Broadband dispersive delay line for compressive receiver on quartz substrate

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1. Introduction

It is well known that surface acoustic wave (SAW) chirp transformation is an analog technique enabling the Fourier transform of signals in real time [1÷3]. In the multiplication-convolution-multiplication configuration, SAW dispersive delay lines (DDL) have been used.

The number of the transform points depends on time-bandwidth (*TB*) product of chirp filters. The width of impulse response *T* of the DDL is limited by its substrate size, hence, its bandwidth *B* should be as large as possible. There are several methods to design a dispersive delay line [4÷6]. The method described in Refs. [5,6] provides design of DDL of high quality.

The DDL consists of a simple interdigital transducer used to SAW generation and a second dispersive transducer of non-periodical [4] or periodical type [5, 6]. In such case we cannot achieve the ratio B/f larger than 25% (B and f are the bandwidth and the central frequency of a dispersive signal, respectively).

The insertion loss of a DDL would increase with the increasing of the bandwidth because of small number of electrodes existing in periodic simple interdigital transducer used for SAW generation. The broadband DDLs are also used in compressive receivers, where Fourier analysis of input signal in real time is required. In such case the bandwidth of dispersive delay lines should be as large as possible.

In this article the new, patented [7] method is presented. It allows the synthesis of a dispersive delay line with 100% passband (i.e., the line with the bandwidth B equal to the central frequency *f*). The method has been also verified experimentally using (*Y, X*) quartz substrate.

2. Computer simulation of the broadband SAW DDL

Let us consider SAW dispersive filter consisting of two interdigital transducers. To apply the method described in Refs. [5, 6] we first assume that the first of the two transducers is wideband and the second one has the long-time impulse response.

The insertion loss of the dispersive filter will increase with its bandwidth increase because of simple wideband transducer is used for SAW signal generation. For 100% passband the number of fingers of the interdigital transducer is 2. Two types of wideband dispersive transducers are used in the method [7].

To apply this method for synthesis of 100% bandwidth we have assumed that the dispersive filter is composed of two transducers. The first one is wideband with nonlinear phase characteristic and the constant finger length. Its amplitude characteristic is H_N. The second one has variable length and constant distance between fingers and the amplitude characteristic H_D.

The amplitude characteristic *H* of the delay line is the product of frequency characteristics of both transducers (neglecting second-order effects): $H=H_N H_D$. The dispersive delay line with a flat amplitude characteristic *H* in the passband is synthesized using the method proposed in Ref. [5]. The apodisation of the transducer with frequency response H_D is calculated numerically using fast Fourier transform (FFT) algorithm. It is assumed in computer simulation that the central frequency $f=70$ MHz, bandwidth $B=70$ MHz, and the impulse response $T=10$ ms.

The amplitude characteristic *H* of the DDL should be flat in the passband range, as it is shown in Fig. 1. The characteristic resulting from computer simulation is presented in Fig. 2. Note small ripples within the passband. Such amplitude characteristic yields to impulse response of the DDL given in Fig. 3.

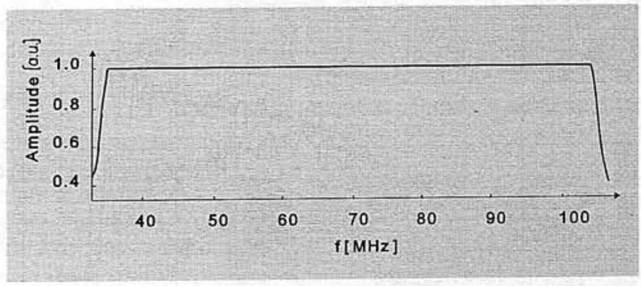

Fig. 1. Required amplitude characteristic of the dispersive delay line

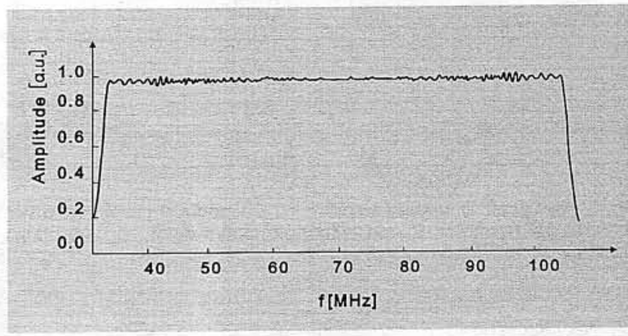

Fig. 2. Computed amplitude response of the dispersive delay line

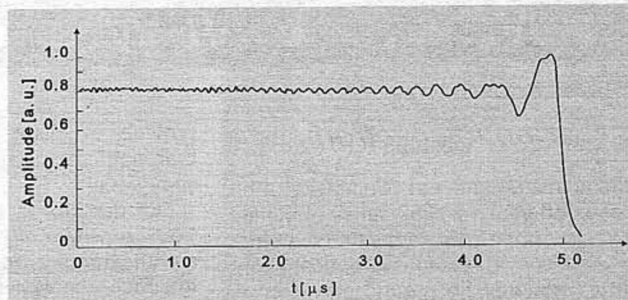

Fig. 3. Computed impulse response of the dispersive delay line (1/2*T*)

3. Experimental results

Experimental dispersive delay line has been manufactured on the base of (*Y, X*) quartz. It consists of two interdigital transducers, the first has nonperiodical electrodes of constant length and the second has periodical and apodized ones.

The amplitude characteristic of the dispersive delay line obtained experimentally is presented in Fig. 4. The central frequency is 70 MHz and the insertion loss is about 70 dB. As we can see, only small passband ripples and 100% passband have been obtained.

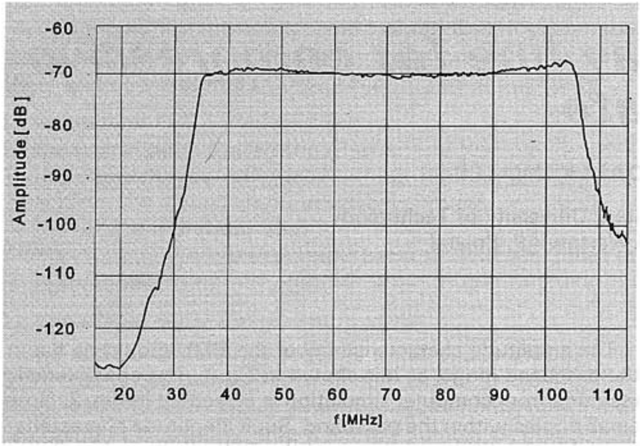

Fig. 4. Measured amplitude response of the dispersive delay line

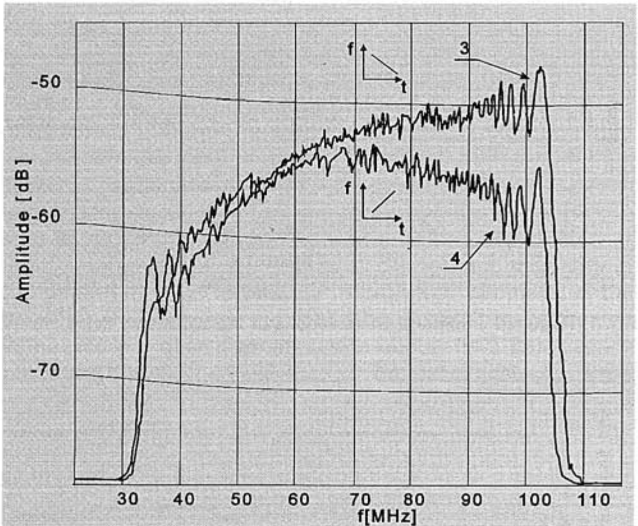

Fig. 5. Measured amplitude response of unapodized linear FM SAW chirp filters (numbers *3* and *4* denote down-chirp and up-chirp, respectively)

For comparison, a separate experiment was carried out, with dispersive delay line designed in the standard way. In such case the DDL consists of two nonperiodic dispersive transducers with constant overlap and 100% passband. The amplitude characteristic of this line is shown in Fig. 5. As we can see, this standard method of design leads to the larger ripples in the passband.

4. Conclusions

It has been shown that the method presented in Refs. [7, 8] enables the synthesis of broadband dispersive delay line with 100% bandwidth and flat amplitude response. As it results from experiments, this method gives better frequency response than the standard one, even in the same technological conditions.

Acknowledgement

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