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GOLAY CODE EXCITATION OF ULTRASONIC TRANSDUCERS WITH DIFFERENT BACKING

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Two 3.7 MHz focused ultrasonic transducers were built. One without backing and the second loaded on back. The primary application of the first transducer is Doppler blood flow measuring ultrasonic devices, the second is most useful for the B-mode imaging devices. The electrical and acoustical properties were tested and finally the results of the different Golay code excitations were compared. Efficiency of the not backed transducer was 4.1 dB higher. The not backed transducer performed maximum sensitivity for 8 bit two periods per bit code excitation. The backed transducer achieved maximum axial resolution for 16 bit one period per bit excitation.

Keywords: ultrasonic transducers, imaging, backing coded excitation, Golay codes.

1. Introduction

Ultrasonic transducers applied to medical diagnostics must have maximum sensitivity – efficiency and wide bandwidth corresponding to the short pulse response time. High sensitivity is important for sufficient penetration in the ultrasonic attenuating tissue. The short pulse response is required for the increased axial resolution. However for the imaging transducers the maximum resolution is preferred and for the Doppler transducers the maximum sensitivity is required. The ultrasonic transducer is built from the piezoelectric ceramic, which has acoustical matching layer on the front and highly attenuating backing on the other side. This backing reduces pulse response time and decreases sensitivity of the transducer. As a result, the backed transducers are used for imaging and the Doppler devices use transducers without backing.

To increase the penetration depth for the chosen ultrasonic frequency and limited peak acoustical power, the coded excitation was used. The most popular codes are chirp, Barker and Golay [1, 2]. Authors tested Golay codes of different bandwidth, matched to the spectral characteristics of the transducer [3]. The 16 bit, one period per bit and 8 bit, two periods per bit codes were used. Both transmitted signals have the same length and carry the same energy. Those codes and their spectra are presented in Fig. 1. The aim of this work is a comparison of two transducers with different backing. The electrical and acoustical properties were tested and finally the results of the different Golay code excitations were compared.

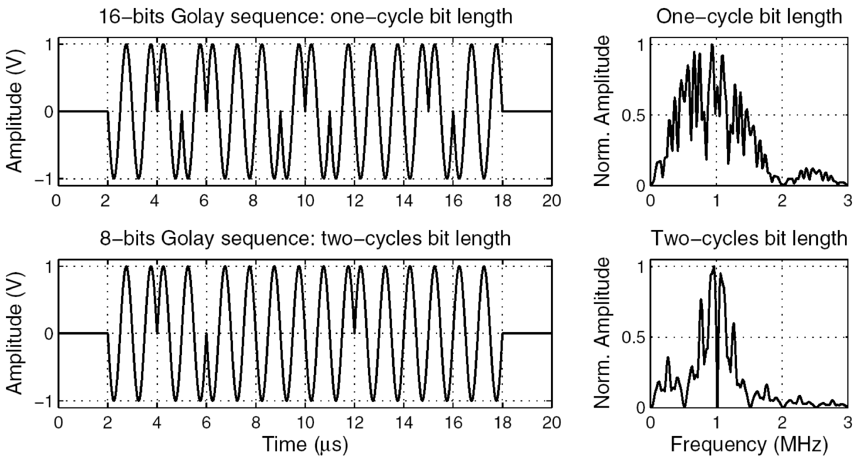

Fig. 1. Comparison of two 1 MHz, 16 sine periods Golay codes and corresponding signal spectra: 16 bit one cycle per bit (top) and 8 bit two cycles per bit (bottom) [3].

2. Materials

Two ultrasonic transducers were built. The PZT convex-concave disks were used. Disks have 15 mm diameter, 90 mm focal length and 3.7 MHz central frequency. The first transducer was assembled without backing, the second was loaded with acoustically attenuating backing material. Both transducers were supplied with acoustical impedance matching layer on front, optimised for the shortest pulse response [4]. Their complex electrical impedance was measured by means of Agilent 4395A impedance analyzer. Measurements were performed either in air or in the water bath in condition similar to the tissue contact. In the next step, the pulse response was measured. The echoes from the steel plate were recorded. Transducers were excited by 40 ns pulse generated by JSR DPR300 pulser and echo signals were stored in the Agilent 54641D digital oscilloscope. Finally, the echoes from the Dansk Fantom 525 (RMI 405 equivalent) tissue phantom were recorded. 60 consecutive ultrasonic lines spaced 0.5 mm were recorded. Transducers were excited either 16 bit one period per bit or 8 bit two period per bit Golay codes with 3.7 MHz center frequency. Codes were generated by means of LeCroy 9109 arbitrary function generator and ENI 3100LA RF power amplifier. The received echoes were amplified by Ritec BR-640 broadband receiver and stored in HP infinium 54810A oscilloscope. The recorded signal after the decompression was used to generate ultrasonic image of the tissue phantom. Bright echoes correspond to the strings built in the phantom. The gray background presents echoes scattered on the tissue mimicking media. All data were processed using Matlab software.

3. Results

Measured electrical admittance is presented in Fig. 2. The narrow bandwidth resonances of the not backed transducer are visible. The admittance of the first transducer measured in water is similar to the characteristics of the second (backed) transducer in air. In those conditions both transducers were loaded from one side. Those four drawings may be interpreted as a admittance of the not loaded transducer (a), loaded on front (b), loaded on back (c) and the both sides loaded (d).

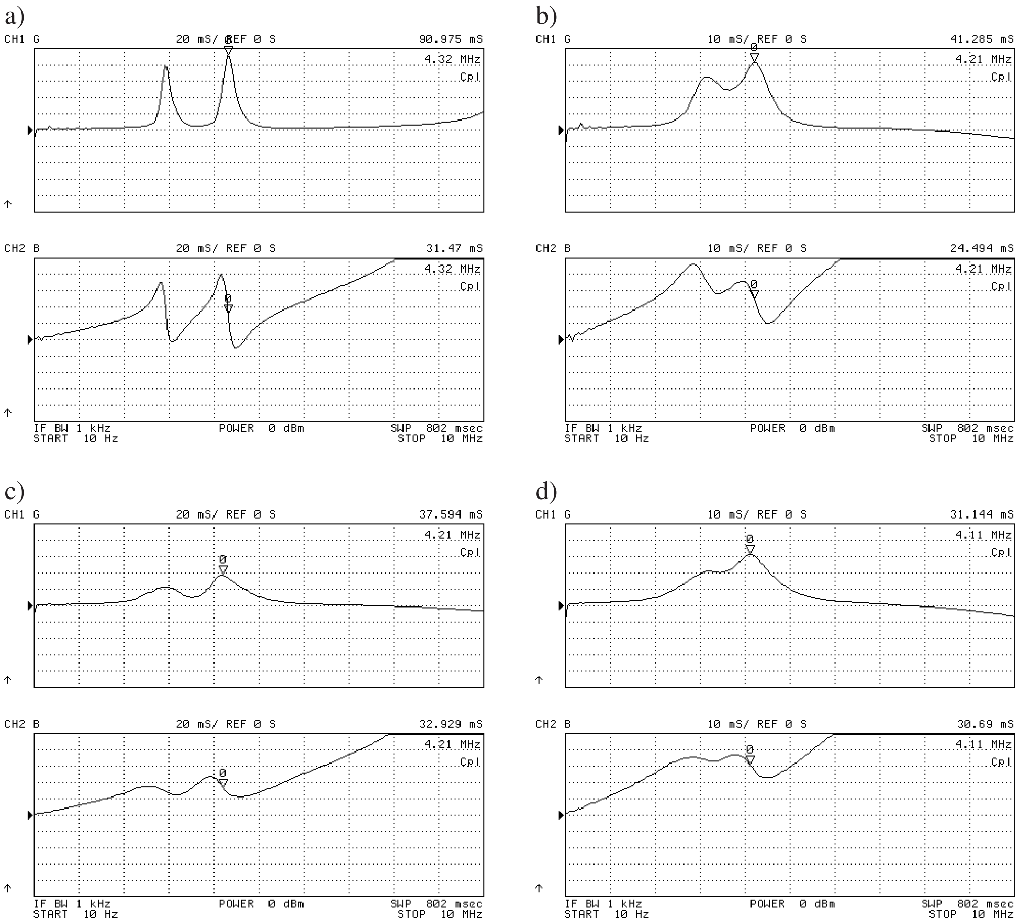

Fig. 2. Complex admittance of the measured transducers. Real (top) and imaginary part (bottom): a), b), transducer without backing in air and immersed in water, c), d), transducer with backing in air and immersed in water. The measured admittance Y was a: 91 + j31 mS, b: 41 + j24 mS, c: 38 + j33 mS, d: 31 + j31 ms at resonance frequency $f = 4.2$ MHz.

The pulse responses of the transducers are presented in Fig. 3. Not backed transducer has longer pulse response and 2.7–4.7 MHz (54%) -6 dB bandwidth. The shape of the pulse response may be divided on the first two sine periods carrying most of the energy and relatively long, slowly decreasing oscillations. This transducer has higher efficiency and 1.41 V_{pp} echo amplitude. The second, backed transducer generated shorter pulse with 2.5–4.7 MHz (59%) -6 dB bandwidth. The echo amplitude was 0.88 V_{pp}, -4.1 dB lower than the first transducer (Fig. 3).

a)

b)

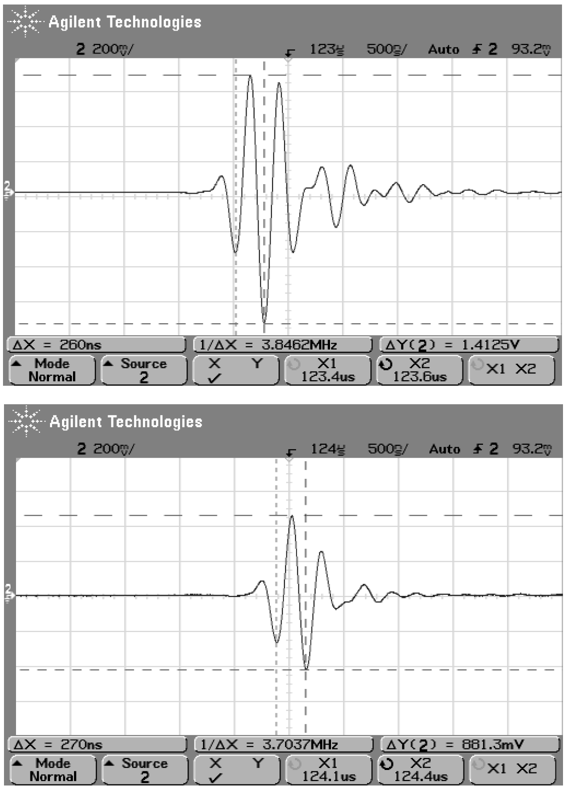

Fig. 3. Pulse response of the transducer without backing (a) and with backing (b).

In the Fig. 4 and Fig. 5 the signal envelope is presented, recorded from the one line of the tissue phantom using first and second transducers respectively. The equally spaced strong reflections from the strings and low amplitude scattered from tissue signal and noise are visible. For the first not backed transducer 8 bit two periods code increases echoes amplitude of 4.2 dB and clearly reduces noise level (Fig. 4). Decrease of the resolution is invisible and on the 20 mm depth, the double echo is visible. This double echo was caused by the long pulse response of the not backed transducer. For the second transducer, the increase of the echo amplitude was only 1.8 dB for two different Golay codes (Fig. 5). However higher axial resolution is visible for the 16 bit one period code and reduced noise floor for the 8 bit two periods excitation.

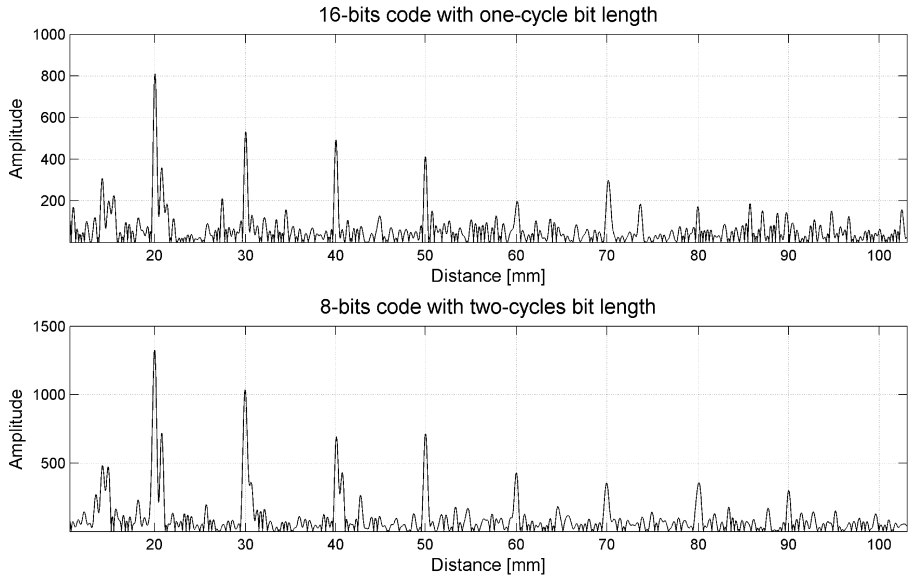

Fig. 4. Envelope of the echo signal recorded in the tissue mimicking phantom using transducer without backing. 16 bit one cycle per bit (top) and 8 bit two cycles per bit (bottom).

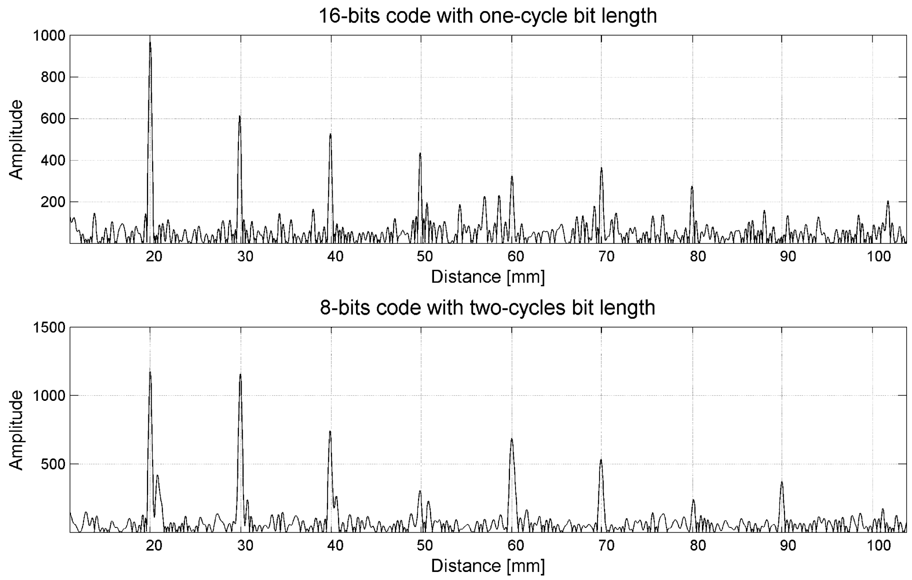

Fig. 5. Envelope of the echo signal recorded in the tissue mimicking phantom using transducer with backing. 16 bit one cycle per bit (top) and 8 bit two cycles per bit (bottom).

Ultrasonic B-scan image of the tissue phantom is presented in Fig. 6. The best signal to noise ration (black background) was obtained for the non backed transducer and 8 bit two period code (b) and the best resolution is visible for the backed transducer and 16 bit one period code (c).

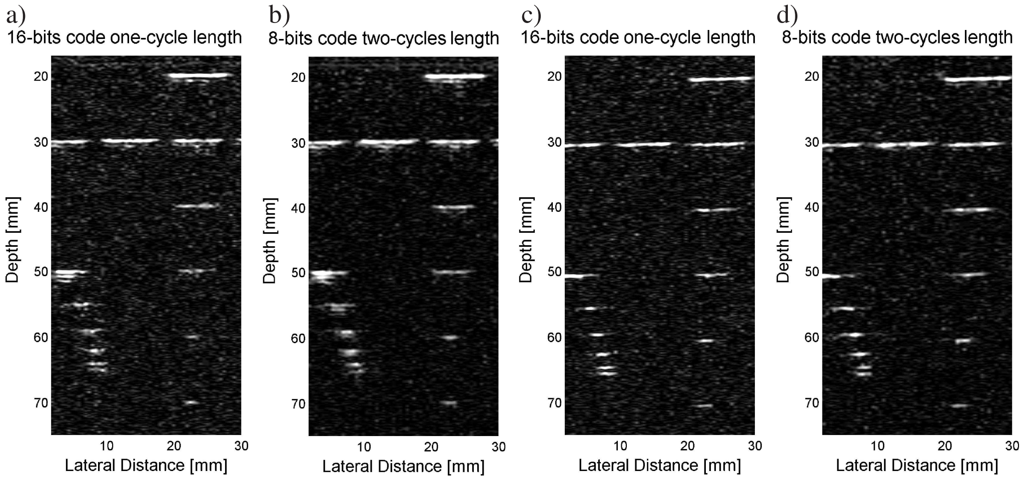

Fig. 6. B-mode images of the tissue mimicking phantom using transducer without backing (a, b) and with backing (c, d).

4. Conclusions

Two ultrasonic transducers were built. One without backing and the second loaded on back. The transducer had similar bandwidths 54% and 59% respectively. Efficiency of the not backed transducer was 4.1 dB higher. Different pulse response caused different transducer behaviour during Golay code excitations. The not backed transducer performed maximum sensitivity for 8 bit two periods per bit code excitation. The backed transducer achieved maximum axial resolution for 16 bit one period per bit excitation. The primary application of the first transducer is Doppler blood flow measuring ultrasonic devices, the second is most useful for the B-mode imaging devices.

Acknowledgment

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