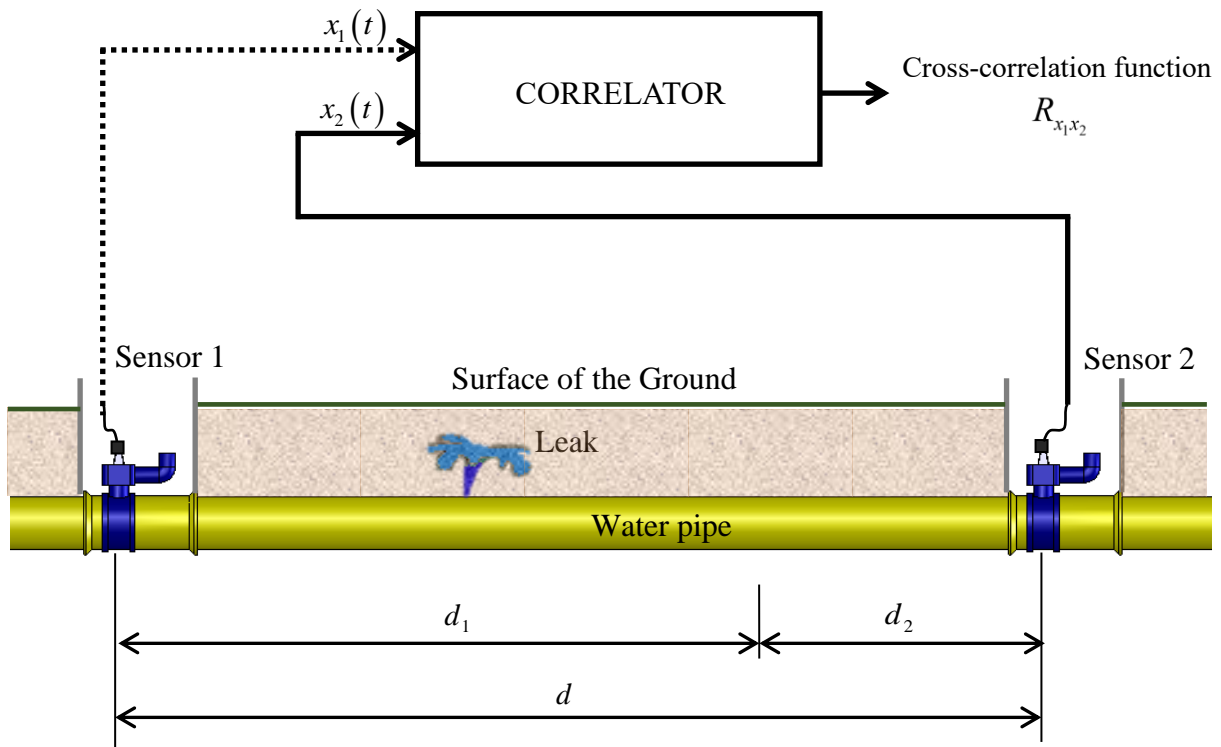**Figures**

Figure 1. Schematic of the process of leak detection in a buried water pipe using acoustic signals with a leak bracketed by two sensors.
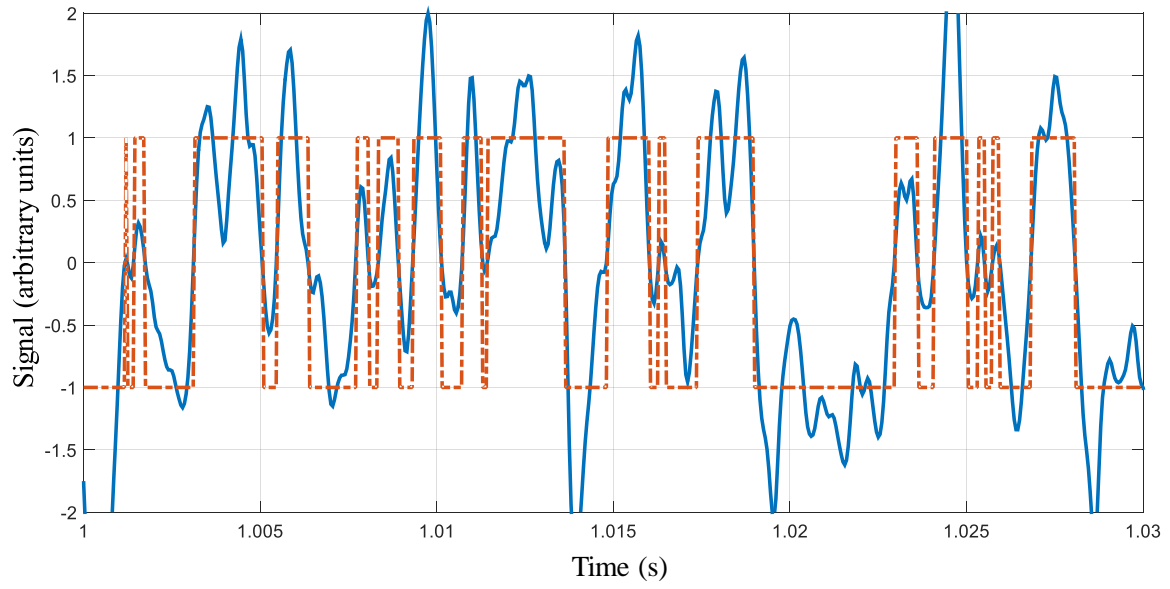
Figure 2. A typical leak noise signal. Unclipped signal, blue solid line; severely clipped signal, red dashed dotted line.
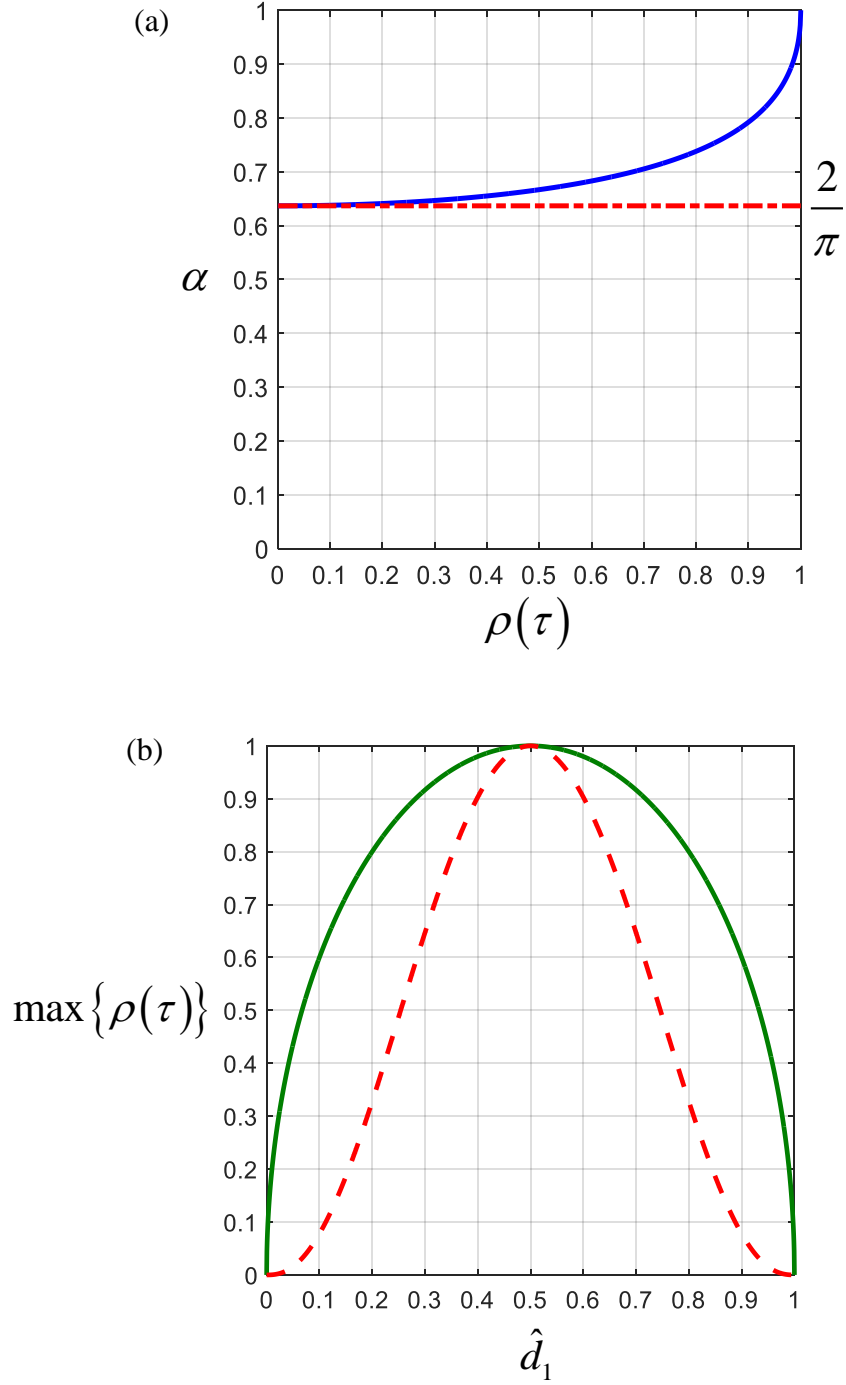
Figure 3. Effects of some factors on the cross-correlation coefficient. (a) Effect due to severe clipping; $\alpha = \rho_{x_1 x_2}(\tau)\big|_{\text{clipped}} \big/ \rho_{x_1 x_2}(\tau)$ (b) Effect on the maximum value of the cross-correlation function of the unclipped signal $\max\{\rho_{x_1 x_2}(\tau)\}$, as a function of the position of the leak. Pressure measurements, solid green line; Acceleration measurements, dashed red line.
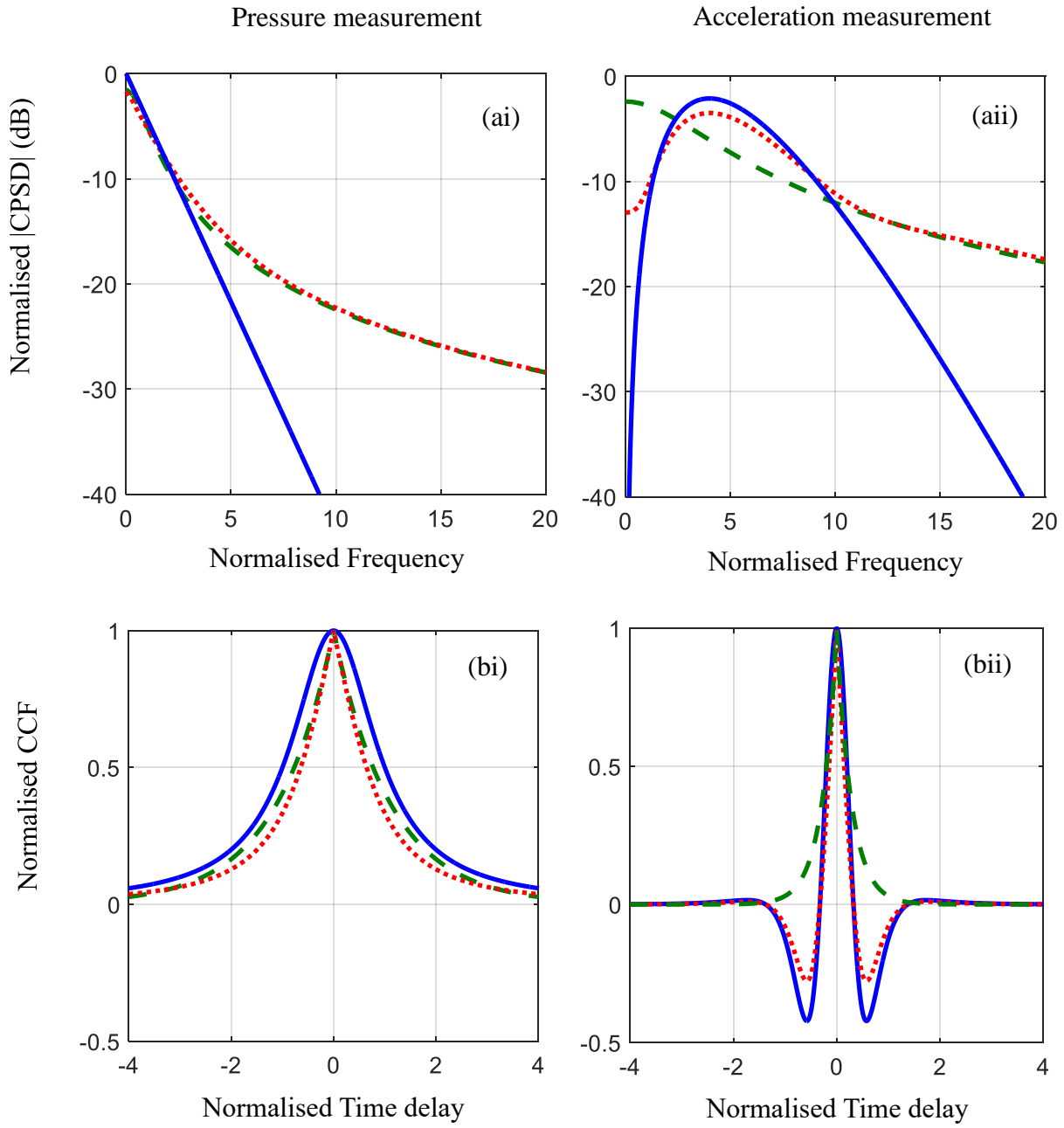
Figure 4. Comparison between the normalised CPSD and normalised CCF of the unclipped data, the severely clipped data processed using the Van Vleck theory, and the random telegraph theory for pressure and acceleration data. (a) normalised CPSD, (b) normalised CCF, (i) pressure data, (ii) acceleration data. Unclipped data, solid blue line; Van Vleck theory, red dotted line; random telegraph theory, dashed green line.
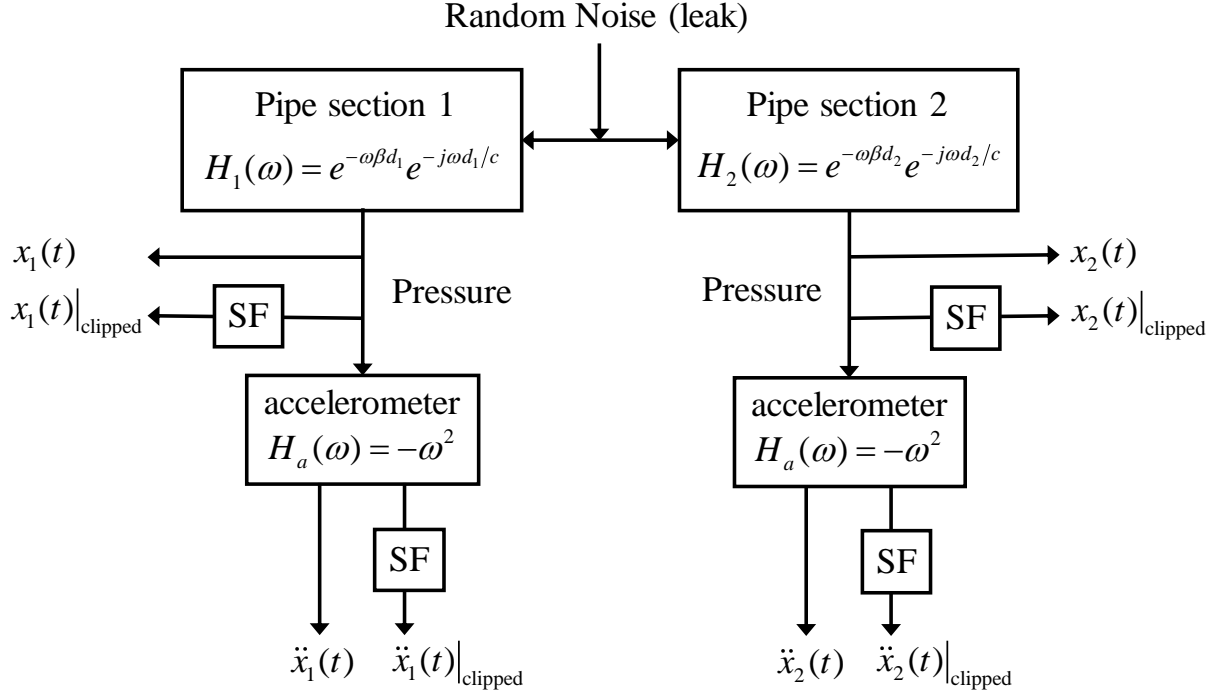
Figure 5. Block diagram of the pipe system used to generate leak noise signals at sensors 1 and 2. The block SF denotes the signum function is applied.
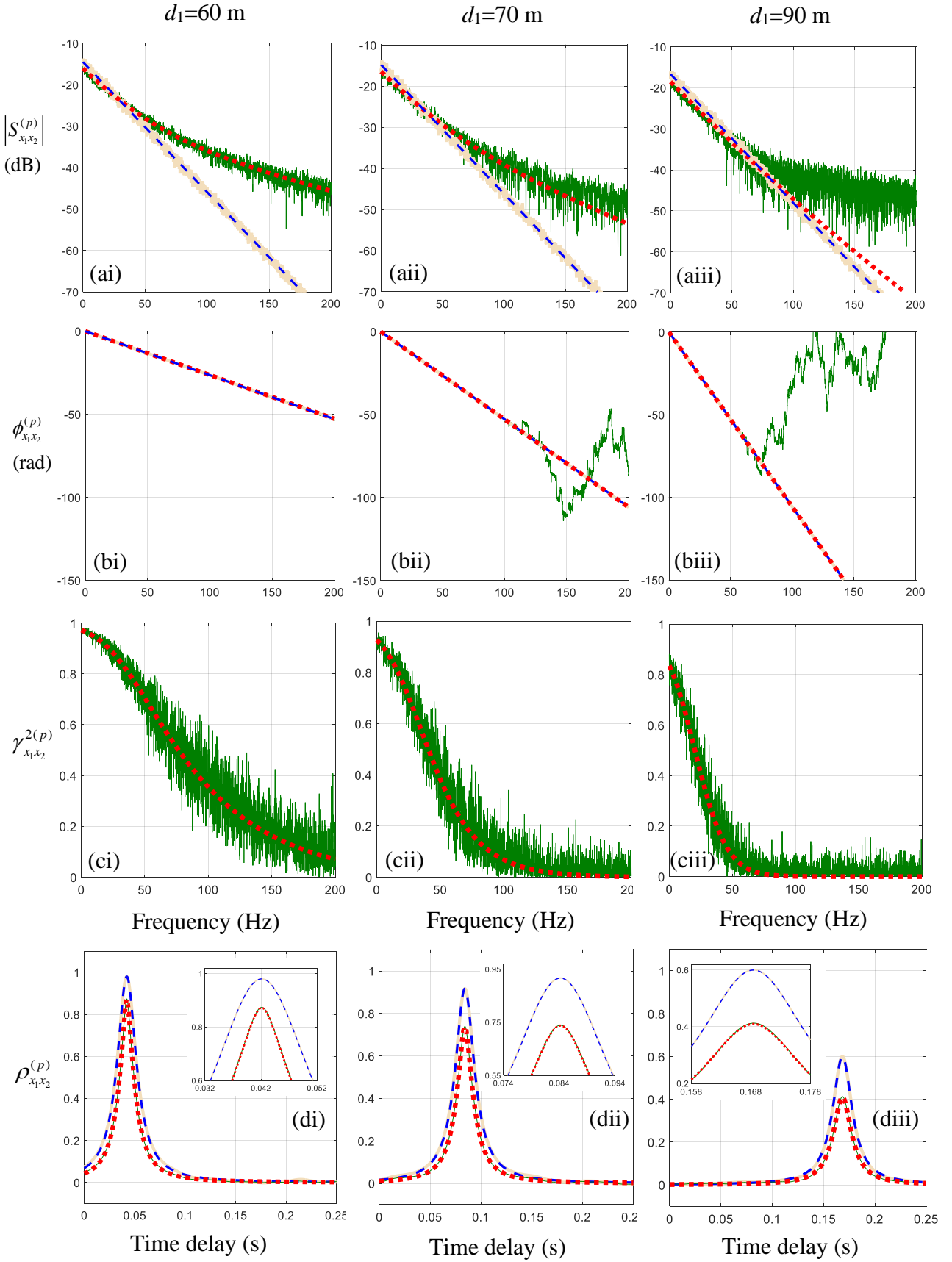
Figure 6. Processed data from simulated pressure signals, for three leak positions on a 100 m long pipe, 60 m, column (i), 70 m, column (ii), 90 m, column (iii). (a) modulus of the CSD (dB ref 1 Pa^2/Hz), (b) Phase of the CSD, (c) coherence, (d) CCC. Numerical unclipped, thick solid yellow line; Analytical unclipped, dashed blue line; Numerical clipped, thin solid green line; Analytical clipped, dotted red line.
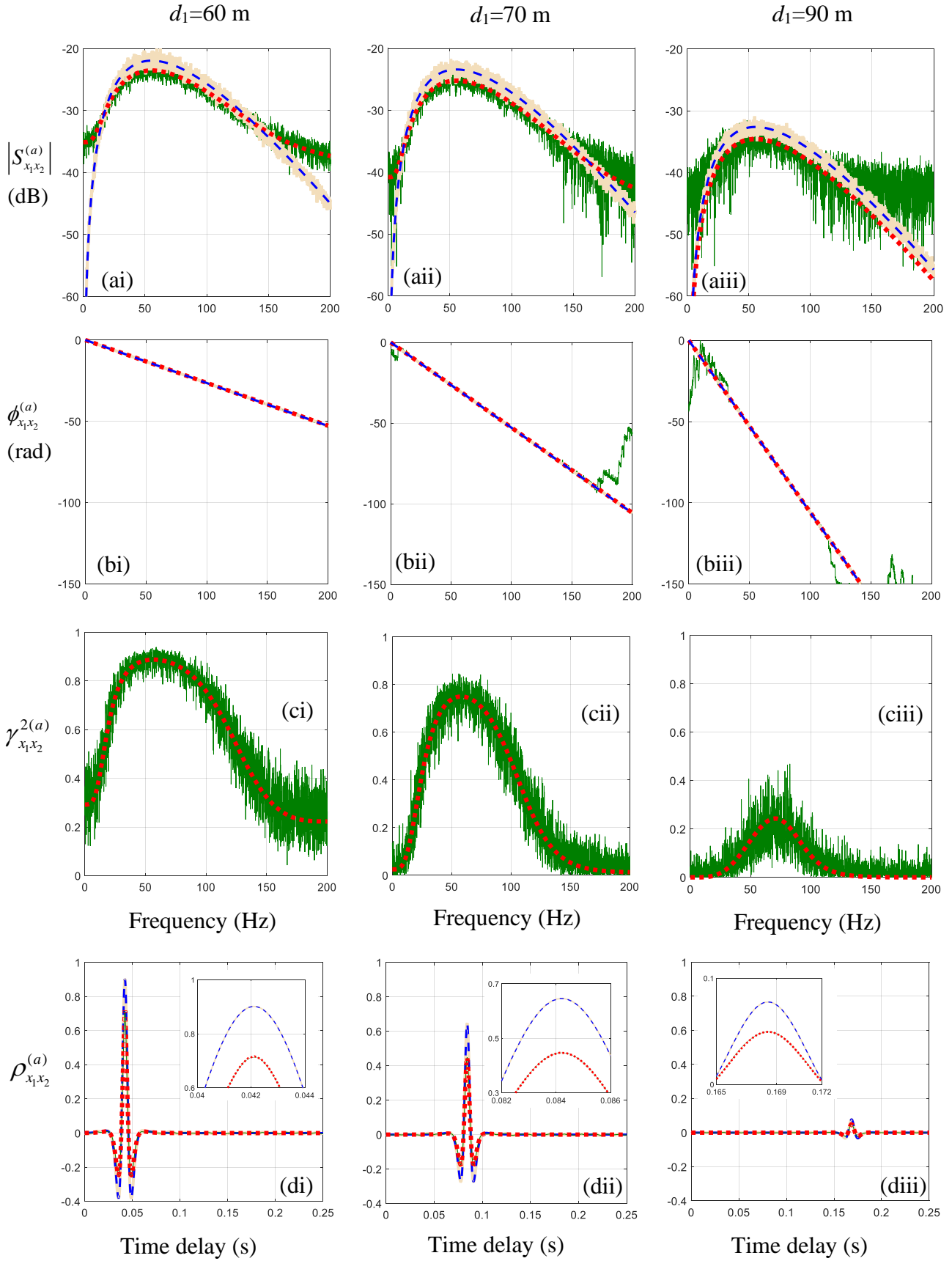
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Figure 7. Processed data from simulated acceleration signals, for three leak positions on a 100 m long pipe, 60 m, column (i), 70 m, column (ii), 90 m, column (iii). (a) modulus of the CSD (dB ref 1 m/s^2/Hz), (b) Phase of the CSD, (c) coherence, (d) CCC. Numerical unclipped, thick solid yellow line; Analytical unclipped, dashed blue line; Numerical clipped, thin solid green line; Analytical clipped, dotted red line.

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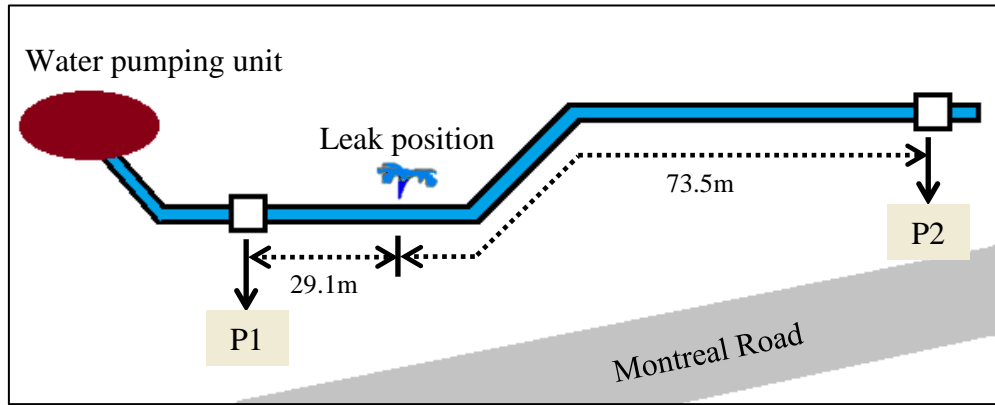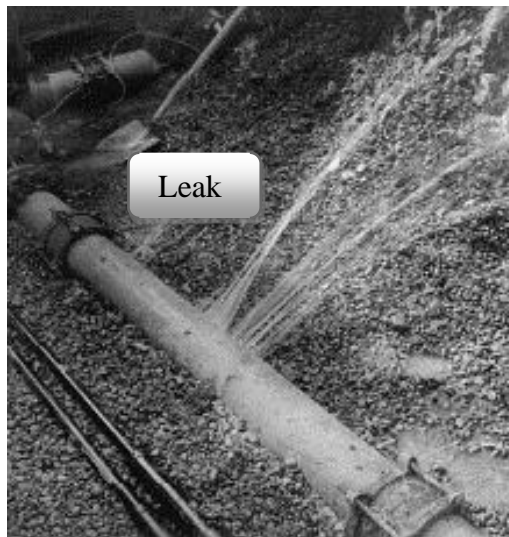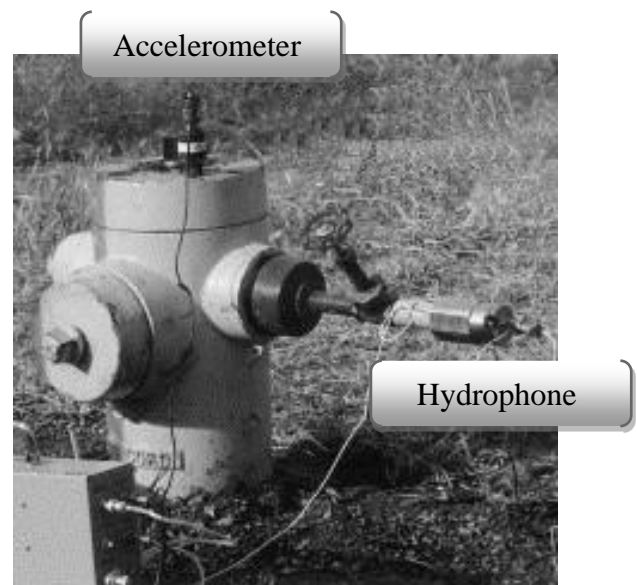
Figure 8. Details of the experimental test rig. (a) schematic of the pipe system in Ottawa, Canada used to simulate leaks under controlled conditions [2]. The measurement points are labelled P1 and P2. Note that the drawing is not to scale. (b) leak generation mechanism shown prior to the back-fill. (c) hydrophone and accelerometer attached to one of the hydrants to measure the leak noise.
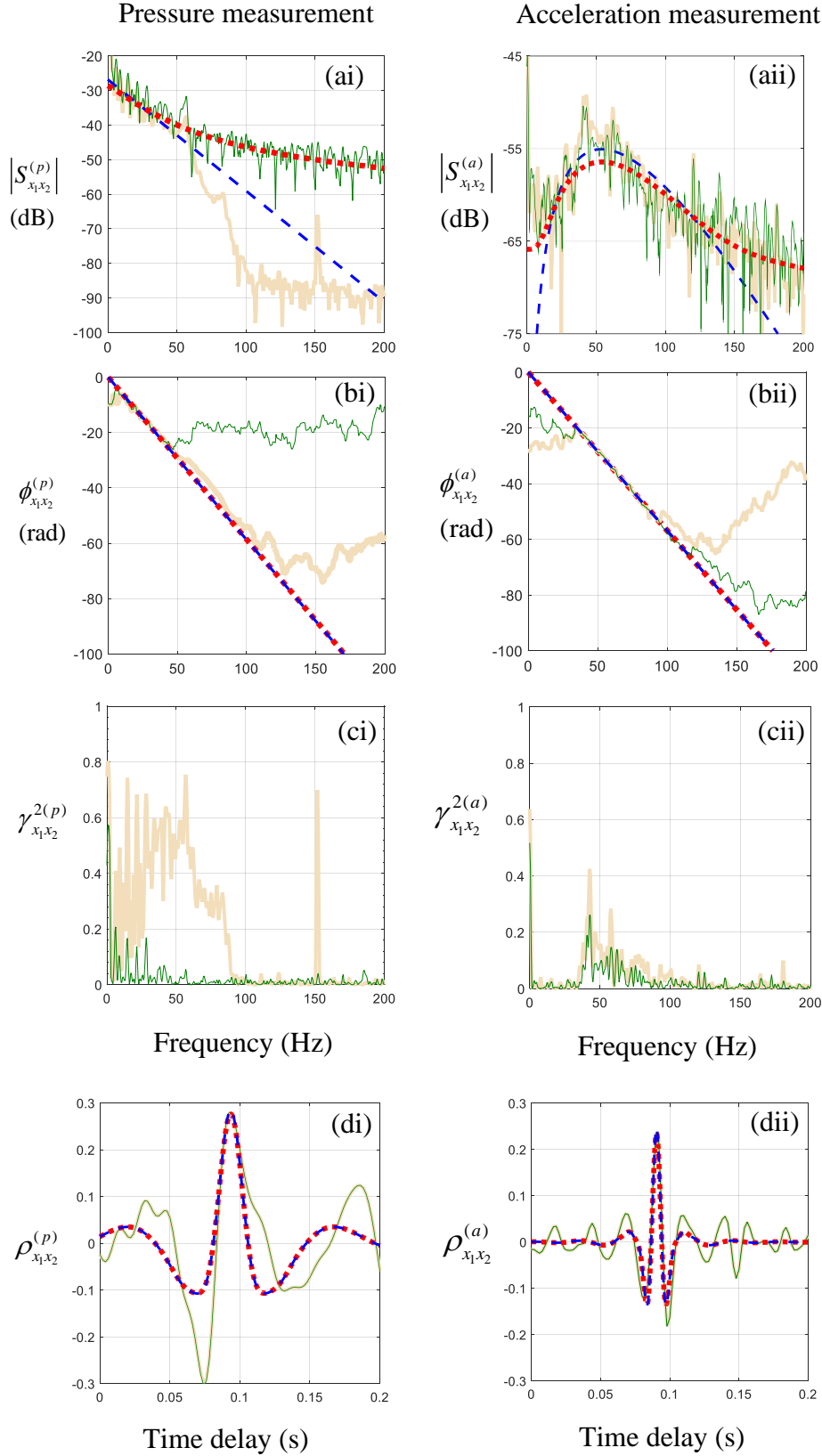
Figure 9. Processed data from measured data from the test rig shown in Fig. 6. (i) pressure measurements, (ii) acceleration measurements. (a) modulus of the CSD (dB ref 1 Pa^2/Hz for pressure), (dB ref 1 m/s^2/Hz for acceleration), (b) Phase of the CSD, (c) coherence, (d) CCC. unclipped measured data, thick solid yellow line; analytical predictions unclipped, dashed blue line; clipped measured data, thin solid green line; analytical predictions clipped, dotted red line.