Evaluation of cross correlation technique to measure flow in pipes using two NaI(Tl) scintillators detectors and radioactive source

Eddie J. Avilán[1,2,3], Verginia Reis[1], Luis E. Barreira[2] and Cesar M. Salgado[2]

e-mail: epuertas@nuclear.ufrj.br, verginia@nuclear.ufrj.br, brandao@ien.gov.br, otero@ien.gov.br

[1] PEN/COPPE, [2]IEN, [3]UCV

Keywords: flow rate measurement, cross correlation, delay time

The present report is concerned with the use of the cross correlation technique to measure delay time between two simulated signals displaced in time, in order to develop a cross correlator system that will be used to measure the rate flow in water and oil pipes in which the detection system is composed by two external radioactive sources and two gamma detectors of low activity located along the tube. The purpose of the detection system is to use the natural disturbances in the flow rather than to inject radioactive tracers to the fluid flow as usually is carried out. In the design of this correlator is evaluated one calculation method for the cross correlation function [1]. This method is: The point-by-point calculation. This one works at the same time in three modes of operation: Direct, Relay and Polarity. To carry out the evaluation was used simulated signals. The main objective of the simulated signals is to develop and improve a cross correlator system with these kinds of signals before to test it with real ones.

1. Examples of Signals

1.1 Two squared shifted signals. The two signals are identical but the second one is delayed two seconds in relation to the first one (see Fig.1).

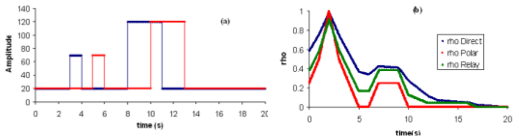

Figure 1. (a) Simulated square signals x(t) and y(t) with two seconds delay between them. (b) Graphics of the normalized cross covariance function of the signals x(t) and y(t) in Direct, Relay and Polar Mode, respectively. The covariance has a maximum at two seconds.

1.2 Two Gaussian signals. In this case the delayed time between these is 7 seconds and the signals are overlapped as is shown in the Fig.2.

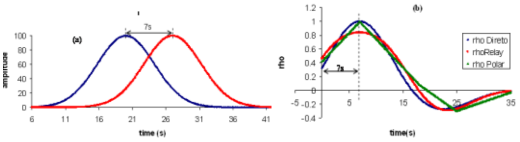

Figure 2. (a) Gaussian signals x(t) and y(t) with seven seconds delay between them. (b) blue, red and green are the normalized cross covariance function of the signals x(t) and y(t) in Direct, Relay and Polar Mode, respectively. The covariance has a maximum at seven seconds.

Trying to find a quantitative estimation of the accuracy was calculated in each mode of operation the kurtosis and the skewness of the normalized curves, with these values was made the table 1 as is shown below.

Table 1. Values of kurtosis and skewness in each mode of operation.

Figure Nº	Direct mode		Relay mode		Polar mode	
	kurtosis	skewness	kurtosis	skewness	kurtosis	skewness
1	-0.57	0.712838	2.27	1.719403	0.10	1.024193
2	-0.75	0.855857	-1.24	0.579055	-0.94	0.688007

When the input and output signals are not Gaussian, the cross correlation function neither. In each mode of operation the width of the curve may vary, being wider in the Direct Mode and narrower in the Polar Mode. This could be an indication that the uncertainty may depend of the operation mode.

In the articles of the 60´s of the last century talks about that the Direct Mode involves many computational operations and takes a longer time that the Polar Mode calculation to evaluate the cross correlation function, but with the evolution of the electronic devices this situation no longer exist. These methods are been studied for our team work at the present day [2].

References

[1] BECK, M. S.; PLASKOWSKY, A. **Cross correlation flowmeters**: their design and application. Manchester: Adam Hilger, 1987.
[2] AVILÁN, E. J.; REIS, V. Evaluation of cross correlation technique to measure flow in pipes using two NaI(Tl) scintillators detectors and radioactive source. In: INTERNATIONAL NUCLEAR ATLANTIC CONFERENCE, 24-29 nov., 2013, Recife, PE. **Proceedings…** Recife, PE: ABEN, 2013.