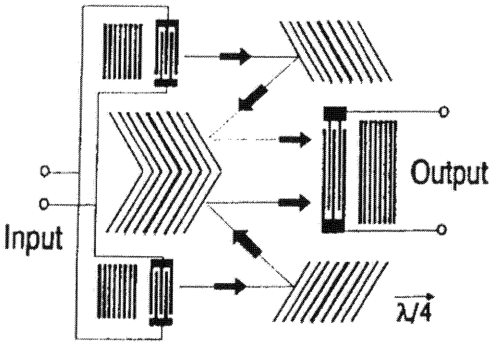

Fig. 2. Schematic layout of a twin Z-path filter: sourious signals from upper and lower input transducers cancel but main signals add constructively due to a λ/4-shift of one of the inclined reflectors

Two almost identical Z-path filters operate in parallel but are electrically inversely connected. Consequently all direct signals from input to output cancel, even capacitive feedthrough when balanced operation is used. In order to obtain constructive interference of the main signals we shift one of the inclined reflectors in one of the paralel filters by a quarter wave length $\lambda/4$.

But of course we end up with four tracks and need rather broad chips (in the order of 20 % to 30 % of the chip length). Yet many of the packages available offer this space and the size of the final device remains unchanged.

4. CONCLUSION

Z-path filters allow the desidn of high selectivity SAW devices on comparatively small chips. The transversal design techniques employed are based on simple one dimensional models. Moderate loss, steep passband skirts and excellent reproducible stopband rejection can be achieved when twin configurations are used.

REFERENCES

[1] Scholl, G. etc: New Resonator Filter with High Sidelobe Suppression. IEEE Ultrasonics Symp. Proc., 1992, pp. 12-16

[2] Kappacher, C. : Design and Analysis of Single Phase Unidirectional Transducers. IEEE Ultrasonics Symp. Proc., 1991, pp. 1-4

[3] Riha, G.: RAC-Filter with Position Weighted Metallic Strip Arrays. IEEE Ultrasonics Symp. Proc., 1982, pp. 83-87

[4] Scholl, G.: Efficient Analysis Tool for Coupled-SAW-Resonator Filters. IEEE Trans. Ultras. Ferroelec. Freq. Control, vol. 38, no. 3, 1991

[5] Datt, S.: An Analytical Theory for the Scattering of Surface Acoustic Wave by a Single Electrode in a Periodic Array on a Piezoelectric Substrate. J. Appl. Phys. 51(9), 1980, pp.4817-4823

[6] Wright, P. V.: Modeling and Experimental measurement of the Reflection Properties of SAW Metallic Gratings. IEEE Ultrasonics Symp. Proc., 1984, pp. 54-63