Program Digest, 2019 IEEE International Ultrasonics Symposium (IUS)
Glasgow, Scotland, October 6-9, 2019

Optimized Signal Generation Circuit for Coded GHz Acoustic Microscope

Anton Rantamaa, Jere Hyvönen, Antti Meriläinen, Ari Salmi, Edward Hæggström
Department of Physics (Electronics lab.)
University of Helsinki
Helsinki, Finland
anton.rantamaa@helsinki.fi

***Abstract*—We present a modulator circuit for our 0.9 GHz acoustic microscope, that employs a LTC5598 chip to provide a broad, high frequency bandwidth. Compared to [1], this modulator circuit features improved balancing and DC-coupling that allows a continuous band across the local oscillator frequency. A PLL circuit (ADF4351) creates a local oscillator signal. Since 900 MHz frequency is widely used, e.g. in cell phone networks, SNR can be improved by removing this external noise. We shielded the acoustic microscope electrically by assembling a metal casing for the T/R switch and the modulator.**

***Index Terms*—GHz ultrasound microscopy, Arbitrary coded signals, Modulation, Pulse Echo Switch**

I. Introduction

An ultrasound microscope can measure mechanical properties at the micrometer scale. Challenges arise when lateral µm scale resolution is required (with GHz signals): the signal-to-noise ratio (SNR) is poor and working distances are short [2]. To retain good temporal resolution, short pulses are used [3]. SNR can be improved by using coded signals [4]. Previously, we showed that this method can be used in the GHz domain [1]. In this contribution, we demonstrate that with a custom-made signal generation circuit, arbitrary coded signals can be used for GHz ultrasonic imaging.

II. Materials and Methods

The ultrasonic setup is described in [1] and Figure 1. Compared to [1], we use a redesigned modulator circuit with adjustable balancing and DC-coupling. The modulation is done by a LTC5598 chip.

A. Improvements to the modulator

A simplified diagram of the modulator is presented in Figure 2. Local oscillator (LO) signal is created with ADF4351 wideband synthesizer. The local oscillator circuit and the LTC5598 chip are controlled with Arduino. This allows easy modifications to the frequency of the local oscillator signal. A 900 Mhz LO frequency was selected because it is the median frequency of the transducer used in the microscope. The ADF4351 produces a square wave so a bandpass filter (Mini-Circuits VBFZ-925-S+) is used to block the harmonic frequencies.

Common mode inputs are converted to differential inputs with three LMH6550 operational amplifiers. A DC level of 0.5 V is added to the channels as required by the common mode

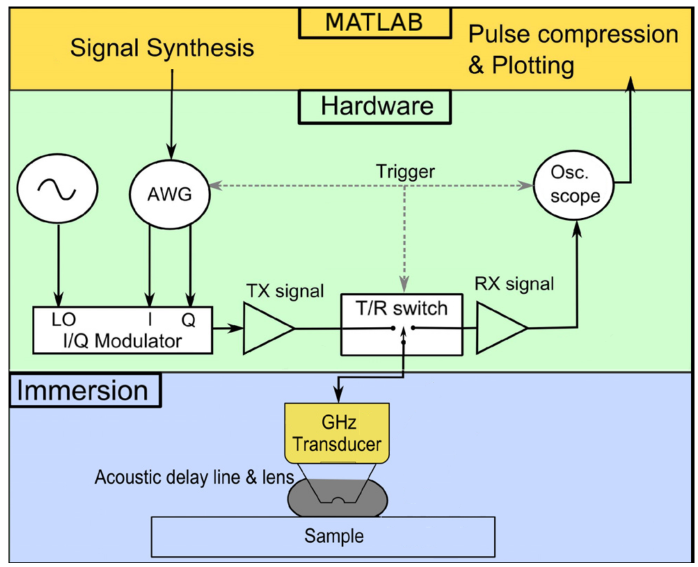

Fig. 1: Schematic of the ultrasound microscope.

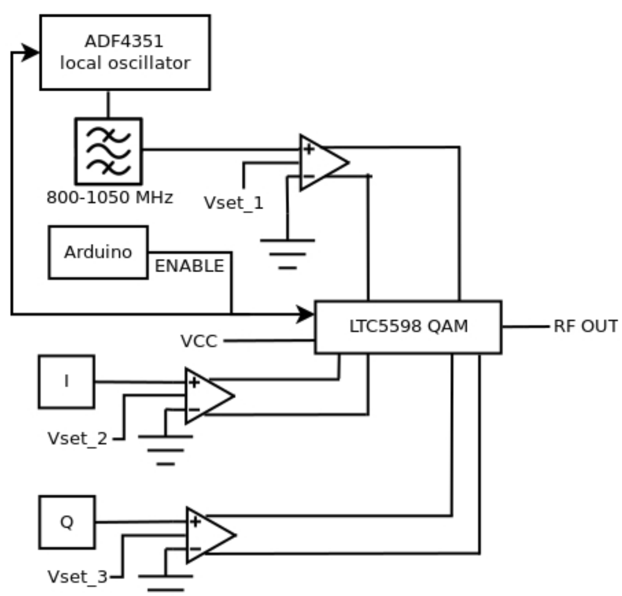

Fig. 2: Schematic of the modulator setup.

voltage specification of the LTC5598 chip. `V_set` voltages can be fine-tuned using adjustable resistors in the regulation circuit. Local oscillator crosstalk can be reduced by tuning these DC levels. While measuring the noise level, resistors can be adjusted to achieve the best SNR available.

B. Other SNR improvements

Shielding is important considering SNR in the setup, as there is interference in the 900MHz band caused by cell phone networks etc. Metal cases were constructed for the modulator and the T/R switch, see Figures 3A and 3B. The PCB connecting the transducer to the z-stage was previously exposed so a 3D printed case was designed for the PCB. The case was painted with conductive paint for effective shielding, see Figures 3C and 3D.

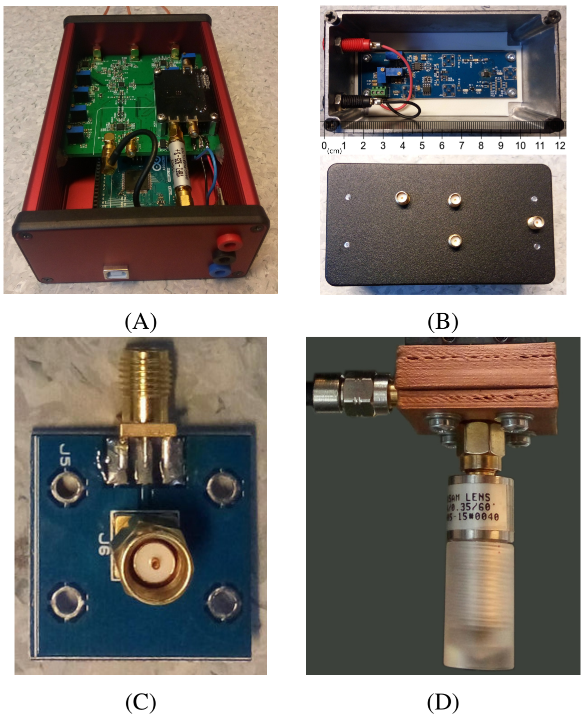

Fig. 3: (A): An image showing the local oscillator circuit (top, black PCB) and the modulator (green PCB). Both are controlled by Arduino Mega at the bottom.
(B): A metal case was constructed for the T/R switch.
(C, D): A 3d-printed shield was installed into the transducer holder PCB

III. Results

Figure 4 shows a B-scan along z-axis with A-line and power spectrum of the received echo as insert. This shows that the signal generation circuit is suitable for generating GHz signals for ultrasound imaging.

We determined the microscope's resolution with a USAF 1951 resolution sample, see Figure 6. Fifth element of group 7 is still visible. The resulting resolution is 2.46 µm.

The focused echo was dominated by other signals resulting from the structure of the lens in the transducer, see Figure 5. In order to reduce this noise, the resolution sample was scanned three times and the resulting images were combined.

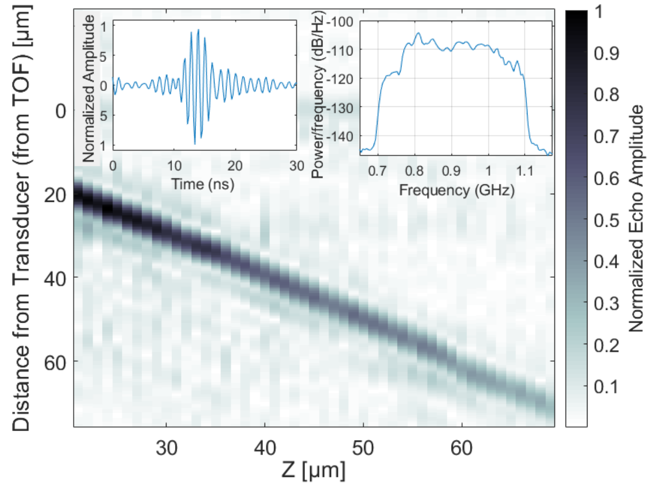

Fig. 4: Measured B-scan along z-axis with the amplitude as color-coding and with distance derived from TOF on the y-axis and translation stage encoder values on the x-axis. Insert: An A-line and a power spectrum of a single echo.

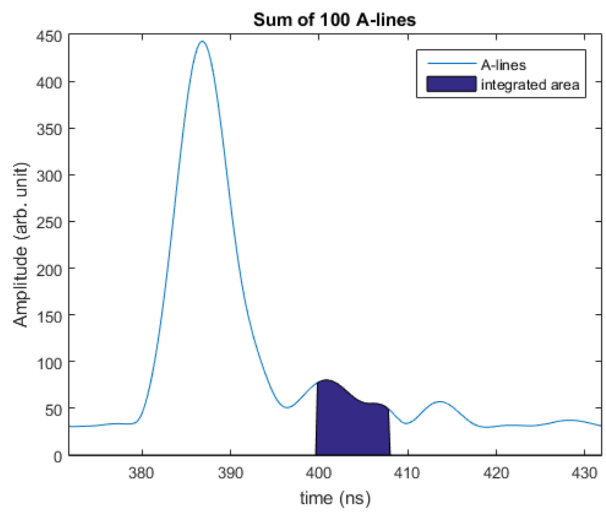

Fig. 5: The average of 100 A-lines shows that the focal echo interferes with the strong planar field produced by the edges of the lens structure.

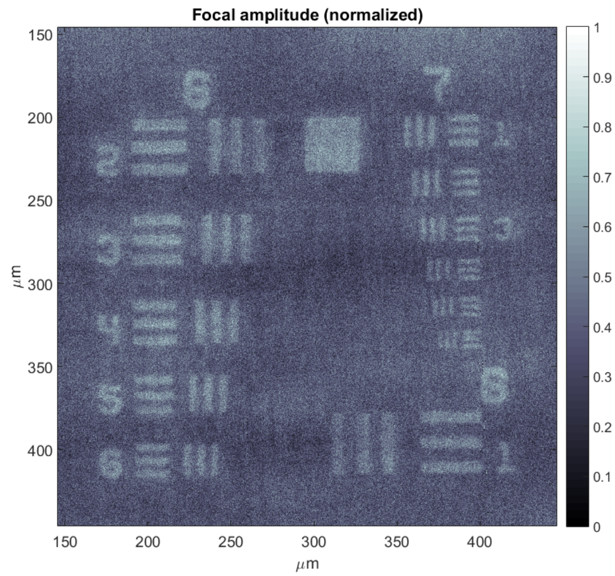

Fig. 6: A picture depicting groups 6 and 7 of the USAF 1951 resolution sample.

Discussion

This contribution presents the first image acquired with our coded excitation scanning acoustic microscope using GHz coded signals. There is still some improvements that can be suggested to the setup.

The local oscillator crosstalk is reduced by manually adjusting the DC coupling for both channels. The performance of the GHz setup is still not optimal because of additional noise from local oscillator and modulator. The z-stage of the device is sloppy, which prevents finding optimal work distance. Better images are possible by improving the SNR and the stages.

The lens structure of the transducer creates a plane wave and a focused beam to the coupling medium. As the propagation speed is higher in the lens, the echo from the plane wave occurs first. It can be seen from Figure 5, that the focused echo is not a dominant feature in the signal. Therefore an integral needs to be calculated from a range which contains the focused echo. The integration limits were chosen where the resulting image is sharpest with minimal interference from other features in the signal.

Conclusion

We presented the performance of the modulator circuit of our 0.9 GHz ultrasound microscope. We determined the resolution of the microscope with a USAF 1951 resolution sample. The resulting resolution was 2.46 µm.

References

[1] A. I. Meriläinen, V. Kananen, C. Fridlund, J. Eskelinen, E. Hæggström, and K. Raum, "Ghz ultrasonics with arbitrary code excitation," in *2013 IEEE International Ultrasonics Symposium (IUS)*, pp. 703–706, July 2013.

[2] M. Nikoonahad, G. Q. Yue, and E. A. Ash, "Pulse compression acoustic microscopy at 750 mhz," *Electronics Letters*, vol. 19, pp. 782–784, Sep. 1983.

[3] A. Briggs and O. Kolosov, *Acoustic Microscopy*. Oxford Univ. Press, 1992.

[4] M. O'Donnell, "Coded excitation system for improving the penetration of real-time phased-array imaging systems," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 39, pp. 341–351, May 1992.