PERFORMANCE OF ACOUSTIC CHARGE TRANSPORT CHIRP FILTERS

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Abstract The measured performance of Acoustic Charge Transport (ACT) based linear FM dispersive delay line filters is presented and compared to modelled performance. The excellent agreement between the theoretically predicted device performance and the measured results shows clearly that apodisation of the Nondestructive Sensing Array is an effective means for achieving weighted ACT filter responses.

I. Introduction

Acoustic charge transport delay lines have been employed to achieve a variety of signal processing functions. Devices demonstrated to date include fixed tap transversal filters, programmable tapped delay lines, convolvers, variable delay analog memory devices, and analog to digital data conversion (1).

The objective of this work is to report the development of acoustic charge transport (ACT) based linear FM chirp filters.

The following section provides a brief overview of the principles of ACT device performance (2). The third section of this paper presents the results of the initial efforts to construct and measure the performance of chirp filters. This is followed by a section describing measured data from other ACT delay lines and filters.

II. ACT delay line operation

The ACT device is a new type of high frequency monolithic charge transfer device, and so is similar to CCD's and other transversal filter signal processors. In the ACT device, illustrated in Figure 1, a powerful, single frequency surface acoustic wave (SAW) is generated by the transducer, when an appropriate electrical excitation is provided. The SAW travels from left to right in Figure 1, from the transducer, past the input contact, through the channel and then past the output contact. The channel is composed of semiconductor material which has been depleted of mobile carriers by DC bias voltages.

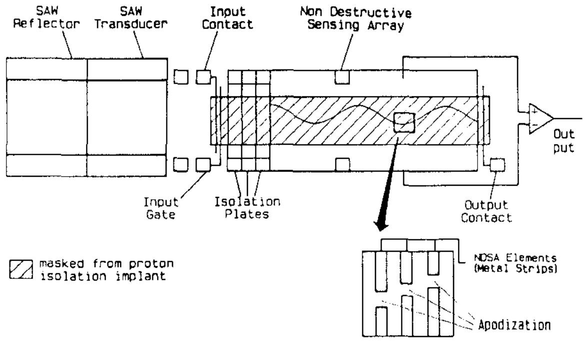

Figure 1. Overhead view of a proton isolated ACT delay line. Direction of SAW propagation is from left to right.

This is illustrated in Figure 2, which depicts a cross section of the device along the direction of propagation of the SAW. In Figure 2, DC bias voltages are shown applied to the (ohmic) input and (forward biased Schottky barrier) output contacts relative to the (reverse biased Schottky barrier) nondestructive sense array (NDSA). The channel is electrically isolated from the rest of the device by proton bombardment of the GaAs epitaxial layer outside of the channel area.

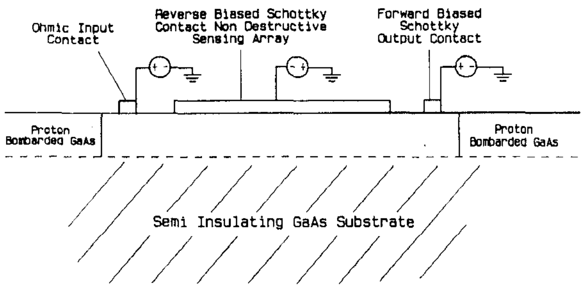

Figure 2. Cross section of ACT delay line and typical bias voltage scenario. SAW propagation is from left to right.

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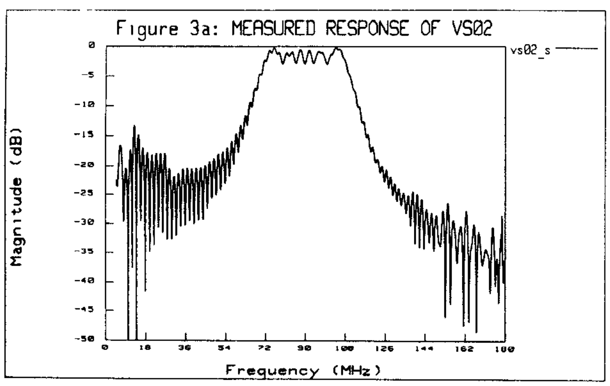
During operation of the ACT device, mobile carriers are injected into the semiconductor channel by the RF voltage applied to the input contact. Here, they are bunched by and transported within the electrical potential extrema of the powerful SAW. The high frequency SAW is thus the sampling clock for an ACT device. The injected charge samples are then transported, at the SAW velocity, through the channel, past the NDSA, and finally they are removed from the channel by means of a positive DC bias voltage on the output contact. The NDSA structure is capacitively coupled to the charge samples in the channel, forming the basis for a transversal filter. The desired filter response can be embedded in the NDSA structure by apodisation of the electrode lengths over the channel. Other means for weighting the NDS element responses are available as well.

III. ACT linear FM filter response

The objective of this work is to develop techniques for designing and constructing linear FM dispersive delay lines, or chirp filters, utilizing ACT technology. The devices discussed here are the result of the initial ACT chirp filter device efforts.

A. Frequency domain response

The filters shown as examples here are monolithic GaAs signal processors, having bandwidths of 45 MHz, center frequencies of 90 MHz, clock frequencies of 360 MHz, and a dispersive delay of 0.5 microseconds, providing a time bandwidth product of 22.5. Measured chirp filter performance is compared to predicted performance in Figure 3, and excellent agreement is obtained. The tap weight error, obtained by comparing the measured magnitude versus frequency response to the computed response, is -43.9 dB rms.



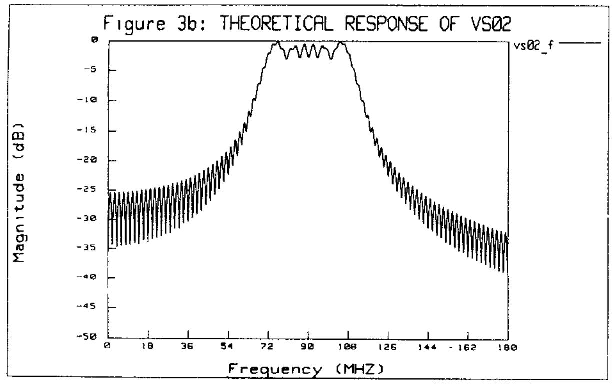


Figure 3. Measured performance of ACT chirp filter (upper) and modeled performance (lower).

B. Time domain response

Two ACT devices were used to measure the convolution of their impulse responses when connected in cascade. This is performed experimentally by impulsing the first device and then mixing the device impulse response with a signal at twice the filter center frequency. The signal resulting from the difference between the LO and device response frequencies has the opposite chirp slope of the device impulse response, and has the same center frequency. This signal is the equivalent of the time reversed device impulse response. After lowpass filtering to obtain the opposite chirp direction, the time inverted impulse response of the first device is recompressed by filtering it with the second device.

Time domain sidelobe levels for the expander and a Hammming weighted compressor connected in cascade are measured to be 21.5 dB and are theoretically computed to be 22.7 dB. The measured result is illustrated in Figure 4.

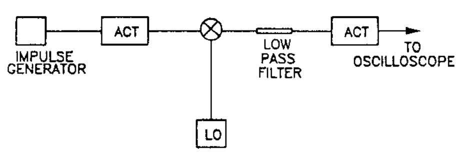


Figure 4. Test setup used to convolve impulse responses of two upchirp filters.

Time domain sidelobe levels for the expander and a Hammming weighted compressor connected in cascade as in Figure 4 are measured to be 21.5 dB and are theoretically computed to be 22.7 dB. The measured result is illustrated in Figure 5.

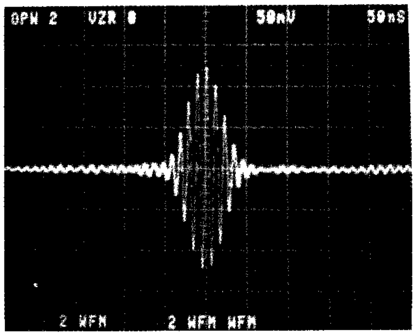


Figure 5. Measured time domain device response for two chirp filters (one with Hamming weighting, one as in Figure 3) in setup depicted in Figure 4.

The weighting technique employed to achieve the desired frequency response and to compensate for the frequency dependence of the ACT NDS output signal (3) relies on apodisation of the NDSA structure (a grid of one eighth acoustic wavelength electrodes, connected to summing busses at either end, and extending across the channel as shown in Figure 1). The apodisation of the charge sensing structure is similar to that employed in SAW and CCD filters.

IV. Measured ACT delay line parameters

In the time since the initial chirp filter work was done, several extensions of the work have been accomplished. ACT devices using a clock frequency of 600 MHz have been designed, fabricated, and tested. These devices have demonstrated charge transfer efficiencies in excess of .99998, measured by the frequency response method (4).

Recent work, using ACT devices employing 127 bit minimal sequence codes rather than a linear FM apodisation, has provided measured time domain sidelobe levels of -53 dB rms. This level is set by deviations from the ideal device response. The physical origins of the deviations from the ideal are not known precisely at this time. As such, the ultimate limits of device performance do not appear to have been reached. A correlation response from such a device is illustrated in Figure 6.

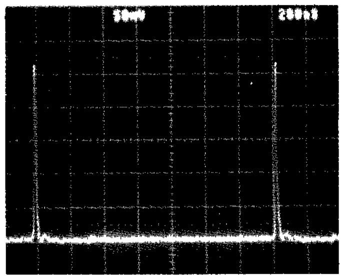


Figure 6. Compressed pulse from 127 bit psuedo noise correlator device when input signal is derived from an ECL code generator.

Additionally, a group of four such devices have been connected such that the delay lines are in cascade, while their NDS outputs were connected in parallel.

The delay line output is obtained from the forward biased contact at the far right in Figures 1 and 2.

This has resulted in the demonstration of an extension of the time bandwidth product for the group of devices by a factor of four over that of an individual device. These results are made possible by two properties of the ACT devices which are unique in the frequency range being considered here.

The first of these properties is that the delay line output has no frequency dependence over the Nyquist bandwidth of the delay lines (the delay line frequency response is flat to .1 dB). Cascading of devices without bandlimiting due to a frequency dependence of the delay lines is thus possible in practice.

The second property significant to cascading the devices is that the output of a time domain sampled device has a stability which is set by the clock stability, rather than by the stability of the device delay.

These unique properties of the ACT delay lines allow them to be cascaded without suffering the limitations present for other technologies, such as SAW.

This psuedonoise correlator device provides a signal to noise dynamic range of 92 dB when the compressed pulse amplitude is monitored.

This was measured by varying the input signal amplitude from a level just below that large enough to result in increased sidelobe levels in the NDS output signal to a small input signal level which provided an NDS output pulse which was 3 dB above the noise level.

Blocking dynamic range measurements have provided measured blocking dynamic ranges of 82 dB for ACT delay lines.

In this blocking dynamic range measurement, the NDS output signals due to a large and a small amplitude input signal are measured on a spectrum analyser. In the absence of the large signal, the level of the small signal is adjusted to achieve a signal to noise ratio of 3 dB. The large signal is increased in amplitude until the output due to the weak input signal is compressed in amplitude by 1 dB.

V. Summary and conclusions

The absence of second order effects which are particularly troublesome in SAW filters results in simplified design procedures for ACT filters.

If present, such effects would result in discrepancies between the measured and the predicted filter responses.

The excellent agreement between the theoretically predicted device performance and the measured device performance shows clearly that apodisation of the NDS array is an effective means for achieving weighted transversal filter responses.

The measured transfer efficiency and dynamic range results to date indicate that the ACT based transversal filters can support time bandwidth products in excess of 10,000 with an attendant dynamic range of 60 dB. As such, this class of devices is able to support a broad variety of system needs.

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