# Fetal heart rate measurements using a flexible Ultrasound transducer matrix

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**Background** Electronic fetal heart rate (fHR) monitoring is standard in clinical practice to detect deviations from the normal fHR pattern. Typically, an ultrasound (US) transducer, operating in a pulsed-wave Doppler mode, measures the periodic motion of the fetal heart, from which the fHR can be derived. However, as the fetus moves through the birth canal, the fetal-heart location (fHL) changes continuously. Consequently, the clinical staff needs to manually track the fHL and reposition the US transducer accordingly. This can drastically compromise the clinical workflow and possibly affect the assessment of the fetal well-being.

**Aim** In this research, a new flexible US patch with multiple transducer elements is designed; it allows measuring the fHR over a large range of possible fHLs. Further, a method for dynamic combination (DCW) of the receiving channels is presented, with the aim of improving the Doppler signal and, therefore, the accuracy of the fHR estimation.

**Materials and Methods** A first prototype of a flexible ultrasound patch was realized by casting and curing a 1 mm thick layer of silicone (PDMS) into a mould. After curing at ~65 C°, 25 circular ceramic elements (PZT) were pressed into the layer at predefined positions. Each element was wired via 0.2 mm thick coaxial cables to an open US research platform (Vantage 256, Verasonics), which provides individual control over all elements. Eventually, a second layer of casted PDMS embeds the elements.

Fig. 1 shows the dynamic channel weighting method for combination of individual receive channels. In transmission, all elements are active. After extraction of the Doppler signal, the power of each individual Doppler signal is computed. The relative power in each element is then used to dynamically adapt the weighting factors $w_i$. This way, elements not directed towards the fHL will be deemphasized in the summation signal. The obtained signal is finally passed to an fHR estimator, making use of an autocorrelation function (ACF) [1].

A dedicated *in-vitro* fHR setup was realized (Fig. 2), for validation of the fHR at varying fHL.

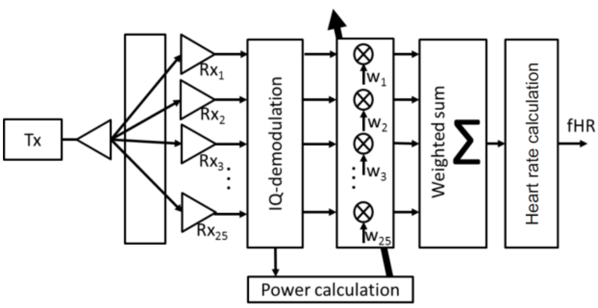


*Figure 1: Dynamic channel weighting of Doppler signals for fetal heart rate measurements.*

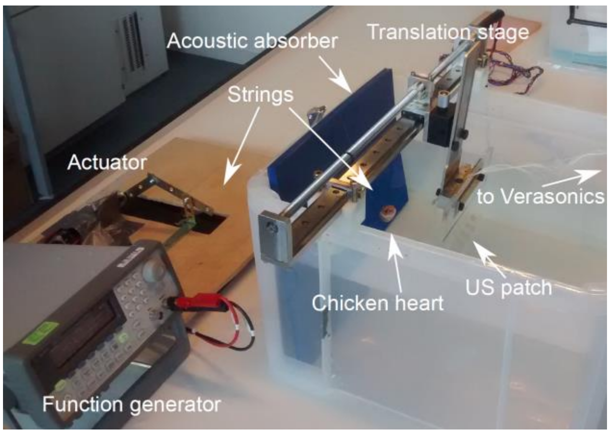


*Figure 2: Flexible Ultrasound patch used in a dedicated in-vitro beating fetal heart rate setup. The function generator drives the motor with a predefined waveform. The strings attached to the motor pull on the chicken heart, causing a beat-like motion pattern at 120 beats per minute.*

## Results

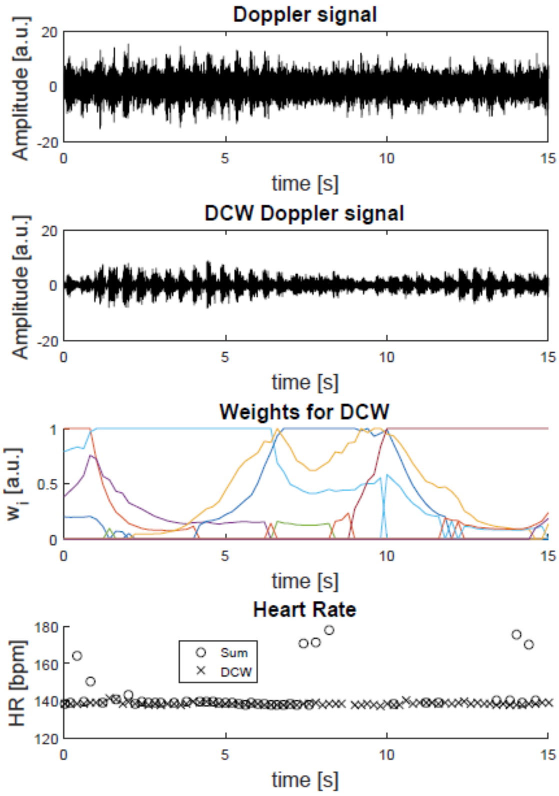


*Figure 3: Measurement where the chicken heart was translated through the measurement volume of the flexible sensor matrix. From top to bottom: plain summation Doppler signal (Sum), dynamic channel weighted Doppler signal (DCW), adaptively changing weights and estimated heart rate. The coloured lines represent the weights $w_i$ corresponding to the different elements.*

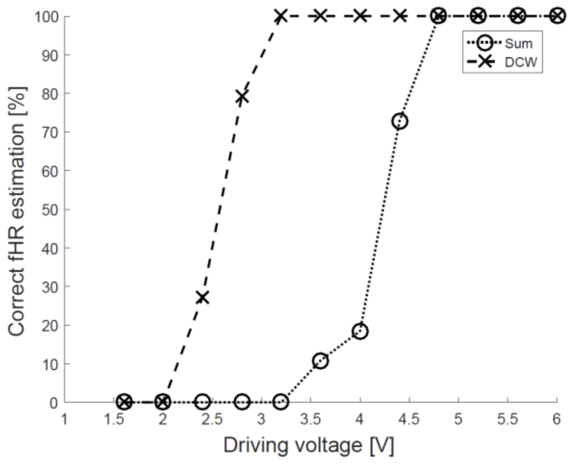


*Figure 4: Comparison of fHR estimation performance using the simple summation method (Sum) and the new described dynamic channel weighting (DCW) method. The percentage of correct estimated heart rate is given as function of increasing driving voltage of the transducer elements, i.e., decreasing noise level. For the different driving voltage levels, a 30-s long measurement was recorded.*

The results (Fig. 3 and Fig. 4) show that dynamic channel weighting (DCW) improves signal quality and allows measuinrg the fHR more reliabily compared to a standard method (Sum) where no channel weighting is applied.

**Conclusion** A new design of a flexible sensor matrix is realized. The dynamic weighting of the channel summation produces improved signal quality. This improvement, along with the possibility to measure the fHR at varying fHLs without user interaction, represents an asset for the clinical assessment of fetal well-being.

## *Bibliography*

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