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An Energy Detector Based on Negative Energy Fluctuations Coupled with Sub-band Decomposition as a Robust Micro-embolus Detection System

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Context: Robust detection of the smallest circulating cerebral micro-emboli is an efficient way of preventing Cerebrovascular Accidents. Transcranial Doppler ultrasound is widely considered the most convenient system for the detection of micro-emboli. Commercially realized standard detection is achieved through the whole Doppler energy spectrum where constant empirical thresholds are implemented. In this study, we propose a new type of micro-embolic detectors composed of N detectors associated to N Doppler frequency sub-bands. Moreover, we couple this sub-band decomposition with an original detection method. The N sub-band energy detectors are built from negative fluctuations of energy.

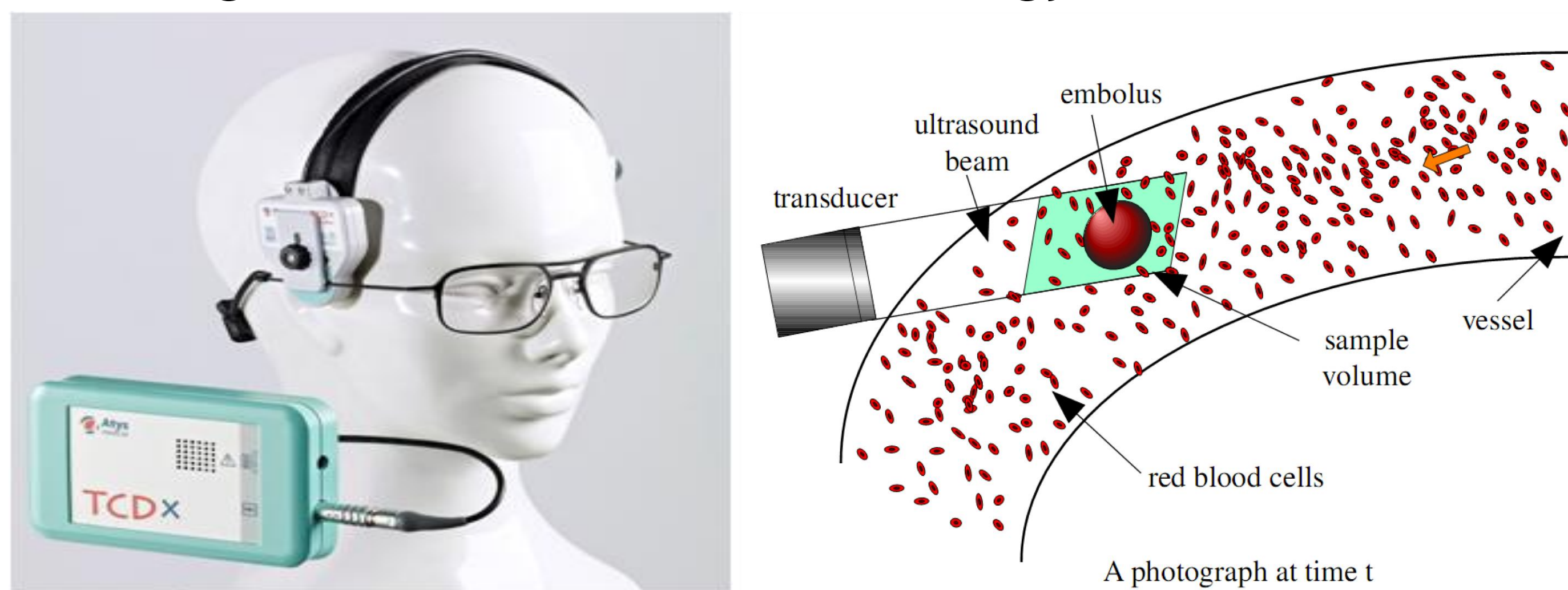
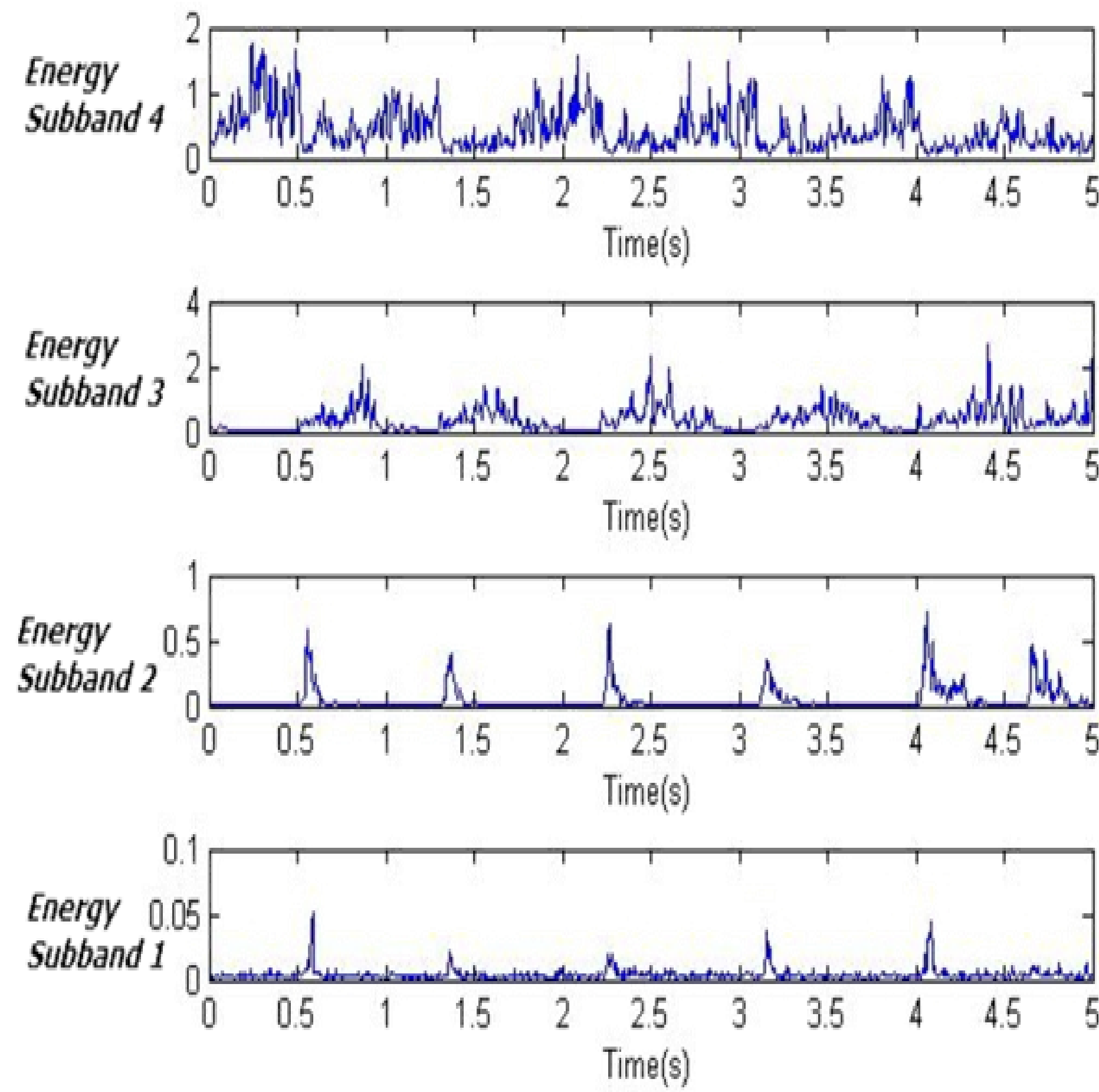


Fig. 1: Holter Transcranial Doppler System, TCD-X, Atyx Medical, Soucieu en Jarrest, France

Problem to be solved: The common hindering drawback is the detection of small micro-emboli having amplitudes much lower than that of the blood Doppler signal.

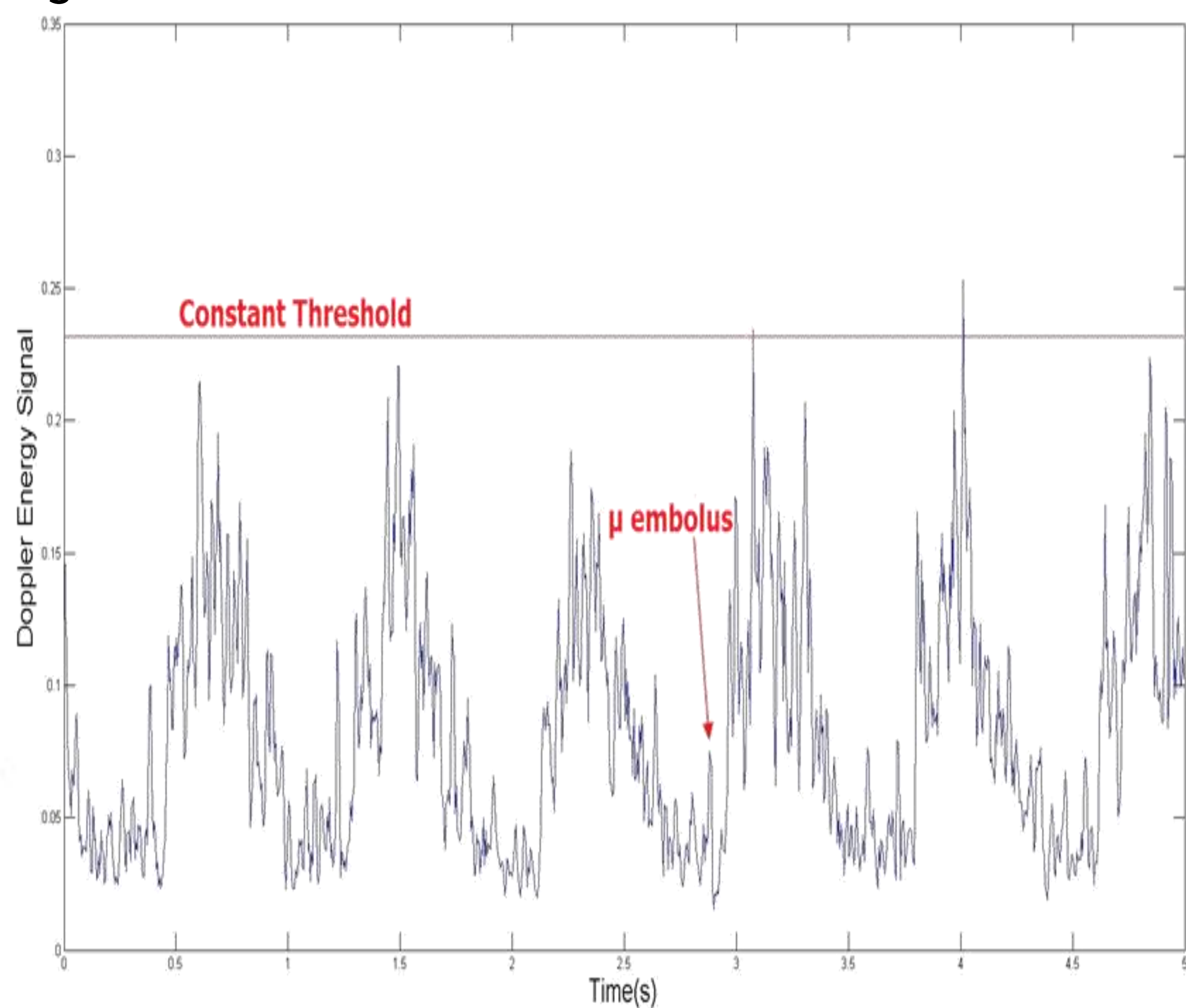


Fig. 2: The constant threshold-based detector remains mute during the transit passage of a micro-emboli

Proposed solution: We propose to detect low intensity micro-embolic signals in a robust manner through an authentic approach based on the joint use of several hypotheses.

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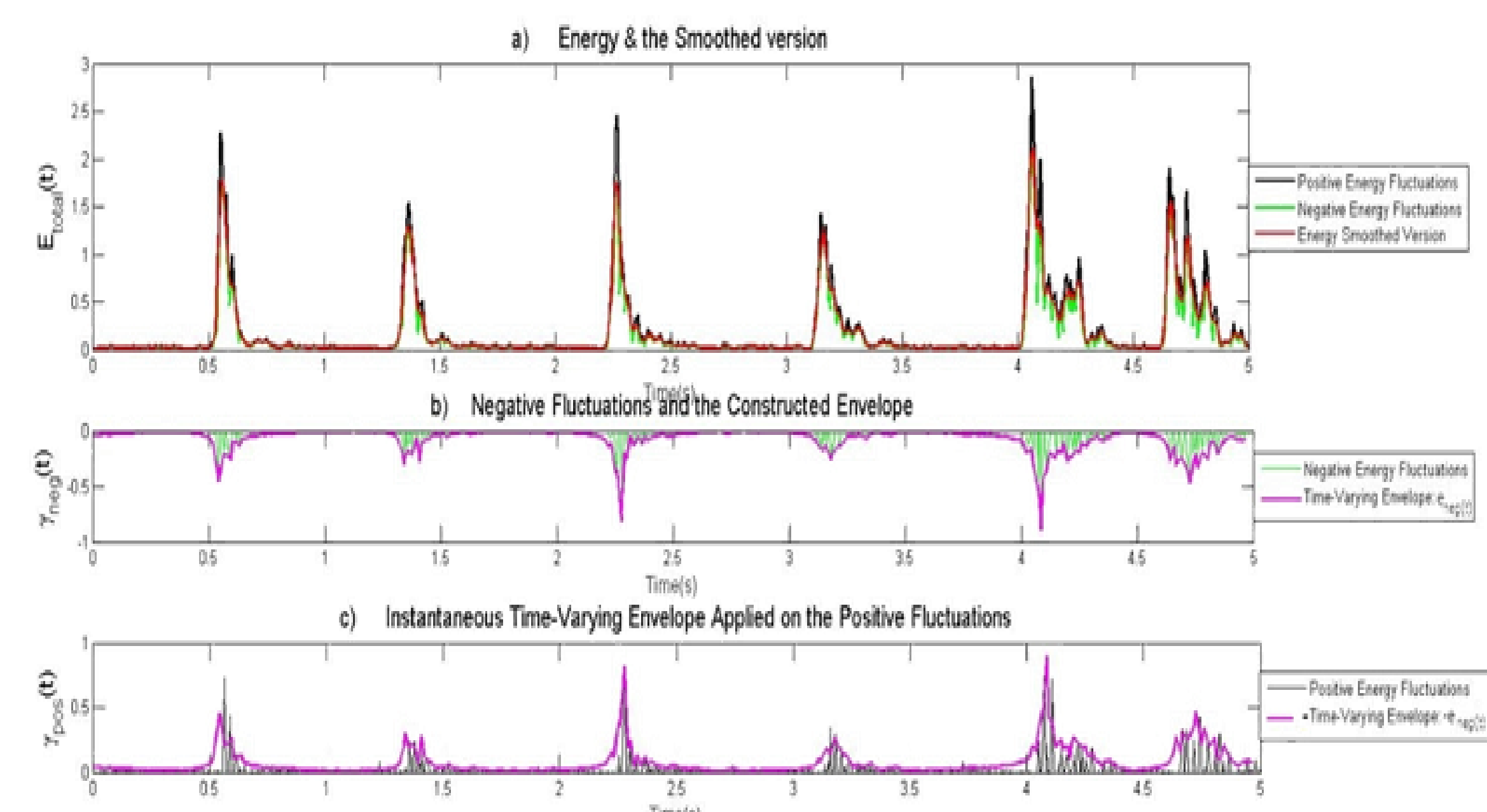


Fig. 3: Sub-band detection process with negative energy fluctuations-based detector. Due to space complications we represent the detection process in sub-band 2 only. However, the same embolus detection process is applied in each sub-band.

Results: Our dataset is composed of 17 signals. 8 out of these 17 signals were excluded and used in a purpose to determine the optimal number of sub-bands. This phase is referred to as training phase. The other 9 signals were used in a testing phase where the different detectors' are evaluated.

TABLE I COMPARISON OF THE DETECTION RATE, FAR, AND RII RESULTS FOR SUB-BAND DETECTORS WITH CONSTANT THRESHOLD, WHOLE BAND DETECTOR WITH TIME-VARYING THRESHOLD AND SUB-BAND DETECTORS WITH TIME-VARYING THRESHOLDS

Number of Sub-band Decomposition	Detection Rate (%)	FAR (%)	Relative Intensity Increase (dB)
4 Sub-band detector with constant threshold	79	37	15
Whole band detector with time-varying threshold	87	15	18
4 Sub-band detector with time-varying threshold	93	6	23

Discussions: Sub-band decomposition is a relatively strong tool to improve micro-embolus detection. By coupling sub-band detection with a time-varying threshold constructed from negative energy fluctuations an extremely high performing embolus detection system is obtained. This coupling is able to detect nearly all micro-emboli that may occur during the cardiac cycle.