A ROBUST FETAL ECG DETECTION METHOD FOR ABDOMINAL RECORDINGS

Biomedical Signal Processing Project

Niccolò Pizzocri - 75095A

INTRODUCTION

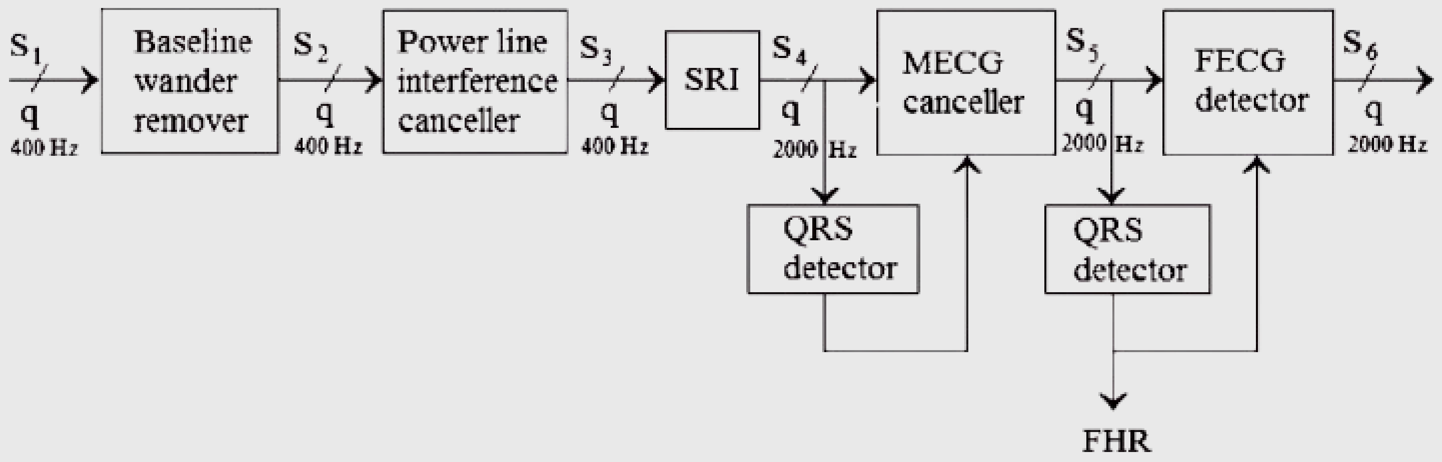
Monitoring the fetal cardiac activity can provide important information to obstetricians for the assessment of the **fetal well-being**.

Abdominal FECG provide a **non-invasive** diagnostic tool to do so.

However, the **fetal signal** has **small amplitude** and it's **overwhelmed by** a large number of **interference signals** such as baseline drift, power-line interference, motion artifacts and the mother's ECG itself

The paper proposes a non-blind method for FECG detection in abdominal recordings during pregnancy and labour.

METHOD



The method proposed detects the FECG by estimating and removing the interference signals step-by-step:

1. Baseline wander remover
2. Power-line interference canceller
3. Sampling-rate increaser
4. Mother QRS detector → MECG canceller
5. Fetal QRS detector → FECG extractor

DATASET

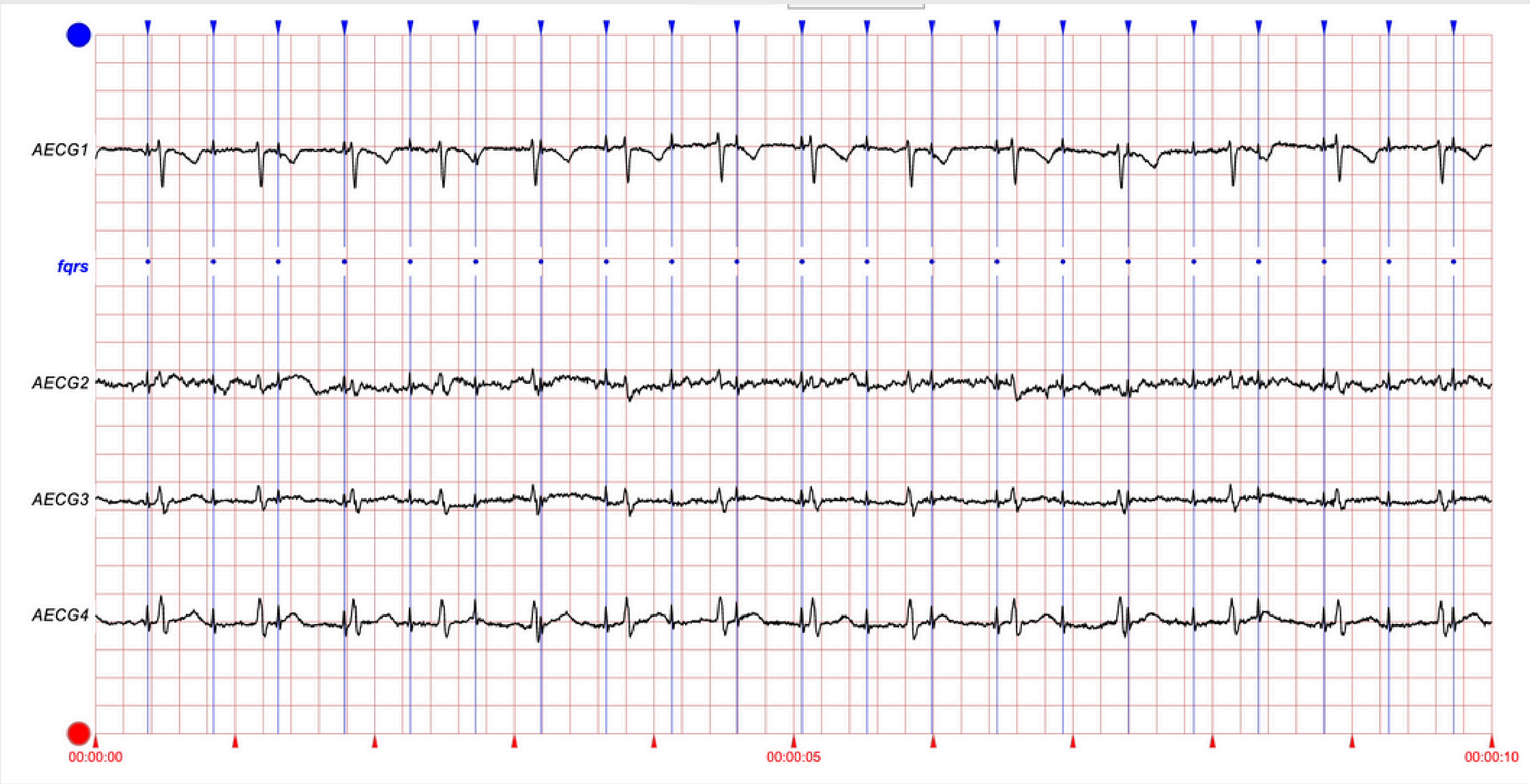
2013 Computing in Cardiology Challenge's dataset:

One-minute of fetal ECG Recordings that include

four non-invasive abdominal signals

1000 Hz sampling rate

The dataset also contains the locations of each fetal QRS produced



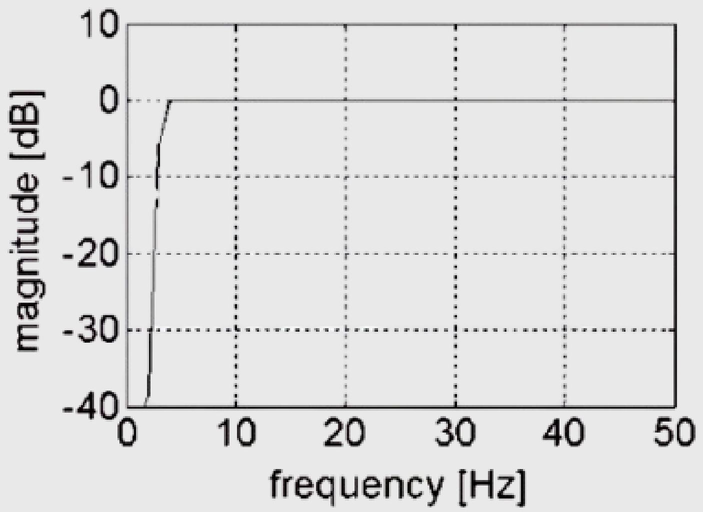
BASELINE WANDER REMOVER

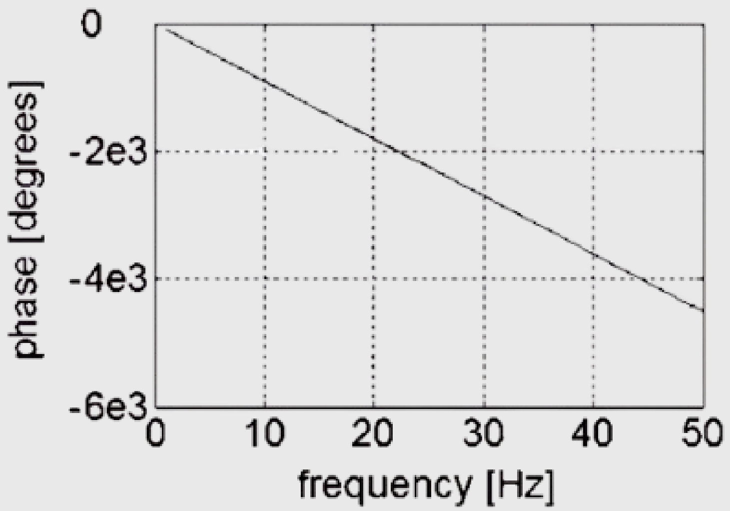
Adaptive filtering and **Polynomial or Cubic Spline Subtraction** are rejected

SOLUTION ➔ Linear-phase high pass FIR filter

It attenuates the large amount of baseline wander though it may cause a slight FECG distortion

Cut-off frequency: 3Hz
Filter Order: 1000 (+1)
Window: Hamming

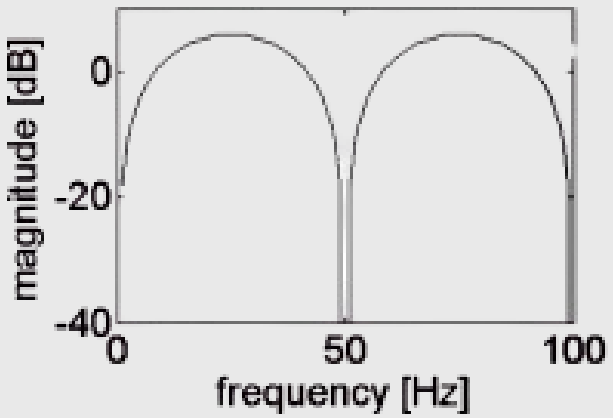


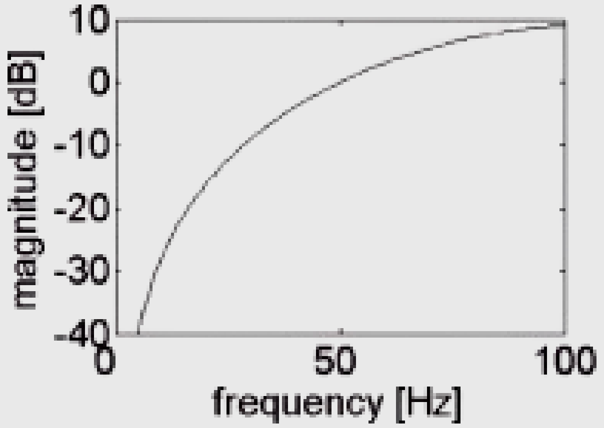


ADAPTIVE PLI CANCELLER

Blocking detection to protect QRS complexes:
Comb Filtering → Threshold Detection → Mask Generation

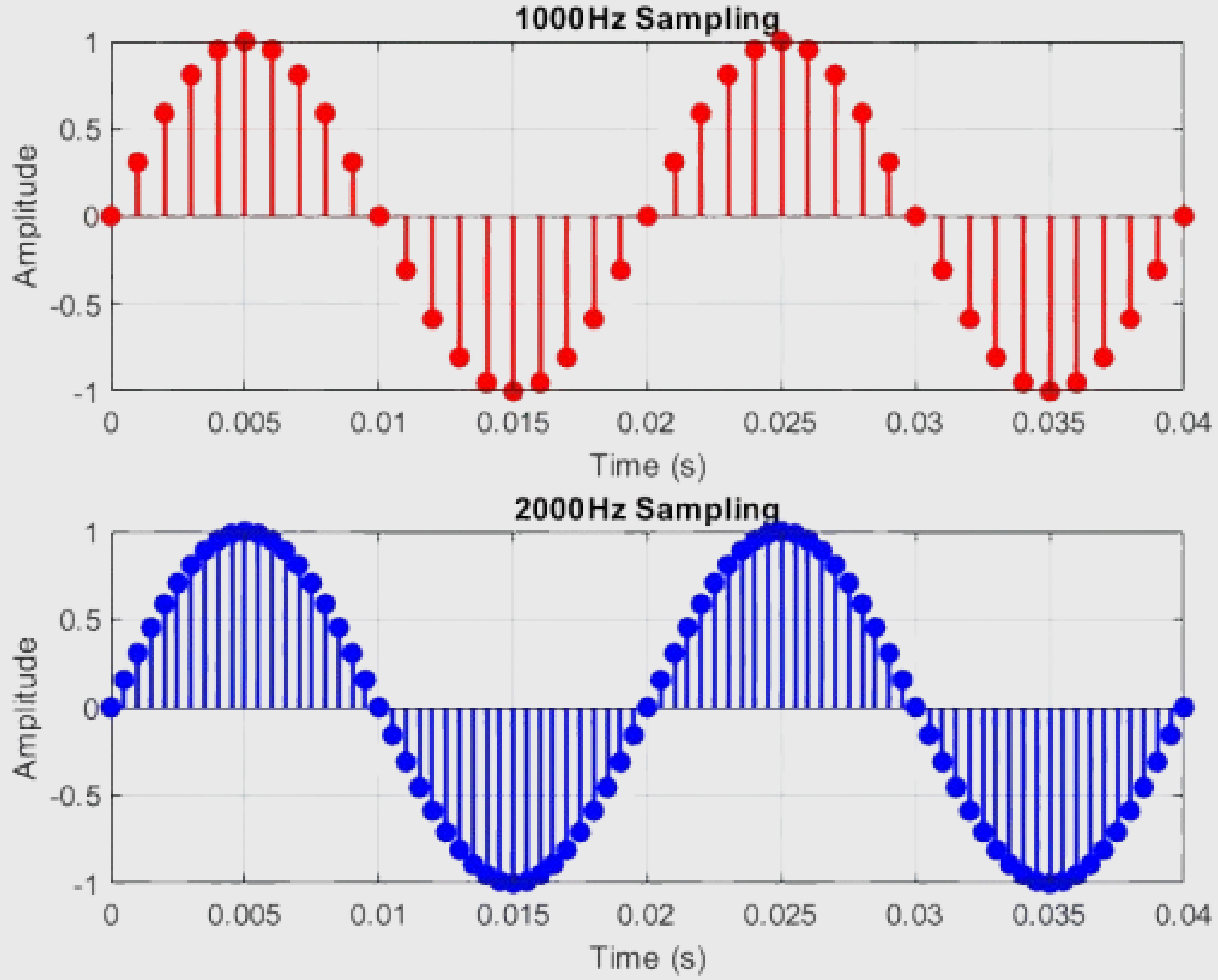
Adaptive Cancellation Loop:
Reference Generation → Error Calculation → Error Filtering
Reference Generation parameters Update using LMS





SAMPLING RATE INCREASER

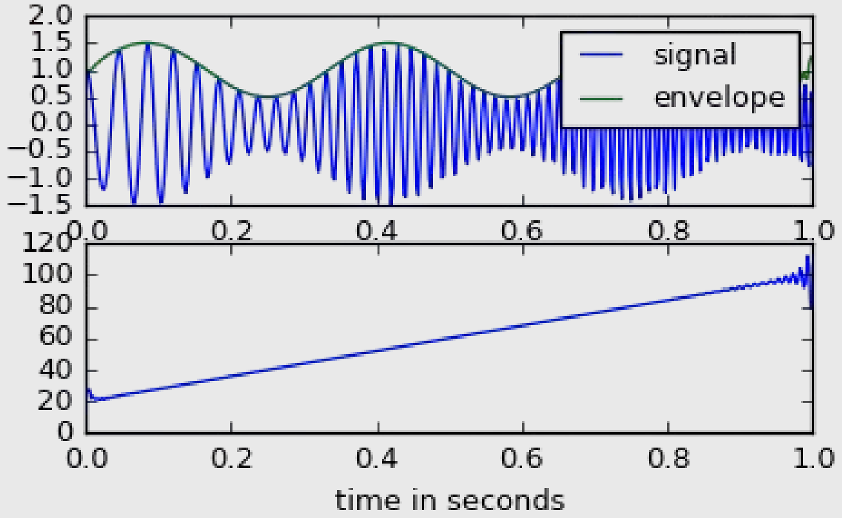
Sampling rate increased to **2000 Hz** for removing MECG with high precision



MECG CANCELLER

MQRS DETECTOR:

1. PCA
2. Detection with Hilber Envelope and Dynamic Thresholding
3. Perfect Template Overlap via Cross-Correlation



MECG CANCELLER:

1. Average Beat Template
2. Beat Segmented into P Wave, QRS complex and T wave
3. Adaptive Fitting with Ridge Regression

$$M = \begin{pmatrix} | & 0 & 0 \\ \underline{\mu}_P & 0 & 0 \\ | & 0 & 0 \\ 0 & | & 0 \\ 0 & \underline{\mu}_{\mathrm{QRS}} & 0 \\ 0 & | & 0 \\ 0 & 0 & | \\ 0 & 0 & \underline{\mu}_T \\ 0 & 0 & | \end{pmatrix}. \quad \underline{a} = (M^T M)^{-1} M^T \underline{m}.$$

FECG EXTRACTOR

FQRS DETECTOR

2 different approaches:

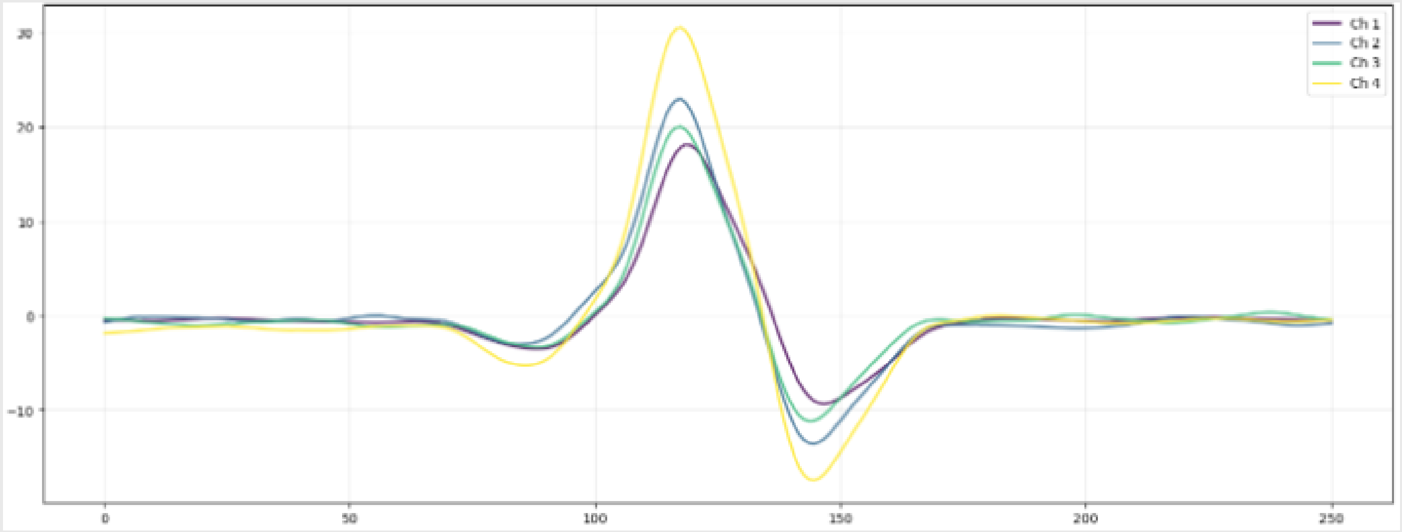
1. PCA-Hilbert
2. Energy-Based

ENERGY BASED DETECTION

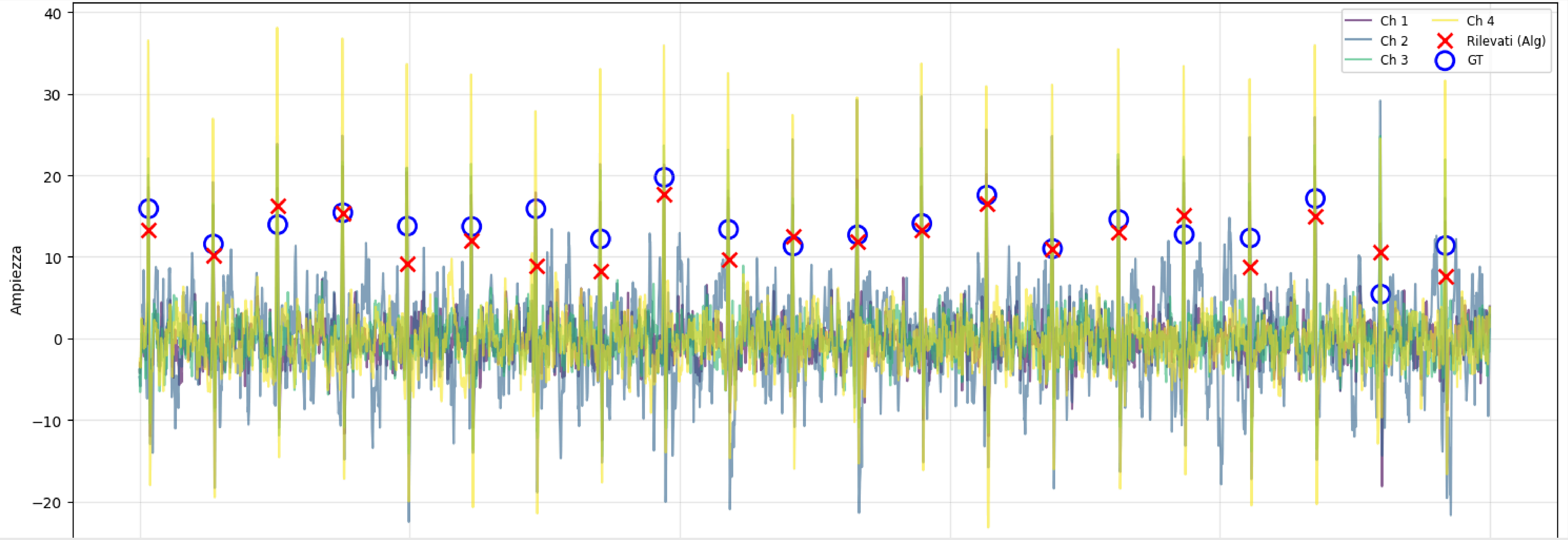
- Compute Cubic Energy to enhance peaks
- Percentile Threshold

FETAL BEAT RECONSTRUCTION

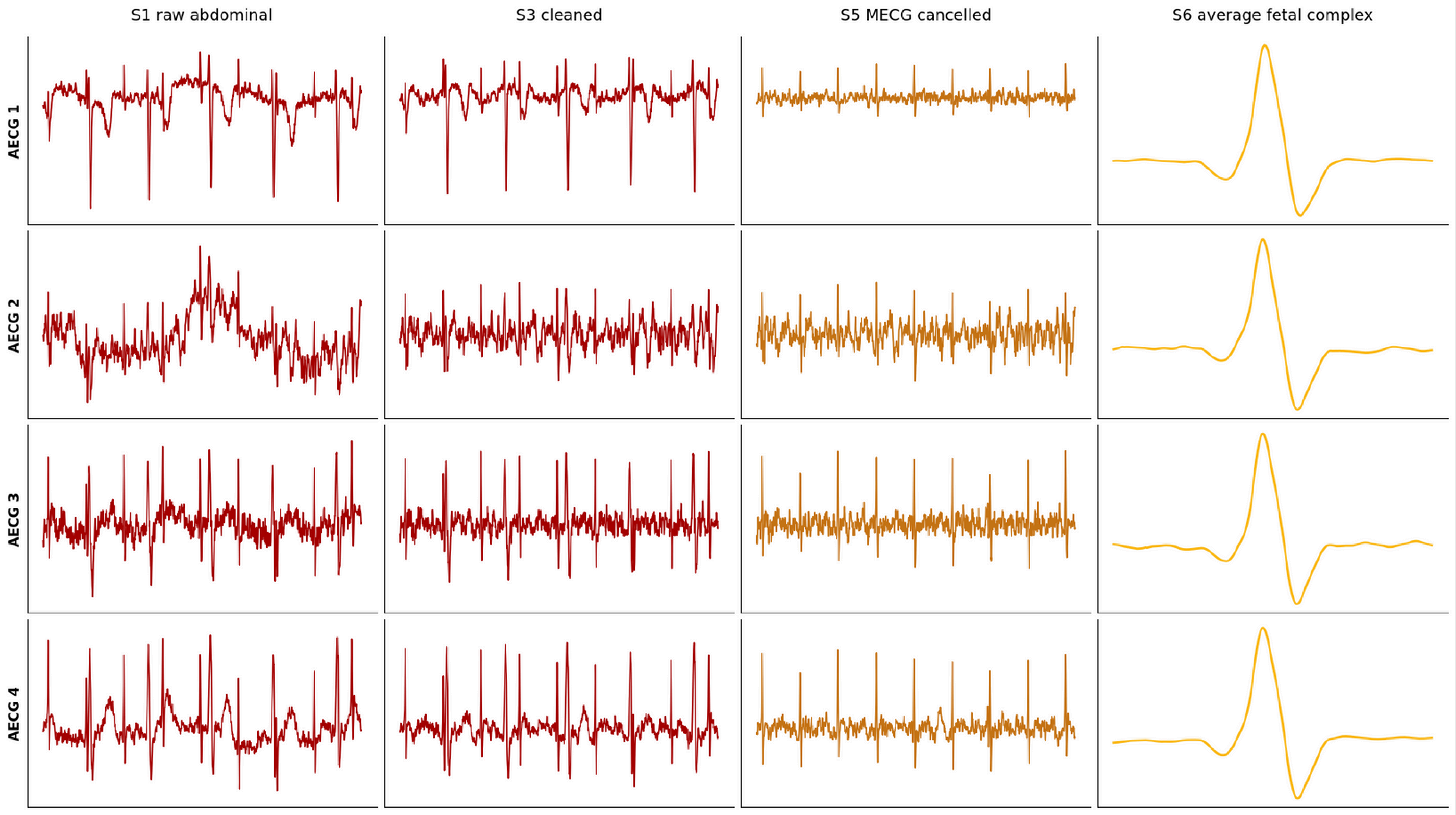
- Synchronization
- Averaging of ALL beats



FECG EXTRACTOR



PIPELINE OUTPUT



METRICS

$$Reliability = 1 - \frac{N_{outliers}}{N_{total}}$$

$$\mathrm{SNR}_j = \frac{P_{F_j}}{P_{M_j}} = \frac{P_{S_{6,j}}}{P_{S_{5,j}-S_{6,j}}},$$

$$\mathrm{SIR}_j = \frac{P_{F_j}}{P_{N_j}} = \frac{P_{S_{6,j}}}{P_{S_{4,j}-S_{5,j}}}.$$

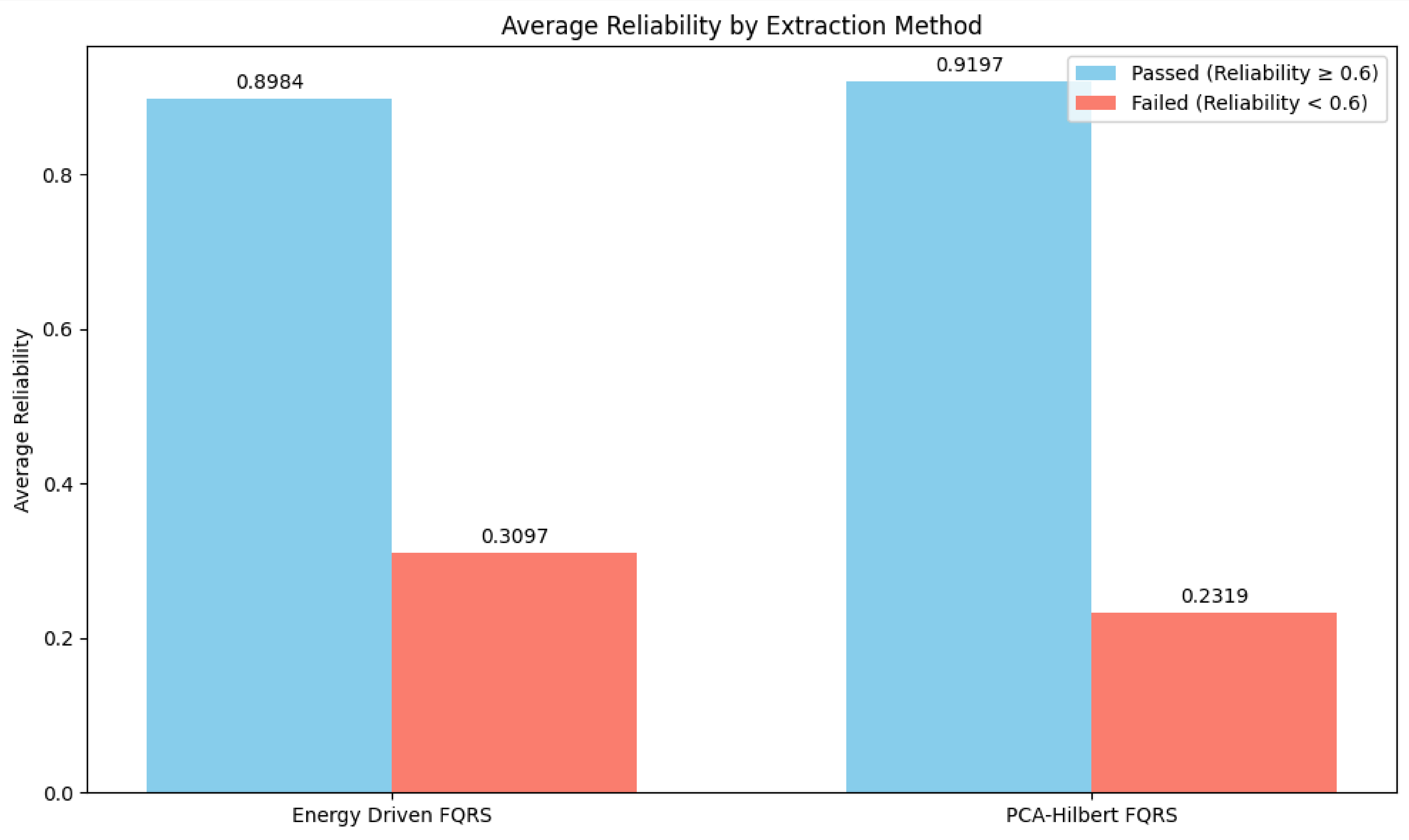
$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

$$\text{Sensitivity} = \frac{TP}{TP + FN}$$

$$\text{PPV (Precision)} = \frac{TP}{TP + FP}$$

$$\text{F1 Score} = \frac{2 \cdot TP}{2 \cdot TP + FP + FN}$$

RESULTS

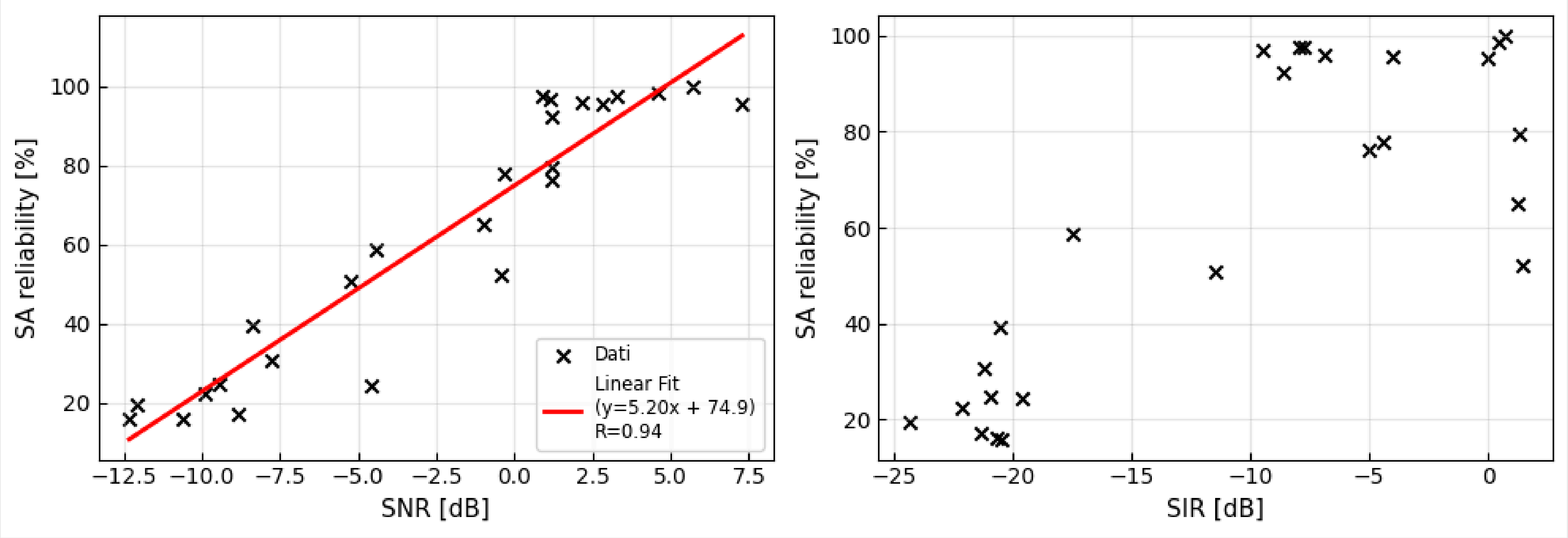


Average Reliability by Extraction Method
Passed (Reliability ≥ 0.6)
Failed (Reliability < 0.6)
Average Reliability
0.0
0.2
0.4
0.6
0.8
0.8984
0.3097
0.9197
0.2319
Energy Driven FQRS
PCA-Hilbert FQRS

RESULTS

Metric Comparison: Passed vs Failed Reliability
Passed (≥0.6)
Failed (<0.6)
100
80
60
40
20
0
−20
Mean Value
92.72
95.81
96.04
95.91
21.43
28.79
39.67
32.89
0.47
-13.56
-5.34
-24.12
SNR
SIR
Accuracy
Se
PPV
F1
Metrics

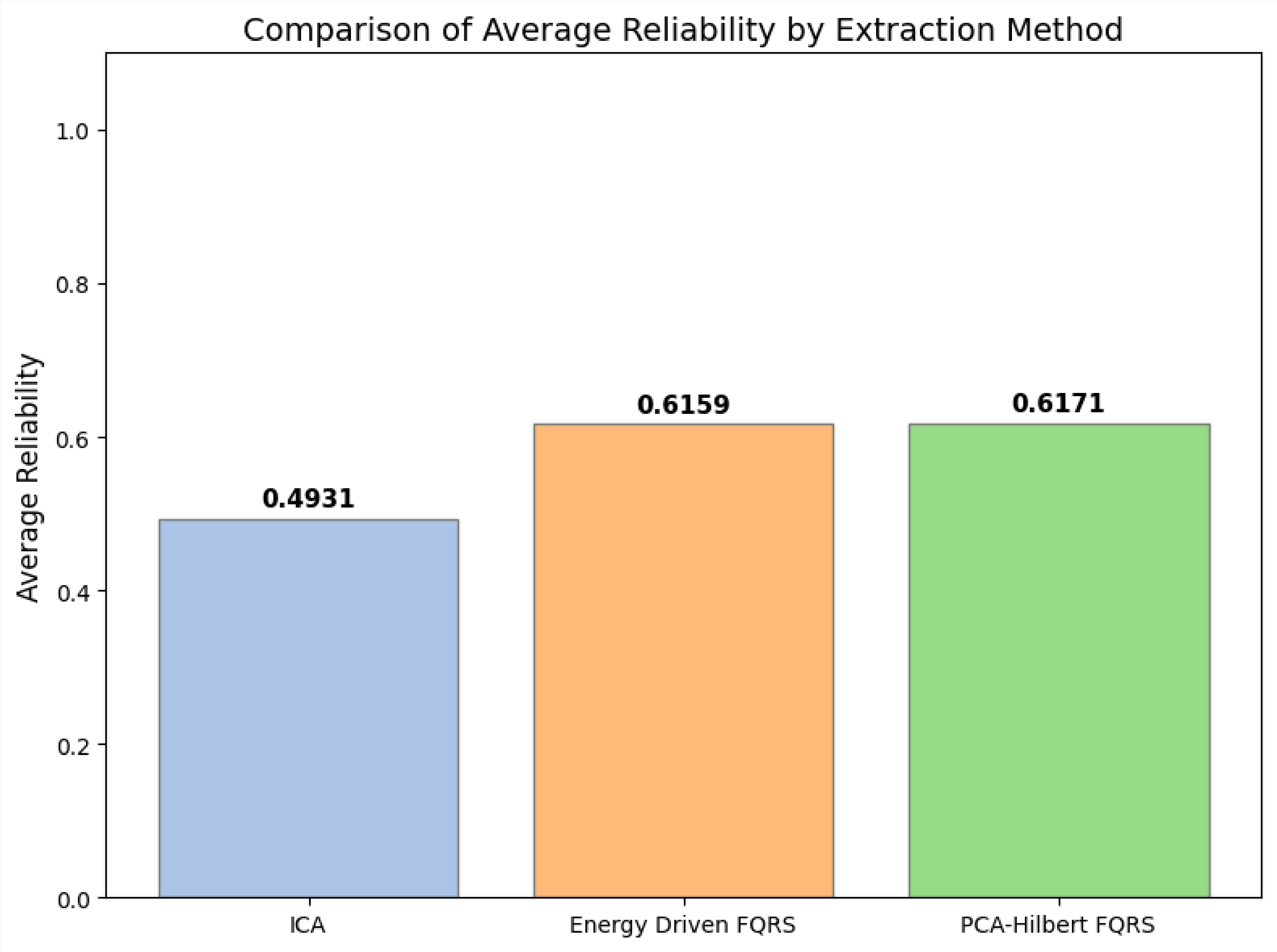
RESULTS



PEARSON CORRELATION MATRIX

	Reliability	SNR	SIR
Reliability	1	0.94	0.81
SNR	0.94	1	0.89
SIR	0.81	0.89	1

ICA COMPARISON



THANK YOU